Investigation of Indoor Propagation Models At 900 1800 And 1900 MHz Bands

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Abstract: - In this study indoor propagation path loss calculations and comparison of path loss techniques according to propagation environment have been investigated in detail. The accuracy of the models was examined and simulated for different environmental parameters, frequencies, separation distances and transmitted powers. By taking the application values of the GSM operators and cellular phones, mobile radio system d esign parameters for site –specific environment for enclosed spaces were calculated and presented in order to decide cell radius, received signal power and dynamic range.

Key-Words: - Indoor cellular communication, optimization, path loss, propagation mod el

1 Introduction

With the rapid growth of wireless communications, cell sizes are getting smaller and site–specific propagation information is needed for design of mobile systems. Indoor radio coverage is a primary consideration in the implementation of indoor wireless networks. Coverage is simply the distance that a wireless network can transmit data at a given data rate subject to the regulations in its frequency band and the standard under which it operates. Especially in the frequency range between 500MHz and 5GHz indoor applications and services require efficient planning tools.

The indoor radio propagation differs from the outdoor one, because the distance between transmitter and receiver is shorter due to high attenuation caused by furniture, and because of the lower transmitter power.

Indoor coverage is important for mobile telephone network operators in order to calculate the optimum place for their repeaters or base stations; where the indoor coverage directly impacts the critical capacity and cost.

Emprical narrow band models, empirical wide band models, models for time variations and deterministic models are the ones widely used in path loss calculations**.** Emprical narrow band models are expressed in a form of mathematical equations which give the path loss as the output. These models have been recreated from a set of actual field measured data with taking into account all propagation factors both known and unknown.[1],[2][3],[8].

Empirical wide band models are expressed in a form of table listing average delay spread values and power delay profiles shapes.Models for time variations are used to estimate the Doppler spectrum of the received signal. Deterministic models are calculation methods which physically simulate the propagation of radio waves. These models yield both narrow band and wide band information of the channel.[4],[5],[6].

In this study the propagation models were used to predict large scale coverage for mobile communication system design. Empirical narrow band models are chosen to calculate the propagation path loss in order to decide cell radius, received signal power and dynamic range.

2 Indoor Propagation Models

Free Space Propagation Model

The model relates the situation where the transmitter and receiver are in “free space”, that is, Friis formula where there are no objects in the vicinity that reflect or absorb transmitted energy. In this model the intensity of an electromagnetic wave is known to decay with the square of the radio path length.

$$L_{fs}(dB) = 32.44 + 20\log(f) + 20\log(d) \qquad (1)$$

Ground Reflection (2-ray) Model

This model treats the received power as an interference of two waves-a direct wave and a reflected wave. The received power at d is related to the square of the electric field. The received power at a distance d is expressed as

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4} \qquad (2)$$

for $d >> h_t h_r$.

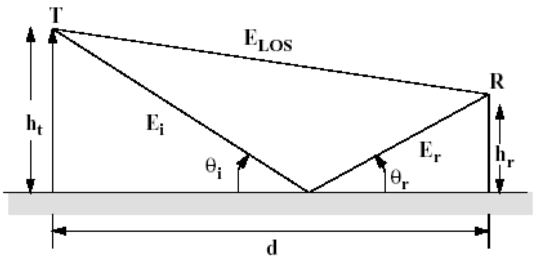

Fig.1. Two ray model

Log-distance Path Loss Model

The model treats the average large-scale path loss for an arbitrary T-R separation which is expressed as a function of distance by using a path loss exponent, *n*.

$$\overline{PL}(d) \propto (\frac{d}{d_o})^n \quad \text{or}$$

$$\overline{PL}(d) = \overline{PL}(d_o) + 10n\log(\frac{d}{d_o}) \qquad (3)$$

where n indicates the rate at which the path loss increases with distance , d_o is the close-in reference distance which is determined from measurements close to the transmitter, and d is the T-R separation distance. The bars in the equations above denote the ensemble average of all possible path loss values of d. Path loss exponents for indoor environments are presented in Table-1.[7]

Table-1- Typical Path Loss exponents

Environment	Path Loss Exponent N
Free Space	2
In building Line of sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

COST – 231 Multi-Wall Model (MW)

The multi wall model gives the path loss as free space loss added with losses introduced by the walls and floors penetrated by the direct path between the transmitter and receiver .The total floor loss is a non-linear function of the number of penetrated floors. This characteristic is taken into account by introducing an empirical factor b. The indoor path loss model expressed in dB is in the following form, which is derived from the COST 231 indoor model:

$$PL(dB) = L_{fs} + L_C + \sum_i k_{wi} L_{wi} + L_f . n^{((n+2)/(n+1)-b)} \qquad (4)$$

L_{fs} free space loss between transmitter and receiver

L_C constant loss

d transmitter-receiver separation given in meters

k_{wi} number of penetrated walls of type i

L_{wi} loss of wall type i

n number of penetrated floors

b empirical parameter

L_f loss between adjacent floors

Two types of internal walls are considered. Light internal walls with a loss factor of 3.4 dB and regular internal walls with a loss factor of 6.9 dB.

