Bit Error Rate Reduction of Multi-user By UWB Antennas

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Abstract- In this paper, a new ultra wideband circular antenna array (UCAA) combining genetic algorithm to minimize the bit error rate (BER) is proposed. Based on the topography of the antenna and the BER formula, the array pattern synthesis problem can be reformulated into an optimization problem and solved by the genetic algorithm. Simulation results show that the synthesized antenna array pattern is effective to focus maximum gain to the multi-user which scales as the number of array elements. In other words, the receiver can increase the received signal energy to noise ratio. The synthesized array pattern also can mitigate severe multipath fading in complex propagation environment. As a result, the BER can be reduced substantially in indoor UWB communication system.

1. INTRODUCTION

Ultra wideband (UWB) technology is an ideal candidate for a low power, low cost, high data rate, and short rang wireless communication systems. According to the Federal Communication Commission (FCC), UWB signal is defined as a signal having fractional bandwidth greater than 20% of the center frequency [1]. Ultra wide bandwidth of the system causes antenna design to be a new challenge [2].

Smart antennas employ arrays of antenna elements and can integrate multiple antenna elements with a signal processing. These smart antennas combine the signals from multiple antennas in a way that mitigates multipath fading and maximize the output signal-to-noise ratio. It can dramatically increase the performance of a communication system. The smart antenna technology in wireless communication can apply to the receiver [3] and the transmitter [4].

In this paper, the genetic algorithm is used to regulate the antenna feed length of each array element to minimize the BER performance of the communication system. The remaining sections of this paper are organized as follows: section 2 briefly explains the formulation of the problem about channel modeling. Section 3 describes the genetic algorithm. The propagation modeling and numerical results are then presented in section 4 and conclusion is made in section 5.

2. SYSTEM DESCRIPTION

A UWB Channel modeling

Because the UWB communication span a wide bandwidth in the frequency domain, the channel impulse response variations are significant for different type antennas [5]. As a result, we do not only describe the antenna radiation pattern which varies with different frequencies but also use the SBR/Image technique to calculate the channel impulse response which includes angular characteristics of radiation patterns and the variation between different frequencies of wave propagation.

SBR/Image techniques are good techniques to calculate channel frequency response for wireless communication [6]. In this paper, we develop SBR/Image techniques including antenna pattern to model our simulation channel. It can perform the identification of major scattering objects causing reflection, diffraction and penetration in our simulation environment. The SBR/Image technique conceptually assumes that many triangular ray tubes (not rays) are shot from a transmitter. The triangular ray tubes whose vertexes are on a sphere are determined by the following method. First, we construct an icosahedron which is made of 20 identical equilateral triangles. Then, each triangle of the icosahedrons is tessellated into a lot of smaller equilateral triangles. Finally, these small triangles projected on to the sphere and each ray tube whose vertexes determined by the small equilateral triangle are constructed. Then each ray tube will bounce and penetrate in the simulate environments. If the receiver falls within the reflected ray tube, the contribution of the ray tube to the receiver can be attributed to an equivalent source (image). Using these images and received fields, the channel frequency response can be obtained as following

$$H(f) = \sum_{i=1}^{N_i} |a_i(f)| e^{j\theta_i(f)} \tag{1}$$

Where f is the frequency of sinusoidal wave, i is the path index, θ_i is the i-th phase shift, $|a_i|$ is the i-th receiving magnitude which depend on the radiation vector of the transmitting and receiving antenna in. Note that the receiving antenna in our simulation is only one omnidirectional UWB dipole antenna and the transmitter is the UWB circular antenna array (UCAA) which has been described in above section. The channel frequency response of UWB can be calculated by equation (1) in the frequency range of UWB.

The frequency is response are transformed to the time domain by using the inverse fast Fourier transform with the Hermitian signal processing [7]. Therefore, the time domain impulse response of the equivalent baseband can be written as follows

$$h_b(t) = \sum_{m=1}^{M} \alpha_m \delta(t - \tau_m) \tag{2}$$

Where M is the number of paths observed at time. α_m and τ_m are the channel gain and time delay for the n-th path respectively.

