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Tuning the Physical Parameters of Most Influence Effect for Enhanced Receiver Performance of Pulsed-Based Ultra-Wideband in Short-Range Wireless Solutions

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Abstract: This paper proposes enhancements to receiver performance by tuning the most critical parameters of the generated pulses as pulse modulations and frame timing structure. These parameters are significant influences on the performance of the receiver. This performance can be described as the probability of the lost packet using the signal-to-noise ratio in varying distances and data rate scenarios. The method used to validate the achievements of the enhancements of the receiver performance is usually defined as proposing a communication link of a certain pulse-based wireless system where initially the physical parameters are set as reference parameters. Consequently, tuning each parameter separately to determine the enhancements of the receiver performance in different data rates and distances. Results indicated that the performance could be enhanced significantly in terms of the received signal errors for specific signal noise to power ratio with approximately up to 50% by tuning some physical parameters that significantly affect received signal quality. Tuning these parameters allows enhanced performance for certain scenarios and application requirements.

Keywords: *Ultra-wideband, Time Hopping (TH), pulse position modulation, physical parameters, signal to noise ratio, bit error rate*

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I. INTRODUCTION

UWB is recently of great interest for short ranges wireless application due to its unique characteristics as a very short a train of pulses in ultra-wide bandwidth. In addition, the significant reduction of power consumption can be achieved by the discontinuous emitted pulses, where these pulses can be tuned to achieve different data transmissions [1, 2]. Since this technology considered carrier-less technology, modulation can be performed by altering the pulse positions, amplitude or polarity. Moreover, Impulse Radio-UWB (IR-UWB) emitter can be designed without an RF stage, which means less power and receiver complexity [3, 4, 5]. These advantages can be utilized for many short-range wireless applications sharing the same power and design constraints (such as WSN and RFID) [6, 7, 8, 9]. The re-configurability flexibility of IR-UWB technology utilized for short to medium ranges as well as low to high data transmission rate requirements. Where tracking and accurate position detection applications are IR-UWB low data rate technology [10], while transmission high resolution images in medical applications are considered UWB high data rate technology [11, 12]. Enhancements of this technology have been carried out to allow this technology to satisfy different

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wireless requirements in one solution such as optimized resource allocations, MAC-PHY cross-layer utilizations and adaptive antenna designs [13, 14]. As found in literature, many works have been done on enhancements of the control and management functionalities of the MAC layers, whereas the enhancements of the parameters of the physical layers have given less attention [15, 16, 17]. The main motivation of this paper is to highlight the efficient selection of the physical parameters with their tuned associated values that enable the MAC layer to serve different requirements of distances and data transmissions. Furthermore, the generated signal parameters and their tunings for managing the different requirements of distance and data transmission at the MAC layer are defined in this work. Reference receiver performance is determined by a set of default parameters to generate the reference transmitted signal and then each parameter tuned separately with different possible values to detect and validate the performance enhancements by comparisons. However, the main objectives of this paper are to show the different enhancements which can be achieved on the received time-hopping UWB signal by tuning its physical parameters as well as how this can be utilized for the proposal of the cross-layer solution of the communication system.

The remainder of this paper is organized as follows: the follows section describes the generated referenced signal with all its related parameters thereafter, the receiver performance in term of BER for certain SNR is evaluated after tuning these parameters. These parameters include the number of generated pulses, generated pulses per bit, pulses shaping factors, pulses modulations and pulses spreading spectrum techniques and finally, the results are concluded along with consideration for a future extension is discussed.

II. PULSED-BASED UWB MODEL AND PARAMETERS

The signal generated with TH with M-ary with pulse position modulation for K-th user can be mathematically modeled as [16]:

$$S^{K}(t)\sum_{j=-\infty}^{\infty}A^{(k)}_{d[J/Ns]}p\left(t-T_f-C^{(k)}_j-\delta_d(k)_{[J/N\varepsilon]})\right) \quad (1)$$

Where P(t) is the pulse shaping of the second derivative of Gaussian pulse with pulse width T_p. T_f is the frame time and each frame is divided into N_h time slots with duration time T_c. $C^{(K)}_j$ is the pulse shaping patterns, which is pseudorandom numbers with period T_c, it represents the TH sequence for K-th users. d is the sequence for the data stream generated by the K-th user after channel coding. δ is the shift introduced to modulate the pulse by M-ary PPM.

