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다중사용자 기반 DS-BPAM과 TH-BPPM UWB 시스템의 성능분석

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Performance Analysis of Multi-user based DS-BPAM and TH-BPPM UWB System

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요 약

본 논문에서는 다중사용자 기반 DS-BPAM UWB 시스템과 TH-BPPM UWB 시스템의 평균 비트에러 확률 계산 방법을 분석하였다. 최근에는 TH-BPPM UWB 시스템이 각광받고 있으며 다중사용자 기반에서는 DS-BPAM UWB 시스템에서 좋은 성능을 보인다. 본 논문에서는 이상적인 AWGN 채널 환경과 상관 수신기로 다중사용자 기반에서 DS-BPAM UWB 시스템과 TH-BPPM UWB 시스템에서의 정확한 BER 산출 방법을 제안하였다.

Key Words : Direct Sequence (DS), Time Hopping (TH), Pulse Position Modulation (PPM), Multiple Access (MA), Ultra Wideband (UWB)

ABSTRACT

In this paper, analytical methods for calculating the average probability of bit error of direct sequence binary pulse amplitude modulation ultra wideband (DS-BPAM UWB) system and time hopping binary pulse position modulation ultra wideband (TH-BPPM UWB) system are given. For the multi-user DS-BPAM UWB system, the bipolar pulse amplitude modulation is used in order to achieve better performance. As we know, more attention is paid to the TH-BPPM UWB systems recently. In this paper, we first introduce the accurate BER calculation methods of the multi-user DS-BPAM UWB and TH-BPPM UWB systems and then give the performance analysis over the ideal AWGN channel and a correlation receiver.

Ⅰ. Introduction

UWB technology proposed in [1][2] is currently being investigated as a promising solution for high-capacity wireless personal area network (WPAN) for its significant characteristics. The very small power spectral densities (PSD) of UWB systems ensure only minimal mutual interference between UWB and other communication applications. In UWB system, data is transmitted using sub-nanosecond baseband pulses without the need for mixers or power amplifier (PA), and the occupied frequency band is from near direct current (DC) to several GHz. The high data transmission rate makes UWB technology attractive for multimedia communications. The characteristics of low cost and low power usage make

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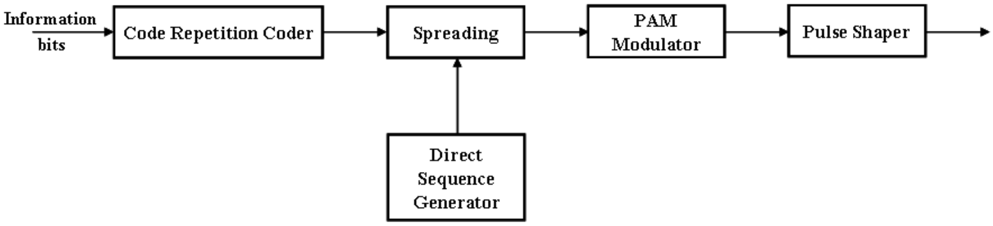

Fig. 1 Transmission diagram of DS-PAM-UWB

it promising for mobile applications. Through Shannon's capacity equation: $C=W\log_2\left(1+\frac{S}{N}\right)$, we can get some characteristics of UWB system. UWB system can provide the fading robustness; wideband nature of the signal reduces time varying amplitude fluctuations (fading). This reduces fade margin in link budgets. UWB technology also has other characteristics, such as, position location capability and application flexibility.

In our knowledge, there are no much literatures about the analysis of the scheme of multi-user DS-BPAM UWB system [4] and its application in multimedia communication. In this paper, the bit error rate (BER) of the multi-user DS-BPAM UWB system and the multi-user TH-BPPM UWB system are presented and analyzed in detail over AWGN channel. The results of computer simulation in data and image transmission show that the DS-BPAM UWB system can achieve better performance with the smaller complexity compared with the multi-user TH-BPPM UWB system.

The organization of this paper is as follows. In Section II, an overview of the multiuser-bsed DS-UWB system model using antipodal PAM and the TH-BPPM multi-user UWB system is provided. Section III presents the system multiple access performance in terms of the number of total active users supported as well as the total multiple access transmission capacity. Section IV describes the simulation results obtained and interpretations. Finally, conclusions are presented in Section V.

