Analysis and Simulation of Relay Assisted Pulse Position Modulation Scheme using UWB System

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Abstract— In modern world of communication system, a coded M-ary pulse position modulation (PPM) scheme for transmitted reference ultra-wideband (TR-UWB) systems is proposed. The modulation level M in conventional M-ary PPM TR-UWB scheme, is defined only with a number of possible pulse positions Z. So, Z radio frequency (RF) wideband delay lines are required in order to map data bits into the proper pulse position. The number of required delay lines in the proposed scheme is reduced by mapping data bits in both different orthogonal codes and pulse position on frame level of the signal, producing a modulation level of M = KZ. The analytical model for realistic IEEE standard UWB channel models is developed to evaluate the performances of the proposed coded M-ary PPM scheme, The performances of the proposed scheme are compared with these of the conventional 4-ary PPM scheme for the same modulation level M.

The results show that the hardware complexity is lower in terms of number of required RF delay lines with the proposed coded M-ary PPM scheme, while it achieves approximately the same bit error probability (BEP), higher data rate and higher bandwidth efficiency. However, by increasing the number of used orthogonal codes the minimum number of frames per one information symbol rises and consequently the maximum achievable data rate is limited. The trade-off between the number of orthogonal codes and target data rate thus should be made.

Keywords—PPM, cooperation, relay, diversity, power allocation, Ultra-wideband, decode-and-forward, DF, performance analysis, cooperative diversity, correlated noise.

INTRODUCTION

A. *Objectives:*

1. Create understanding about 4-ary PPM.
2. Demonstrate the need for using PPM.
3. Propose and analysis a novel method for implementing the 4-ary PPM that is more efficient in using the available bandwidth in a multiuser access system

B. *Introduction and Overview:*

Ultra Wideband (UWB) technology is the primary candidate for the physical layer of the upcoming standards for wireless personal area networks, since it provides reliable high-speed data transmission at short ranges over severe multipath conditions. It also exhibits robust Multiple Access (MA) performance with little interference to other communication systems sharing the same bandwidth due to its very low Power Spectral Density (PSD). It also offers a promising solution to the RF spectrum drought by allowing new services to coexist with current radio systems with minimal or no interference. The advantage of avoiding the expensive spectrum licensing fees is achieved using this coexistence that providers of all other radio services must pay.

The fundamental characteristic of UWB is the extremely large bandwidth, which is required since very narrow pulses of appropriate shape and sub nanosecond duration, are being used by the transmitted signal. One of the most widely studied schemes for UWB communications employs Pulse Position Modulation (PPM) combined with Time Hopping (TH) as its multiple access technique. The UWB pulses are time hopped within a fixed time window (frame) and each transmitted symbol is spread over several pulses in order to facilitate multiple users. In PPM the position of each pulses varied by each instantaneous sampled value of the modulating wave in relation to the position of a recurrent reference pulse, it used exclusively for transferring digital signals and cannot be used with analog systems. Also it used for transferring simple data and is not effective at transferring files. Due to the important role of the M-ary PPM modulation technique, we will focus our study on its performance and propose a novel improvement for such a technique with main target of improving the overall system performance under interference dominated system.

C. *Applications:*

Pulse position modulation has many purposes, especially in RF (Radio Frequency) communication such as, pulse position modulation is used in remote controlled aircraft, cars and boats. Also it's often used in optical communication, such as fiber opticswhich has a little or no multipath interference, we can see how PPM is used in optical fibers, i.e. sending a laser pulse in a random location after dividing the frame into number of frames.

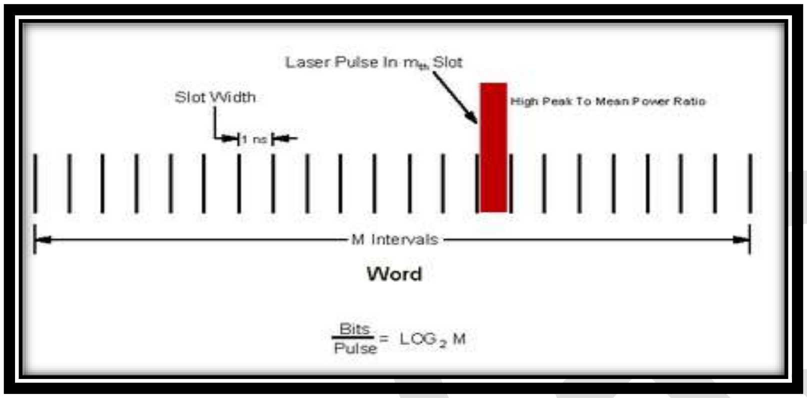

Fig.1. *Pulse Position Modulation in optical fibers*

PULSE POSITON MODULATION

Pulse Position Modulation, sometimes known as pulse phase modulation is used for digital signal transition. It is used in fiber optics and IR (infrared) remote controls where there is a lack of interference; this technique uses pulses of the same breath and height but is displaced in time from some base position according to the amplitude of the signal at the time of sampling.

