Performance Enhancement of a TH-PPM UWB System Using a Near-Interference Erasure Scheme

Min Jeong Kim, Bang Chul Jung, Jo Woon Chong and Dan Keun Sung
Dept. of EECS, Korea Advanced Institute of Science and Technology
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, KOREA
E-mail: mjkim82@lge.com, jwchong@cnr.kaist.ac.kr, bcjung@cnr.kaist.ac.kr, dksung@ee.kaist.ac.kr

***Abstract*— In this paper, we mathematically analyze the performance of a near-interference erasure scheme for TH-PPM UWB systems and derive an equation for an optimum threshold which minimizes the bit error rate (BER). We also apply the optimum threshold derived mathematically to practical TH-PPM UWB systems and investigate the effect of the threshold on the system performance. Finally, we compare the BER performance obtained by the mathematical analysis with that of computer simulation.**

***Index Terms* - Ultra-wideband, Interference, Access control.**

I. INTRODUCTION

Recently, ultra-wideband (UWB) technologies have been considered as a promising technology for wireless personal area networks (WPANs). As a multiple access and modulation scheme for the UWB technology, a time hopping-based pulse position modulation (TH-PPM) system has been proposed [1], [2] and the performance of the TH-PPM UWB systems has been studied [2], [3], [4]. They assumed that the received signal powers from users in a network are equal. However, in practical TH-PPM UWB systems, the received signal powers from the users are different since every user transmits signals with a fixed power and the distances between the target receiver and the transmitting users are not the same. If interfering users are located much closer to a target receiver than does a target transmitting user, much stronger interference from interfering users dominates the received signal and, thus, significantly degrades the bit error rate (BER) performance. We call this situation a near/far problem.

To solve this near/far problem, a near-interference erasure scheme has been proposed for TH-PPM UWB systems [5]. This scheme adopts an erasure threshold which determines whether the received signal is interfered by near-interference or not. Some pulses affected by a strong near-interferer are discarded in a bit decision. The BER performance of the near-interference erasure scheme was analyzed by varying the values of erasure thresholds [5]. The study proved that the near-interference erasure scheme works well with an appropriate threshold value in strong near-interference environments and efficiently improves the BER performance. However, how to obtain an optimum threshold in various environments, including strong near-interference environments, is not presented in [5].

In this paper, we propose a method to obtain the optimum erasure threshold value in various TH-PPM UWB environments. To find the optimum threshold which maximizes the performance enhancement in TH-PPM UWB systems, we mathematically analyze the performance of the near-interference erasure scheme and derive an equation for finding an optimum threshold value which maximizes the BER performance. Moreover, we propose a parameter extraction method in the optimum threshold equation from various TH-PPM UWB systems.

This paper is organized as follows: In Section II, the mathematical model of the near-interference erasure scheme for the TH-PPM UWB systems is described. The BER performance is analyzed in order to obtain an optimum erasure threshold in Section III. A parameter extraction method is proposed from the optimum threshold equation in various TH-PPM UWB systems environments in Section IV. Finally, conclusions are presented in Section V.

II. SYSTEM MODEL

A. General TH-PPM UWB Systems

In general TH-PPM UWB systems, one bit is transmitted N_s times. The bit decision is made by the sum of the correlator outputs of N_s consecutive pulses. If the N_s consecutive pulses are not affected by interference, the N_s correlator output values are similar. If some of N_s pulses are affected by near-interference, the variation of correlator output values is relatively large and the bit is decided depending on these output values. The correlator outputs can be classified into two cases [5]. The first case is that the correlator output is interfered only by relatively far interferers and additive white gaussian noise (AWGN). This can be modeled as a gaussian random variable Y. The second case is that the correlator output is interfered not only by relatively far interferers and AWGN, but also by near interferers. This can be modeled as W which is the sum of a Laplacian random variable X and a Gaussian random variable Y. W and the probability density function (PDF) of X, Y and W are expressed, respectively, as follows.

$$W = X + Y. \tag{1}$$

$$f_X(x) = \frac{a}{2}\, e^{-a|x|}, \quad m_X = 0, \quad \sigma_X^2 = \frac{2}{a^2}. \tag{2}$$

$$f_Y(y) = \frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{(y-m)^2}{2\sigma^2}}, \quad m_Y = m, \quad \sigma_Y^2 = \sigma^2. \tag{3}$$