Ⅱ. SYSTEM DESCRIPTION

2.1 DS-UWB System Model

We give a direct sequence spread spectrum UWB system with N_u multiple access users. The basic single user transmission case of DS-BPAM UWB system is shown in Figure 1. Assume that each user has a unique pseudo-noise (PN) sequence with N_c chips per message symbol period T_f such that $N_c T_c = T_f$, where N_c is the spread spectrum processing gain. A typical transmitted signal of the k-th user can be expressed as

$$s_{tr}^{(k)}(t)=\sum_{j=-\infty}^{\infty}\sum_{n=0}^{N_c-1} d_j^{(k)} c_n^{(k)} w_{tr}(t-jT_f-nT_c) \qquad (1)$$

where $w_{tr}(t)$ is the transmitted monocycle waveform, seen in [1], $\{D_j^{(k)}\}$ is the binary information bit and $\{d_j^{(k)}\}$ is the modulated data symbols with $d_j^{(k)}=2D_{j/N_s}^{(k)}-1$, N_s is the pulse repetition time, $\{c_n^{(k)}\}$ is the spread chips with duration T_c.

When we consider there are N_u active users in the system, the received signal $r(t)$ can be expressed as

$$r(t)=\sum_{k=1}^{N_u} A_k s_{rec}^{(k)}(t-\tau_k)+n(t) \qquad (2)$$

in which A_k, τ_k represents the channel attenuation and the channel delay corresponding to the kth transmitter, and $n(t)$ is the AWGN noise modeled as $N(0,\sigma_n^2)$. Since an ideal channel and antenna system modifies the shape of the transmitted monocycle $w_{tr}(t)$ to $w_{rec}(t)$ at the output of the receiver antenna. For the purpose of analysis, we have assumed that the true transformed pulse shape $w_{rec}(t)$ is known at the receiver. In the receiver end, we can decide the received information bit according to the output of correlator. Since we assume that the receiver has achieved perfect clock and sequence synchronization for the signal transmitted by the first transmitter. The template can be set as

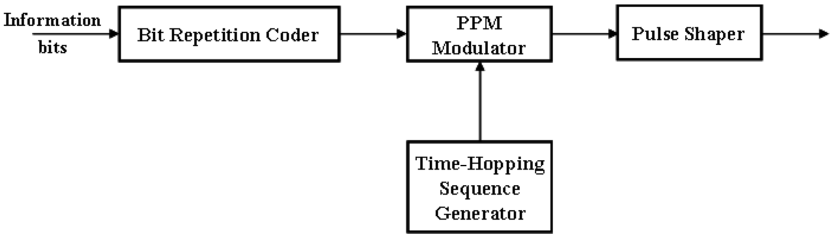

Fig. 2. Transmission diagram of TH-PPM UWB System

$$v(t)=\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t) \text{ and}$$

$$v_{bit}(t)=\sum_{j=iN_s}^{(i+1)N_s-1}\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t-jT_f-nT_c-\tau_1) \quad (3)$$

$$=\sum_{j=iN_s}^{(i+1)N_s-1} v(t-jT_f-nT_c-\tau_1)$$

The correlation output can be expressed as

$$\alpha=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+1)T_f} r(t)\,v_{bit}(t)dt \quad (4)$$

$$=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+1)T_f} r(t)\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c)\,dt$$

The decision consists of

$$\text{if} \quad \alpha>0, \quad D_l^1=0; \quad \text{if} \quad \alpha<0, \quad D_l^1=1 \quad (5)$$

We can further write the received signal as

$$r(t)=A_1\sum_{n=0}^{N_c-1} d_l^1 c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c)+n_{tot}(t) \quad (6)$$

where the interference and noise part is

$$n_{tot}(t)=\sum_{n=2}^{N_u} A_k s_{rec}(t-\tau_k)+n(t) \quad (7)$$

Now, we go on with the calculation of the output of the correlator and denote it as

$$\alpha=m+n_d \quad (8)$$

$$m=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+1)T_f}\begin{bmatrix} A_1\sum_{n=0}^{N_c-1} d_l^1 c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c) \\ \times\sum_{m'=0}^{N_c-1} c_m^{(1)} w_{rec}(t-\tau_1-lT_f-m'T_c)\end{bmatrix} dt$$

$$=\sum_{l=0}^{N_s-1}\int_0^{T_f} A_1\sum_{n=0}^{N_c-1} d_l^1 w_{rec}^2(t-nT_c)\,dt=N_sN_cA_1d_l^1E_w \quad (9)$$

where

$$E_w=\int_{-\infty}^{\infty} w_{rec}^2(x)\,dx \text{ and}$$

$$n_d=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+11)T_f} n_{tot}(t)\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c)\,dt \quad (10)$$

