UWB Communication Characteristics for Different Distribution of Pedestrian

Chien-Hung Chen[1], Min-Hui Ho[2], Shu-Han Liao[2], and Chien-Ching Chiu[2]

[1]Department of Computer and Communication Engineering Taipei College of Maritime Technology Shilin, Taipei, Taiwan, R.O.C.
[2]Electrical Engineering Department, Tamkang University, Tamsui, Taiwan, R.O.C.

Abstract-A comparison of UWB communication characteristics for different distribution of pedestrian is investigated. The impulse responses of these cases are computed by applying shooting and bouncing ray/image (SBR/Image) techniques and inverse Fourier transform. The frequency dependence utilized in the structure on the indoor channel is accounted for in the channel calculation. The bit error rate (BER) performance for UWB indoor communication is calculated. The outage probability for binary antipodal-pulse amplitude modulation (B-PAM) system has been presented. Numerical results have shown that the multi-path effect by pedestrian is an important factor for BER performance. Finally, it is worth noting that in these cases the present work provides not only comparative information but also quantitative information on the performance reduction.

1. INTRODUCTION

UWB technology has received significant interests, particularly after the Federal Communications Commission (FCC)'s Report and Order in 2002 for unlicensed uses of UWB devices within the 3.1–10.6-GHz frequency band [1]. The analysis and design of an UWB communication system require an accurate channel model to determine the maximum achievable data rate, to design efficient modulation schemes, and to study associated signal-processing algorithms [2]. Reference [3] proposes a deterministic propagation model to analyze the channel capacity of a narrowband 2.45-GHz 8x8 MIMO system within a small room for different distribution of pedestrian. However, to the best of our knowledge, there is no paper dealing with the effect of pedestrian on the indoor channel for the UWB communication system. In this paper, a comparison of UWB communication characteristics for different distribution of pedestrian in real environments is investigated. Results of this research provide valuable insights into the BER performance and outage probability in the UWB communication system. In section II, a channel modeling and system description is presented. In section III, we show the numerical results. Finally, the conclusion is drawn in section Ⅳ.

2. CHANNEL MODELING AND SYSTEM DESCRIPTION

A. Channel Modeling

The following two steps are used to calculate the multi-path radio channel.

(1)Frequency responses for sinusoidal waves by SBR/Image techniques

The SBR/Image method can deal with high frequency radio wave propagation in the complex indoor environments [4], [5]. It conceptually assumes that many triangular ray tubes are shot from the transmitting antenna (TX), and each ray tube, bouncing and penetrating in the environments is traced in the indoor multi-path channel. If the receiving antenna (RX) is within a ray tube, the ray tube will have contributions to the received field at the RX, and the corresponding equivalent source (image) can be determined. By summing all contributions of these images, we can obtain the total received field at the RX. In real environment, external noise in the channel propagation has been considered. The depolarization yielded by multiple reflections, refraction and first order diffraction is also taken into account in our simulations. Note that the different values of dielectric constant and conductivity of materials for different frequency are carefully considered in channel modeling.

(2) Inverse Fast Fourier Transform (IFFT) and Hermitian Processing

The frequency responses are transformed to the time domain by using the inverse Fourier transform with the Hermitian signal processing [6]. By using the Hermitian processing, the pass-band signal is obtained with zero padding from the lowest frequency down to direct current (DC), taking the conjugate of the signal, and reflecting it to the negative frequencies. The result is then transformed to the time domain using IFFT [7]. Since the signal spectrum is symmetric around DC. The resulting doubled-side spectrum corresponds to a real signal in the time domain. The impulse response of the channel can be written as follows [8]:

$$h_b(t) = \sum_{n=1}^{N} a_n \ \delta(t - \tau_n) \tag{1}$$

where N is the number of paths observed at time. $\delta(\ )$ is the Dirac delta function. a_n and τ_n are the channel gain and time delay for the n-th path respectively.