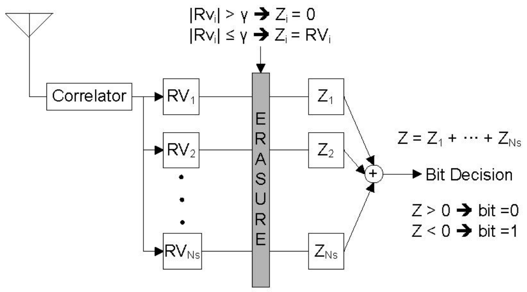


Fig. 1. Near-Interference Erasure Scheme for the TH-PPM UWB Systems

$$\begin{aligned} f_W(w) &= \int_{-\infty}^{\infty} f_X(w-x) f_Y(x) dx \\ &= \frac{a}{2} e^{\frac{a^2\sigma^2}{2}} e^{a(m-w)} Q\left(\frac{m-w+a\sigma^2}{\sigma}\right) \\ &+ \frac{a}{2} e^{\frac{a^2\sigma^2}{2}} e^{a(w-m)} Q\left(\frac{w-m+a\sigma^2}{\sigma}\right), \end{aligned} \tag{4}$$

where m is the correlator output value of the received pulse from a target transmitter.

B. TH-PPM UWB Systems with a Near-Interference Erasure Scheme

Fig. 1 shows a near-interference erasure scheme for the TH-PPM UWB Systems. In this scheme, a bit is decided by the sum of the N_s erasure output values. As shown in Fig. 1, some correlator outputs which are greater than an erasure threshold γ are removed ($Z_i = 0$). In other words, we can erase the pulses which are interfered by near-interference in the bit decision procedure.

$\Gamma(\gamma)$ and $\Lambda(\gamma)$ denote the probability that the absolute value of Y is smaller than γ and the probability that the absolute value of W is smaller than γ, respectively. Then, $\Gamma(\gamma)$ and $\Lambda(\gamma)$ are expressed as follows.:

$$\begin{aligned} \Gamma(\gamma) &= \int_{-\gamma}^{\gamma} f_Y(y) dy \\ &= 1 - Q\left(\frac{\gamma+m}{\sigma}\right) - Q\left(\frac{\gamma-m}{\sigma}\right). \end{aligned} \tag{5}$$

$$\begin{aligned} \Lambda(\gamma) &= \int_{-\gamma}^{\gamma} f_W(w) dw \\ &= \frac{1}{2} e^{\frac{a^2\sigma^2}{2}} e^{a(m+\gamma)} Q\left(\frac{m+\gamma+a\sigma^2}{\sigma}\right) \\ &- \frac{1}{2} e^{\frac{a^2\sigma^2}{2}} e^{a(m-\gamma)} Q\left(\frac{m-\gamma+a\sigma^2}{\sigma}\right) \\ &+ \frac{1}{2} e^{\frac{a^2\sigma^2}{2}} e^{a(\gamma-m)} Q\left(\frac{\gamma-m+a\sigma^2}{\sigma}\right) \\ &- \frac{1}{2} e^{\frac{a^2\sigma^2}{2}} e^{-a(\gamma+m)} Q\left(\frac{-\gamma-m+a\sigma^2}{\sigma}\right) \\ &+ 1 - Q\left(\frac{\gamma+m}{\sigma}\right) - Q\left(\frac{\gamma-m}{\sigma}\right). \end{aligned} \tag{6}$$

As mentioned in Subsection II-A, we classify the correlator outputs into two cases, Y and W. Two truncated erasure outputs Y_{tr} and W_{tr} are newly defined random variables by excluding the values greater than γ from outputs Y and W, respectively. The PDF, mean, and variance of Y_{tr} and W_{tr} are expressed, respectively, as follows.:

$$f_{Y_{tr}}(y) = \frac{1}{\Gamma(\gamma)} f_Y(y), \quad -\gamma \le y \le \gamma. \tag{7}$$

$$\begin{aligned} m_{Y_{tr}}(\gamma) &= \int_{-\gamma}^{\gamma} y f_{Y_{tr}}(y) dy \\ &= m + \frac{\sigma}{\Gamma(\gamma)\sqrt{2\pi}} \left(e^{-\frac{(\gamma+m)^2}{2\sigma^2}} - e^{-\frac{(\gamma-m)^2}{2\sigma^2}}\right). \end{aligned} \tag{8}$$

