INDOOR PROPAGATION MEASUREMENT FOR WIRELESS SYSTEMS OPERATING IN 2.45 GHZ ISM BAND

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Abstract

For a planning of indoor Wireless LAN systems working in the ISM band, the signal propagation prediction is needed. In this article, the measurement campaign based on two types of measurements at 2.45 GHz is introduced.

The first type of the measurement was a classical narrowband signal level measurement within indoor scenario without presence of people. The aim of this measurement was to find empirical parameters for COST231 Multi-Wall and One-Slope models.

In order to statistically describe the time varying nature of the received envelope of the signal, at WLAN 2.45 GHz band, the second part of measurement campaign was accomplished. In this case, the signal level was measured using commercial WLAN PCMCIA cards in two notebooks. Probability density functions and corresponding cumulative distribution functions were set and discussed based on the specific locations and orientation of one of the notebooks.

Results from both measurement campaigns were compared and conclusions are drawn for the needs of practical planning of indoor WLAN systems coverage.

Keywords

Wireless LAN, indoor propagation prediction, picocell, path loss, fading

1. Introduction

Wireless LAN (Wireless Local Area Network) is a computer network system that uses radio air interface for data transmission instead of conventional metallic or optical wire. Nowadays, several standards for WLAN air interface for various frequency bands exist. IEEE 802.11b is the most successful standard for WLANs in 2.45 GHz ISM (Industrial, Scientific & Medical) band [1].

For planning of indoor Wireless LAN systems working in the ISM band, the signal propagation prediction is needed. Indoor scenarios are usually very complicated and due to moving people rapidly changing environment. Since the WLAN systems use wideband transmission, QoS (Quality of Service) is highly dependent not only on average signal strength in specific location, but also on fading statistics.

Due to the multipath propagation where several waves arrive at the receiver via different paths and with different phases, rapid variations of the received signal envelope occur (see Fig. 1). This phenomenon is described in detail in [2] [3]. Time variations of the received signal and wide bandwidth of the transmission are the reasons why the statistical evaluation of measurement results is necessary.

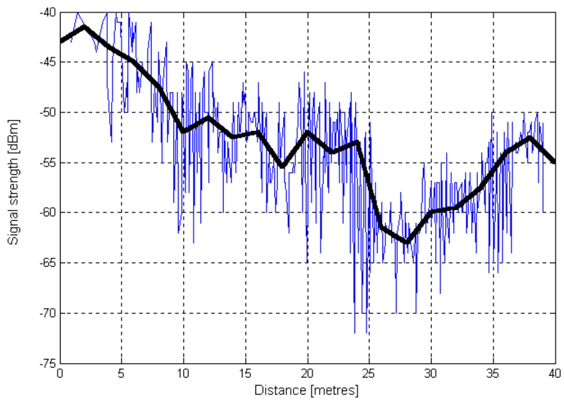

Fig.1 Example of received signal level versus distance; thick line was obtained using averaging window of 20 wavelengths

That is why the indoor measurement campaign consisting of two measurement methods was accomplished.

The aim of the first narrowband measurement was to find empirical parameters for COST231 Multi-Wall and One-Slope models [4]. The models allow mean signal level prediction for initial coverage planning [5].

The second part of the measurement campaign - the wideband measurement - was focused on the long-term signal power level measurement using commercial WLAN system to investigate statistical distributions of fades. Probability density functions and corresponding service time-availability (cumulative distributions functions) were set and discussed taking into account the specific location, the notebook orientation in azimuth and the specific environment arrangement in the near vicinity of the notebook. Using the results necessary power margin and resulting QoS can be determined for WLAN system implementation.

2. Measurement Campaign

2.1 Location

The measurement campaign was performed on the 6th floor of the CTU building in Prague as in [5]. It is a typical modern multi-floored building. Many walls and partitions divide measured floor and there are two metal lifts in the scenario as well (Fig. 2). Very untypical is an antenna chamber with full metal walls situated in the middle of the measured area.

