Improving the Outage Probabilities of Rake Receivers for Ultra-wideband Outdoor Communication

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***Abstract*—The BER performance for ultra-wide band (UWB) outdoor communication is investigated. By using the impulse response of multipath channels, the BER performance for binary pulse amplitude modulation (BPAM) communications over the radio UWB system is evaluated. Numerical results have shown that the multi-path effect caused by moving vehicles in the outdoor environment has a great impact on BER performance. Rake receivers are used to improve the outage probability.**

Keywords- UWB; SBR-Image; Rake receivers

I. Introduction

When the Federal Communications Commission (FCC) agreed in February 2002 to allocate the 7500 MHz bandwidth for unlicensed use of ultra-wideband (UWB) communications in the 3.1 – 10.6 GHz frequency region [1], the UWB technology has received wide research attention ever since. There are two task groups for Ultra Wideband systems. One is the 802.15.3a for high data rate (100M/bps) and short operation distance (10 meters). The other is 802.15.4a for lower data rate (2M/bps) and longer propagation distance (up to 100m) [2].

UWB system offers many potential advantages, such as high resolution in multipath, reducing fading margins in link budget analysis, allowing for low transmit powers and low complexity [3], [4]. All wireless systems must be able to deal with the challenges of operating over a multipath propagation channel, where objects in outdoor environment can cause multiple reflections and shadow effect. The bit error rate (BER) degradation is caused by intersymbol interference (ISI) due to a multipath propagation arising from radio wave reflections by buildings, vehicles, trees, and even pedestrians.

The remainder of this paper is organized as follows. In Section II, Channel modeling and system description are presented. Several numerical results are included in Section Ⅲ, while Section Ⅳ concludes the paper.

II. Systen Description

A. Channel Modeling

By using these images and received fields, the channel frequency response can be obtained as following

$$H(f)=\sum_{p=1}^{N_p} a_p(f)e^{j\theta_p(f)} \tag{1}$$

where p is the path index, N_p is the number of paths, f is the frequency of sinusoidal wave, $\theta_p(f)$ is the p-th phase shift and $a_p(f)$ is the p-th amplitude. Note that the channel frequency response of UWB systems can be calculated by Eq. (1) in the frequency range of UWB for both desired signal and interference signal.

The equation used to model the multipath radio channel is a linear filter with an equivalent impulse response given by

$$h_b(t)=\sum_{l=1}^{N} \alpha_l \delta(t-\tau_l) \tag{2}$$

Where l is the path index, α_l is the amplitude of $l-\text{th}$ path and τ_l is the time delay of the $l-\text{th}$ path. $\delta(.)$ is the Dirac delta function [5].

B. System Description

The average probability of error is thus expressed by:

$$P_e[Z(t=nT_d)|\vec{d}_n]=\frac{1}{2}erfc\left[\frac{V(t=nT_d)}{\sqrt{2}\sigma}\cdot(d_n)\right] \tag{3}$$

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where $erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-y^2} dy$ is the complementary error function and $\{\vec{d}_n\} = \{d_0, d_1, ..., d_N\}$ is the binary sequence. Finally, the BER for the BPAM IR UWB system can be expressed as

$$BER = \sum_{n=0}^{N} P(\vec{d}_n) \cdot \frac{1}{2} erfc\left[\frac{V(t = nT_d)}{\sqrt{2}\sigma} \cdot (d_n)\right] \quad (4)$$

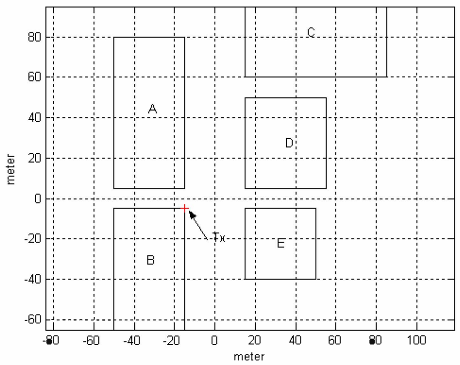

Figure 1. Layout of the simulated outdoor environment

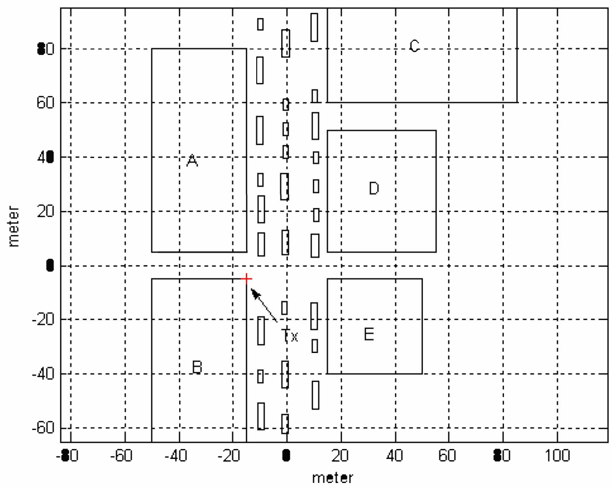

Figure 2. Layout for Area I with traffic

C. *Rake Receiver techniques*

Signal reception in a multipath fading channel can be enhanced by a diversity technique using the rake receiver. Rake receivers combine different signal components that have propagated through different paths in the channel. This is a time diversity technique. The combination of different signal components will increase the signal-to-noise ratio (SNR), thus improving the reception performance. There are three major types of rake receivers to be considered here, i.e., I-rake, S-rake and P-rake. First, I-rake is an ideal rake receiver that