The Pulse Position Modulation (PPM) is a modulation technique designed to achieve the goals like simple transmitter and receiver circuitry, constant bandwidth, noise performance and the power efficiency and constant transmitter power. The amplitude of the pulse in Pulse Position Modulation is kept constant as in the case of the FM and PWM to avoid noise interference. Unlike the Pulse Width Modulation the pulse width is kept constant to achieve constant transmitter power. The modulation is achieved by varying the position of the pulse from the mean position according to the variations in the amplitude of the modulating signal. The Pulse Position Modulation (PPM) can be actually easily generated from a PWM waveform which has been modulated according to the input signal waveform. The Pulse Position Modulation can be demodulated both synchronously and asynchronously. The synchronous demodulation requires synchronization of the receiver with the transmitter and hence it is complex. The quality will be comparatively less when using the asynchronous demodulation technique, but with an advantage of very simple circuit for demodulation.

A. *Block Diagram of PPM*

There are different methods for extracting the message signal from a PPM wave synchronously and asynchronously. The asynchronous demodulator uses a low pass filter to filter out the message signal from the modulated wave. The implementation of a PWM modulator is represented in following block diagram.

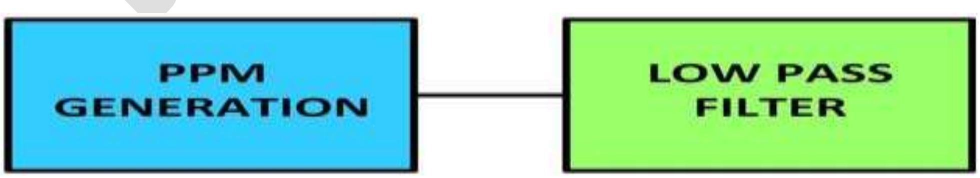

Fig.2. *Simple PPM Block diagram*

B. *PPM Generation:*

The PPM required for this project is generated from a PWM wave which is modulated with the message signal. This message signal used here is a pure sine waveform generated using the Wien Bridge Oscillator (WBO). A ramp signal is generated with the help of a RC charging circuit and a comparator IC. Another comparator IC which is having ramp signal as one of its input and the message signal as other can produce a PWM wave at its output. This Pulse Width Modulation wave is then used to generate the PPM wave using a mono-stable multi-vibrator. The given block diagram of the PWM generation circuit is given below:

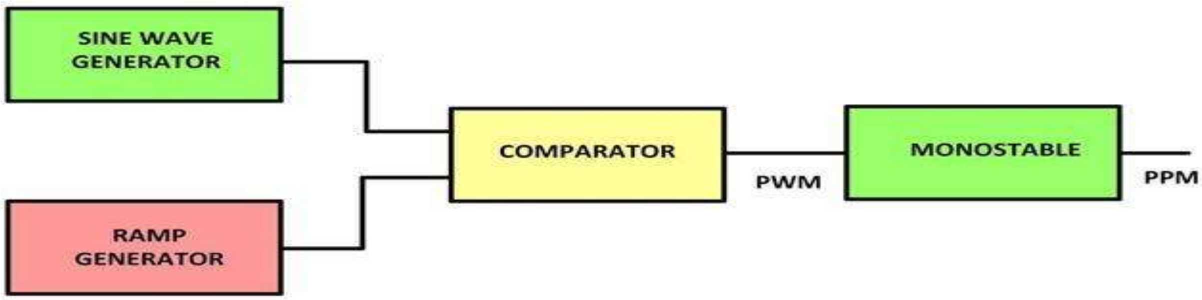

Fig.3. *PPM Generation*

C. *Sine Wave Generator*

The circuit which is based on the Wien Bridge Oscillator (WBO) circuit. The WBO circuit can produce distortion less sinusoidal sweep at its output. This circuit is designed in such a way that both the amplitude and frequency of the oscillator can be adjusted using potentiometers. The sine wave generator is adjusted to produce a waveform of frequency 1 KHz. The Ramp generator used in this circuit is designed with an RC charging circuit and an op-amp. The RC charging circuit is connected to the output of the op-amp and the voltage across the capacitor is connected to one of the input of the op-amp. The variable pin of a potential divider is connected to another input of the op-amp to which divides the voltage from the output of the op-amp. The ramp waveform is applied to one of the input of another comparator circuit and the output of the comparator circuit will be a PWM waveform. The PPM generation is achieved with the help of a mono-stable multi-vibrator designed using a 555 timer IC.

