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Design and Develop an Efficient UWB Communication Mechanism Involves a Measured Energy Detection, P-Rake and S-Rake Receiving

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ABSTRACT

Reducing the power consumption is one of the major feature and main advantages required in all kinds of wireless communication applications. Hardware based (designing the wireless devices) and software based (implementing a protocol, configuring layers) energy saving mechanisms are used proposed in various earlier research works. In case of single sensor based WSN applications, without any external energy backup, running for long time may lose the energy quickly and the sensor become inactive. Industries using surveillance monitoring based applications are growing with a big market in terms of wireless applications. One of the main applications is healthcare monitoring application under WSN, various kinds of body monitoring and measuring sensors are used. In this paper, a hospital environment considered as a model WSN application, where the elder people health condition is also monitored using wireless body measurement devices. All these devices (human body sensors) are restricted with resources mainly battery life. So that, it is essential to increase the battery life time in such kind of emerging applications. In this paper it is motivated to design a high performance receiver type suitable for WBAN with low cost solution is provided in medical industry. To do this short communication an Ultra Wide Band (UWB) system to be implemented followed by IEEE 802.15.4a standards.

Keywords: Ultra Wide Band, Transceiver, Energy Efficiency, Wireless Communication, Wireless Body Area Network.

1. BACKGROUND STUDY

One of the techniques used to provide a high speed in wireless communication is Ultra Wide Band (UWB). The frequency range of the UWB communication signals is from 3.1 GHz to 10.6 GHz. UWB permits huge amount of data transmission at high data rate. The data rate of the UBB is defined as 2 GB/s with less energy [1]. After UWB applied into the industry frequently there are various kind of portable devices are utilizing UWB technique with less energy as input [2]. UWB transmits the data in terms of pulses within a short period where it imposes in frequency domain, is ultra-wideband [3]. In order to define the physical layer characteristics of the UWB, IEEE 802.15.3a process has grouped four channel models to their tasks as (CM1, CM2, CM3 and CM4) [4].Rake receiver is also a technique which can provide multipath gains and relays with various delays gathered from path diversity gain [5]. Thus, in order to utilize the components in UWB environment effectively it is essential to select the rake-receiver for strong signal based communication in different paths. The strong signal communication can bring more performance in transmission with increased SNR.

Due to more population, healthcare industries are rapidly looking for more improvement in technology. WSN based applications are providing more challenges due to populations [6].The theoretical information discussed in [7-8] said that he environment is mainly affecting the propagation of UWB signal. Due to the complex in structure,

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size and difference in tissues of the human body makes impact on the propagation [9-10]. These are the two main aspects which are integrated in WSN attached in a human body for health care monitoring. During the sensor attached in the human body, the human is instructed to move around in various environments. Because of this a battery life and complexity can be compared for different applications. From this kind of experiment it is found that coherent receivers can save only less energy than the non-coherent receivers [11]. In this paper the system model is derived and used from IEEE 802.15.4a standards based UWB [12]. This standard follows impulse radio signaling based transceivers.

From the background study it is essential to investigate the energy detection, utilizing rake receivers in UWB applications. In this paper it is aimed to use different types of rake receivers and verify the energy detection. S and P rake receivers are used with N number of human body sensors deployed in a health care industry and examined. From the examination, it can be identified that the energy of sensor nodes can be reduced in terms of energy consumption by using the rake receivers. The reason for utilizing UWB characteristics are due to this application is transmitting a high data rate within a short distance in a stipulated interval. The UWB standard used in this paper is IEEE 802.15.3a.

