



AN ENHANCED SPATIAL PULSE POSITION MODULATION FOR ULTRA-WIDE BAND (UWB) COMMUNICATION LINK

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ABSTRACT

Transmission rate and bit error rate (BER) performance are two important parameters for ultra-wideband (UWB) communication system. Among the widely used modulation schemes, pulse position modulation (PPM) is attractive for its high energy efficiency. However, PPM scheme suffers low data rate and poor bit error rate performance due to the symbol pattern (duration) required for high number of M bits. The study employed combination of Spatial Pulse Position Modulation (SPPM) and On-Off-Keying (OOK) in order to improve the BER performance. While SPPM results in high bit error rate performance, the OOK is predicted to improve the BER at low signal to noise Ratio (SNR). The enhanced scheme combined SPPM and OOK, results has an improved BER by an order of two and an increase in the data rate by two orders of magnitude relative to the standard PPM. The study revealed that two schemes could be combined to enhanced transmission rate and low SNR. The scheme could be recommended optical communication system (OCS).

Keywords: UWB, OOK, SSK, SPPM

INTRODUCTION

Transmission rate and bit error rate (BER) performance are two major concerns for ultra-wideband (UWB) communication systems (Abdullah and Nazmal, (2008); Cui, 2011). The BER of a communication system specifies the number of bit errors as a fraction of the transmitted bits, while the bit transfer rate is defined as the number of bits transmitted per second. The bit transfer rate is the product of the number of bits per symbol and the signaling rate, and indicates a direct relationship between the bandwidth and the bit transfer rate. This relationship makes Ultra-Wide Band (UWB) communication systems attractive due to the resultant high bit transfer rates (Allen, *et. al*; 2014); Mu and Qui, 2008). UWB communication system is a wireless technology that uses high bandwidth (larger than 500 MHz) for data communications. UWB systems have variously been implemented using modulation techniques such as Pulse Position Modulation (PPM), On-Off Keying (OOK) and Space Shift Keying (SSK), especially in free space optical (FSO) communication systems (Thakre and Dhenge, 2012; Mesleh *et. al*; 2008). Pulse Position Modulation (PPM) uses $2M$ possible pulses, of constant width and amplitude, to represent M number of bits. PPM is limited and prone to poor BER performance and slow transfer rates, but is attractive due to its energy efficiency. Space Shift Keying (SSK) on the other hand encodes the spatial arrangement of a number of transmitters in data transmission and thus results in a very good bit error rate performance (Jeganatham *et. al*; 2009). Hybrid technique could be deployed to enhance performance and better data rate with low energy. Spatial Pulse Position Modulation (SPPM) could be combined with Space Shift Keying (SSK) with Pulse Position Modulation (PPM) for optical wireless communication systems, utilizing the high energy efficiency of the PPM and high bit error rate error performance of the SSK (Popoola *et. al*; 2012). The SPPM has superior BER performance in comparison to the standard PPM. The enhanced scheme clearly indicates that the waveform from each transmitter is in the OOK return-to-zero (RZ) format. If an RF receiver is tuned to the frequency of the voltage controlled oscillator (VCO) at the transmitter, the pulse will be recovered when it passes through a peak detector. The recovered pulse signal is then processed and decoded. The study combined SPPM and On-Off Keying (OOK), thereby enhancing performance mode of transmission from an optical channel to a band pass channel. An evaluation of its bit error rate performance is carried out through theoretical analysis and computer simulations suggested (Mesleh *et. al*; 2008 and Popoola *et. al*; 2012).

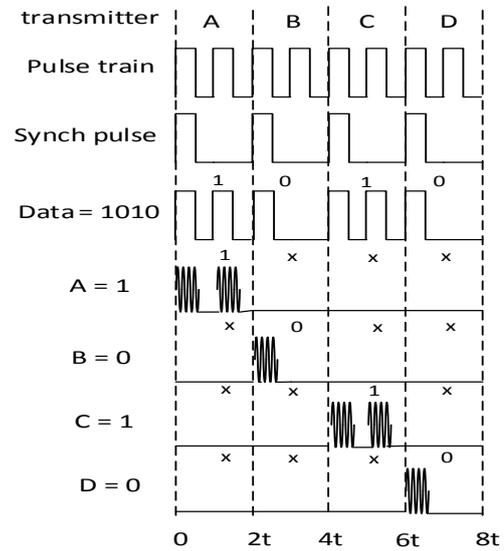


Figure 1: The Enhanced SPPM signal (Popoola *et. al.*, 2012)

MATERIAL AND METHODS

Simulation Methodology

The study employed MATLAB R2018b for the simulation and adapting equation 1 (Popoola *et. al.*, 2012). M bits information per transmitter in the SPPM scheme, the BER is expressed as shown in the equation 1:

$$BER_{sppm} = 1 - \left(\frac{2M-1}{N_t}\right) \left(\frac{2}{N_t} \sum_{i=1}^{N_t-1} \sum_{j=i+1}^{N_t} Q\left(\left|h_i - h_j\right| \sqrt{\frac{\gamma}{2}}\right)\right) \times \sum_{k=1}^{N_t} \frac{1}{2M-1} - Q\left(h_k \sqrt{\gamma}\right) \dots (1)$$