B Formulation of BER

As shown in Fig. 1, {a} is the input binary data stream and $\{\hat{a}\}$ is the output binary data stream after demodulator and decision device. When {a} passing through the B-PAM modulator, the transmitted UWB pulse stream is expressed as follows:

$$x(t) = \sqrt{E_t} \sum_{n=0}^{\infty} p(t - nT_d) d_n \tag{3}$$

The average BER for B-PAM IR UWB system can be expressed as

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

3. GENETIC ALGORITHM

Genetic algorithms are the global numerical optimization methods based on genetic recombination and evaluation in nature [8]. They use the iterative optimization procedures, which start with a randomly selected population of potential solutions. Then gradually evolve toward a better solution through the application of the genetic operators. Genetic algorithms typically operate on a discretized and coded representation of the parameters rather than on the parameters themselves. These representations are often considered to be “chromosomes”, while the individual element, which constitutes chromosomes, is the “gene”. Simple but often very effective chromosome representations for optimization problem involving several continuous parameters can be obtained through the juxtaposition of discretized binary representations of the individual parameter.

When analyzing the circular antenna array, the feed length of each array element provides the phase delay of excitation current which varies with different frequencies.

3. NUMERICAL RESULTS

A realistic environment was investigated. It consists of a living room with dimensions 10mx10mx3m, housing one metallic cupboard and three wooden bookcases. Both of the cupboard and bookcase are 2 meter in height. The radio wave can penetrate through the wooden bookcase and totally reflect by the metallic cupboard. The plan view of the simulated environment is shown in Fig. 2. Tx and Rx1, Rx2 antennas were all mounted 1 meter above the floor. The transmitter Tx position is (7m,5m,1m). We simulated scenarios with different Rx positions. Scenario has two receivers: one is a line-of-sight path to the Rx1(3m,8.5m,1m) and the other is no line-of-sight path to the Rx2 (6m,2m,1m). Tx and Rx1 are at a distance of approximately 5.315 meter. Tx and Rx3 are at a distance of approximately 3.2 meter. The height of the wooden bookcase was higher than that of the Tx, Rx2. A three-dimensional SBR/Image technique combined antenna radiation pattern has been presented in this paper. This technique is used to calculate the UWB channel impulse response for each location of the receiver.

Three kinds of transmitting antennas were used in this simulation scenario: (a) Only one UWB printed antenna (OUA) (b) A circular array of eight UWB printed Dipole antenna, each element antenna has the same feed Length without GA regulating (NOGA-UCAA) (c) A circular array of eight UWB printed dipole antenna , each element antenna feed length was regulated by GA(GA-UCAA).

Channel impulse response of TX – RX 1 was shown in Fig. 3. In this scenario, GA-UCAA was used as the transmitting antenna. Channel impulse response of TX – RX2 was presented in Fig. 4. Similar to Fig 3., the transmitting antenna was GA-UCAA.

Fig. 5 shows the BER V.S. SNR for Tx-Rx1, which is a line-of-sight path, using three kinds of transmitters. Fig 5 also shows the BER V.S. SNR for Tx-Rx1-Rx2, whose transmitter is GA-UCAA. Here SNR is defined as the ratio of the average transmitting power to the noise power. The results show that the BER curve decrease greatly when using the GA-UCAA to be transmitter. It is due to the fact that the GA-UCAA can minimize the fading and reduce the mulitpath effects. It also can focus the synthesized antenna array pattern to optimize available processing gain to the receiver.