2. IMPULSE RADIO UWB

UWB stands for Ultra-wideband; it represents short distance based communication and communicates with highest bandwidth. It uses radio spectrum for communication mainly. Most of the communication standards allocates 7500 MHz of spectrum under 3.1 GHz to 10.6GHz frequency bandwidth. UWB technology generates a high bandwidth signal with short period like nano second pulses utilize the targeted bandwidth. A continuous pulse train represents a data stream according to a specific modulation applied on the pulses. In addition to the traditional modulation techniques, pulse position modulation and orthogonal modulation methods are getting more popular. The repetition time of the pulse determines the maximum achievable data rate where the pulse of the data streams covers the spectral bandwidth. The pulse repetition time is lower than the utilized bandwidth. This indicates that the transmission power utilization is less. At the same time multi-band UWB is used for wide band signal by multiple signals having less bandwidth. There are various kinds of modulation schemes were used like OOK [14], PPM [15], BPSK [16, 17], and PAM [18] and so on. The general characteristics of the UWB technology are:

- High Data rate
- Multi path Fading
- Short and Long Distance Communication
- Applications
- Interference

One of the main advantages of UWB communication system is it is able to achieve a high data rate without any additional frequency bands. Also UWB uses the channel capacity instead of narrow-band communication systems. UWB can provide IEEE 802.15.4a data rates [up to 100 MB/s or 10 meters, 48 MB/s for 4 meter distance. UWB chooses the available path among multiple paths to improve the data rate. This property makes UWB to be applied more for indoor communications. The UWB communication technology is restricted in terms of signal bandwidth, range and with the distance. Also the UWB transceivers can be integrated as a SoC (System n Chip). The cost of the SoC is very less comparing with other Integrated circuits. UWB technology is used in so many consumer applications like TV, computers etc. at home. Other than home applications, UWB can be utilized in WSN, ad-hoc networks, RFID, consumer electronics, asset location and medical applications. UWB is highly susceptible to narrow band interferers. IEEE 802.11a WLAN is particularly deliberated a problem because 7 it has an operating frequency of 5.5 GHz, which are located at about the center of the FCC mask. This leads to the motivation of the paper.

3. CHOOSING THE RAKE RECEIVER

In the earlier rake receiver models chooses a best choice of rake receiver combined with the bining weight and finger delays of the receiver. During this process it is verified that the finger delay should be equal to the path delay and the channel order equal to the rake order. Hence the performance of the rake receiver is improved in terms of gain with respect to weight. The vector of the rake finger delay is represented as

$$\ominus = [\theta_0, \theta_0, ..., \theta_{M-1}]^T$$

From the vector the rake delay is chosen with significantly lower MSE. Rake receiver is designed in a specific manner. For a basic wave form w(t), a multipath profile is created as s(u, t), s(u*, t) with determined delay. One of the most important components in UWB communication environment is multipath whereas it can be obtained using rake receiver. A rake receiver can combine various signal components to be propagated through channels using multipath. It is clear that the idea of using rake receiver is to monitoring the branches of the building rake utilized to gather leaves spread all over the building. Since the rake receivers are used to fetch the multipath components of a single signal spread in a particular time interval. The different types of rake receivers are named as A-rake, P-Rake, S-Rake and so on. According to the mathematical models like MRC, MSE, MMSE and EGC a rake receiver can be selected.

According the certain characteristics the rake receivers are selected. In this paper from the experimental evaluation the computed performance evaluation parameters are given in the following Table-1.Table-1 shows the signal quality in each room available in the building using UWB communication.

The main objective of integrating two different rake receivers is to increase the performance in terms of multipath. Here the S-rake and P-rake are utilized to improve the quality of service. The S-rake chooses a best path among different number of paths constructed among source to destination. The best path selection is done using MRC measurement [19-21], available fingers and multipath components. Similarly P-rake is used for selecting diversity paths among various numbers of paths. Before selecting the path the P-rake finds the original position with less complexity.