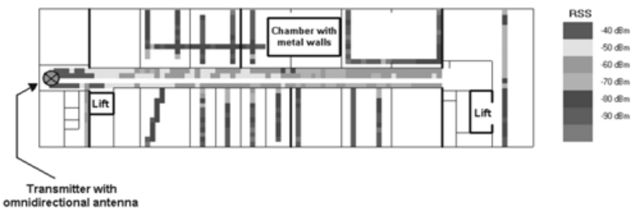

Fig. 2 Floor layout with the measured signal level distribution

2.2 Narrowband Measurement

A narrowband system was developed at the Dept. of Electromagnetic Field consisting of a transmitter, portable receiver and two wire omni-directional ground-plane antennas. The system was designed for 2.45 GHz ISM band. Full computer control is made through the standard serial interface RS232 by the PDA computer PalmIIIx. A value of the signal level was taken automatically every second and saved in the computer while the receiver was moving along a measured path. More information about system and measurement method can be found in [6], [7].

Fig. 3 Measurement using commercial PCMCIA WLAN cards

2.3 Wideband Measurement

A simple Wireless LAN peer-to-peer connection was built up using two notebooks - both supplied with identical standard WLAN PCMCIA cards [8]. Omnidirectional antennas are integrated in the cards. The test software included in the product package was used to measure the signal power level and QoS.

One of the notebooks was situated at the same positions as the transmitter in the case of narrowband measurements. The second notebook was placed on the slowly rotating turntable, so that the azimuth in all 360 degrees may have been scanned with 5-degrees step (Fig. 3). The signal power level was measured at several turntable locations for a few hours. Three of the locations are shown in Fig 6.

3. Measured Data Processing

3.1 Narrowband Measurement

Empirical parameters for COST231 One-Slope (1) and Multi-Wall (2) models were optimized based on the measured data and compared with parameters at 1.9 GHz. The same data processing techniques were used as in [6].

$$L(d) = L_0 + 10\,\gamma\,\log(d) \tag{1}$$

$$L_{MW}(d) = L_0 + 10\gamma\log(d) + \sum_{i=1}^{M} L_i \tag{2}$$

$L(d)$ is path loss [dB] in distance d [m], L_0 denotes reference loss value [dB] for 1 m, γ is path-loss exponent, L_i is floor loss factor for the i-th wall [dB] and M denotes number of walls between antennas. Three types of walls were considered for Multi-Wall Model: light wall, heavy wall and metal wall (antenna chamber walls).

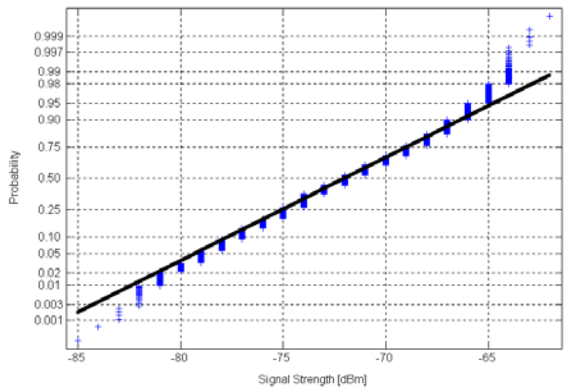

Fig. 4 Log-normal probability plot of received signal level

3.2 Wideband Measurement

All the measured data were collected and analyzed with respect to the direction where the WLAN PCMCIA card antenna was facing (notebook azimuthal orientation on the turntable). Probability density function of the received signal level was determined in each receiver direction and for every position of the turntable. The log-normal fading distribution was utilized. The comparisons of the log-normal distribution with the measured data in Fig. 4 and 5 demonstrate a good fit of the selected distribution.