The expression in equation (10) is further simplified as

$$n_d=\sum_{k=2}^{N_u} A_k n^{(k)}+n_{rec} \quad (11)$$

where $n^{(k)}$ is caused by multiple-access noise from the k-th user and is given by

$$n^{(k)}=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+1)T_f}\begin{bmatrix} s_{rec}^{(k)}(t-\tau_k) \\ \times\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c)\end{bmatrix} dt \quad (12)$$

n_{rec} is caused by the receiver noise and other sources of non-monocycle interference,

$$n_{rec}=\sum_{l=0}^{N_s-1}\int_{\tau_1+lT_f}^{\tau_1+(l+1)T_f}\left[n(t)\sum_{n=0}^{N_c-1} c_n^{(1)} w_{rec}(t-\tau_1-lT_f-nT_c)\right] dt \quad (13)$$

Under assumption in [1], the mean value and variance of n_{rec} are given by zero and σ_{rec}^2, respectively, where

$$\sigma_{rec}^2=N_sN_c\sigma_n^2E_w \quad (14)$$

2.2 TH-PPM UWB System

A typical TH-PPM UWB transmission system is shown in Figure 2. The transmitted signal of the k-th user is expressed as

$$s_{tr}^{(k)}=\sum_{j=-\infty}^{\infty} A^{(k)} w_{tr}\left(t-jT_f-c_j^{(k)}T_c-d_j^{(k)}\delta\right) \quad (15)$$

$\{D_j^{(k)}\}$ is the binary information bit and $\{d_j^{(k)}\}$ is the modulated data symbols with $d_j^{(k)} = 2D_{j/N_s}^{(k)} - 1$, N_s is the pulse repetition time, $\{c_n^{(k)}\}$ is the TH sequence with duration T_c and period N_p. We set $0 \le c_n^{(k)} \le N_h$ with $N_h T_c \le T_f$. δ is the time delay used in modulation. When we consider there are N_u active users in the system, the received signal $r(t)$ can be expressed as

$$r(t) = \sum_{k=1}^{N_u} A_k s_{rec}^{(k)}(t-\tau_k) + n(t) \tag{16}$$

In the receiver end, we do the correlation similar with the DS-UWB system. We would use the assumptions like before. The deduction process is same with [1]. The template can be set as

$$\begin{aligned} v(t) &= w_{rec}(t) - w_{rec}(t-\delta) \\ w_{bit}(t) &= \sum_{j=iN_s}^{(i+1)N_s-1} w\left(t - jT_f - c_j^{(1)}T_c - \tau_1\right) \text{ and} \\ v_{bit}(t) &= w_{bit}(t) - w_{bit}(t-\delta) \\ &= \sum_{j=iN_s}^{(i+1)N_s-1} v\left(t - jT_f - c_j^{(1)}T_c - \tau_1\right) \end{aligned} \tag{17}$$

The correlation output can be expressed as

$$\begin{aligned} \alpha &= \int_{t\in T_i} r(t) v_{bit}(t) dt \\ &= \sum_{j=iN_s}^{(i+1)N_s-1} \int_{t\in T_i} r(t)\, v\left(t - jT_f - c_j^{(1)}T_c - \tau_1\right) dt \end{aligned} \tag{18}$$

The decision is

$$\text{if} \quad \alpha > 0, \quad D_l^1 = 0; \quad \text{if} \quad \alpha < 0, \quad D_l^1 = 1 \tag{19}$$