Table 1
Signal Quality Verified

Distance in Meters	*Min (dB)*	*Max (dB)*	*Mean (dB)*	*Median (dB)*	*STD (dB)*	*Number of samples*
6	-12.321	-8.5	-9.12	-11.6813	0.801	45
6.5	-15.435	-9.12	-9.89	-14.769	0.5983	45
6.8	-15.121	-10.43	-11.23	-14.282	0.8021	45
7.1	-16.112	-13.21	-13.54	-14.5538	0.8291	45
7.4	-16.987	-13.981	-14.87	-18.23	0.7734	45
7.5	-17.21	-14.928	-14.99	-13.32	1.0563	45
7.8	-17.894	-12.342	-18.32	-13.67	1.124	32
8.1	-20.003	-15.232	-12.89	-13.987	0.8024	45
8.4	-20.458	-15.839	-19.43	-14.231	0.596	45
8.7	-21.012	-16.643	-20.6	-14.11	0.8686	45
9	-21.839	-17.045	-21.243	-14.879	0.6439	45
9.3	-22.31	-18.324	-22.123	-15.726	1.0332	40
9.6	-22.69	-19.012	-22.254	-19.422	1.1512	45
9.9	-22.991	-19.984	-22.289	-22.34	0.886	45
10.2	-23.324	-20.204	-22.984	-21.23	1.0028	45

4. PROPOSED TRANSMITTER

In this paper MATLAB software is used for implementing UWB WBAN simulation under a time domain. The protocol of the simulation requirement follows IEEE 802.15.4a standard [12] and configured accordingly. The simulation concentrates on the impulse radio signaling based UWB transceiver. For example, the symbol a**k^th^** interval of transmitter signal is expressed as:

$$x^{(k)}(t)=\left[1-2g_1^{(k)}\right]\sum_{n=1}^{N_{cpb}}\left[1-2S_{n+kN_{cpb}}\right]\times p\left(t-g_0^{(k)}T_{BPM}-h^{(k)}T_{burst}-nT_c\right) \quad (1)$$

Where, the notations used in the above equation (1) described as follows:

$g_0^{(k)}$	Position modulated bit
$g_1^{(k)}$	Phase modulation bit
N_{cpb}	Number of pulses per burst
S	Belongs to {0, 1}, n = 0, 1, …,
K^{th}	Interval time
$P(t)$	Transmitted pulse
T_{BPM}	Half length of the symbol
T_{burst}	Length of the burst
T_c	Length of the pulse
$x^{(k)}(t)$	Transmitted signal
$h(t)$	Impulse response
$n(t)$	White Gaussian noise added in the symbol

Similarly, the symbol received at k^{th} interval is expresses as:

$$r^{(k)}(t) = x^{(k)}(t) * h(t) + n(t) \quad (2)$$

5. MODULATION SCHEME USED

The transmitter signal is obtained from the channel impulse response according to the state convolution added with noise. In this paper there are two modulation schemes such as PPM and BPSK are used to do modulation on the signal. The modulated bits obtained from PPM are feed into BPSK to check the redundancy through the convolutional parity bit. In order to utilize the redundant bits to improve the performance, including this modulation the entire structure combined with information bits are given to both coherent and non-coherent receivers. IEEE 802.15.4a standard enables the channel coding can be utilized in receivers to improve the performance. This channel coding is Reed Solomon method where it follows a systematic encoding method, hence it transmit the information without any modifications. So that, a receiver can either decode the party bits to increase the performance in terms of simplicity. All the required information regarding configuring the symbol structure according to the standard it is referred from [12].

6. TYPE OF THE RECEIVER

In order to improve the performance as much as possible, the coherent receiver is used as the original receiver. In this proposed simulation, the position modulated bits are assumed to be known and detects only the modulated bits, so that it can obtain a good reference point for comparison. Also an exact synchronization method is assumed. During the implementation of rake receivers it requires a good channel selected, channel estimated and coherent detection. Actually configuring the transceiver is too complex and it too expensive to integrate in WBAN solutions.