The signal amplitude $A^{(v)}$ can be assumed one for the M-ary PPM signal, then the equation (1) can be written as:

$$S^{(v)}(t)=\sum_{j=-\infty}^{\infty}p(t-jT_f-c^{(k)}_jT_c-\delta d^{(k)}_{[j/Ns]} \quad (2)$$

The generated referenced Pulse-Based UWB signal with its associated values can be summarized in Table 1. While Fig. 1. illustrates the generated transmitted IR-UWB according to the default values listed in Table 1.

TABLE 1
GENERATED PULSE-UWB WITH THEIR ASSOCIATED VALUES

Tunable IR-UWB Transmission Parameter	Description of the Parameter
Average transmitted power (Pow) in dBm unit	-30
Sampling frequency (Fc)	$50*10^9$
Number of bits generated by the source	1000
Average pulse repetition (Ts)	$3*10^{(-9)}$
Number of pulses per bit (Ns)	1
Chip time (Tc)	$1*10^{(-9)}$
Cardinality of the TH code (Nh)	3
Period of the TH code (Np)	2
Pulse duration (Tm)	$0.5*10^{(-9)}$
Shaping factor for the pulse (Tau)	$0.25*10^{(-9)}$
Modulation techniques	Binary-PPM
Channel models	AWGN

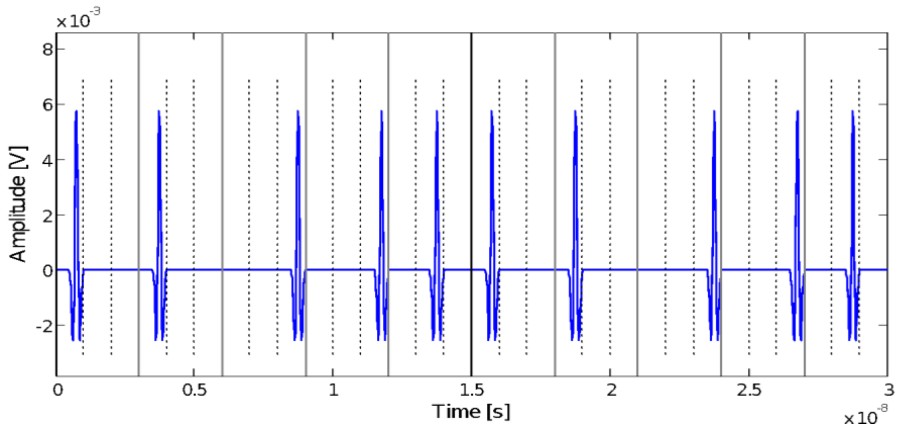

Fig. 1. Simulation of Generated Pulsed-Based UWB

Fig. 2 summarizes the methodology followed in order to tune the PHY layer parameters according to certain performance requirements in MAC layer in cross-layer design solution as the PHY parameters tuned until met the criteria set by the MAC layer.