Where $\gamma = (1 + \log_2 M) \times SNR$ as expressed as the ratio of the power per bit to the noise power; N_t is the number of transmitters and correlated (Thambidurai and Krishnagura, 2011); with bandwidth (B), bits/symbol (M), and L is symbols revealed in equation 2.

$$\frac{B}{N_t L} \log_2(N_t L) = \frac{B}{2MN_t} \log_2(1 + MN_t) \dots (2)$$

The equations 1 and 2 provides the numerical approach to estimate the error probability of the data contained in the SPPM signal using simulated SNR in MATLAB environment, this could be evaluated as well using SPPM models. The study adapted Figure 2, to investigate BER in the enhanced SPPM model as suggested (Ikki and Mesleh, 2012; Chen, 2014).

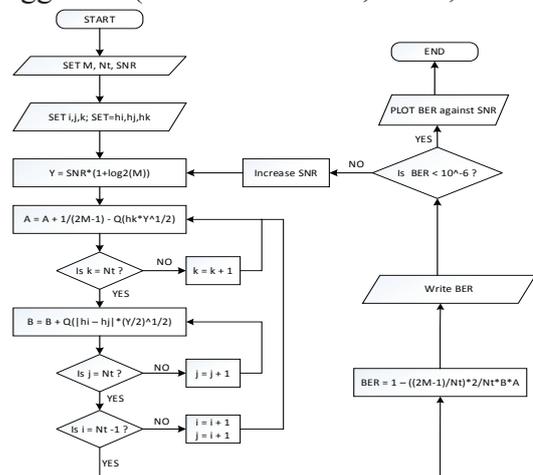


Figure 2: Flow chart for the enhanced SPPM (Chen, 2014)

RESULTS AND DISCUSSION

Bit error rate (BER), defined as the ratio between the total error bits and the total bits of the data stream in a communication channel, is mainly affected by noise, interference, multipath distortion or bit synchronization errors (Mungale and Thakare, 2009; Mesleh *et al.* 2012). In this simulation, the study assumed that the communication system does not experience inter-symbol-interference (ISI) and bit synchronization errors. The discussion here focuses on the modified or enhanced SPPM signal with respect to the bit error rate performance and the bit rate. The study have accounted for channel noise in the simulations by assuming Additive White Gaussian Noise (AWGN) environment.

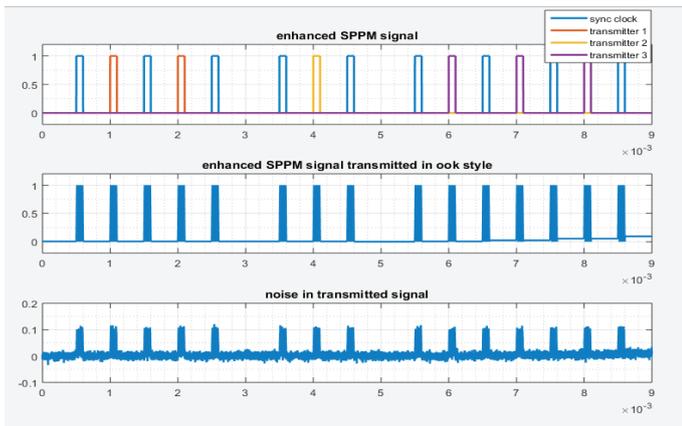


Figure.3: Comparative view

Figure 3 (Comparative view) shows the SPPM signal (upper), the enhanced SPPM signal (middle) and the signal in the additive white gaussian noise (lower). Three transmitters are used to propagated 3bits/symbol at a pulse rate of 1kHz (symbol duration of 3ms). From the figure 3, each transmitter generates 3 leading synchronizing pulses (in blue) with 3 lagging empty slots; red, yellow, and purple slots for the first, second and third transmitter respectively. The presence of a pulse in any of the slots represents a 1 and a 0 if otherwise. In the first 3 slots for transmitter 1, the absence of a pulse represents a 0 in the first slot, the presence of a pulse represents a 1 in the second slot, and presence of a pulse represents a 1 in the third slot, thus transmitter 1 is sending 011. Similarly, transmitter 2 and 3 are sending 010 and 111 respectively. The receiver decodes the data by comparing the pulse in each time slot with the sync pulse. Inter-symbol interference (ISI) will occur if all the transmitters are sending data simultaneously and the receiver will not be able to decode the data correctly. The link could develop bandwidth limitation with respect high signal ratio. The bit/symbol per transmitter is 3, the transmitters must send 3 bits sequentially this can avoid inter-symbol interference (ISI) development. The three transmitters may transmit 000 to 111 sequentially in a cyclic manner; 001 by first transmitter 010 by the second and 001 by

the third, 100 by the first transmitter again, and so on.