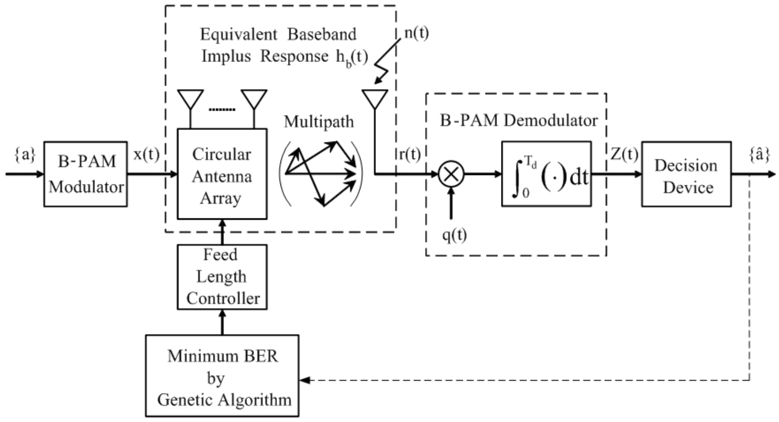

Figure 1. Block diagram of the simulated system

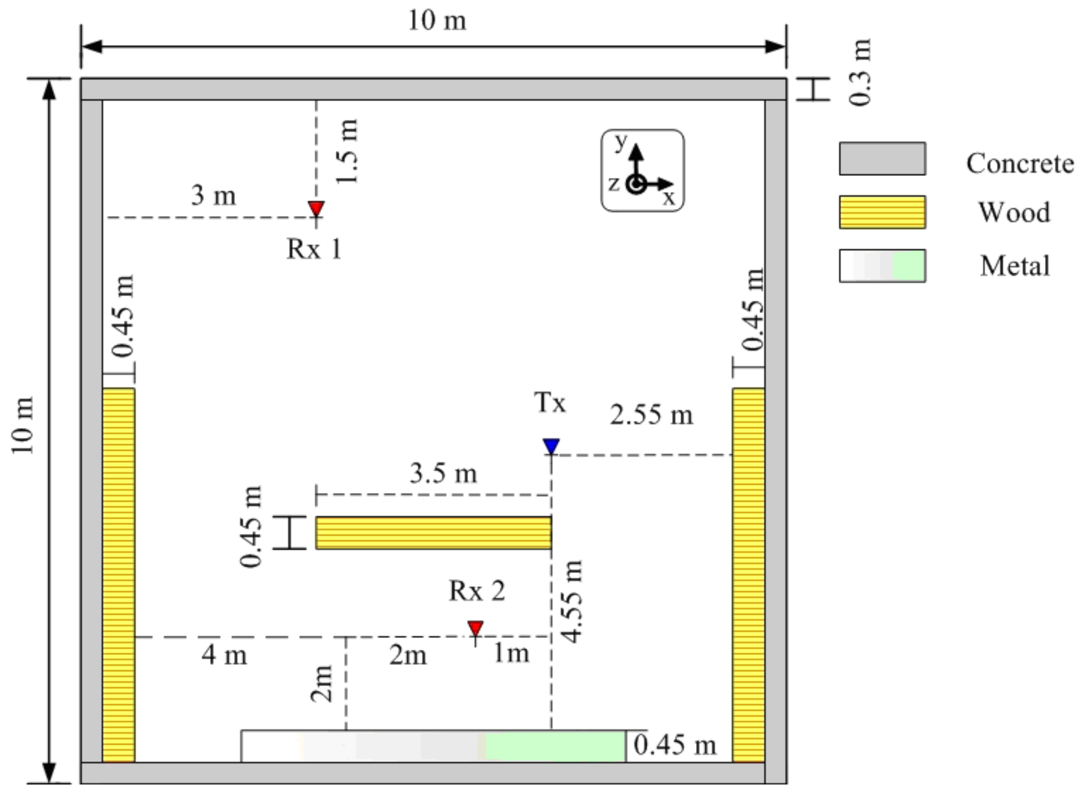

Figure 2. Block diagram of the simulated system

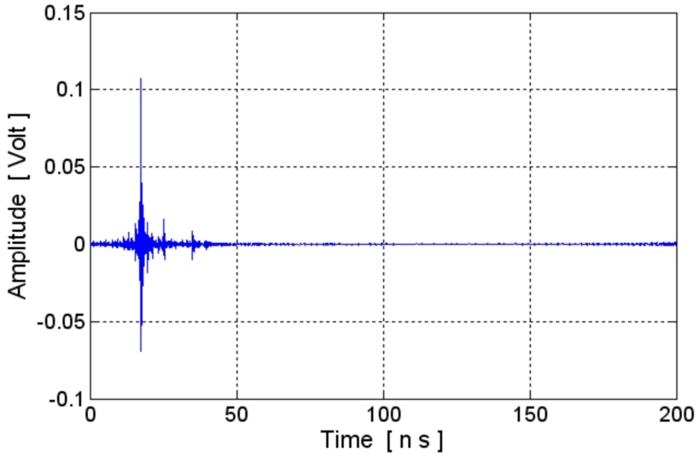

Figure 2. The channel impulse response of TX – RX 1 using GA-UCAA as transmitting antenna

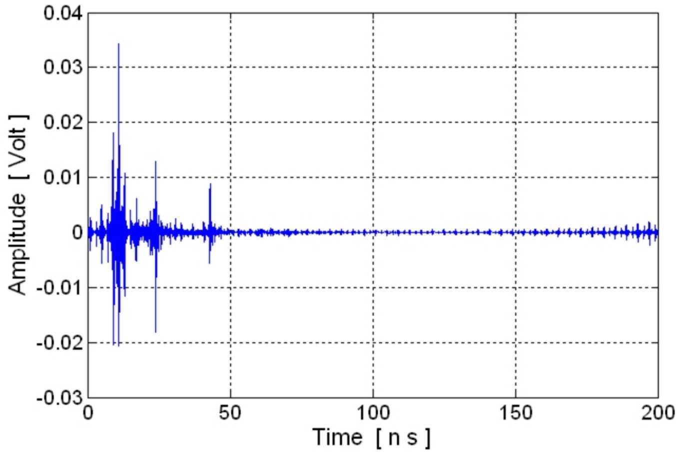

Figure 3. The channel impulse response of TX – RX 2 using GA-UCAA as transmitting antenna

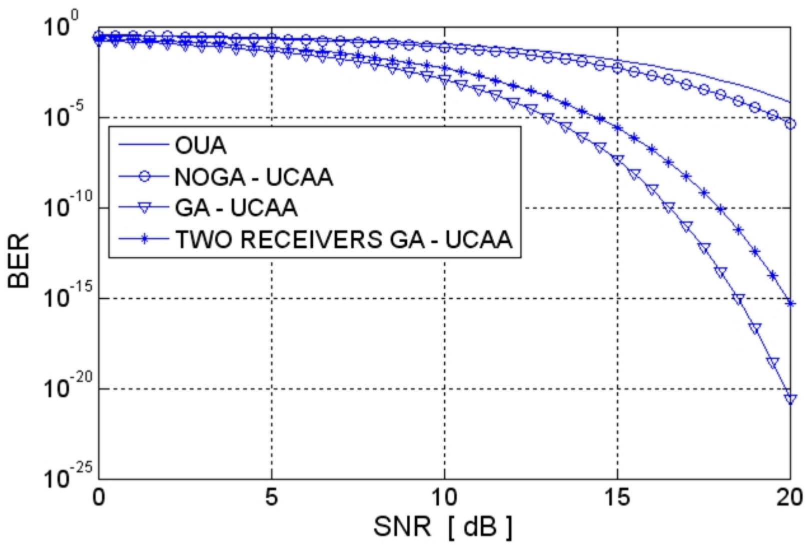

Figure 4. BER V.S. SNR over Scenario for kinds of transmitter

4. CONCLUSIONS

Using the smart UWB circular antenna array to minimize the BER performance in indoor wireless local loop is presented. The impulse response of the channel is computed by SBR/Image techniques, inverse fast Fourier transform and Hermitian processing. By using the impulse response of the multipath channel and the genetic algorithm synthesizing optimal antenna radiation pattern, the BER performance of B-PAM IR UWB communication system is investigated. Base on the BER formulation, the synthesis problem can be reformulated into an optimization problem. In this paper, the fitness function is defined as the reciprocal of BER of the system. The genetic algorithm maximizes the fitness function by adjust the feed length of each antenna. Numerical results show that the BER can be reduced substantially in indoor UWB communication system.

ACKNOWLEDGEMENT

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