An Optimization of UWB Antenna Location

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Abstract

A novel optimization procedure for the location of transmitting antenna in ultra-wideband (UWB) wireless communication systems is presented. The impulse responses of different transceiver locations are computed by ray-tracing techniques and inverse fast Fourier transform (IFFT). 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, outage probability of arbitrary region of receivers for any given location of the transmitter can be computed. The optimization of location of transmitting antenna in this paper is using non-uniform steady-state genetic algorithm (NU-SSGA) to minimize the outage probability. The optimization algorithm includes not only good searching accuracy but also calculating efficiency.

1. Introduction

UWB technology based on the WiMedia standard brings the convenience and mobility of wireless communications to high-speed interconnects in devices throughout the digital home and office. UWB transmissions can legally operate in the range from 3.1 GHz up to 10.6 GHz at a limited transmit power of -41dBm/MHz [1].

All wireless systems must be able to deal with the challenges of operating over a multi-path propagation channel, where object in the environment can cause multiple reflections to arrive at the receiver. BER degradation is caused by inter-symbol interference (ISI) due to a multi-path propagation made up of radio wave reflections by walls, ceilings, floors and office fixtures. In general, effective antenna selection and deployment strategies are important for reducing BER in indoor wireless systems [2], [3].

The remainder of this paper is organized as follows. In Section II, channel modeling and system description are presented. Section III shows the numerical results. Finally, the conclusion is drawn in section IV.

2. CHANNEL MODELING AND SYSTEM DESCRIPTION

Ray-tracing techniques can deal with high frequency radio wave propagation in the complex indoor environment [4], [5]. It conceptually assumes that many triangular ray tubes are shot from the transmitting antenna (Tx), and each ray tube, bouncing and penetration 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, the total received field at the Rx can be calculated. The depolarization yielded by multiple reflections on walls and floors is also taken into account in our simulations.

The equation for modeling the multi-path radio channel is a linear filter with an impulse response given by

$$h(t)=\sum_{k=1}^{L}\alpha_k\delta(t-\tau_k) \qquad (1)$$

where k is the path index, α_k is the path attenuation, τ_k is the time delay of the k th path and $\delta(\cdot)$ is the Dirac delta function. The goal of channel modeling is to determine the α_k and τ_k for any transmitter-receiver location.

The Block diagram of the UWB communication system is shown in Fig. 1.

$$s(t)=\sqrt{E_t}\sum_{i=1}^{N}p(t-(i-1)T_d)A_i \qquad (2)$$

Finally, the average BER on the nth receiving bit can be expressed as

$$P_e(z(n)|\vec{A})=\sum_{i=1}^{2^m}P(\vec{A}_m)\times\frac{1}{2}erfc\left(\frac{v(n)}{\sqrt{2}\sigma}\times A_n\right) \qquad (3)$$

Actually, in the practical communication systems, it is important to investigate the BER in the sense of outage probability. An outage probability is defined as the event that the BER is less than a certain threshold level. If we give a threshold level BER_{TL} , then the outage probability can be written as

$$P_o=P(P_e<BER_{TL}) \qquad (4)$$

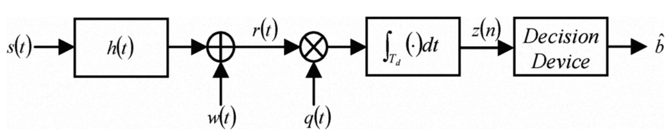

Figure 1: Block diagram of the UWB communication systems.

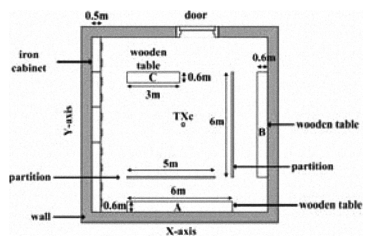

Figure 2: Top view of the indoor environment, which A, B and C are all wooden table.

3. NUMERICAL RESULTS

Fig. 2 is the top view of the indoor environment with dimensions of 10 m (length) x 10 m (width) x 3 m (height). Note that the relative dielectric constant and conductivity of materials will change with the frequency in the UWB channel [9], [10].Therefore, the frequency dependence of the dielectric and conductivity of materials is carefully considered in the channel simulation [11].

Two difference cases for different definition of transceiver locations are considered. The transmitting antenna TXc (5.25m, 5m, 1m) located in the center of the indoor environment is used for reference in Fig. 2, which the reference position is often chosen without any optimization in general situation. The outage probability versus SNR for the position of TXc and optimal transmitting antenna location (GA-1) by NU-SSGA are shown in Fig. 3. The GA-1 expresses that the outage probabilities are calculated when transmitting antenna is located on an optimal position (2.65 m, 2.02 m, 1 m). The outage probabilities versus SNR for different searching regions are shown in Fig. 4, which GA-2A, GA-2B and GA-2C express that the outage probabilities are calculated when transmitting antenna are located on the optimal position (7.89 m, 0.02 m, 1 m) of the wooden table A, (9.4 m, 6.26 m, 1 m) of the wooden table B and (4.99 m, 7.87 m, 1 m) of the wooden table C, respectively. It is seen that the outage probability at SNR = 40dB are about 10%, 19% and 33% for the GA-2A, GA-2B and GA-2C respectively. As a result, the best location for transmitter is located on the wooden table A (7.89 m, 0.02 m, 1 m) in this case.

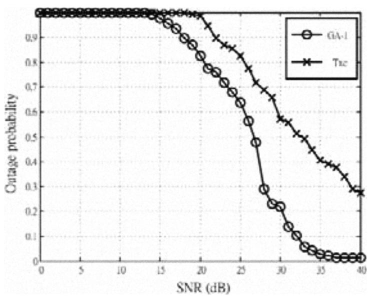

Figure 3: Outage probability versus SNR for case 1.

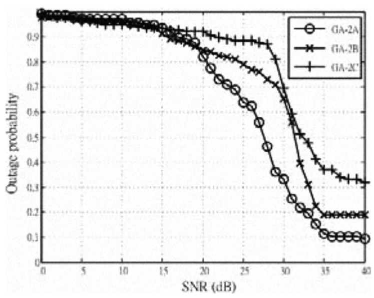

Figure 4: Outage probability versus SNR for case 2.

4. Conclusions

The study has shown that we can deploy antenna position by NU-SSGA to improve wireless communication system performance in real environment. By using the impulse responses of these multi-path channels, the BER performance for UWB communication system with BPAM modulation are calculated.

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