$$\begin{aligned} \sigma^2_{Y_{tr}}(\gamma) &= \int_{-\gamma}^{\gamma} (y - m_{Y_{tr}}(\gamma))^2 f_{Y_{tr}}(y) dy \\ &= \sigma^2 + m^2 - m^2_{Y_{tr}}(\gamma) \\ &- \frac{\sigma}{\Gamma(\gamma)\sqrt{2\pi}} (\gamma - m) e^{-\frac{(\gamma+m)^2}{2\sigma^2}} \\ &+ \frac{\sigma}{\Gamma(\gamma)\sqrt{2\pi}} (\gamma + m) e^{-\frac{(\gamma-m)^2}{2\sigma^2}}. \end{aligned} \tag{9}$$

$$f_{W_{tr}}(w) = \frac{1}{\Lambda(\gamma)} f_W(w), \quad -\gamma \le w \le \gamma. \tag{10}$$

$$\begin{aligned} m_{W_{tr}}(\gamma) &= \int_{-\gamma}^{\gamma} w f_{W_{tr}}(w) dw \\ &= \frac{1 - a\gamma}{2a\Lambda(\gamma)} e^{\frac{a^2\sigma^2}{2}} e^{a(m+\gamma)} Q\left(\frac{m+\gamma+a\sigma^2}{\sigma}\right) \\ &+ \frac{a\gamma - 1}{2a\Lambda(\gamma)} e^{\frac{a^2\sigma^2}{2}} e^{a(\gamma-m)} Q\left(\frac{\gamma-m+a\sigma^2}{\sigma}\right) \\ &- \frac{a\gamma + 1}{2a\Lambda(\gamma)} e^{\frac{a^2\sigma^2}{2}} e^{a(m-\gamma)} Q\left(\frac{m-\gamma+a\sigma^2}{\sigma}\right) \end{aligned}$$

$$+ \quad \frac{a\gamma+1}{2a\Lambda(\gamma)} e^{\frac{a^2\sigma^2}{2}} e^{-a(\gamma+m)} Q\left(\frac{-\gamma-m+a\sigma^2}{\sigma}\right)$$
$$+ \quad \frac{1}{\Lambda(\gamma)} \frac{\sigma}{\sqrt{2\pi}} \left(e^{-\frac{(\gamma+m)^2}{2\sigma^2}} - e^{-\frac{(\gamma-m)^2}{2\sigma^2}}\right)$$
$$+ \quad \frac{m}{\Lambda(\gamma)} \left(1 - Q\left(\frac{\gamma+m}{\sigma}\right) - Q\left(\frac{\gamma-m}{\sigma}\right)\right). \quad (11)$$

$$\begin{aligned}\sigma^2_{W_{tr}}(\gamma) &= \int_{-\gamma}^{\gamma} (w - m_{W_{tr}}(\gamma))^2 f_{W_{tr}}(w)dw \\ &= \frac{a^2\gamma^2 - 2a\gamma + 2}{2a^2\Lambda(\gamma)} e^{\frac{a^2\sigma^2+2a(m+\gamma)}{2}} Q\left(\frac{m+\gamma+a\sigma^2}{\sigma}\right) \\ &+ \frac{a^2\gamma^2 - 2a\gamma + 2}{2a^2\Lambda(\gamma)} e^{\frac{a^2\sigma^2+2a(\gamma-m)}{2}} Q\left(\frac{\gamma-m+a\sigma^2}{\sigma}\right) \\ &- \frac{a^2\gamma^2 + 2a\gamma + 2}{2a^2\Lambda(\gamma)} e^{\frac{a^2\sigma^2+2a(m-\gamma)}{2}} Q\left(\frac{m-\gamma+a\sigma^2}{\sigma}\right) \\ &- \frac{a^2\gamma^2 + 2a\gamma + 2}{2a^2\Lambda(\gamma)} e^{\frac{a^2\sigma^2-2a(\gamma+m)}{2}} Q\left(\frac{-\gamma-m+a\sigma^2}{\sigma}\right) \\ &- \frac{\sigma}{\Lambda(\gamma)\sqrt{2\pi}} \left((\gamma-m)e^{-\frac{(\gamma+m)^2}{2\sigma^2}} + (\gamma+m)e^{-\frac{(\gamma-m)^2}{2\sigma^2}}\right) \\ &+ \frac{a^2\sigma^2+2+a^2m^2}{a^2\Lambda(\gamma)} \left(1 - Q\left(\frac{\gamma+m}{\sigma}\right) - Q\left(\frac{\gamma-m}{\sigma}\right)\right) \\ &- m^2_{W_{tr}}(\gamma). \end{aligned} \quad (12)$$