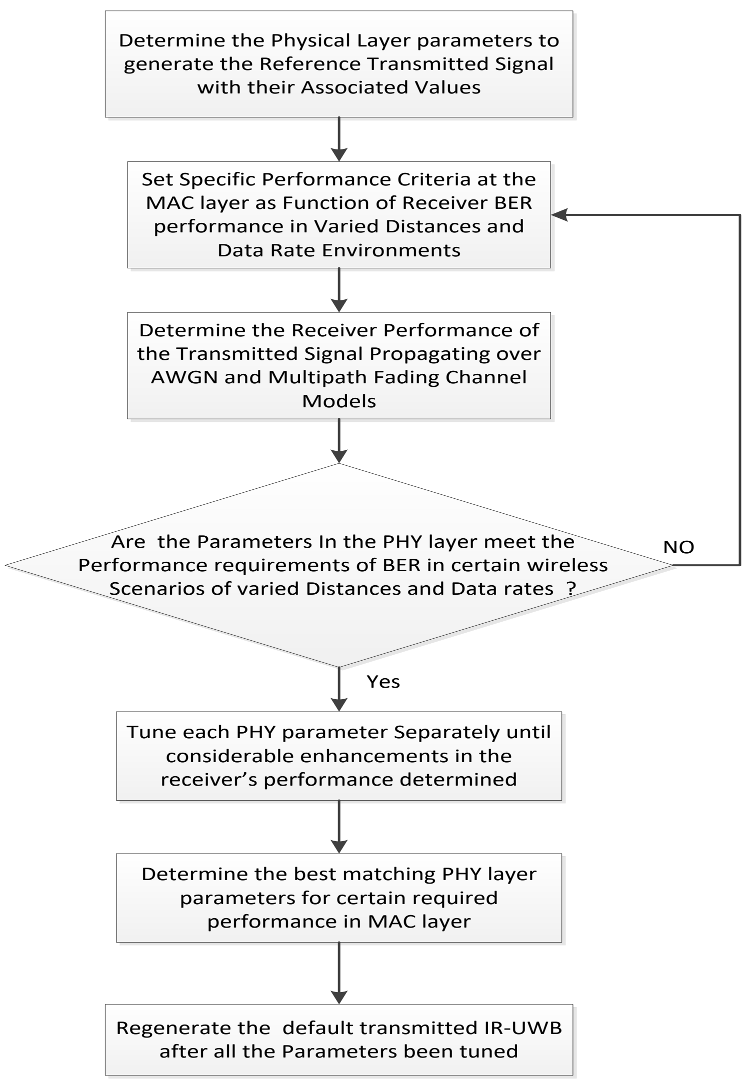

Fig. 2. Flowchart of the proposed tunable PHY-MAC layer solution of IR-UWB for certain application requirements

III. RECEIVER PERFORMANCE WITH TUNABLE UWB GENERATED PULSES

The performance of the proposed tunable impulse-based UWB system is evaluated using BER criteria for different pulse shapes, coding, and signal timing structures. The physical parameters of the pulses are tuned to achieve different transmission rate requirements in various distance scenarios. Channel conditions of AWGN and IEEE 802.15.3a multipath fading channel models are considered in the simulation. System performance can be simplified as predetermined BER versus different data rate requirements in various distance scenarios. Pulses can be generated with different transmission rates depending on the Pulse Repetition Interval (PRI), pulse modulation (M), and the number of generated bits (N). Therefore, the relationship between system design and evaluation can be defined as BER versus (PRI, M, N, and D) in different channel conditions. To evaluate different IR-UWB signal parameters, the receiver performance of reference signal parameters is considered a reference scenario, which can be considered as a function of the BER for the certain value of the SNR over AWGN channel model as shown in Fig. 3.