D. *Ramp Generator:*

The Ramp generator used in this circuit is designed with an RC charging circuit and an op-amp. The RC charging circuit is connected to the output of the op-amp and the voltage across the capacitor is connected to one of the input of the op-amp. The variable pin of a potential divider is to another input of the op-amp connected to which divides the voltage from the output of the op-amp.

E. *Comparator:*

The ramp waveform is applied to one of the input of another comparator circuit and the output of the comparator circuit will be a PWM waveform.

Features

1. On-board message signal with variable amplitude
2. Three different frequency message signal
3. On Board carrier signal
4. PPM Modulation using Timer IC
5. PAM Demodulation using Low Pass Filter
6. Amplifier using Op-Amp
7. Internal Power Supply +5V , +12V/ 500 mA
8. Number of test point to study the PPM system
9. User friendly front panel block diagram

F. *PPM Vs. PAM:*

PPM is superior to PAM and PDM in the sense that it has higher noise immunity since the only thing the receiver needs to do is to detect the pressure of the pulse at the correct time. The amplitude and duration of the pulses are irrelevant.

Pulse Amplitude Modulation (PAM), like PPM is a form of signal modulation where it differs the message information is encoded in the amplitude of a series of signal pulses. Pulse Amplitude Modulation is an analogy pulse modulation scheme in which the amplitude of train of carrier pulse is varied according to the sample value of the message signal. Pulse Duration Modulation (PDM), is a pulse modulation technique that transmits analogue signals. PDM is not dependent on the height of the pulse but does depend on its duration.

WORKING

A. *How PPM Works:*

In PPM, data are transmitted with short pulses. All pulses have both the same amplitude and width. The parameter that changes is the delay between each pulse. Below is the example of a PPM signal:

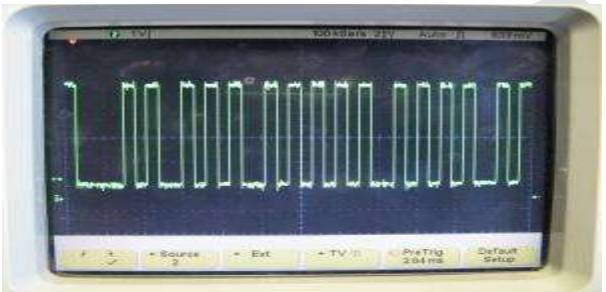

Fig.4. PPM encoded signal captured from a TV remote control

It is obvious that the signal has similar pulses (in terms of width and amplitude), yet the duration between them differs. Let's start with digital PPM to explain how exactly this method works.

B. *PPM for Digital Data Transmission:*

Modulating a digital signal to Pulse Position is pretty much straight forward. Digital 0 or 1 will represent the duration between the pulses. A large duration represents digital 1, and a small duration represents digital 0. The duration is not standard and varies according to the system requirements. The IR TV remote controls an example. The Sony IR protocol for example uses PPM transmission. A delay of 1.8mSec represents digital 1, and a delay of 1.2mSec represents digital 0. Here is an 8-bit data transmission example: example uses PPM transmission. A delay of 1.8mSec represents digital 1, and a delay of 1.2mSec represents digital 0. Here is an 8-bit data transmission example:

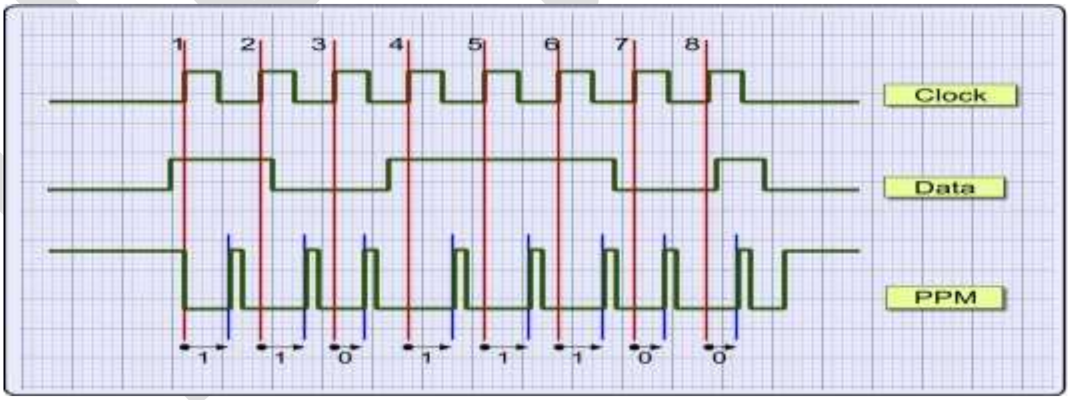

Fig.5. PPM data transmission

The byte '11011100' is encoded with PPM so that it can be transmitted with infrared light. For the first bit, after the rising edge of the clock, the transmitter will send a pulse 1.8 mSec. For the second bit, the transmitter will send a pulse 1.8 mSec right after the second rising edge of the clock. But after 1.2 mSec, the transmitter will send a pulse from the third rising edge of the clock which is 0. Same algorithm applies for all other bits.