We can further write the received signal as

$$r(t) = A_1 s^{(1)}(t-\tau_1) + n_{tot}(t) \tag{20}$$

where the interference and noise part is

$$n_{tot}(t) = \sum_{n=2}^{N_u} A_k s_{rec}(t-\tau_k) + n_t(t) \tag{21}$$

Now, we can denote the output of the correlator as

$$\alpha = m + n_d \tag{22}$$

$$\begin{aligned} m &= \int_{t\in T_i} A_1 w_{bit}(t) v_{bit}(t)\, dt \\ &= A_1 \sum_{l=0}^{N_s-1} \int_{-\infty}^{\infty} w(t)[w(t) - w(t-\delta)] dt = A_1 N_s m_p \end{aligned} \tag{23}$$

where

$$\begin{aligned} m_p &= \int_{-\infty}^{\infty} w(t)[w(t) - w(t-\delta)]\, dt \text{ and} \\ n_d &= \int_{t\in T_i} n_{tot}(t)\, v_{bit}(t)\, dt \end{aligned} \tag{24}$$

The expression in equation (10) is further simplified as

$$n_d = \sum_{k=2}^{N_u} A_k n_k + n_{rec} \tag{25}$$

where n_k is defined like the precious DS-UWB system.

$$\begin{aligned} \sigma_d^2 &= \sigma_{rec}^2 + \sum_{k=2}^{N_u} A_k^2 E\{n_k^2\}, \\ n_k &= \int_{t\in T_i} s^{(k)}(t-\tau_k)\, v_{bit}(t)\, dt \end{aligned} \tag{26}$$

where $E\{n_k^2\} = N_s \sigma_a^2$ and

$$\sigma_a^2 = T_f^{-1} \int_{-\infty}^{\infty} \left[\int_{-\infty}^{\infty} w(t-\tau)\, v(t)\, dt \right]^2 d\tau.$$

n_{rec} is caused by the receiver noise and other sources of non-monocycle interference,

$$n_{rec} = \int_{t\in T_i} n(t)\, v_{bit}(t)\, dt \tag{27}$$

Under assumption in [1], the mean and variance of n_{rec} are given by zero and σ_{rec}^2, respectively, where

$$\sigma_{rec}^2 = E\left\{ \left[\int_{t\in T_i} n(t)\, v_{bit}(t)\, dt \right]^2 \right\} \tag{28}$$

Ⅲ. Performance Analysis

In our proposed DS-UWB system, the SNR is defined as

$$SNR(N_u) = \frac{m^2}{E\left[|n_d|^2\right]} \tag{29}$$

Since each of the variable defined in the expression of n_d defined in are independent with zero mean, the quantity $E\left[|n_d|^2\right]$ becomes

$$E\left[|n_d|^2\right] = N_s N_c \sigma_n^2 E_w + N_s N_c \sigma_a^2 \sum_{k=2}^{N_u} A_k^2 \tag{30}$$

where

$$\sigma_a^2 = T_c^{-1}\int_{-\infty}^{\infty}\left[\int_{-\infty}^{\infty} w_{rec}(x-t)\,w_{rec}(x)\,dx\right]^2 dt \qquad (31)$$

Then the receiver SNR can be expressed as

$$SNR(N_u) = \begin{pmatrix} \left[\dfrac{N_s N_c A_1^2 E_w}{\sigma_n^2}\right]^{-1} \\ + \left[\dfrac{N_s N_c E_w}{\sigma_a^2}\right]^{-1} \displaystyle\sum_{k=2}^{N_u}\left(\dfrac{A_k^2}{A_1^2}\right)\end{pmatrix}^{-1} \qquad (32)$$

When the single use case is considered, the SNR is

$$SNR(N_u = 1) = \frac{N_s N_c A_1^2 E_w}{\sigma_n^2} \qquad (33)$$

The system probability of error can be shown as

$$P_e = Q\left(\begin{pmatrix} \left[\dfrac{N_s N_c A_1^2 E_w}{\sigma_n^2}\right]^{-1} \\ + \left[\dfrac{N_s N_c E_w}{\sigma_a^2}\right]^{-1} \displaystyle\sum_{k=2}^{N_u}\left(\dfrac{A_k^2}{A_1^2}\right)\end{pmatrix}^{-\frac{1}{2}}\right) \qquad (34)$$

In this TH-PPM UWB system, the SNR is defined as $SNR(N_u) = \dfrac{m^2}{E\left[\,|n_d|^2\right]}$.

