Performance of a TH-PPM Ultra Wideband System in Different Scenarios Environments

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Summary
We propose an accurate analytical method for the evaluation of the ultra wideband system performance in a time hopping binary pulse position modulation scheme (TH BPPM-UWB) in the additive white Gaussian noise (AWGN) channel. We have extended the method used in different scenarios environments and a comparison is made between them.

Key words:
Ultra Wideband, TH-PPM, Performance, multipath, multi-user

1. Introduction

Impulse Radio (IR) is based on an ultra-wideband (UWB) time-hopping (TH) spread-spectrum technique, in which subnanosecond pulses are modulated to convey information by shifting the relative time position of the pulses. According to the FCC (Federal Communication Commission) based in USA regulation of February 2002, signals belonging to this category are required to possess a -10dB bandwidth which exceeds 500 MHz or 20% of its fractional bandwidth [1]. UWB technology has attracted considerable interest from research due to its promising ability to provide high data rate at low cost with relatively low power consumption.

Theoretical tools for evaluating the performance in terms of bit error rate are important in simplifying the system design. In the recent past, such theoretical evaluations of the BER (Bit Error Rate) of various UWB systems have been reported under different conditions. Performance of UWB with time-hopping spread-spectrum (THSS) IR under ideal propagation conditions, where there is only a single path between each user's transmitter and receiver, has been investigated in [2]. Due to the large bandwidth, an IR multiple access system can accommodate many users. Single user in multi-path fading channel case was handled in [3], and the problem was somewhat analytically tractable due to the absence of MAI.

In this paper, we propose a method to evaluate the performance of Time Hopping Pulse position modulation (TH-PPM) Ultra Wide Band systems. Our method is based on the decision that enables to decode the information transmitted in a transmission chain of an UWB system. This decision is then developed by equations in order to compute the performance in terms of errors rate by bit. We firstly provide basic features of TH-PPM system model and then determine the probability of error using a simplified channel model. Thereafter, the performance of this system model in multi-user and multipath environments are also derived. Finally, the analytical performance results are compared and we provide the conclusions which one draws.

2. TH-PPM UWB System Model

TH-UWB impulse radio is built upon position shift of pulses with a certain shape in the time domain. The studied system's model is based on Time Hopping (TH) combined with pulse position modulation (PPM) scheme applied in the context of UWB. The TH-PPM block diagram used in our case is shown in figure 1.

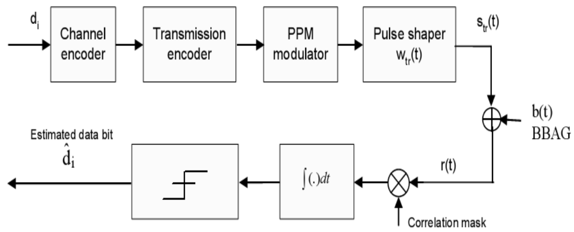

Fig. 1 TH-PPM Block Diagram.

The transmitted signal $S_{tr}(t)$ in the TH-PPM UWB systems is described by the following model [4]:

$$s_{tr}(t) = \sum_{k=1}^{+\infty} a_k \sum_{i=-\infty}^{+\infty}\sum_{j=0}^{+\infty} w_{tr}(t - iT_s - jT_f - c_j^{(k)}T_s - d_i^{(k)}\delta) \quad (1)$$

Where $w_{tr}(t)$ is the transmitted pulse waveform, which is usually referred to monocycle. T_s is the symbol (or bit) duration, K is the number of users and a_k is the amplitude of different users. In order to allow the channel to be shared by many users and eliminate catastrophic collision, each user is assigned a distinctive time-shift pattern $c_j^{(k)}$

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called as TH sequence, which takes values in {0,1,...,N_h-1}. The frame time T_f and the chip time T_c are chosen to satisfy $N_h T_c \leq T_f$. The binary information stream $\{d_i^{(k)}\}$ is transmitted employing a PPM modulation format and introducing an additional shift δ to distinguish between pulses carrying the bit 0 and the bit 1.

We suppose that the model of the TH-PPM system is synchronized. This enables us to avoid dealing with the problems involved in synchronization.

3. Analytical Analysis of BER in the TH-PPM System Model

First of all, we will consider the TH-PPM system model performance for only one path and one user. In multi-user and multipath environments, the approach will be the same. In order to determine the error probability, we start by studying the reception of the TH-PPM system for the emission for one bit [5]. We will suppose that the temporal support in this case is disjoins. After computation, we arrive at the performance of our system model:

$$P_e = Q\left(SNR.\left[1-\tau\left(1-\frac{\delta^2}{\tau^2}\right)\exp\left(-\frac{\delta^2}{2\tau^2}\right)\right]\right) \qquad (2)$$

Where Q is the function of Marcum, SNR is the signal-to-noise rate and τ represents a constant of time that determines the length of the Gaussian pulse used in our case.