B. System Block Diagram

The transmitted UWB pulse stream is :

$$x(t) = \sqrt{E_{tx}} \sum_{n=0}^{\infty} p(t - nT_d) \ d_n \tag{2}$$

Where E_{tx} is the average transmitted energy and $p(t)$ is the transmitted waveform. T_d is the duration of the transmitting signal. $d_n \in \{\pm 1\}$ is a B-PAM symbol and is assumed to be independent identically distributed (i.i.d.). To be radiated in an efficient way, however, a basic feature of the pulse is to have a zero dc (direct current) offset. Several pulse waveforms might be considered, provided that this condition is verified. Gaussian derivatives are suitable. Actually, the most currently adopted pulse shape is modeled as the second derivative of a Gaussian function. The second derivative Gaussian waveform $p(t)$ can be described by the following expression:

$$p(t) = \frac{d^2}{dt^2}\left(\frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-t^2}{2\sigma^2}} \right) \tag{3}$$

where t and σ are time and standard deviation of the Gaussian wave, respectively.

The average transmit energy symbol E_{tx} can be expressed as

$$E_{tx} = \int_0^{T_d} p^2(t)\,dt \quad (4)$$

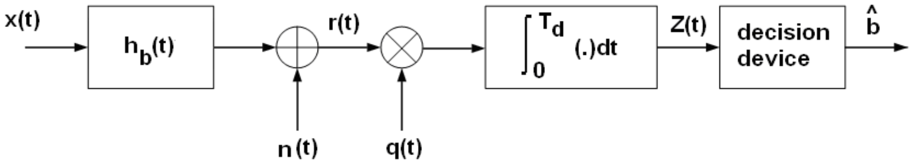


Fig. 1 Block diagram of the simulated communication system

Block diagram of the simulated communication system is shown in Fig. 1. The received signal *r(t)* can be expressed as follows:.

$$r(t) = [x(t) \otimes h_b(t)] + n(t) \quad (5)$$

where *x(t)* is the transmitted signal and $h_b(t)$ is the impulse response of the channel, *n(t)* is the white Gaussian noise with zero mean and variance $N_0/2$. The correlation receiver samples the received signal at the symbol rate and correlates them with suitably delayed references given by

$$q(t) = p(t - \tau_1 - (n-1)T_d) \quad (6)$$

where τ_1 is the delay time of the first wave. The output of the correlator at $t = nT_d$ is [9], [10]

$$Z(n) = \int_{(n-1)T_d}^{nT_d} \left\{ \left[\sqrt{E_{tx}} \sum_{n=0}^{\infty} p(t - nT_d) d_n \right] \otimes h_b(t) \right\} \cdot q(t)\,dt + \int_{(n-1)T_d}^{nT_d} n(t) q(t)\,dt = V(t) + \eta(t) \quad (7)$$

It can be shown that the noise components η(t) of Eq. (7) are uncorrelated Gaussian random variable with zero mean. The variance of the output noise η is

$$\sigma^2 = \frac{N_0}{2} E_{tx} \quad (8)$$

The conditional error probability of the Nth bit is thus expressed by:

$$P_e[Z(n) | \vec{d}\,] = \frac{1}{2} erfc \left[\frac{V(n)}{\sqrt{2}\sigma} \cdot (d_N) \right] \quad (9)$$

where $erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-y^2} dy$ is complementary error function and $\{\vec{d}\} = \{d_0, d_1, ..., d_N\}$ is the binary sequence.