III. Performance Analysis of the Near-Interference Erasure Scheme for TH-PPM UWB Systems

A. Mathematical Analysis of the near-interference erasure scheme for TH-PPM UWB Systems

In the receiver, a bit is decided by a random variable Z which is the sum of the erasure outputs Z_i. As mentioned in Section II, the erasure outputs Z_i can be either Y_{tr} or W_{tr}. To express Z_i as a combination of Y_{tr} and W_{tr}, we define two binomial random variables: $B_{Y_{tr}}$ and $B_{W_{tr}}$ as expressed in Eq. (13).

$$Z_i = B_{Y_{tr}} Y_{tr} + B_{W_{tr}} W_{tr}. \quad (13)$$

$B_{Y_{tr}}$ is 1 if a pulse which is interfered only by far interferers is not erased. Otherwise, $B_{Y_{tr}}$ is 0. Since the probability that a pulse is interfered only by far interferers is p_f and the probability that the absolute value of the random variable Y is less than the threshold γ is $\Gamma(\gamma)$, the probability that the binomial random variable $B_{Y_{tr}}$ is 1 is $p_f \cdot \Gamma(\gamma)$. The binomial random variable $B_{W_{tr}}$ is 1 if a pulses which is interfered not only by far interferers but also by near interferers is not erased. Otherwise, $B_{W_{tr}}$ is 0. Hence, the probability that the binomial random variable $B_{W_{tr}}$ is 1 is $p_n \cdot \Lambda(\gamma)$ where p_n is $1 - p_f$.

The mean and variance of Z_i are expressed, respectively, as follows.:

$$m_{Z_i}(\gamma) \;=\; p_f\Gamma(\gamma) \cdot m_{Y_{tr}}(\gamma) + p_n\Lambda(\gamma) \cdot m_{W_{tr}}(\gamma). \quad (14)$$

$$\begin{aligned}\sigma^2_{Z_i}(\gamma) \;=\; & p_f\Gamma(\gamma)\left(\sigma^2_{Y_{tr}}(\gamma) + (1-p_f\Gamma(\gamma))m^2_{Y_{tr}}(\gamma)\right) \\ & + p_n\Lambda(\gamma)\left(\sigma^2_{W_{tr}}(\gamma) + (1-p_n\Lambda(\gamma))m^2_{W_{tr}}(\gamma)\right) \end{aligned} \quad (15)$$

Since the decision random variable Z is the sum of Z_i, the mean $m_Z(\gamma)$ and variance $\sigma^2_Z(\gamma)$ of Z are N_s times the values of $m_{Z_i}(\gamma)$ and $\sigma^2_{Z_i}(\gamma)$, respectively. If the near-interference erasure scheme works well with the optimum threshold, the correlator output values of the pulses affected due to near-interferers are mostly erased. In other words, the Laplacian random variables are mostly erased. Hence, the Gaussian random variables still remains. Therefore, the decision random variable can be approximated as Gaussian random variables with a mean of $m_Z(\gamma)$ and a variance of $\sigma^2_Z(\gamma)$ of Z as follows.:

$$Z = Z_1 + \cdots + Z_{N_s}. \quad (16)$$

$$m_Z(\gamma) \;=\; N_s \cdot m_{Z_i}(\gamma). \quad (17)$$

$$\sigma^2_Z(\gamma) \;=\; N_s \cdot \sigma^2_{Z_i}(\gamma). \quad (18)$$

The bit error probability of the TH-PPM UWB system using the proposed near-interference erasure scheme is expressed as Eq. (19). Since it is a function of threshold γ, we can find the optimum erasure threshold γ, which yields a minimum BER value, by differentiating Eq. (19) with respect to γ.

$$\begin{aligned} P_e(\gamma) \;&=\; \int_{-\gamma N_s}^{0} \frac{1}{\sqrt{2\pi\sigma^2_Z(\gamma)}} e^{-\frac{(z-m_Z(\gamma))^2}{2\sigma^2_Z(\gamma)}} dz \\ &+ \left(\frac{1-p_f\Gamma(\gamma)}{2}\right)^{N_s} + \left(\frac{1-p_n\Lambda(\gamma)}{2}\right)^{N_s} \\ &= Q\left(\frac{m_Z(\gamma)}{\sqrt{\sigma^2_Z(\gamma)}}\right) - Q\left(\frac{\gamma N_s + m_Z(\gamma)}{\sqrt{\sigma^2_Z(\gamma)}}\right) \\ &+ \left(\frac{1-p_f\Gamma(\gamma)}{2}\right)^{N_s} + \left(\frac{1-p_n\Lambda(\gamma)}{2}\right)^{N_s}. \end{aligned} \quad (19)$$