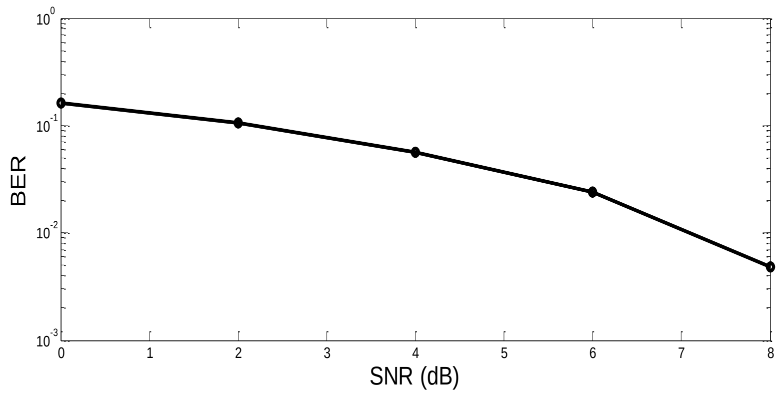

Fig. 3. Receiver performances of TH-PPM

RAKE receiver performance of UWB for time hopped pulse position modulated signal propagating over a multipath channel is evaluated. Results show that the ideal RAKE (ARAKE) receiver processes all the multipath components and their contributions. The Selective RAKE (SRAKE) has eight multipath components and selects the multipath contribution which exhibits the best signal quality. Thus, the transmitted symbol selects based on the observation of this contribution only. The Partial RAKE (PRAKE) is the simplest receiver structure and has two branches. The selection process in this receiver considers only the first two multipath components.

The BER performance can be enhanced significantly as shown in Fig. 4. which is comparing the performance of the three different RAKE structures. In ARAKE, the BER $=10^{-1.9}$, while in the case of PRAKE, BER $=10^{-0.9}$. The SRAKE outperforms the PRAKE which process the eight randomly by almost 10% enhancement on the BER performance at SNR = 9 dB.

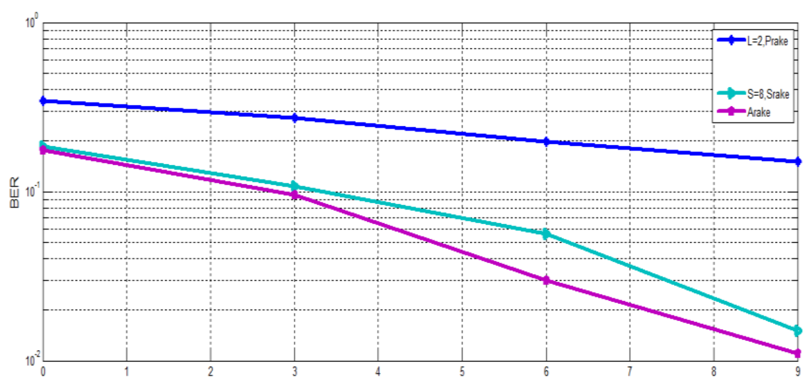

Fig. 4. RAKE receiver performance: ARAKE, SRAKE and PRAKE

However, the performance of the receiver degrades significantly, when the number of processed channel components is reduced. From this analysis, it's clearly seen that in designing a tunable IR-UWB solution is essential to select a proper RAKE receiver structure with a good trade-off between the receiver complexity and the BER application requirements.

Using BER criteria, the effects of pulse repetition rates, widths, shaping factors, and modulation are analyzed to indicate the significance of each parameter. Figure 5 illustrates the BER curve observations. As the number of generated bit increased from 1000 to 6000, the BER performance decreased $10^{-2.7}$ to $10^{-1.7}$ for the same SNR = 9 dB. This is due to the number of bits increases; more bits are susceptible to noise so that, more errors can occur. Therefore, the trade-off should be made when tuning the IR-UWB system based on the number of bits.