Finally, the average BER for B-PAM IR UWB system can be expressed as

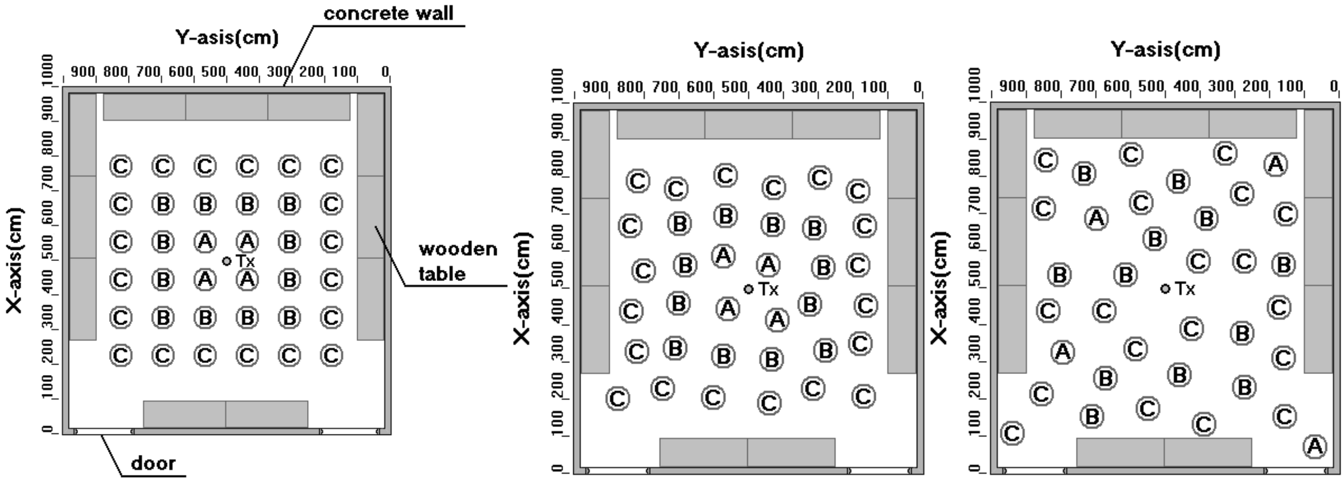
$$BER = \sum_{n=1}^{N} P(\vec{d}) \cdot \frac{1}{2} erfc \left[\frac{V(n)}{\sqrt{2}\sigma} \cdot (d_N) \right] \quad (10)$$

where $P(\vec{d})$ is the occurring probability of the binary sequence $\vec{d}$.

3. NUMERICAL RESULTS

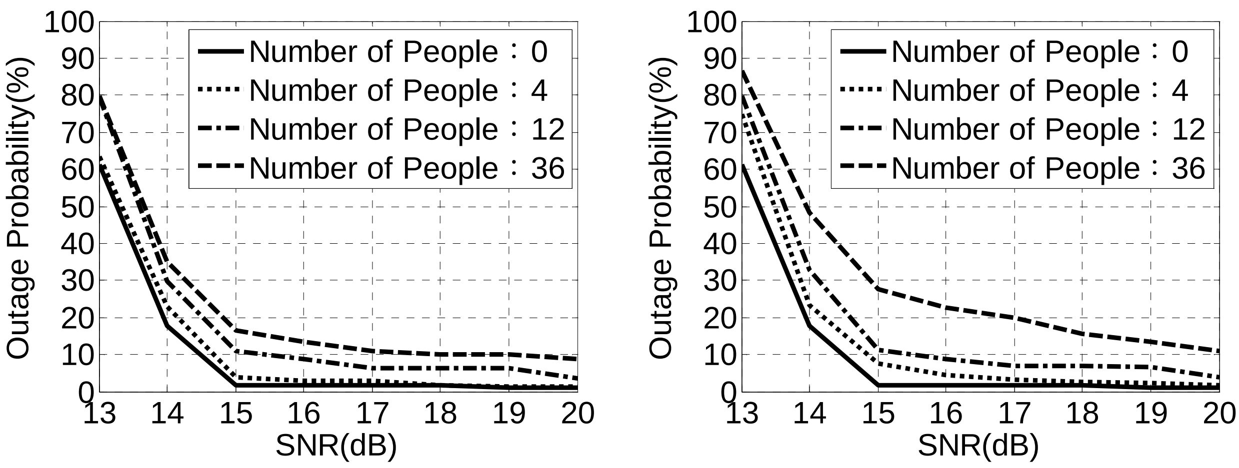
The channel characteristics for different distribution of pedestrian in the indoor environments are investigated. Fig. 2 is the top view of indoor environment with dimensions of 10m (Length) x 10m (Width) x 4.5m (Height).