4. Analytical Analysis of BER in the TH-PPM System Model in Multi-user Environments

In this part, we are interested in performance of multi-user UWB TH-PPM systems. We assume that the amplitudes a_k of different users are known (assuming that we use later in our analytical analysis). As before, we begin by studying the reception of this system. After computation, we can deduce the performance's expression in an arrangement of TH-PPM modulation in multi-user environments:

$$P_e = Q\left(\frac{N_h}{\sigma_b^2}\left[a_1\left[R_w(0)-R_w(\delta)\right] + \sum_{k=2}^{K} a_k\left[R_w\left(d_i^{(k)}\delta\right) - R_w\left(\left(1-d_i^{(k)}\right)\delta\right)\right]\right]\right) \qquad (3)$$

With R_w is the autocorrelation's function of the transmitted signal and:

$$R_w\left(d_i^{(k)}\delta\right) = \frac{\sqrt{2\pi}}{8}\left[\tau^2 - \left(d_i^{(k)}\delta\right)^2\right]\exp\left(-\frac{\left(d_i^{(k)}\delta\right)^2}{2\tau^2}\right) \qquad (4)$$

$$R_w\left(\left(1-d_i^{(k)}\right)\delta\right) = K\frac{\sqrt{2\pi}}{8}\left[\tau^2+\delta^2\right]\left(1-d_i^{(k)}\right)\left(1-3d_i^{(k)}\right) \qquad (5)$$

Knowing that:

$$K = \exp\left(-\frac{3}{4}\delta^2\right)\exp\left(-\frac{\delta^2}{2}d_i^{(k)}\right)\exp\left(\frac{3}{4}\delta^2\left(d_i^{(k)}\right)^2\right) \qquad (6)$$

5. Analytical Analysis of BER in the TH-PPM System Model in Multipath Environments

In this part, we are interested in performance of multipath UWB TH-PPM systems. We take a Rayleigh channel which is given by:

$$h(t) = \sum_{l=1}^{N_L}\alpha_l\delta(t-\tau_l) \qquad (7)$$

Where α_l is the (real) amplitude of the l^{th} path, τ_l their delay and N_L is the number of paths and we assume that these parameters are known. Similarly to the previous parts, we begin by studying the reception. To simplify our calculation, we take first the case of 2 paths and then try to generalize the found results for N_L paths. Thus, we obtain:

$$P_e = Q\left(SNR.\left[(\alpha_1)^2+(\alpha_2)^2\right].\left[1-\left(1-\frac{\delta^2}{\tau^2}\right)\exp\left(-\frac{\delta^2}{2\tau^2}\right)\right]\right) \qquad (8)$$

From this result for 2 paths, we can deduce the expression of the probability of error in an arrangement of TH-PPM modulation in multipath environments:

$$P_e = Q\left(SNR.\left[\sum_{l=1}^{N_L}(\alpha_l)^2\right].\left[1-\left(1-\frac{\delta^2}{\tau^2}\right)\exp\left(-\frac{\delta^2}{2\tau^2}\right)\right]\right) \qquad (9)$$

5. Simulation Results

The modulation's performance of TH-PPM system model in multi-user environments is shown in figure 2. According to this figure, it is clear that more the number of users increase more the performance deteriorates. This result confirms our forecasts and the validity of our analytical method. The Fig.3 represents the modulation performance of TH-PPM in multipath environments. We can see from this figure that more the number of paths increase more the performance deteriorates. Note that the system performance even in the presence of several paths remains correct; this is one of the characteristics of the ultra wideband technology. This result confirms our forecasts.

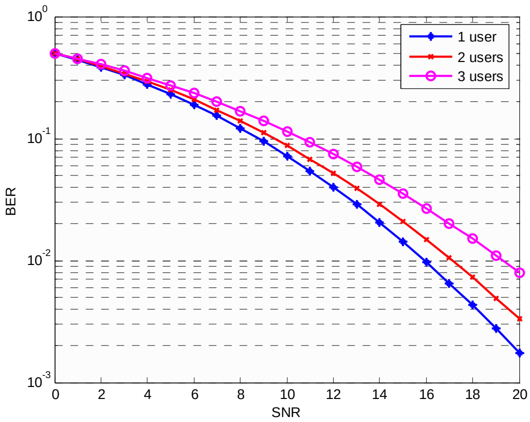

Fig. 2 Modulation's performance of TH-PPM in multi-user environments

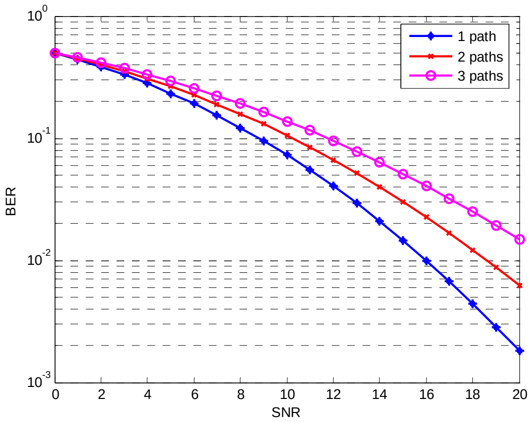

Fig. 3 Modulation's performance of TH-PPM in multipath environments

6. Conclusion

In this paper, we propose an analytical method to exactly compute the performance in the case of UWB TH-PPM systems in different scenario environments. The results have confirmed our forecasts and demonstrated the ability to give simple expressions that allows us further to use them in more complexes cases and therefore benefit in computing time.

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