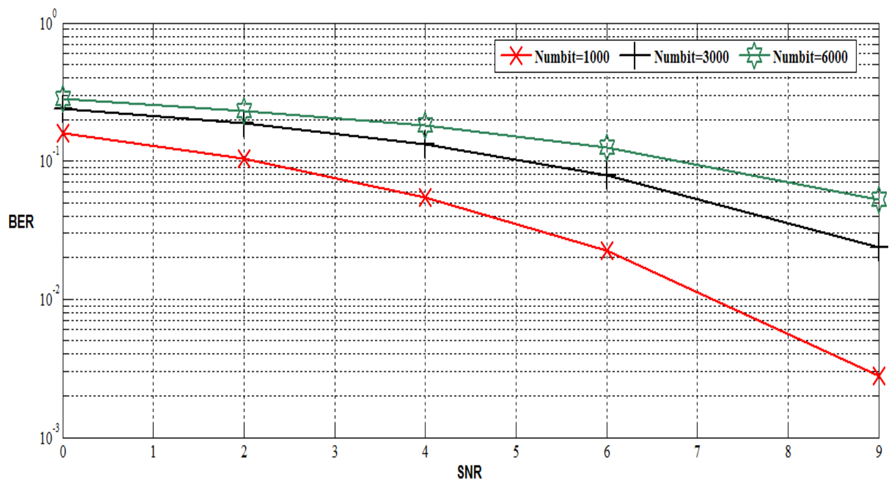

Fig. 5. TH-PPM receiver performance with different numbers of source bits

By contrast, the BER performance is enhanced significantly as the number of pulses per bit increases as shown in Fig. 6. As the number of pulses per bit increased by multiple of 6, the BER performance enhanced from ($10^{-1.2}$ to $10^{-4.5}$) for the SNR = 9 dB. Thus, an average BER of the system is proportional to the Number of Pulses. Therefore, the designer can make an optimum trade-off between the numbers of pulses per bit requirements to transmission rates suitable for the propagation condition. This work provides contributions due to existing difficulties to make trade-off directly on the IR-UWB system with different transmission rates.

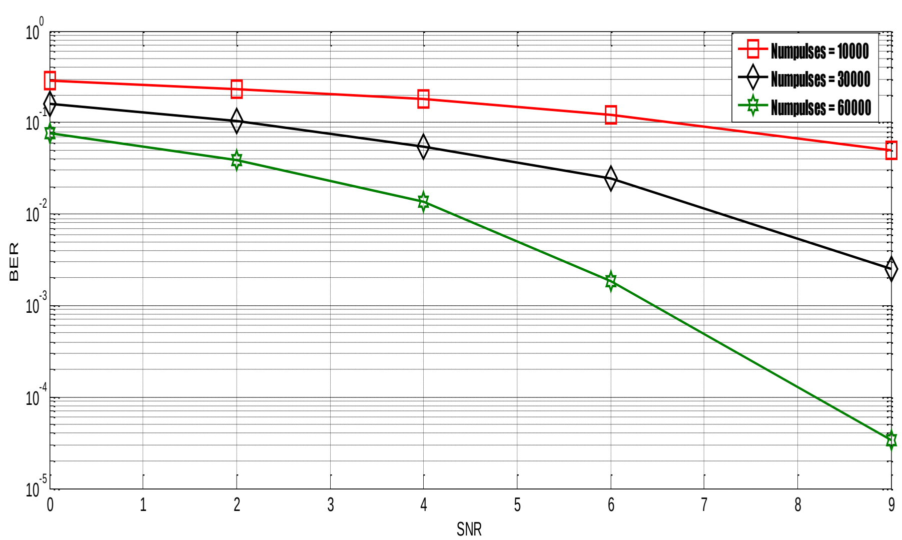

Fig. 6. TH-PPM receiver performance for pulses per number of pulses per bit

Fig. 7, shows that the decrease in pulse repetition period 8×10^{-4} s to 3×10^{-9}s enhances BER performance with BER at the same SNR of 9 dB from 10^{-2} to $10^{2.9}$. This can be explained as the system is more susceptible to noise and interferences if the pulse repetition period is increased.