If internal walls are not modelled individually, the indoor path loss model is represented by the following formula

$$PL(dB) = 37 + 30\log(d) + 18.3n^{((n+2)/(n+1)-0.46)} \qquad (5)$$

where:

d transmitter-receiver separation given in meters;

n number of penetrated floors

Keenan - Motley Model

The Linear Path Attenuation Model often referred to as the Keenan -Motley or Devasirvatham model is selected to describe a signal path loss model for the case where the transmitter and the receiver are located on the same floor. According to this model, the indoor path (radiated power) loss, in dB, is given by the free space path loss plus a factor that is linear with range. This factor is used to account for the radio wave absorbing obstacles regularly encountered in an indoor environment. The Keenan - Motley average signal path loss is given in the following equation:

$$PL(d, f) = L_{fs}(d, f) + a.d \qquad (6)$$

where d is the distance, f the operating frequency, L_{fs} is the free space path loss and a is the linear attenuation coefficient.

3 Practical Link Budget Design Using Path Loss Models

The limiting factor on a wireless link is the signal to noise ratio (SNR) required by the receiver for useful reception. The power received from a transmitter at a separation distance of d directly impacts the SNR. The desired signal level in the communication channel is represented in the received power

$$P_r(dBm) = P_t(dBm) + G_t(dB) + G_r(dB) - \overline{PL}(d) \qquad (7)$$

The noise power is defines as the combination of thermal noise generated in the receiver, co-channel or adjacent channel interference in frequency division or time division multiple access systems or multiple access interference in code division multiple access spread spectrum systems.

If only the thermal noise is considered the noise power N is given in terms of band width and noise figure as

$$N(dBm) = -174(dBm) + 10\log B + F(dB) \qquad (8)$$

F is the noise figure of the receiver whose typical values range from 5 to 10 dB for commercial receivers.

$$SNR = P_r - N(dBm) \qquad (9)$$

By taking the application values of the GSM operators and cellular phones , path losses and received signal power levels were calculated with respect to seperation distances, noise power level with respect to receiver bandwidth were calculated and presented in figures given below in order to define cell radius, received signal power and dynamic range parameters.

4 Conclusion

Four different types of propagation models for indoor scenarios were presented in this paper and compared to one another. The sensitivity of the models was analyzed by changing the environmental parameters and frequency. Free space path loss model only suited for the prediction of rough path loss values. If only a very simple description of the building is available the COST231 path loss models leads the average results. All models were implemented in a software package so the results can be compared to another tools and models.

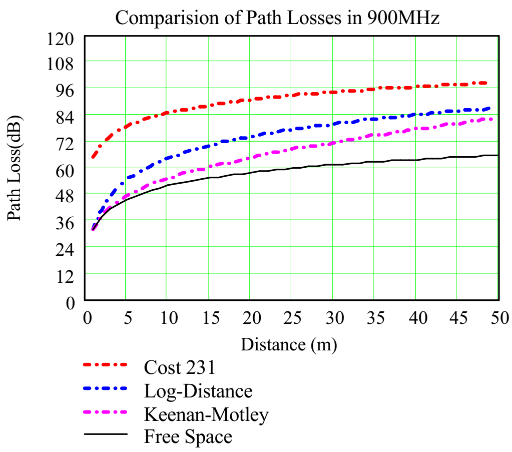

Fig.2. Comparision of path losses in 900 MHz

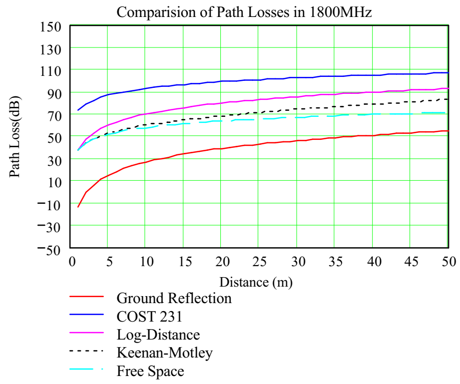

Fig.3. Comparison of Path Losses in 1800MHz

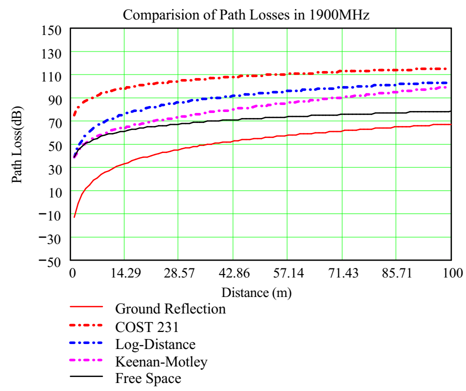

Fig.4. Comparison of Path Losses in 1900MHz

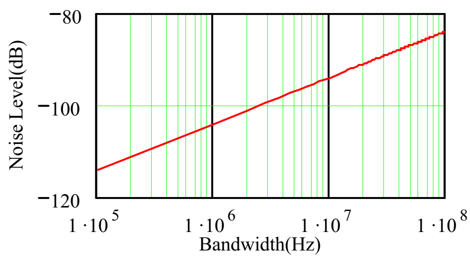

Fig.5. Noise power level versus receiver bandwidth

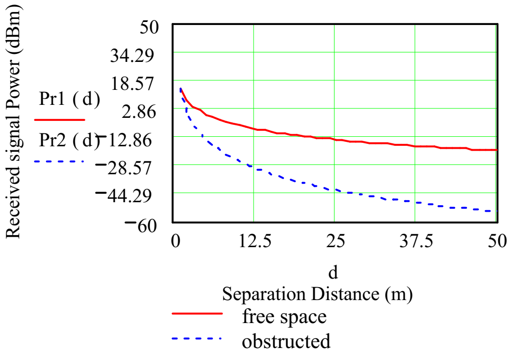

Fig.6. Received power versus separation distance

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