We can get

$$E\left[\,|n_d|^2\,\right] = \sigma_{rec}^2 + N_s \sigma_a^2 \sum_{k=2}^{N_u} A_k^2 \qquad (35)$$

Then the receiver SNR can be expressed as

$$SNR(N_u) = \begin{pmatrix} \left[\dfrac{(A_1 N_s m_p)^2}{\sigma_{rec}^2}\right]^{-1} \\ + \left[\dfrac{N_s m_p^2}{\sigma_a^2}\right]^{-1} \displaystyle\sum_{k=2}^{N_u}\left(\dfrac{A_k^2}{A_1^2}\right)\end{pmatrix}^{-1} \qquad (36)$$

Ⅳ. Simulations Results

In this section, we present some computer simulation results about these two systems. Like the same examples in [1], the received pulse is modeled as $w_{rec}(t) = \left[1 - 4\pi\left(\dfrac{t}{\tau_m}\right)^2\right]\exp\left[-2\pi\left(\dfrac{t}{\tau_m}\right)^2\right]$, shown in Figure 3, where $\tau_m = 0.2$ns, $T_w = 0.5$ns. In DS-BPAM UWB system, we use gold code sequence with the characteristics $N_c = 7$ and $T_c = 1$ns. For each information bit, we repeat it 2 times ($N_s = 2$), this is the same for these two UWB systems. In TH-BPPM

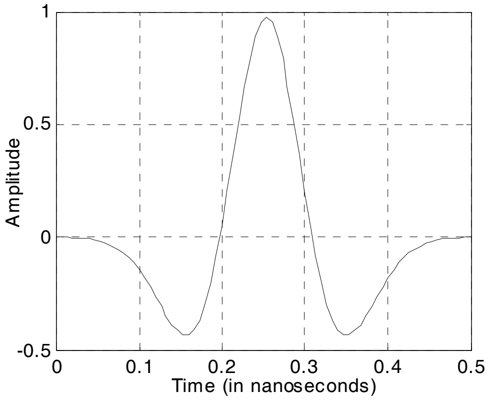

Fig. 3. Transmit Gaussian Waveform

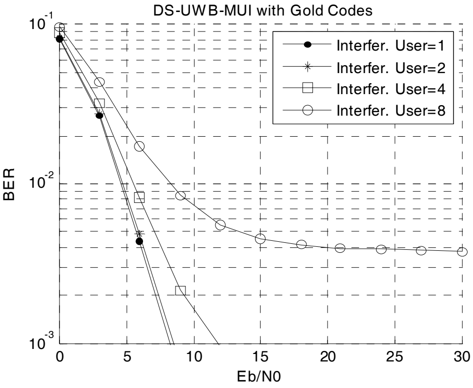

Fig. 4. BER Performance of BPAM DS-UWB

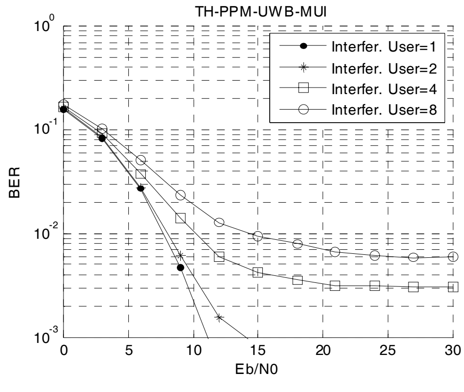

Fig. 5. BER Performance of BPPM TH-UWB

UWB system, the parameters are the same with DS-BPAM UWB system. We set time delay $\delta = T_w$, $T_f = N_h T_c = N_c T_c$. The information bit rate is $R_b = 1/(N_s N_c T_c) \approx 71.43$ Mbps. The image is a Lenna BMP picture. In this paper, we concentrate on the performance and application of multi-user UWB system and do not use the image source compression.

The BER performance of the DS-BPAM UWB and TH-BPPM UWB systems is shown in Figure 4 and Figure 5, respectively. In our simulation, we consider the interference users to be 1, 2, 4 and 8.

Ⅴ. Conclusion

In this paper, the performance of the multi-user DS-UWB system and multi-user TH-UWB system is analyzed over multi-user interference and AWGN, respectively. In order to minimize the power consumption and get better performance, antipodal modulation is used in DS-BPAM UWB system. We also modify some parameters for the comparison between these two systems. The useful BER expressions are deduced for both multi-user DS-BPAM UWB and TH-BPPM UWB scheme.

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