Study on the Performance of Wireless Local Area Network in a Multistory Environment with 8-PSK TCM

Danai Suwattana[1], Jakkapol Santiyanon[1], Thawan Laopetcharat[1],
Monton Charoenwattanaporn[1], Ut Goenchanart, Ph.D[1]. and Settapong Malisuwan, Ph.D[2].
[1]Department of Electrical Engineering
MET program, Rangsit University
Phatumthani, Thailand
[2]Department of Electrical Engineering
Chulachomklao Royal Military Academy
Nakhon-Nayok, Thailand

Abstract: A Wireless Local Area Network (WLAN) is a flexible data communication system implemented as an extension to, or as an alternative for, a wired LAN with in a building or campus. However, communications in an indoor environment present problems not encountered in outdoor wireless communication systems. Since cellular type systems are interference limited, the indoor environment is more hostile than the outdoor environment due to the lower propagation constant. In this paper, the equation for the signal to interference ratio in a multistory building will be derived. Knowing the S/I ratio, the floor frequency reuse can be determined. Finally, the simulation in this research is designed to study the performance (BER) of WLAN system in the multistory environment by applying the 8-PSK Trellis Coded modulation technique. The procedure allows a quick evaluation of BER in Wireless LAN system due to the co-channel interference.

1. Introduction

As we move into the 21st century, the demand for wireless services will increase in all aspects of our lives, with indoor standards such as " Bluetooth" complementing classic outdoor applications. Another indoor example is the research being conducted into the "Wireless Hospital", which would allow physiological monitor for real time viewing and recording by eliminating the restrictions encountered by traditional tethered equipment. However, communications in an indoor environment present problems not encountered in outdoor wireless communication systems. Since cellular type systems are interference limited, the indoor environment is more hostile than the outdoor environment due to the lower propagation constant. In this paper, I will derive an equation for the signal to interference ratio in a multistory building. Knowing the $\frac{S}{I}$ ratio, the floor frequency reuse can be determined.

2. Indoor Radio Propagation

2.1 In-building Propagation Measurement

Narrowband propagation measurements were performed at 900 MHz in a number of typical indoor radio communication environments. In the building, stationary transmitters were placed at several different indoor locations. The measurements were taken on two floors, Where data were collected on one, five and six floors, respectively. Both the transmitting and receiving antennas were vertically polarized quarter-wave monopoles. The transmitting antenna height was between 2 and 3 meters and the output power between 1mW (0 dBm) and 1W (30 dBm). The received signal strength level for a measurement position was sampled while moving the hand-held mobile antenna at a height of about 1.7 meters in a closed loop (circle or ellipse). In small rooms only one loop was measured, while large rooms, open areas and corridors were divided into smaller areas, some or all of which were measured in loops. Between 100 and 500 measurement positions (loops) were selected for each building. The average isotropic path loss between the transmitting antenna and a measurement position was calculated by taking the transmitted power, adding the antenna gains (2 dBi per antenna), and subtracting the median value of the signal strength levels in the loop and the cable losses.

2.2 Path Loss Models

The power of the desired signal (S) divided by the sum of the co-channel interferers (I) defines the co-channel interference ratio and is expressed as:

$$\frac{S}{\sum_{i=1}^{i_o} I_i} \tag{1}$$

For a hexagon cell structure on a single floor, the number of co-channel interferers (i_o) is six. In an indoor multistory structure, the power of the interferers on the other floors must be included. By replicating the cluster pattern on the floors directly above and below, the co-channel interference ratio is now defined as:

$$\frac{S}{\sum_{i=1}^{i_o} I_i + 2\sum_{j=1}^{i_o} I_j + 2I_o} \tag{2}$$

The first term in the denominator is the total power of the nearest interferers on the desired floor. The second term in the denominator is the total power of the interferers directly above and below the desired mobile. The last term is the total power of the interferers directly above and below the base station. A model describing the path loss ($L = \frac{P_r}{P_t}$ in dB) in different indoor environments was developed in [1]. The L in an indoor environment is described by the following equation:

$$L = \frac{P_r}{P_t} = 10n\log(d) + 20\log\left(\frac{4\pi}{\lambda}\right) + kF + pW \qquad (3)$$

Where λ is the wavelength, d is the distance between the transmitter and receiver in meters. F and W are the floor and wall attenuation factors in dB and k and p are the number of floors and walls traversed by the direct ray and n equals the same floor propagation constant. The path loss model considers only the direct wave between the transmitter and receiver. This is a statistical model and does not account for multipath reflections. Simplifying Eq. (3) and representing the path loss as negative path gain yields:

$$L_m(dB) = -10n\log(d) - 20\log\left(\frac{4\pi}{\lambda}\right) - 10k\log F - 10p\log W \qquad (4)$$

$$L_m = \left(\left[\frac{1}{d}\right]^n \left[\frac{\lambda}{4\pi}\right]^2 \frac{1}{F^k W^p}\right) \qquad (5)$$

Defining F^k as the floor attenuation factor (FAF) and W^p as the wall attenuation factor (WAF), equation 5 becomes:

$$L_m = \left(\left[\frac{1}{d}\right]^n \left[\frac{\lambda}{4\pi}\right]^2 \left[\frac{1}{(FAF)(WAF)}\right]\right) \qquad (6)$$