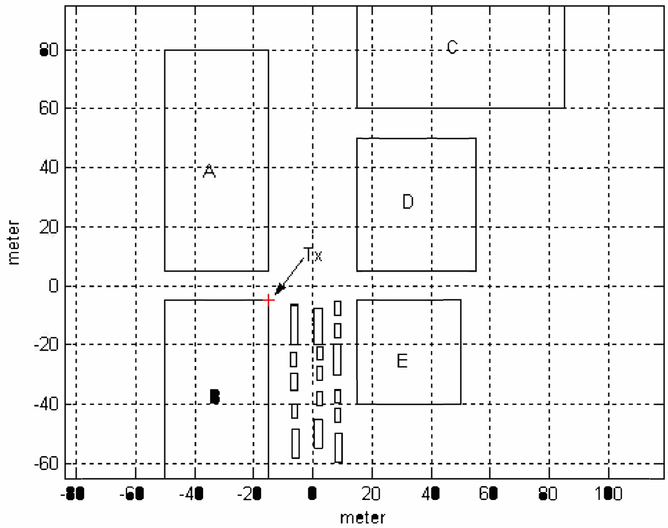

Figure 3. Layout for Area II with traffic

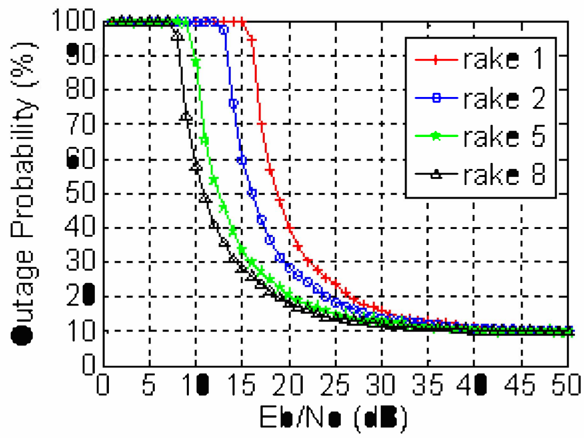

Figure 4. Outage probability versus SNR by different numbers of rake receiver in Area I with traffic

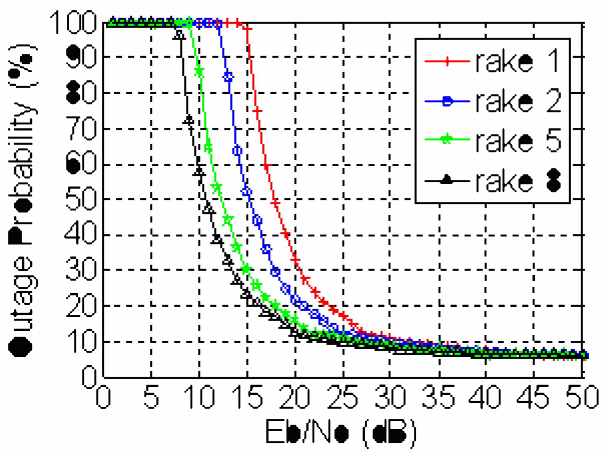

Figure 5. Outage probability versus SNR using different numbers of rake receiver in Area II with traffic

captures all of the received signal power by having numbers of fingers equal to the number of multipath components. Using the I-rake, an infinite number of correlators are required to distinguish infinite multipath components. This is difficult to carry out in reality. Second, S-rake is a selective rake receiver which selects L multipath components having largest signal amplitudes. The S-rake receiver has much less complexity than the A-rake. Third, P-rake is similar to S-rake. The principle is that the first multipath component will be typically strongest and contain the most received signal power. But the disadvantage is that it may not correctly choose the strongest multipath components. In this paper, we shall take the S-rake receiver. We will evaluate system performance using L as a parameter (L = 1, 2, 5, and 8).

III. Numerical results

We employ the ray-tracing technique with simplified input layout geometry in an the outdoor environment. Fig. 1 shows the outdoor environment used for our experiment. There are five buildings from A to E in the area. The building heights are given the numerical order as 20, 30, 35, 20 and 25 m. The transmitting antenna is set on building B with the horizontal coordinate (-15m, -5m) and its height is 15m. The height of the receiving antenna is 1.5m. The transmitting and receiving antennas are both omidirectional antennas. We consider Area I and Area II in the outdoor environment with traffic.

We now consider Area I and Area II in the outdoor environment with traffic. In the Area I and II, we take into account the effect of not only the buildings but also the vehicles. Fig. 2 and Fig. 3 show the dispatch of vehicles in Area I and Area II respectively.

Our goal is to realize the characteristics of wireless communication system in outdoor environments. We use the ray tracing model to simulate the environments in wireless communication systems. Moreover, taking advantage of different techniques to improve the performance of wireless communications systems such as different antenna arrays and rake receivers.

We considered the conditions with and without traffic in the UWB system in this paper. We adopt the S-rake with different number "L" of rakes in our simulations to reduce the BER and improve outage probabilities.

In order to improve the outage probability, we again adopt the S-rake in our experiment. Figures 4 and 5 are given for Area I and II with traffic. We compare the results with different number of rakes. In the Figures 4 to 5, the outage probability is reduced more by taking more numbers of rakes. For BER $<10^{-5}$, at SNR=20dB, the outage probability will be reduced by about 20% when the number of rakes is increased from 1 to 5. Further increase of the number of rakes will not improve the outage probability much.

IV. Conclusion

Ultra-wideband outdoor communication characteristics with traffic are presented. By using the impulse response of the multipath channel, the bit error rate for UWB outdoor communication are evaluated. Also, outage probabilities are calculated for various different scenarios. Moreover, we use the rake receiver technique to improve the performance of outage probability.

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