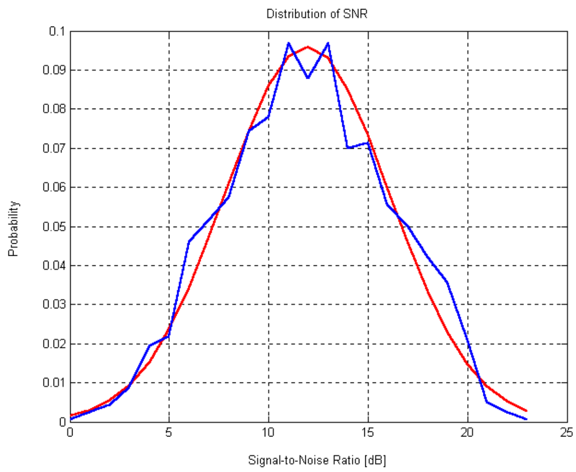

Fig. 5 Probability density function of SNR - measured data versus log-normal distribution

The main goal of the wideband measurement was to find cumulative distribution functions of the received signal level for each location. These functions describe time variations of the received signal. It can be used for calculations of the signal level above the mean for an acceptable percentage of time. This way the corresponding QoS is determined. Detailed information on used calculation procedures can be found in [2],[3].

4. Measurement Results

4.1 Narrowband Measurement

The optimized values of empirical parameters for One-Slope Model and Multi-Wall Model together with their comparison to the results at 1.9 GHz [6] are given in Tab. 1 and 2.

f [GHz]	L_O [dB]	γ [-]
2.45	40.2	4.2
1.9	38.0	3.5

Tab. 1 Optimized parameters for One-Slope Model

As shown in Tab. 1, the path loss exponent optimized for One-Slope Model is higher than in [6]. It was expected because of the higher frequency band. It should be pointed out that the One-Slope Model prediction accuracy is usually very poor. In the presented case, the mean error of the averaged signal level exceeded 12 dB.

The semi-empirical Multi-Wall Model proved much better performance - the mean error around 8 dB with optimized parameters. Thanks to its favorable features [6] the Multi-Wall Model is advisable for indoor coverage predictions for initial WLAN implementation planning.

f [GHz]	L_O [dB]	L_1 [dB]	L_2 [dB]	L_3 [dB]	Γ [-]
2.45	40.2	5.9	8.0	4.1	2
1.9	38.0	2.1	4.4	1.3	2

Tab. 2 Optimized parameters for Multi-Wall Model

4.2 Wideband Measurement

First, the cumulative distribution functions of the received signal power level in each location of the turntable were investigated with respect to the turntable rotation. Fig. 6 shows various curves of inverse cumulative log-normal distribution function for three different locations and three different probabilities. It defines minimum received signal level for probability of 50, 90 and 99% as functions of the measurement notebook location and orientation. The influence of the notebook azimuthal orientation on the standard WLAN transmission can be nicely demonstrated. Using the results, the gain of eventual angle diversity can be determined as well.

Finally, the data were processed regardless the turntable orientation. The resulting cumulative distribution function is shown in Fig. 7. It statistically describes time variations of the received signal level for the three locations. The link availability or QoS based on the signal level can be determined for desired probability. Inversely, the power level margin can be provided for the required probability.

As it can be seen in Fig. 7, there is a significant difference between the location C and other locations. It was caused by less varying signal level due to the presence of anomalous metal antenna chamber and low mean value of the received signal level (compare to Fig. 6).

5. Conclusion

The indoor measurement campaign in 2.45 ISM frequency band was described. Two types of measurements and data processing - narrowband and wideband - were presented.

The empirical parameters for standard indoor propagation models were derived. Time variations of WLAN signal level were investigated and the cumulative distribution functions based on log-normal distribution were determined. The position as well as the azimuthal orientation of the measurement notebook were considered.

Using the results, the indoor coverage planning of WLAN systems is possible including the prediction of link availability and overall QoS. In addition, the measured data can be further used for angle diversity studies.

Further investigations are needed to produce similar results for other types of indoor environments. More general conclusions could be drawn then.