Several assumptions must be made at this point before proceeding. First, all antenna gains are equal. Secondly the transmitted power of each mobile is equal. Finally, the wall attenuation will be neglected. However, the WAF will be carried through to show the final equation. Finally, Eq. (2) can be written as:

$$\frac{\dfrac{P_tG_tG_r\lambda^2}{(4\pi)^2 R_d^n}}{\displaystyle\sum_{i=1}^{i_o}\frac{P_tG_tG_r\lambda^2}{(4\pi)^2 D_i^n} + 2\sum_{j=1}^{i_o}\frac{P_tG_tG_r\lambda^2}{(4\pi)^2 (FAF)(WAF) D_j^n} + 2\frac{P_tG_tG_r\lambda^2}{(4\pi)^2 (FAF)(WAF) H_f^n}} \qquad (7)$$

$$\frac{1}{\dfrac{i_o}{\left(\sqrt[n]{3N}\right)} + \dfrac{2R_d^n i_o}{(FAF)(WAF)D_j^n} + \dfrac{2R_d^n}{(FAF)(WAF)H_f^n}} \qquad (8)$$

where R_d is the distance from the desired mobile to the desired base station on the same floor, D_j is the diagonal distance from the interferers on the floor above and below the desired mobile to the desired mobile's base station and H_f is the vertical distance to the interferers directly above and below the desired mobiles' base station. The same floor propagation factor is defined as n and i_o is the number of interferers.

The dominant term in Eq. (8) is the last term, the interferers directly above the base station. When the desired mobile is at the cells outer edge, the interferers on the floor directly above and the floor below are actually closer to the base station. Figure 1 illustrates how the vertical distance, i.e. the number of floors, between the interferer directly above and below the base station dominates the $\frac{S}{I}$ ratio. After reaching the fourth floor, the $\left(\frac{S}{I}\right)$ ratio reveals as the number of floors between the base station and the interferer increases the $\left(\frac{S}{I}\right)$ ratio approaches $\frac{\sqrt[n]{3N}}{i_o}$, which is the single floor $\left(\frac{S}{I}\right)$ ratio. This suggests a floor frequency reuse factor of four.

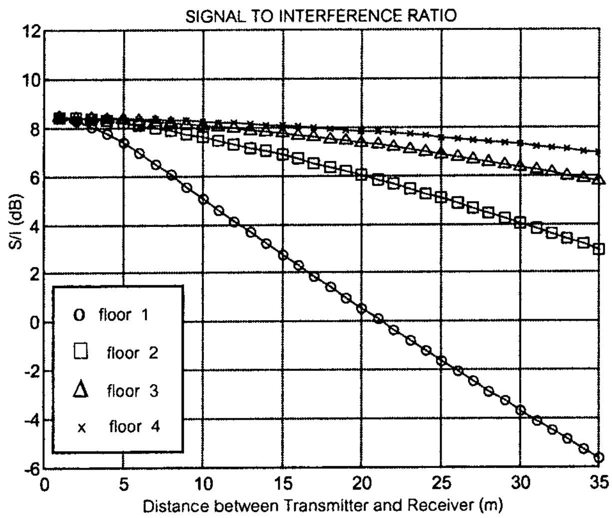

Figure 1. Co-Channel Interference (S/I) in a Multistory Environment

3. BER Performance of 8-PSK Trellis Coded Modulation

In this research, the 8-PSK Trellis coded modulation scheme is selected to study the performance of co-channel interference in a multistory environment. The theoretical BER performance of is 8-PSK TCM given by [2]:

$$BER = Pe = N(d_{free})Q\left(\sqrt{\frac{d_{free}^2 E_s}{2N_0}}\right) \qquad (9)$$

A plot of Eq. (9) is shown in Figure 2.

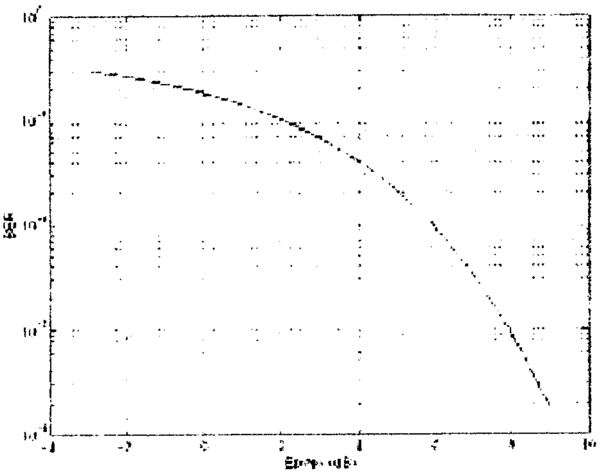

Figure 2. Theoretical BER Performance of 8-PSK TCM

4. Simulation Results

In this section, the simulation was designed to study the performance (BER) of WLAN system in the multistory environment by applying the 8-PSK TCM modulation technique. The result is shown in the Fig. 3.

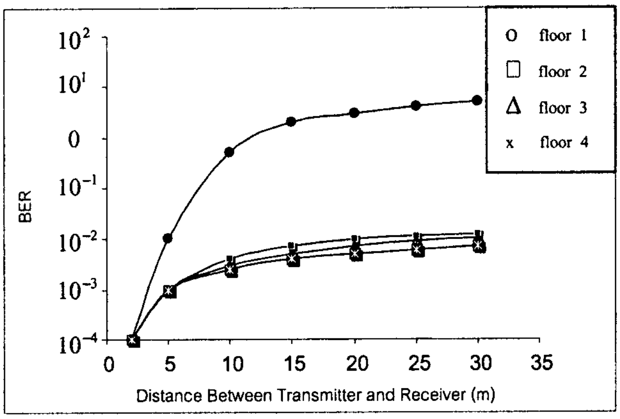

Figure 3. BER performance of WLAN system in the Multistory Environment by applying the 8-PSK TCM modulation technique.

5. Concluding Remarks

In this paper, the effect of co-channel interference on the performance of WLAN system was studied. The results of this research can be utilized for the WLAN system design in the multistory environment with 8-PSK Trellis Coded modulation technique.

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