The derivative of $P_e(r)$ is approximated as follows:

$$\begin{aligned}\frac{d}{d\gamma}\{P_e(\gamma)\} \;&\approx\; \frac{1}{\sqrt{\pi}\left(2\sigma^2_Z(\gamma)\right)^{3/2}} \cdot e^{-\frac{m^2_Z(\gamma)}{2\sigma^2_Z(\gamma)}} \\ &\times \left(m_Z(\gamma) \cdot \frac{d}{d\gamma}\{\sigma^2_Z(\gamma)\} - 2\frac{d}{d\gamma}\{m_Z(\gamma)\} \cdot \sigma^2_Z(\gamma)\right) \end{aligned} \quad (20)$$

Since Eq. (20) is a convex function, the optimum threshold value is obtained from the following equation:

$$\frac{d}{d\gamma}\{P_e(\gamma)\} = 0$$
$$\Longleftrightarrow m_Z(\gamma)\cdot\frac{d}{d\gamma}\{\sigma_Z^2(\gamma)\} - 2\frac{d}{d\gamma}\{m_Z(\gamma)\}\cdot\sigma_Z^2(\gamma) = 0. \quad (21)$$

B. Method of applying a near-interference erasure scheme to the practical TH-PPM UWB Systems

In this subsection, we propose a method to find the optimum threshold in a TH-PPM UWB system using the near-interference erasure scheme. If we find m_Z and σ_Z in the TH-PPM UWB system, we can obtain the optimum threshold from Eq. (21).

σ_Z can be expressed as a combination of N_s, σ_X^2, σ_Y^2 and p_n, as shown in Section II. Since σ_X^2 is the variance of Laplacian distribution and σ_Y^2 is that of gaussian distribution, we define the *near/far* as σ_X^2/σ_Y^2, which means the ratio of the near-interference to the far-interference at the correlator output. When N_s is set to a fixed value in a TH-PPM UWB system, we need to only find the p_n and *near/far* values in various multi-user environments. In the TH-PPM UWB system, the SINR value is obtained by the ratio of the mean-square of the expected value of the correlator output for the desired signal, m_Z, to the variance of the correlator output value RV_i, and is expressed as follows:

$$SINR = \frac{m_Z^2}{\sigma_X^2 + \sigma_Y^2} \quad (22)$$

m_Z can be obtained from the pilot signal or the correlator output of N_s repeated pulses. Moreover, the sum of the variance of the Laplacian random variable σ_X^2 and that of the gaussian random variable σ_Y^2 is obtained from the variance of correlator output value RV_i.

Since we know the SINR and m_Z values, if we know the *near/far* value, we can find the values of σ_X^2 and σ_Y^2.

$$\textit{near/far} = \frac{\sigma_X^2}{\sigma_Y^2}. \quad (23)$$
$$\sigma_Y^2 = \frac{m_Z^2}{SINR}\cdot\left(1+\frac{\textit{near}}{\textit{far}}\right)^{-1}. \quad (24)$$
$$\sigma_X^2 = \frac{m_Z^2}{SINR} - \sigma_Y^2. \quad (25)$$

We can obtain the p_n value by observing the each correlator output value in the TH-PPM UWB system from Eq. (26).

$$\begin{aligned} |m_Z - RV_i| &> \sigma_Y \rightarrow \text{a pulse affected by the near-interference} \\ |m_Z - RV_i| &\le \sigma_Y \rightarrow \text{a pulse affected by the far-interference} \end{aligned} \quad (26)$$

When a pulse is affected by the near-interference, the correlator output value becomes high temporarily. That is, if the difference between m_Z and the correlator output value, RV_i exceeds the σ_Y value, that pulse can be considered to be affected by the near-interference.