The alternate structure of the binary orthogonal non-coherent receiver may or may not include convolutional channel de coding. It denotes that the modulated bits are prepared in non-coherent manner. In order to improve the energy efficiency a low-power consuming receiver is implemented. Due to get improved performance, in this paper a non-coherent receiver is used and it can be expressed as:

$$v_i^{(k)} = \int_q^{q+T_w} T(t-\tau)\, w(t)\, d\,\tau, i = 0,\ 1 \tag{3}$$

where,

$$w(t) = \left(\sum_{n=1}^{N_{cpb}} \left[1 - 2\, S_{n+kN_{cpb}}\right] \times p(t - nT_c) * h(t)\right) \tag{4}$$

is locally generated reference. The length of the $w(t)$ is represented as Tw, the length of the single pulse is denoted as T_c and $q = k2\mathrm{T}_{\mathrm{BPM}} + i\mathrm{T}_{\mathrm{BPM}} + h^{(k)}\mathrm{T}_{\mathrm{burst}}$. While implementing $w(t)$, the impulse response $h(t)$ is used by the receiver as the strongest component in S-rake receiver. The first n numbers of tabs are used for a same task in P-rake, whereas all the measured taps are utilized in a-rake in order to implement the reference burst $w(t)$. So that Tw is larger than the ones of s- or p-rake receivers. Comparing with the absolute values, the position modulated bits are defined as:

$$\left|av_0^{(k)}\right| \underset{"1"}{\overset{"0"}{\gtrless}} \left|av_1^{(k)}\right| \tag{5}$$

If the absolute value $av_0^{(k)}$ is bigger than the $av_1^{(k)}$ then the bit received is "0", else it is "1". Similarly the phase detection is expressed as:

$$av_i^{(k)} \underset{"0"}{\overset{"1"}{\gtrless}} 0 \tag{6}$$

where, v_i is the decision variable, and if the correlation output is bigger than zero then the phase detected bit is "1" else it is "0". Similarly, the energy detection is obtained using a filter where it helps in the way of noise reduction. After noise reduction and energy detection the decision variable can be written as:

$$v_i^{(k)} = \int_q^{q+T_{burst}+T_{opt}} r(t)^2\, dt, i = 0,\ 1 \tag{7}$$

The time is optimized during energy detection for the selected channel. $\mathrm{T}_{\mathrm{burst}}$ is the minimum integration time used for energy detection. The optimized extension of integration time for each burst is denoted as $\mathrm{T}_{\mathrm{opt}}$. According to the length of the burst the energy detection structure will be configured. According to various burst, burst length, an optimized burst length is found.

If the obtained correlation result is > 0 then the detected bit is "1", else it if "0". It is well known that we assumed the receiver is coherent reference receiver and the phase modulated bit is detected using the Equation (2) and (5). In non-coherent receiver without any coding, the position modulated bits are detected from (2) and (4). We know that the convolutional coded bits are always phase modulated. In case of coding utilized based on non-coherent receiver, then the phase detection is derived from (2) and (5) over the data available in (4).

7. RESTRICTED AREA OF NODE DEPLOYMENT

In this paper, the channel model for the wireless body area network is configured according to the operations of the building surroundings where simulation is carried out [13]. The selected channel model follows the line-of-sight link model. The distance between the receiver and the transmitter is few meters only like 1 to 2 meters. The wireless sensors (transmitter and the receiver) are placed in the center of the body and the in the left wrist respectively on a human body. The person is moving within the room in the medical industry where he can sit, walk lie in a bed. These are all the general situations of an industry building and a room used in this paper.

8. SIMULATION AND DISCUSSION

In order to simulate the proposed UWB communication standard the bits per SNR and Eb/No is executed. The energy bit is denoted as and the zero means noise is denoted as . There are various number of users are placed in different lengths of bursts and all are covered within the WBAN. The obtained simulations' results are presented in BER through function. Theoretical as well as simulation based obtained results are compared with curve for 4 dB in theory and get the same results. Same time in order to evaluate the performance of RAKE receivers in UWB the following parameters are used in the simulation given in Table-2.