This method has a great disadvantage that the decoding of the signal requires that the decoder has a perfectly synchronized clock with the transmitter which is impossible most of the times. The signal itself does not provide a method for the decoder to reconstruct the clock (as it happens with Manchester code or PWM). For this reason, the Differential Pulse Position Modulation is used.

ADVANTAGES

Pulse position modulation conveys simple commands that other forms of signal modulation are either simply not made for or are too complex to use in certain situations. Since pulse position modulation only communicates simple commands from a transmitter to a receiver, due to its low system requirements, it is often used in lightweight applications.

DISADVANTAGES

Pulse position modulation requires that both devices are synchronized or differential pulse position modulation is used. In addition, pulse position modulation is highly sensitive to multi-pathway interference, for example echoing, that can disrupt a transmission by altering the difference in arrival times of each signal.

COMPARISON BETWEEN PAM, PWM AND PPM

A. *PAM:*

In PAM, the modulating signal modulates the carrier pulse amplitude. The amplitude of high frequency carrier is varied in accordance with the sampled values of message signal.

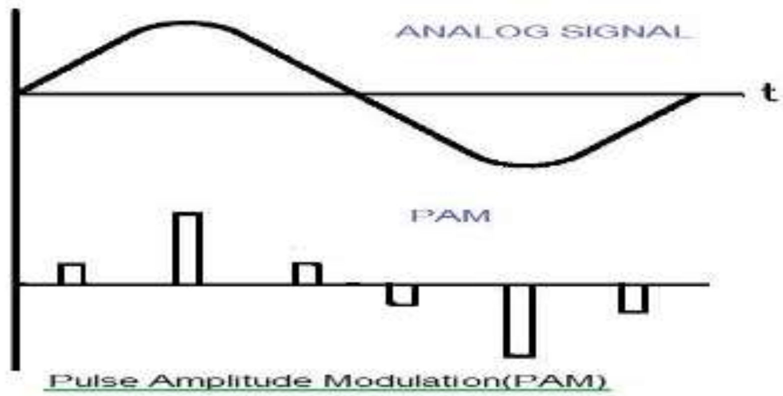

Fig.6. Pulse Amplitude Modulation

The figure represents time domain representation of the PAM technique which mentions analog message signal and PAM modulated signal as output.

B. *PWM:*

The PWM signal is a pulse signal where pulse width is proportional to the amplitude of the modulating analog signal

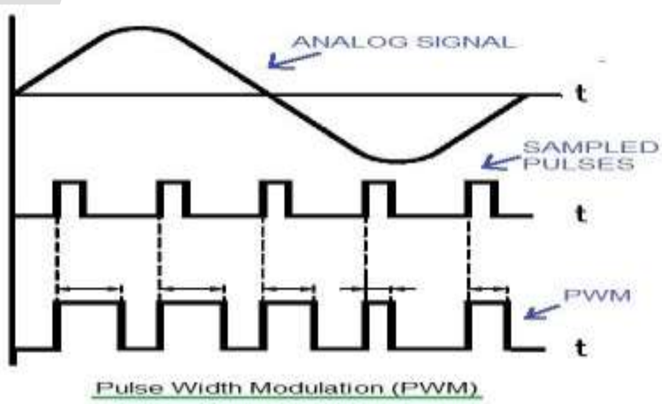

Fig.7. Pulse Width Modulation

The figure represents time domain representation of the PWM. One of the applications of PWM is in speed control of the DC motor.