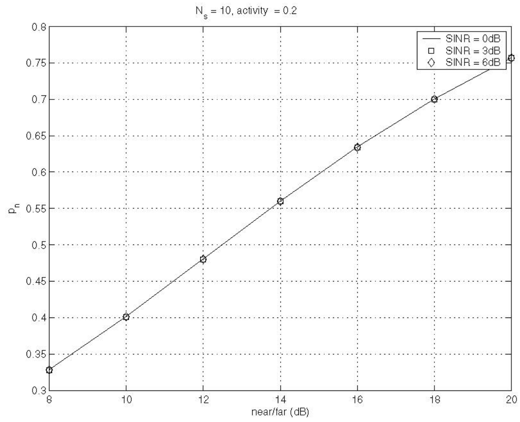


Fig. 2. near/far vs. p_n

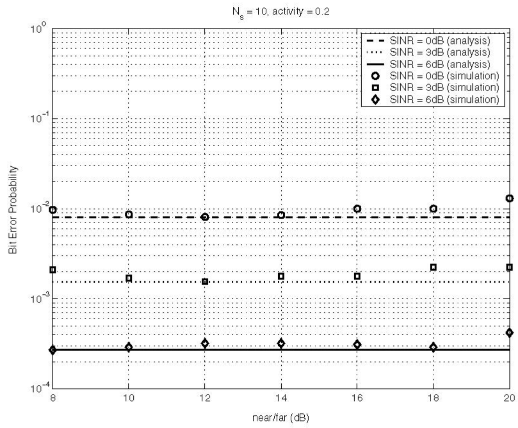


Fig. 3. Performance with the optimum threshold determined by a fixed *near/far*

We assume that we know the *near/far* value and the objective is to find p_n. p_n and the *near/far* ratio has dependency since the p_n value is determined by σ_Y of *near/far* as expressed in Eq. (26). Simulation shows this relationship of σ_Y of *near/far*, as shown in Fig. 2.

Fig. 3 shows the bit error probability versus the *near/far* ratio for varying SINR values. The result shows that the BER performance does not change in the given range of the *near/far* value and the analytical BER performance is similar to that with the optimum threshold obtained by computer simulation. Therefore, we can just set the *near/far* value to a fixed value in the range of Fig. 3 and need to find the p_n values in various TH-PPM UWB system environments.

However, although we know the system parameter N_s, the *near/far* ratio and p_n, Eq. (21) is a negative function of γ and the complexity of finding an optimum threshold is still high. Thus, as mentioned before, in the various system environments, we can set the *near/far* at a fixed value and find the optimum threshold considering the range of SINR and p_n values in advance and store them into a memory. In

TABLE I
TH-PPM UWB System Parameters for the Performance Evaluation

Parameter	Notation	Value
Pulse waveform width parameter	τ_p	0.2877 ns
PPM delay	δ	0.15 ns
Frame width	T_f	7.2 ns
Chip width	T_c	0.9 ns
Pulse width	T_p	0.7 ns
Number of chip per frame	N_h	8
Pulse power	P	-10 dBm
Noise power spectral density	N_0	-180 dBm/Hz
Radius of receiver's coverage	R	10 m
Path-loss at a reference distance of 1m	c_0	51 dB [6]
Path-loss exponent	γ_p	3.5 [6]

the practical system, we just measure the p_n and SINR values, then search the optimum threshold from the memory according to the measured p_n and SINR values.

IV. Performance Evaluation

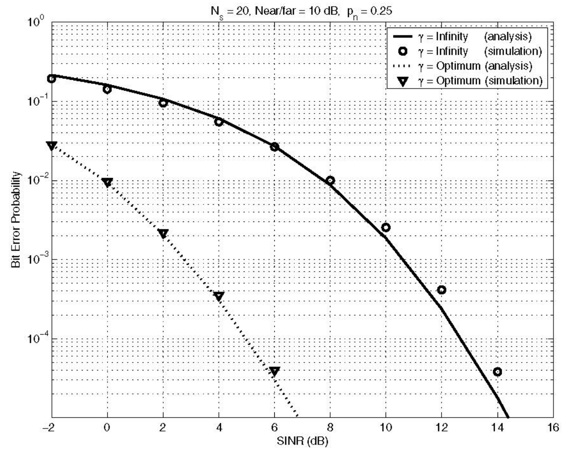
System parameters for the performance evaluation are shown in Table I.

Fig. 4 compares the BER performance of the system with/without a near-interference erasure scheme under the condition that the near/far ratio is 10dB and N_s is 20. The notation 'γ = infinity' indicates that no near-interference erasure scheme is adopted. When the p_n value and the required BER value are fixed to 0.25 and 10^{-3}, respectively, the required SINR value of the near-interference erasure scheme is 8dB smaller than that without the near-interference erasure scheme. When the p_n value and the required BER value are fixed to 1 and 10^{-3}, respectively, the required SINR value of the near-interference erasure scheme to satisfy a BER value of 10^{-3} is similar to that without the near-interference erasure scheme, as shown in Fig. 4(b).