Table 2
Simulation Parameters

Bit Rate	1.5 Mbps
Sample Duration	.15 Ns
Frame Duration	70 Ns
Bit Duration	700 Ns
Number of frames per bit	10
Number of pulses per bit	10
Pulse Duration	1 Ns
Number of Fingers used for S-Rake Simulation	10
Number of Fingers used for P-Rake Simulation	20
Stationary Path	Multipath

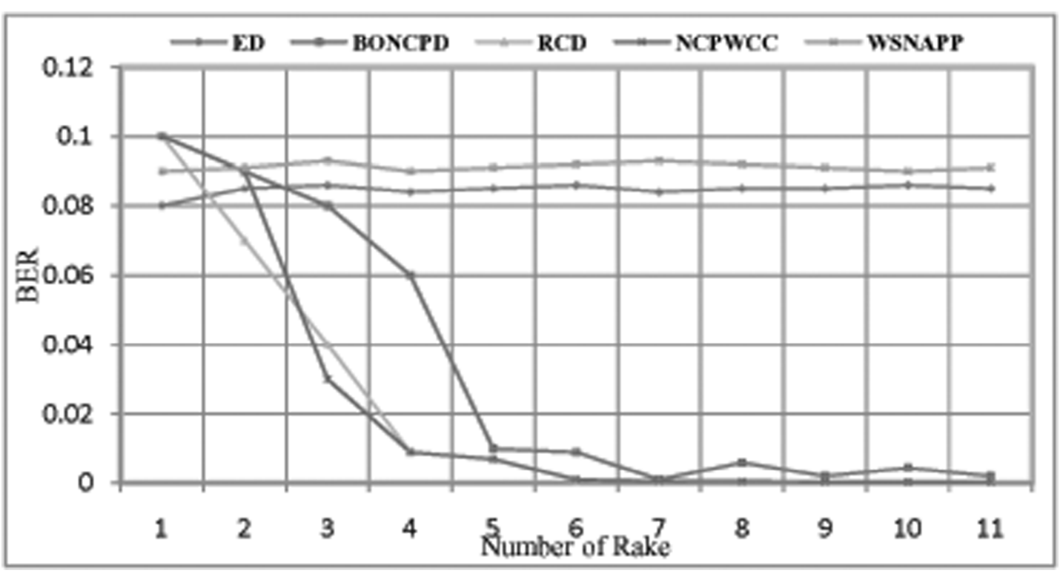

Figure 1:Number of Rakes vs. Energy Detection

From the simulation, BER comparisons in terms of number of rake fingers are obtained between s-rake and p-rake receivers. The simulation is carried out for IEEE 802.15.4a standard with number of WSN nodes is 8 with Rs value is 0.98 MHz. The number of pulses generated per burst is 16. In order to fetch the required E_b/N_0, there are three different constants are selected such as: dB = 8, 13 and 18. The maximum limit of the rake finger is up to 50, and the multipath among the channels in the industry building is assumed as 500. From Figure-1, it is identified that the number of fingers among s and p rake receiver is merely same in terms of BER.

Figure-2, illustrates that there are two different data rates are based on IEEE 802.15.4a standard mode for a short burst of 2 pulses. To do the simulation, the parameters given for short burst are Number of hop =8, Rs = 7.8 MHz and dB value is 13 dB and 18 dB, but E_b/N_0 value is fixed. According to the energy detection structure of the receiver, the length of the burst is increasing with the increased integrated noise. The obtained results is shown in Figure-2 depicts that the obtained BER is better than the IEEE mandatory mode. According to the time duration given for each time slots the performance of energy detection is improved only for shorter bursts. Since, the optimized integration time is applied in the simulation

Here the performance between s-rake and p-rake is examined. This performance level is as close as possible with the performance of ED under various BER values. For increased E_b/N_0, (> 22 dB) and obtained the energy detection for both S and P rakes are merely same. Also it is learned from the simulation that if the number of rake is reduced then the computational complexity is also reduced. By comparing with the existing approaches the proposed approach is simulated within a short range of distance and short time interval. But the number of S and P rake is changed in each time of simulation and the performance is verified. From the simulation, the proposed approach can provide better BER for less E_b/N_0 and less number of rakes. Proposed approach also provides the information that the less number of rakes can reduce the computational complexity in terms of time and memery usage. Hence the applications developed under UWB concept for short range, high speed data transmission. Opposite to this, for higher E_b/N_0 values more fingers are needed to achieve high performance. From the results and the discussion it is concluded that the rake receivers (S, P and A) are performing in equal manner.