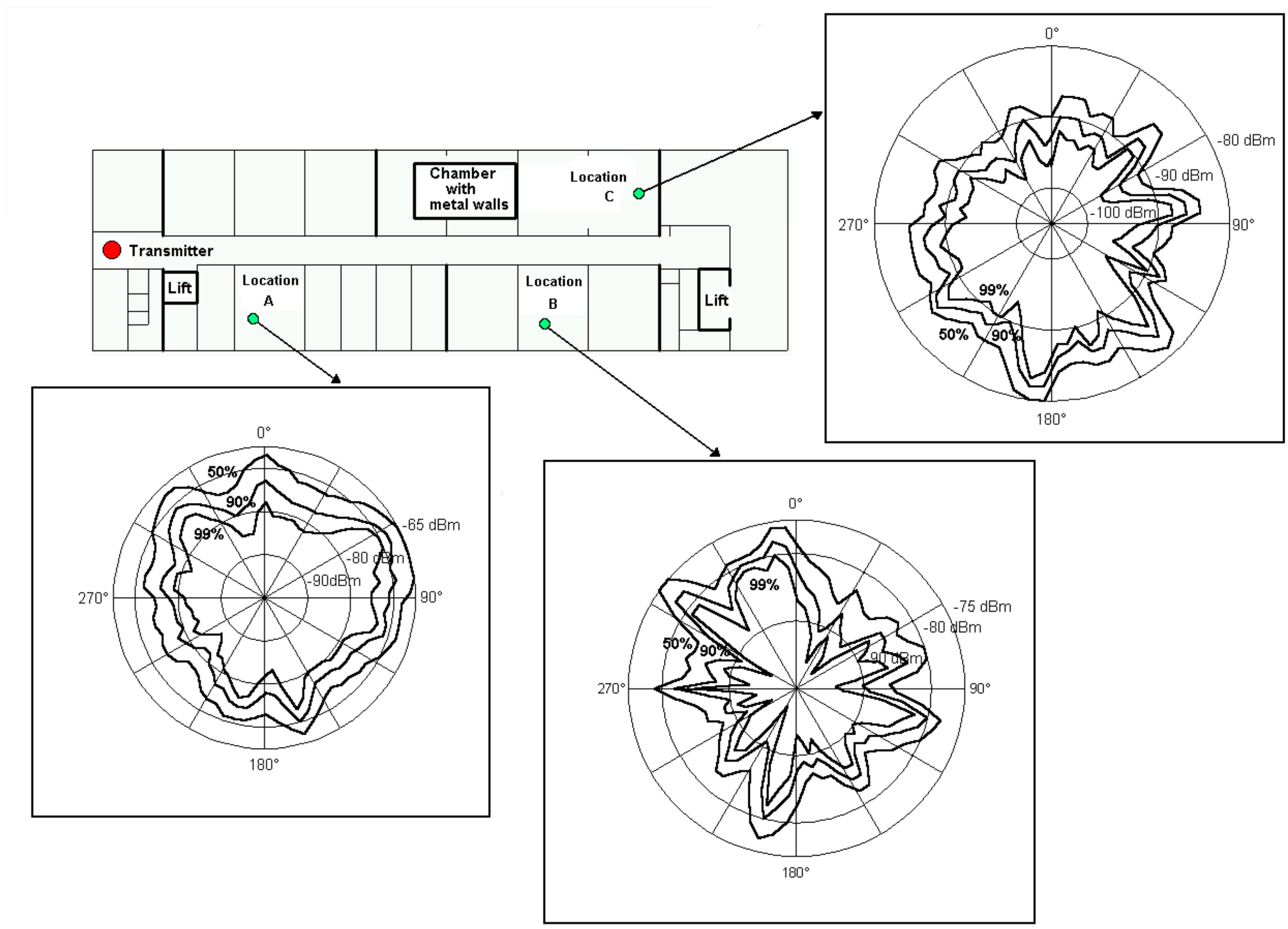

Fig. 6 Minimum received signal power level for probability of 50, 90 and 99% as functions of the notebook location and orientation