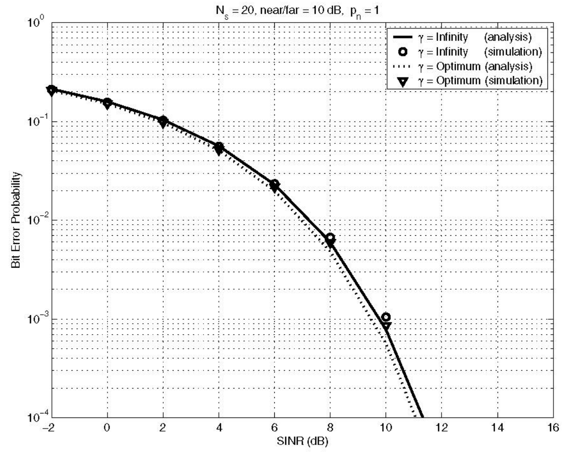
From Fig. 4, we can observe that the simulation results agree with analytical results. Hence, we can show the validity of Eq. (19) and Eq. (20). Moreover, for a fixed near/far value, the BER performance of the near-interference erasure scheme becomes better than the performance without the erasure scheme as the p_n value becomes smaller. This is because the probability that large near-interference is generated becomes higher as the p_n value becomes smaller.

Fig. 5 shows a TH-PPM UWB system environment with multiple users. A designated receiver 'RX' is in the middle of the circle of radius R and N_u transmitting users including a designated transmitter 'TX' are present. In this example, $N_u = 5$. We consider the path loss of the channel and assume that there are no multi-paths.

Fig. 6(a) shows the bit error probability when 101 users are uniformly distributed in a circle of radius $10m$. We set the *near/far* value and the channel activity factor to 14 dB and 0.2, respectively. The BER performance is obtained using the three different optimum thresholds: '$\gamma =$ optimum(analysis)' and 'γ = practical optimum(simulation)', 'γ = infinite(simulation)'.



(a) p_n = 0.25



(b) p_n = 1.00

Fig. 4. BER Performance for two different p_n values

The bit error probability with the optimum threshold obtained from Eq. (21) is similar to that with the optimum threshold obtained by computer simulation. Fig. 6(a) shows that the system with the near-interference erasure scheme performs much better, compared with that without the near-interference erasure scheme.

Fig. 6(b) shows the BER performance when the interferers are relatively close to the designated receiver and Fig. 6(c) shows the BER performance when the interferers are relatively far to the receiver. In both figures, the BER performance with 'γ = optimum(analysis)' and 'γ = practical optimum(simulation)' is similar. Fig 6(b) shows that the system with the near-interference erasure scheme performs much better, compared with that without the near-interference erasure scheme. However, as expected, Fig 6(c) shows that the system with the near-interference erasure scheme and that without the near-interference erasure scheme shows similar BER performance.

The proposed method of obtaining the optimum threshold for the near-interference erasure scheme can be applied to to the TH-PPM UWB system, and simulation results show that