In order to evaluate the performance of the proposed approach the MRC and EGC merging schemes are created. Both rakes are used 10 fingers without narrowband interference. The MRC and EGC performance is experimented and the results are shown in the following graphs. The S-RAKE outperforms than the P-RAKE in EGC is 5dB and in MRC is 8dB. The SNR is improved by combining with EGC gain is shown in the Following Figure-3. BER after BPSK modulation including EGC with the channel performance is experimented and shown in

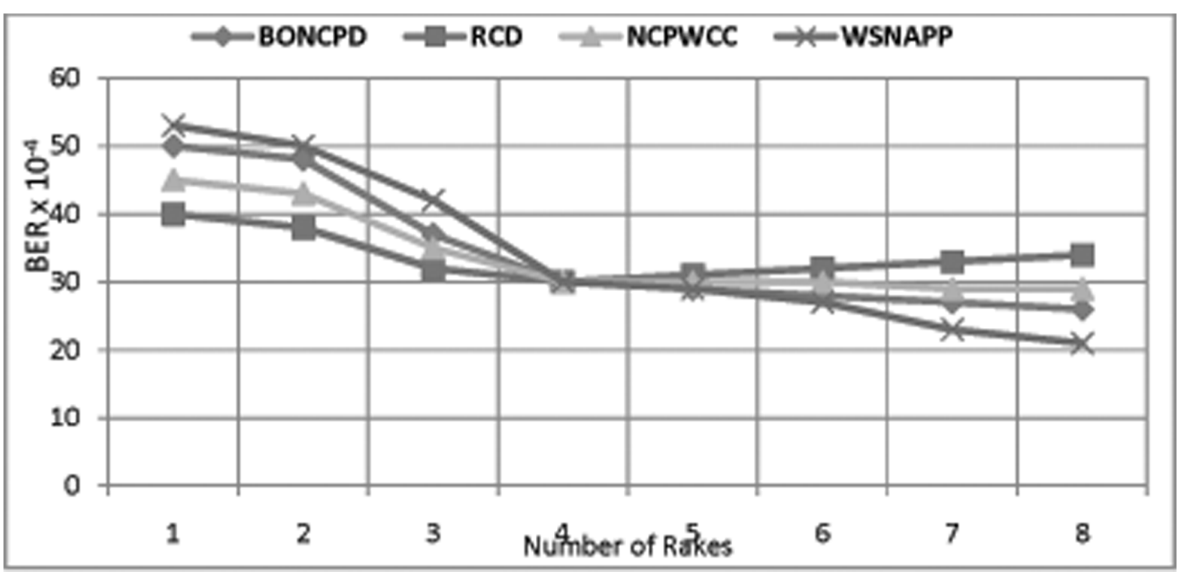

Figure 2: The effect of the environment on p-rake receivers withthe mandatory mode

Figure-4. The number of receiver antenna is increased and the performance is verified. From the results it is clear that SRAKE outperforms then P-RAKE.

