Indoor Propagation Path Loss Modeling for Wireless Sensor Networks

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Abstract – **In this paper path losses during indoor propagation (inside buildings) are considered. Because of serious noisy component, one smart approach is to apply linear regression (obeying "least squares criterion"). Two different scenarios of propagation are considered: a) same floor propagation; b) one floor propagation (here additional losses are due to propagation through a ceiling of one floor).**

Keywords – **Wireless Sensor Network, Path Losses, Electromagnetic Modeling.**

I. INTRODUCTION

Path losses determine the average received power for a given Transmitter – Receiver range. Sometimes shadowing from large obstacles is added in order to improve the accuracy of the model. Fading in the channel represents the short-term effects due to multi-path propagation [1 – 3]. De Friis transmission formula gives the path loss in the case of free-space propagation. Additional losses exist in the feeders of the transmitter and the receiver. All these complicated factors can be taken into account in the "power-loss" model, where the path loss exponent (n) is changing for different scenarios in the interval ($1< n < 4$) [4 – 5]. Particularly, for the free-space path loss exponent is ($n = 2$). The propagation, that takes into account the slow variations, is called "large scale model". On the other hand, the fast variations that take into account the fading effect, is so called "small scale model" [6 – 7]. In this paper one method for accurate estimation of path losses for indoor propagation channel) with two important parameters are considered: (n) the best curve-fitting power-law; and σ – the statistical standard deviation. This model can be applied to variety of scenarios, related to WSN (wireless sensor networks).

II. BRIEF THEORY OF THE LINEAR REGRESSION

A. Path loss model:

This is empirical model that try to approximate analytically the results of measurement. The path loss function of the distance can be represented in the following form

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$$PL(d) = PL(d_0)(d/d_0)^n \tag{1}$$

or in logarithmic form

$$PL_{dB}(d) = PL_{dB}(d_0) + 10n\log(d/d_0) + X_\sigma \tag{2}$$

where (d) is the distance, (d_0) is the distance from the closest point to the observer, and (X_σ) is a Gaussian noise. Here MMSE (*minimum mean square error*) estimation about the path-loss exponent (n) is applied and the standard deviation (σ) is found. The sum that should be minimized is

$$S(n) = \sum_{k=1}^{N}\left(p_k - q_k n\right)^2 \tag{3}$$

where

$$q_k = -10\lg(d_k/d_1) \tag{4}$$

It is assumed that

$$p_1 = 0,\ p_k = -p(d_k) + p_1 \tag{5}$$

Now for the MMSE S(n) is found the following simple expression

$$S(n) = A - 2Bn + Cn^2 \tag{6}$$

where the coefficients are

$$A = \sum_{k=1}^{N} p_k^2\ ;\ B = \sum_{k=1}^{N} p_k q_k\ ;\ C = \sum_{k=1}^{N} q_k^2\ . \tag{7}$$

The necessary condition for minimum

$$\frac{dS}{dn} = 0 \tag{8}$$

leads to the equation

$$n = B/C \tag{9}$$

It can be shown that appropriate expression for the standard deviation is

$$\sigma[dB] = \sqrt{S(n)}/2 \tag{10}$$

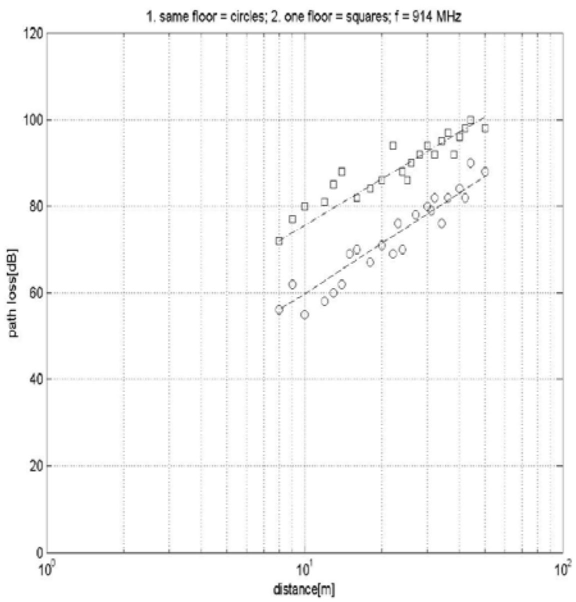

Fig. 1. Best fit linear regressions

III. Results from simulations

Here we are found two different *best fit lines*: 1) for "the same floor" results of measurements (with circles); 2) for "the one floor" results of measurements (with squares). The range of measurements is d = [8 – 50 m]. In these experiments the carrier frequency is f = 914 MHz. Both best fit lines (linear regressions) are shown by dashed lines in Fig.1. More accurate results for the parameters of both linear regression lines are:

1) (same floor) $n = 3.87$; $\sigma = 7.36$ dB;
2) (one floor) $n = 3.60$; $\sigma = 7.27$ dB.

We observe one interesting result from this simulation: the two best-fit lines are *almost parallel*, the only difference between them is *offset about 16 dB more* for one-floor case than for same-floor case. This fact can be explained by "through-ceiling propagation".

In the near future these approach should be extended for the case of (two floors) and (three floors) measurements.

IV. Conclusions

Our best-fit model (with linear regression) could be applied to variety of scenarios in the area of WSN: 1) person-to person interactions (BAN = body-area network, for example); 2) environmental interactions (ESN=environmental sensor network); 3) object-to-object interactions (OSN=object sensor network).

The next step of our research in this field will be an application of the same best-fit algorithm to the case of BAN, where new topic appeared in the last years (RFID = radio-frequency identifications). There is a strong interest here of developing such a system for one hospital environment. There are three different mechanisms of propagation in such an environment: a) in-body propagation; b) on-body propagation; c) off-body propagation.

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