C. *PPM:*

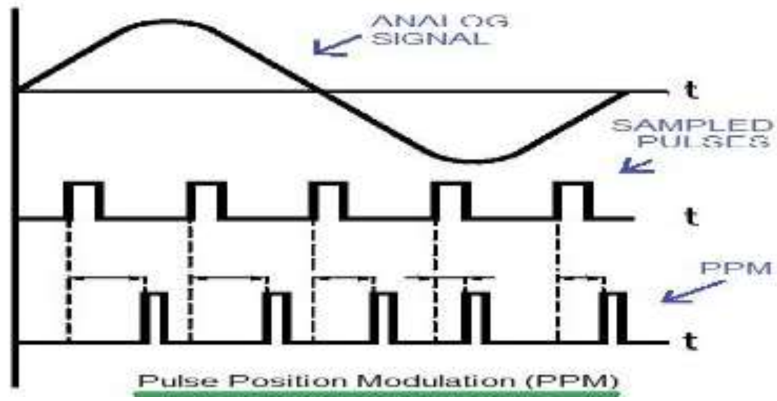

Fig.8. PPM

555 Timer IC is most popular to generate waveforms for PWM and PPM modes. PWM is generated using 555 timer in monostable multivibrator mode. The PPM is generated using 555 timer by using PWM as a trigger signal in monostable multivibrator mode. The following table summarizes difference between PAM, PPM and PWM.

Method	B.W.	Power Efficiency(SNR)	Complexity
PAM	Less	Lowest	Lowest
PWM	High	Moderate	Moderate
PPM	High	Highest	Highest

Table 1. Comparison between PAM, PWM, PPM.

COOPERATIVE DIVERSITY

COOPERATIVE DIVERSITY IS A COOPERATIVE MULTIPLE ANTENNA TECHNIQUE FOR IMPROVING OR MAXIMIZING TOTAL NETWORK CHANNEL CAPACITIES FOR ANY GIVEN SET OF BANDWIDTHS WHICH EXPLOITS USER DIVERSITY BY DECODING THE COMBINED SIGNAL OF THE RELAYED SIGNAL AND THE DIRECT SIGNAL IN WIRELESS MULTIHOP NETWORKS. A CONVENTIONAL SINGLE HOP SYSTEM USES DIRECT TRANSMISSION WHERE A RECEIVER DECODES THE INFORMATION ONLY BASED ON THE DIRECT SIGNAL WHILE REGARDING THE RELAYED SIGNAL AS INTERFERENCE; ON THE OTHER HAND THE COOPERATIVE DIVERSITY CONSIDERS THE OTHER SIGNAL AS CONTRIBUTION. MEANING, COOPERATIVE DIVERSITY DECODES THE INFORMATION FROM THE COMBINATION OF TWO SIGNALS. THUS, IT CAN BE SEEN THAT COOPERATIVE DIVERSITY IS AN ANTENNA DIVERSITY THAT USES DISTRIBUTED ANTENNAS BELONGING TO EACH NODE IN A WIRELESS NETWORK. NOTE THAT USER COOPERATION IS ANOTHER DEFINITION OF COOPERATIVE DIVERSITY. USER COOPERATION CONSIDERS AN ADDITIONAL FACT THAT EACH USER RELAYS THE OTHER USER'S SIGNAL WHILE COOPERATIVE DIVERSITY CAN BE ALSO ACHIEVED BY MULTI-HOP RELAY NETWORKING SYSTEMS.

A. *Relaying Strategies:*

The simplest cooperative relaying network consists of three nodes, namely destination, source, and a third node supporting the direct communication between source and destination denoted as relay. If the direct transmission of a message from source to destination is not (fully) successful, then the overheard information from the source is forwarded by the relay to reach the destination via a different path. Since the two communications took a different path and take place one after another, this example implements the concept of time diversity and space diversity.

The relaying strategies can be further distinguished by the compress-and-forward, decode-and-forward and amplify-and-forward strategies:

- The amplify-and-forward strategy helps to allow the relay station to amplify the received signal from the source node and to forward it to the destination station
- Relays following the decode-and-forward strategy overhear transmissions from the source, decode them and forward them to the destination in case of correct decoding. Whenever unrecoverable errors reside in the overheard transmission, the relay cannot contribute to the cooperative transmission.
- The compress-and-forward strategy allows the relay station to compress the received signal from the source node and forward it to the destination without decoding the signal where Wyner-Ziv coding can be used for optimal compression.

B. *Relay Transmission Topology*

- **Serial relay transmission** is used for long distance communication and range-extension in shadowy regions. It provides power gain. In this topology signals propagate from one relay to another relay and the channels of neighbouring hop are orthogonal to avoid any interference.
- **Parallel relay transmission** may be used where serial relay transmission suffers from multi-path fading. For outdoors and non-line-of-sight propagation, signal wavelength may be large and installation of multiple antennas is not possible. To increase the robustness against multi-path fading, parallel relay transmission can be used. In this topology, signals propagate through multiple relay paths in the same hop and the destination combines the signals received with the help of various combining schemes. It provides power gain and diversity gain simultaneously.

SYSTEM MODEL

We consider a wireless relay system that consists of source, relay and destination nodes. It is assumed that the channel is in a half-duplex, orthogonal and amplify-and-forward relaying mode. Differently to the conventional direct transmission system, we exploit a time division relaying function where this system can deliver information with two temporal phases.