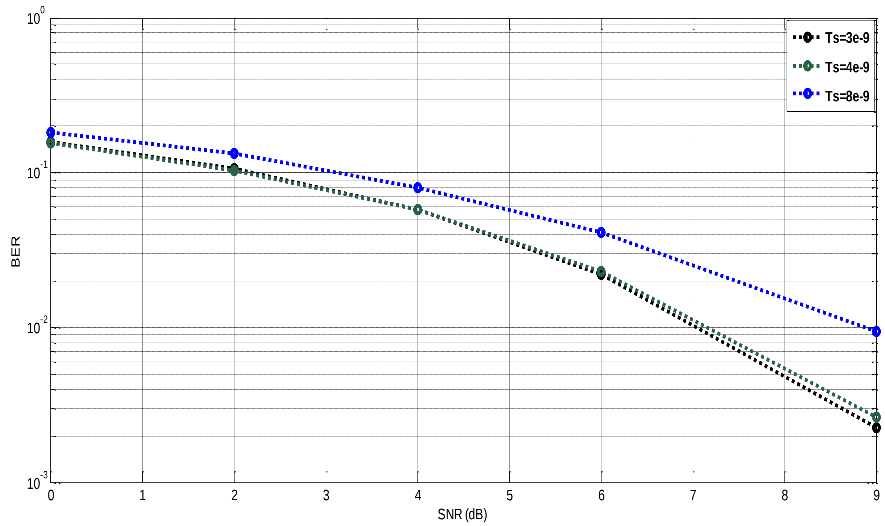

Fig. 7. Effects of different average pulse repetition periods (Ts) on TH-PPM receiver performance

Fig. 8 shows the pulse shaping factor (depends on pulse width) which has minimal effect on BER performance. For the tunable TH-UWB system, the relative best BER performance can be achieved with the value of 0.5 $x10^{-9}$ s of the pulse shaping factor (Tau).

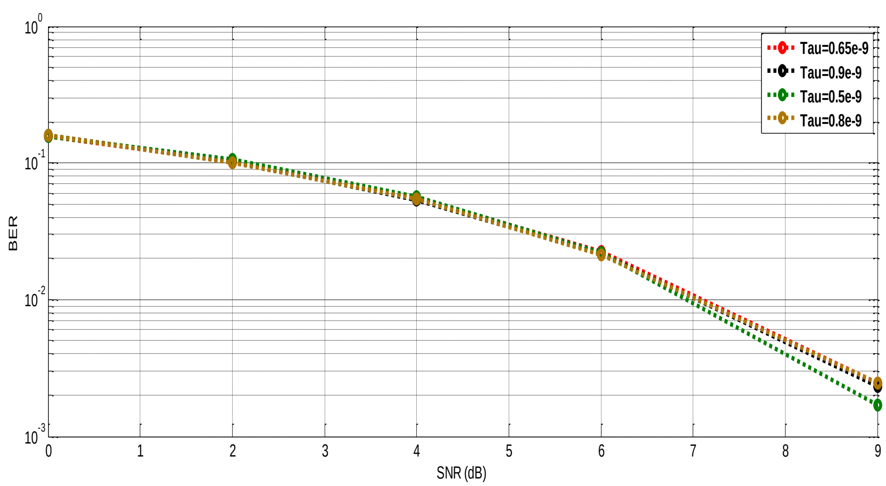

Fig. 8. Effects of different average pulse repetition periods (Ts) on TH-PPM receiver performance

Furthermore, pulse modulations can be tuned for better BER performance. Evaluation of higher order M-PAM signal, as well as M-PPM in term of BER for SNR from 5 to 9 dB, is presented in Fig. 9. The higher orders of M-PPM or M-PAM exhibit better performance over short-range wireless environments. PPM outperforms PAM with regard to the probability of symbol errors.