SPPM in Additive White Gaussian Noise (AWGN)

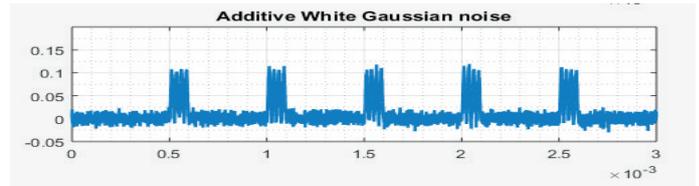


Figure 4: Additive White Gaussian in the SPPM signal

The study evaluated the enhanced SPPM signal with respect subjected to a random noise (AWGN) as shown in Figure 4 using signal to noise ratio (SNR). By comparison, the SNR is 10% of the signal amplitude; the system could accommodate this noise. If the noise increases beyond this, bit error will increase and this will have significant distortion at the receiver. To address this, the three transmitters with 3bits/symbol per transmitter, the input data to each transmitter was fixed at 111 in order to obtain maximum signal to noise ratio.

SPPM and Number of Transmitters

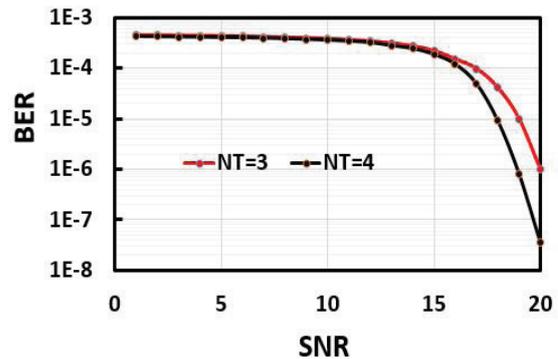


Figure 5: The BER for the Enhanced SPPM for different number of transmitters

Figure 5, the study compared the bit error rate (BER) performance as a function of the number of accommodated transmitters, with $N_t = 3$ (blue curve) and $N_t = 4$ (red curve). The channel characteristic for each transmitter gain is 4 and the receiver is 3.2. The bit error rate decreases as the SNR increases as shown. At lower SNR, the BER is almost the same before the curves disassociated at at 4×10^{-4} , while at higher SNR, the $N_t = 4$ transmitter system increases further. This resulted in better BER performance of 9×10^{-6} at 19 dB, about an order of magnitude higher than the 3-transmitter system.

Enhanced SPPM and Bandwidth Requirement

Figure 6 shows the bandwidth requirement for increasing bit rate as a function of the number of transmitters and the number of bits to represent a symbol. The bandwidth is higher when either the number of bits or the transmitters is increased (Renzo and Haas, 2010; Mungale and Gupta; 2014). However, the study shows that the link can accommodate

more bits with respect to number of transmitter. The communication link is self-adjusted to avoid inter-symbol interference (ISI) in order to full utilize the bandwidth. The enhanced SPPM revealed that modulation scheme could be combined for channel (AWGN) efficacy

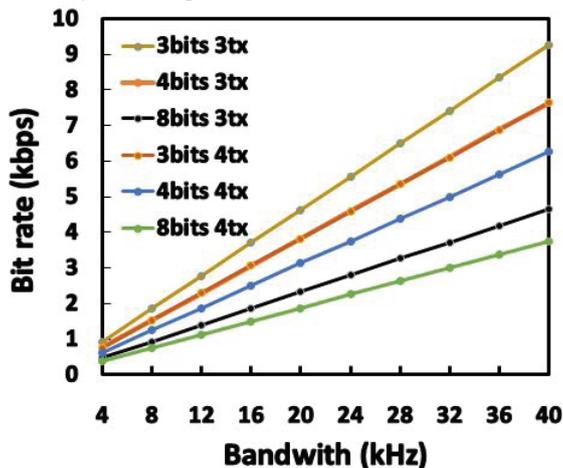


Figure 6: Enhanced SPPM and Bandwidth

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CONCLUSION

The study has effectively combined pulse position modulation (PPM) and On-Off Keying (OOK) to produce an enhanced Spatial Pulse Position Modulation (SPPM) in the context of ultra-wide band communication link. The work adopted bit error rate (BER), signal to noise ratio (SNR), bit rate and bandwidth efficiency to evaluate the enhanced link. The enhanced SPPM scheme has better BER performance with respect to number of transmitters in the modulation and this revealed the scheme can be fully utilized as shown above. The study shows that the scheme can accommodate more bits as the band width increases and this revealed that the communication link can self-adjusted to mitigate noise. However, the scheme is efficient and can avoid inter-symbol interference (ISI) without thinking of application of equalizer and it is recommended to optical communication system (OCS).