On the first phase, the source node broadcasts information x_s toward both the destination and the relay nodes. The received signal at the destination and the relay nodes are respectively written as:

$$r_{d,s} = h_{d,s}x_s + n_{d,s}$$
$$r_{r,s} = h_{r,s}x_s + n_{r,s}$$

where $h_{d,s}$ is the channel from the source to the destination nodes, $h_{r,s}$ is the channel from the source to the relay node, $n_{r,s}$ is the noise signal added to $h_{r,s}$ and $n_{d,s}$ is the noise signal added to $h_{d,s}$.

On the second phase, the relay can transmit its received signal to the destination node except the direct transmission mode.

NON-COOPERATIVE SCHEME

In the non-cooperative scheme, the destination decodes the data using the signal received from the relay on the second phase, which results in the signal power boosting gain. The signal received from the relay node which retransmits the signal received from the source node is written as:

$$r_{d,r} = h_{d,r}r_{r,s} + n_{d,r} = h_{d,r}h_{r,s}x_s + h_{d,r}n_{r,s} + n_{d,r}$$

where $h_{d,r}$ is the channel from the relay to the destination nodes and $n_{r,s}$ is the noise signal added to $h_{d,r}$.

The reliability of decoding can be low since the degree of freedom is not increased by signal relaying. There is no increase in the diversity order since this scheme exploits only the relayed signal and the direct signal from the source node is either not available or is not accounted for. When we can take advantage of such a signal and increase in diversity order results. Thus, in the following we consider the cooperative scheme which decodes the combined signal of both the direct and relayed signals.

COOPERATIVE SCHEME

For cooperative decoding, the destination node combines two signals received from the source and the relay nodes which results in the diversity advantage. The whole received signal vector at the destination node can be modeled as:

$$\mathbf{r} = [r_{d,s} \quad r_{d,r}]^T = [h_{d,s} \quad h_{d,r}h_{r,s}]^T x_s + \left[1 \quad \sqrt{|h_{d,r}|^2 + 1}\right]^T n_d = \mathbf{h}x_s + \mathbf{q}n_d$$

where $r_{d,s}$ and $r_{d,r}$ are the signals received at the destination node from the source and relay nodes, respectively. As a linear decoding technique, the destination combines elements of the received signal vector as follows:

$$y = \mathbf{w}^H \mathbf{r}$$

where $\mathbf{w}$ is the linear combining weight which can be obtained to maximize signal-to-noise ratio (SNR) of the combined signals subject to given the complexity level of the weight calculation.

RESULTS

Simulations are performed over the channel model recommendation. A Gaussian pulse with a duration of *Tw* = 0.5 ns is used. The modulation delay is chosen to verify δ=100 ns which is larger than the maximum delay spread of the UWB channel. The presented results show the variation of the error probability as a function of the SNR per bit .for non-cooperative systems and to *Es***N*0 log2*M/(M*+1)*M* for the proposed cooperation scheme.

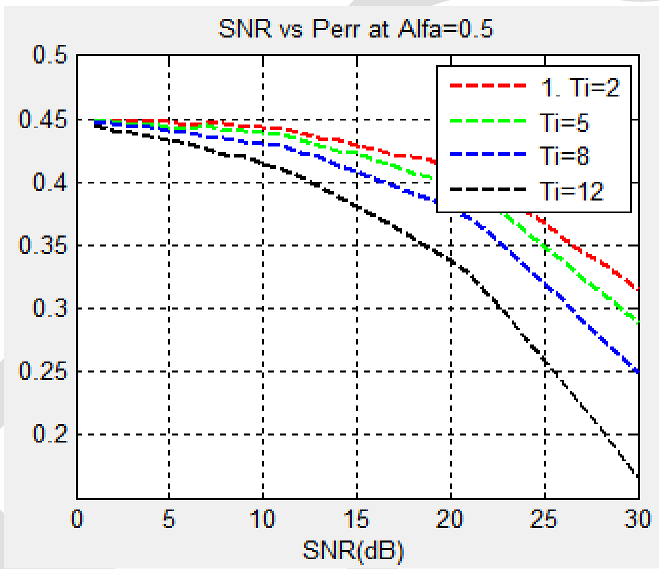

Fig.9. performance of the proposed scheme with relay assisted pulse position modulation is applied withα = 0.5