There are four different distribution of pedestrian considered in the simulation. Four different numbers of pedestrian with 0, 4, 12 and 36 are simulated. The transmitting and receiving antenna are modeled as a UWB antenna with simple omni-directional radiation pattern and vertically polarized. The transmitting antenna is located at Tx (5, 5, 4) m with the fixed height of 4m which is located in the center of the indoor environment, as shown in Fig. 2(a). There are 361 receiving points for indoor environment. The locations of receiving antennas are distributed uniformly with a fixed height, 1m. The distance between two adjacent receiving points is 0.5m. The maximum number of bounces is set to be seven and the first order diffraction is also considered in the simulation. In the Fig. 2(a), there are four pedestrians in the position marked as A where each A represents one pedestrian. Similarly, there are twelve pedestrians on the position which is as marked B. Finally, there are thirty-six pedestrians on the position A, B and C. Fig. 2(a) shows the static stand pedestrians and Fig. 2(b) shows the pedestrians moving one step randomly. Fig. 2(c) shows the pedestrians moving randomly with many steps, and where applicable, pedestrian random movement. UWB channel characteristics in the indoor environment with pedestrian random movement are investigated.



(a) (b) (c)

Fig. 2 Top view of the indoor environment with dimensions. Marks A, B and C are the positions of the pedestrian. (a) static stand pedestrians (b) pedestrians moving one step randomly (c) pedestrians moving randomly with many steps.



(a) (b)

Fig. 3 Outage probability versus SNR. (a) pedestrians moving one step (b) pedestrians moving randomly with many steps.

By using the impulse responses of these multi-path channels, the bit error rate (BER) performance for binary pulse amplitude modulation (BPAM) impulse radio UWB communication system are calculated. Based on the BER performance, the outage probability for given 361 receiving locations of the transceiver can be computed. Outage probability statistical characteristic taken into account over all Rx location. At 100Mbps transmission rate and for a BER <10^{-6}, the outage probability versus SNR are calculated, as shown in Fig. 3. The SNR is defined as the ratio of the average power to the noise power at the front end of the receiver. Fig. 3(a) shows outage probability for different distribution of pedestrians moving one step randomly. It is seen that the outage probabilities at SNR=15dB are about 18% and 2% respectively for the 36 moving pedestrian and with on moving pedestrian. It is clear that the BER performance for without pedestrian is better due to the less severe multi-path effect.

In Fig. 3(b) shows outage probability for different distribution of pedestrian random movement. It is seen that the outage probabilities at SNR=15dB are about 28% and 2% respectively for the 36 moving pedestrian and with on moving pedestrian. The outage probabilities at SNR=15dB pedestrian moving one step is 18% and pedestrians moving randomly with many steps increases about 55% to 28% for the 36 pedestrian. It is seen that the values of the parameters change a lot by comparing the results in Fig. 3(a) and Fig. 3(b).

4. CONCLUSIONS

A method for analyzing and calculating the channel statistical characteristics of UWB indoor communication systems has been presented. A realistic complex environment is simulated in this paper. A comparison of UWB communication characteristics for different distribution of pedestrian are presented. We analyze the static stand pedestrians and pedestrians moving one step and pedestrians moving randomly with many steps. The outage probabilities for 100 Mbps B-PAM and for a BER <10^{-6} versus SNR are calculated. Numerical results show that the values of outage probability increase as the number of pedestrian increase. It is clear that the multi-path effect is severe when the number of pedestrian increases. It is found that value of the parameters change a lot for 36 pedestrian by comparing the results in Fig. 3(a) and Fig. 3(b). The pedestrian's random movement positions, directly increasing the multipath scattering presented in the environment. It is found that the outage probability for the 36 pedestrian is the largest due to the strong pedestrian random movement. The performance of outage probability with pedestrian is worse than that without pedestrian in UWB environment. This is can be attributed to multi-path effect which is severe when pedestrian exist in the room. Finally, it is worth noting that in these cases the present work provides not only comparative information but also quantitative information on the performance reduction.

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