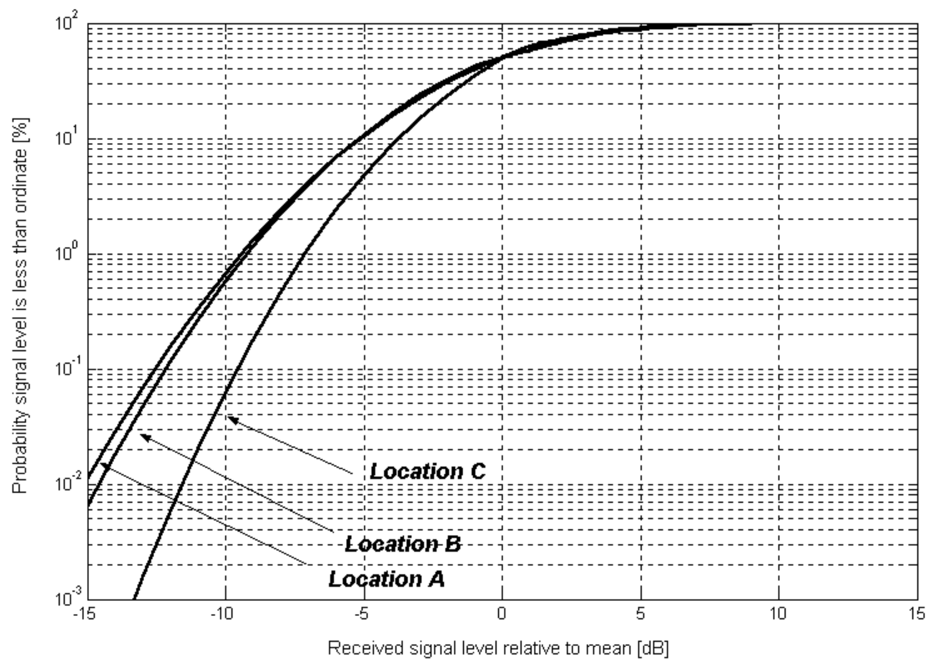

Fig. 7 Probability the received signal level relative to mean value is less than ordinate

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Acknowledgement

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About Authors...

Martin VÁLEK was born in Prague in 1978. Currently, he writes diploma thesis at the Dept. of EM Field at the Czech Technical University Prague. During his master studies, he also stayed at TU of Turin in Italy (2001) and at Siemens ICN in Munich, Germany (2002).

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Pavel PECHAČ – see p. 47.

International Competition STUDENT EEICT 2003

On Thursday, the 29th of May 2003, Czech and Slovak technical universities organize an international competition of students' projects specialized in electrical engineering, information and communication technologies. Since the Faculty of Electrical Engineering and Communication (FEEC) and the Faculty of Information Technology (FIT) of the Brno University of Technology (BUT) have organized already 8 editions of a similar local contest, they were delegated to prepare the first international edition of the competition.

The contest is named STUDENT EEICT abbreviating **E***lectrical* **E***ngineering,* **I***nformation and* **C***ommunication* **T***echnologies*, which emphasize priorities in teaching and research of organizing faculties.

The contest is aimed to motivate students for a creative research and development activity. In the frame of the competition, students defend projects, which yield interesting technical solutions and original results. Since several of presented projects are worked out in a close cooperation with industrial partners, companies play an important role in the frame of the competition.

Each of the participating universities can delegate two or three students (typically winners of a local faculty contents) to the international competition.

The contest is running in three categories: bachelor's, master's, and doctor's.

Each category is subdivided into the following specializations:

- Electronics
- Telecommunication
- Microelectronics and technology
- Mechatronics
- Cybernetics and automation
- Power electronics
- Theoretical electrical engineering
- Information systems
- Modeling, graphics and technical equipment
- Theoretical informatics

The participating faculty registers the nominated student projects to such specializations, which correspond as close as possible to the contents of the project.

Administration of the competition is given on the Internet: **http://www.feec.vutbr.cz/EEICT**

On these pages, also proceedings of the competition stay at one's disposal.

All the people are invited also to the traditional competition of BUT, which will be held on Thursday, the **24th of April 2003**.

Both the local competition and the international one take place in the university campus **Pod Palackého vrchem** in the building **Technická 8**.