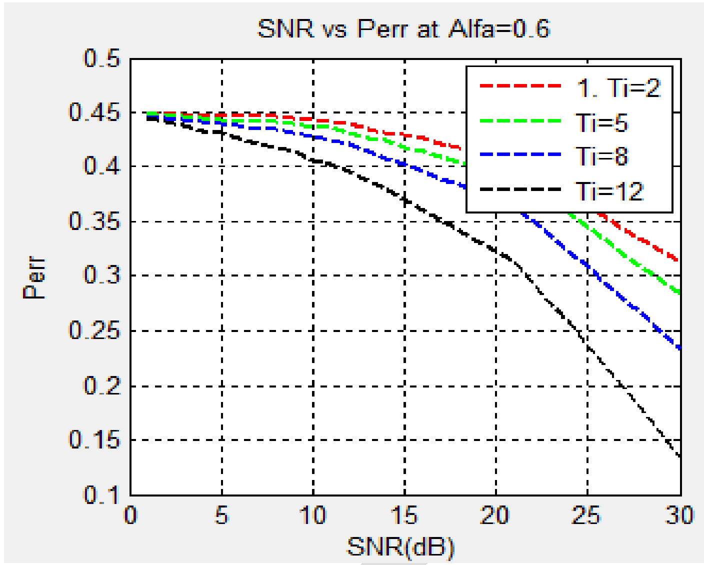

Fig.10. performance of the proposed scheme with relay assisted pulse position modulation is applied with $\alpha = 0.6$

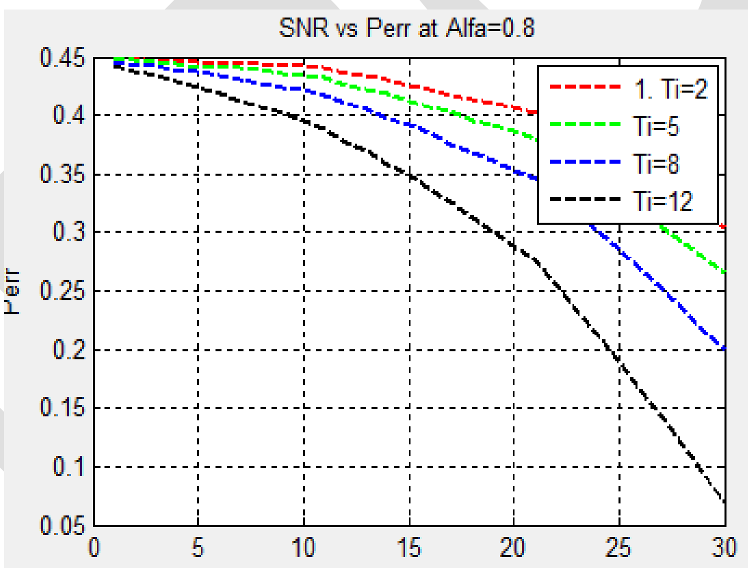

Fig.11. performance of the proposed scheme with relay assisted pulse position modulation is applied with $\alpha = 0.8$

The proposed cooperative system can be coupled with two possible power allocation schemes. In the first one, α is held constant independently from the specific channel realization while the second scheme is based on adapting the value of α to the channel realization according to the strategy proposed previously in this section. The advantage of the first scheme resides in its simplicity while the second scheme has the capability of achieving higher performance levels as shown later. A possible implementation of the second scheme can be based on evaluating α at D and providing this value to S and R via two feedback links. In this case, the noise variance as well as the S-R, S-D and R-D channels need to be known at D.