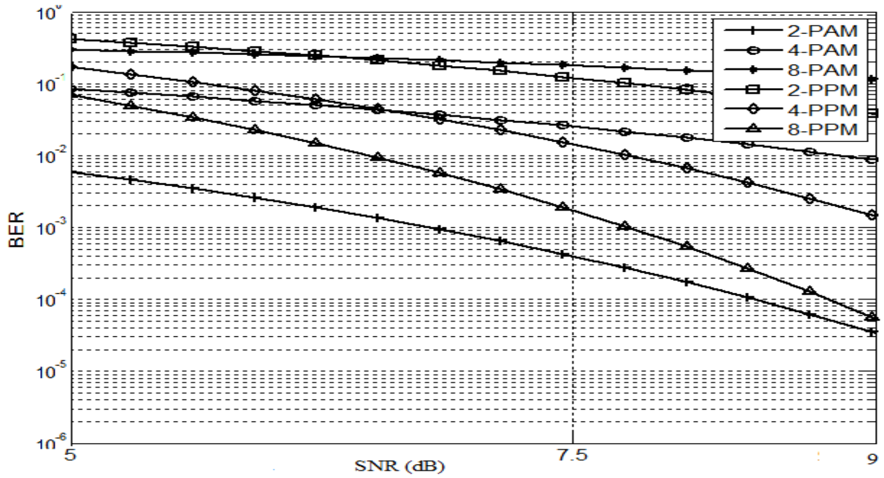

Fig. 9. Receiver performance for different M-PAM and M-PPM modulations

The effect of different spectrum techniques such as sequence spreading or TH spreading can be considered in designing tunable UWB pulsed-based solution. This can be shown by Fig. 10 with scenario using following parameters: fc = 50x10^{-9}; dPPM = 0.5x-9; Ts = 3x10^{-9}; numbit = 5000; and Numpulses = 5000.

Fig. 10 illustrates the outperforming of BER performance of time hopped spreading on direct pulses spreading techniques, as BER at SNR value of 9 shows BER improvement from$10^{-3.5}$ to $10^{-2.4}$. This finding may be attributed to the difference between Direct Sequence (DS) and TH spectrum spreading techniques, especially for low-data-rate UWB pulses.

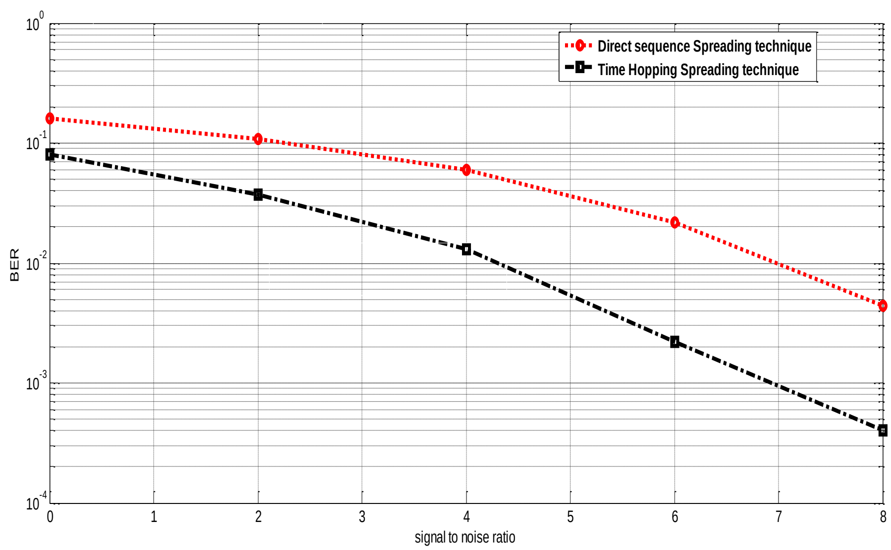

Fig. 10. BER comparison between DS and TH pulses spreading techniques

From above simulation results analysis, it is obvious that some of these physical signal parameters have significant effects on BER such as modulation techniques and the binary order of the modulations, spectrum spreading techniques, the pulse duration factor that determine the pulse shaping and the number of generated pulses per bit. Using these improvements on the BER of the cross-layer system architecture of tunable TH, the objectives of this study have been achieved.

IV. CONCLUSION AND RECOMMENDATIONS

The effects of tuning different parameters of pulses at the physical layer for time-hopped pulsed-based UWB communication system have been investigated. Additionally, the most effective parameters for enhanced received signal performance have been determined. A number of generated pulses, generated pulses per bit, pulses shaping factors, pulses modulations and pulses spreading spectrum techniques are the parameters of high impact of the performance of the UBW pulsed-based communication system. It is clear that tuning these parameters allows enhanced performance for certain scenarios and application requirements. The future extension of this work can be addressed as optimal UWB pulse-based communication using the genetic algorithm with a fitness function that is chosen carefully as weighing function for the three main variables of the communication requirements as BER for different distance and varied data-rates. This can be achieved by tuning the performance for exact predict performance based on a previous statistical analysis of the performance and the required quality of the received signal.

Declaration of Conflicting Interests

There are no competing interests associated with this work.

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