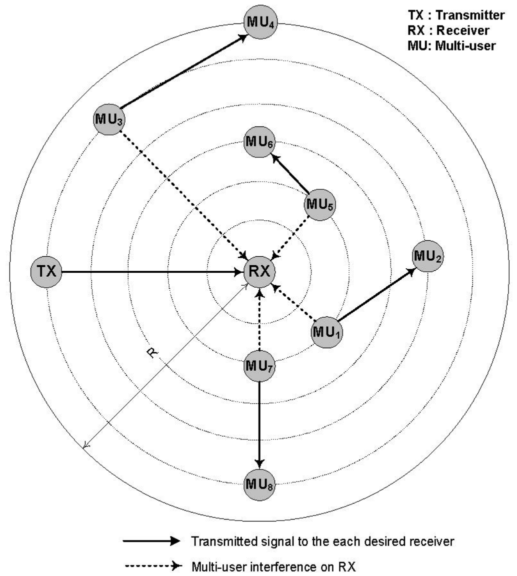


Fig. 5. TH-PPM UWB System Environment with Multiple Users

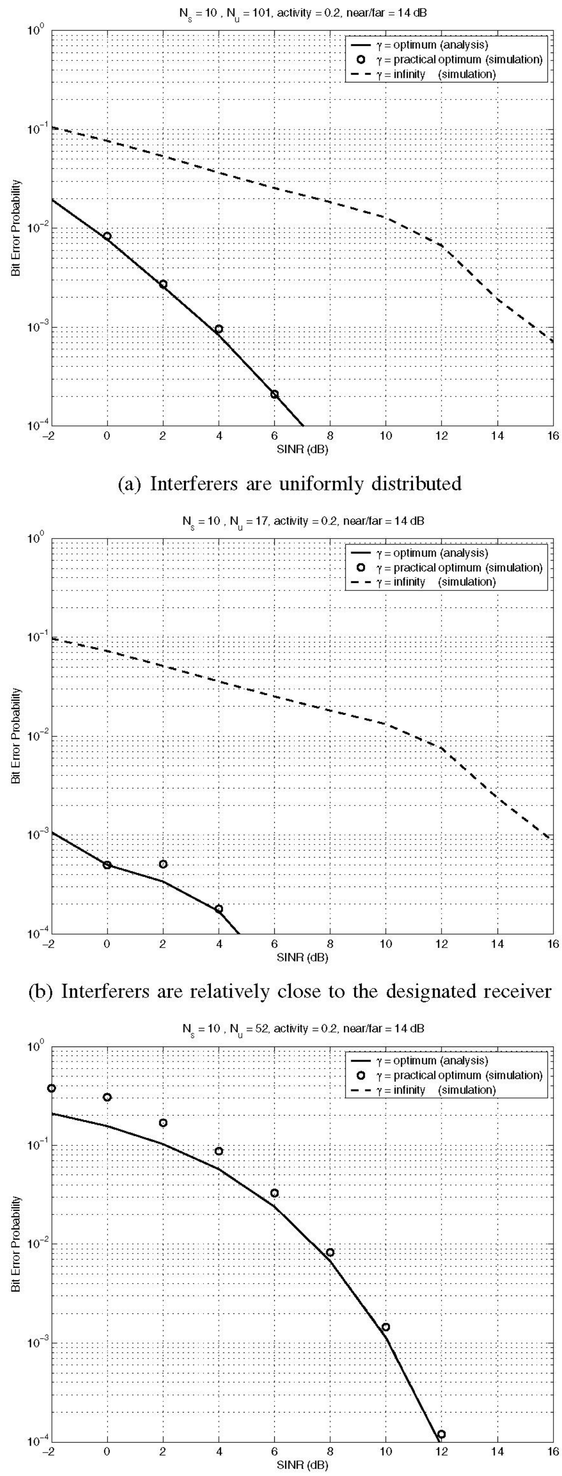
the TH-PPM UWB system with the proposed method enhances the BER performance than does the TH-PPM UWB system without the proposed method

V. Conclusion

In this paper, we mathematically analyzed the performance of a near-interference erasure scheme for TH-PPM UWB systems. We derived the equations for determining the optimum threshold which maximizes the performance. Moreover, we proposed a method to obtain an optimum threshold in a TH-PPM UWB system. To apply the result to TH-PPM UWB systems, we proposed a method for obtaining system parameters. Finally, we showed that the near-interference erasure scheme enhances the BER performance when it is applied to the TH-PPM UWB systems.

References

[1] R. A. Scholtz, "Multiple access with time-hopping impulse modulation," in *Proc. IEEE MILCOM*, Boston, MA, Oct. 13-16, 2003.
[2] M.Z. Win and R.A. Scholtz, "Ultra-wide bandwidth time-hopping spread-spectrum impulse radio for wireless multiple-access communications," *IEEE Trans. Commun.*, vol. 48, pp. 679-689, Apr. 2000.
[3] Bo Hu and Norman C. Beaulieu,"Exact bit error rate analysis of TH-PPM UWB Systems in the presence of multiple-access interference," *IEEE Commun. Lett.*, vol. 7, pp. 572-574, Dec. 2003.
[4] G. Durisi and S. Benedetto, "Performance evaluation of TH-PPM UWB systems in the presence of multiuser interference," *IEEE Commun. Lett.*, vol. 7, pp. 224-226, May 2003.
[5] William M. Lovelace and J. Keith Townsend, "Threshold discrimination and blanking for large near-far power ratios in UWB networks," *IEEE Trans. Commun.*, vol. 53, pp. 1447-1450, Sep. 2005.
[6] Saeed S. Ghassemzadeh, Rittwik Jana, Christopher W. Rice, William Turin, Vahid Tarokh, "Measurement and modeling of an ultra-wide bandwidth indoor channel," *IEEE Trans. Commun.*, vol. 52, pp. 1786-1796, Oct. 2004.



(a) Interferers are uniformly distributed

(b) Interferers are relatively close to the designated receiver

(c) Interferers are relatively far from the designated receiver

Fig. 6. BER Performance for Varying the Distribution of Interferers