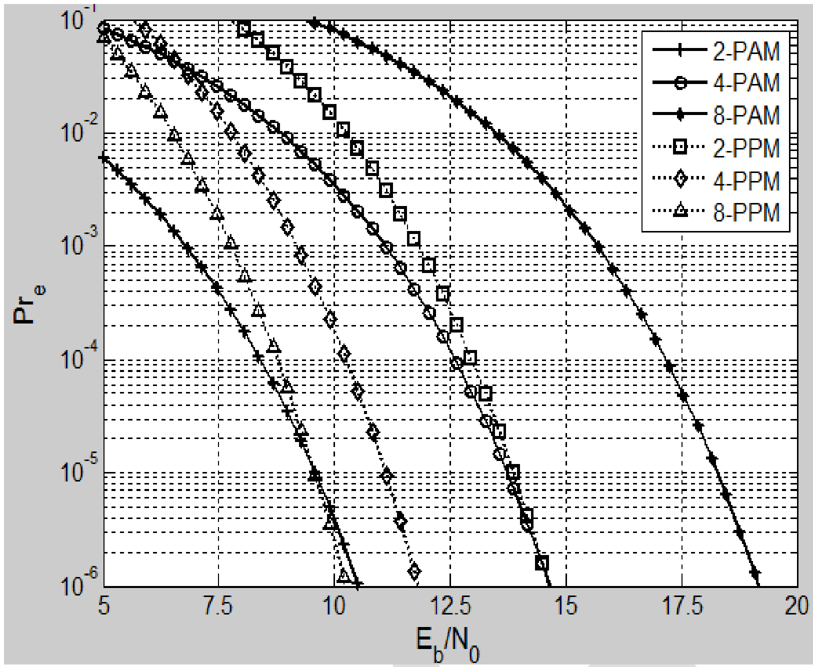

Fig.12. Symbol error probability between PAM and PPM

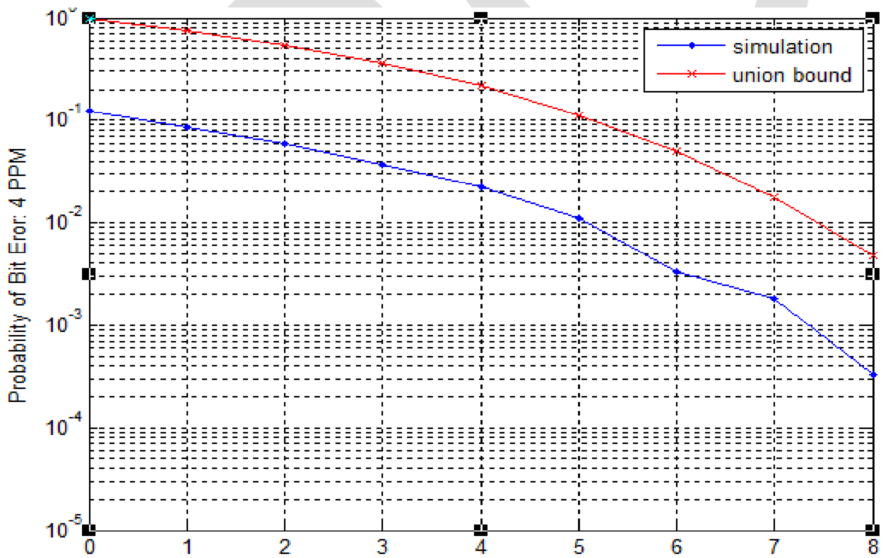

Fig.13. Probability of Bit error for 4 PPM

Fig.13. shows the performance with M=4 and βsr=βrd=4. PAS-1 is applied with α = 0.8. This figure shows that the upper-bound can be accurately used for estimating the performance of the proposed scheme with MPPM (for M >2) especially for large values of the SNR since this bound is very close to the exact error probability for large SNRs. Note that even for the large integration time of Ti= 20 ns where the number of multi-path components captured at the receiver side is large.

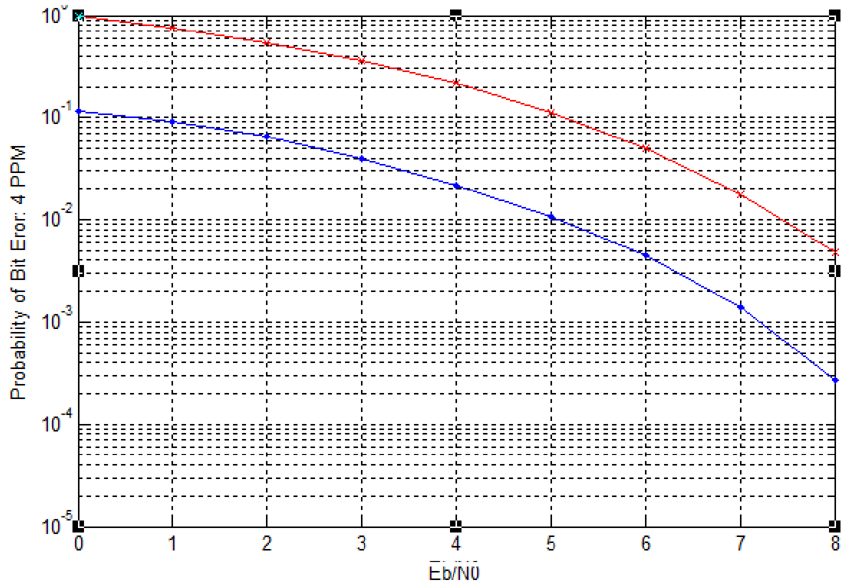

Fig.14. Probability of Bit for 4 PPM

CONCLUSION

We have crated simulation that was described in the report to include both the 4-ary ppm , M-ary PPM, and then we proposed a new novel fixed PPM, that is more robust against interference from other users and utilizes the channel more efficiently. This method involves going to higher orders of PPM modulation but maintaining the duration fixed, in this way a user will finish its transmission faster, concluding that the probability of interference will decrease. The proposed methodology was tested using MATLAB codes, which we built from scratch, the results of the code emphasizes our proposal.

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