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The MRC Combined with PRAKE receiver, where it outperforms MRC in 4dB. Figure-5 depicts the BER rate with MRC. According to the number of fingers including MRC the performance of the system is investigated

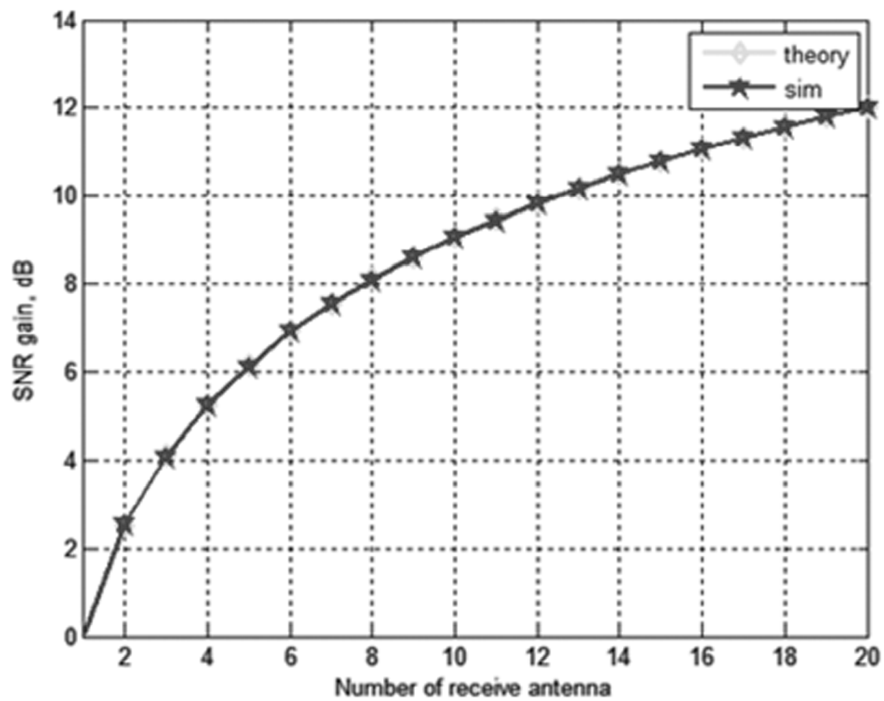

Figure 3: SNR improved combining with EGC

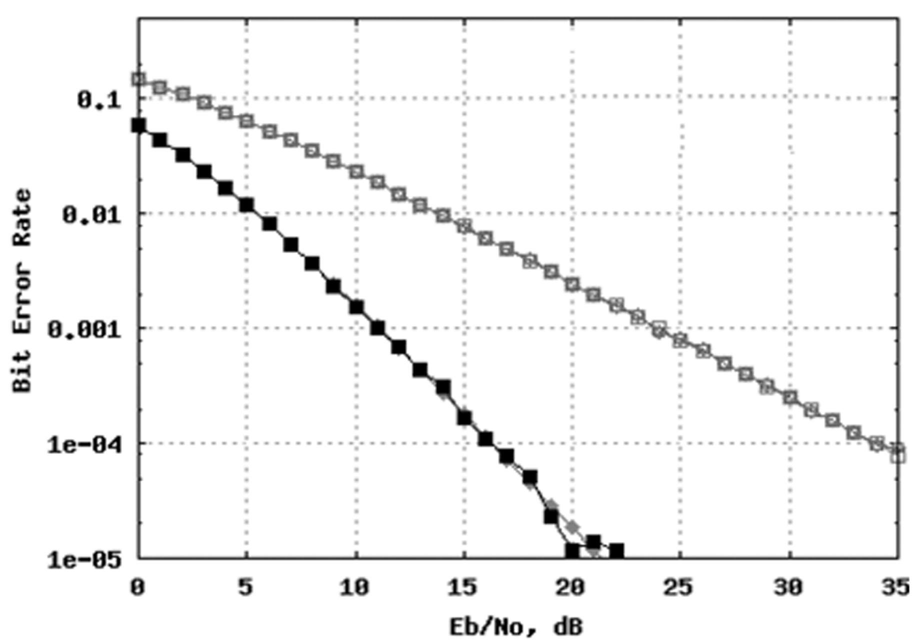

Figure 4: BER-BPSK-EGC Performance

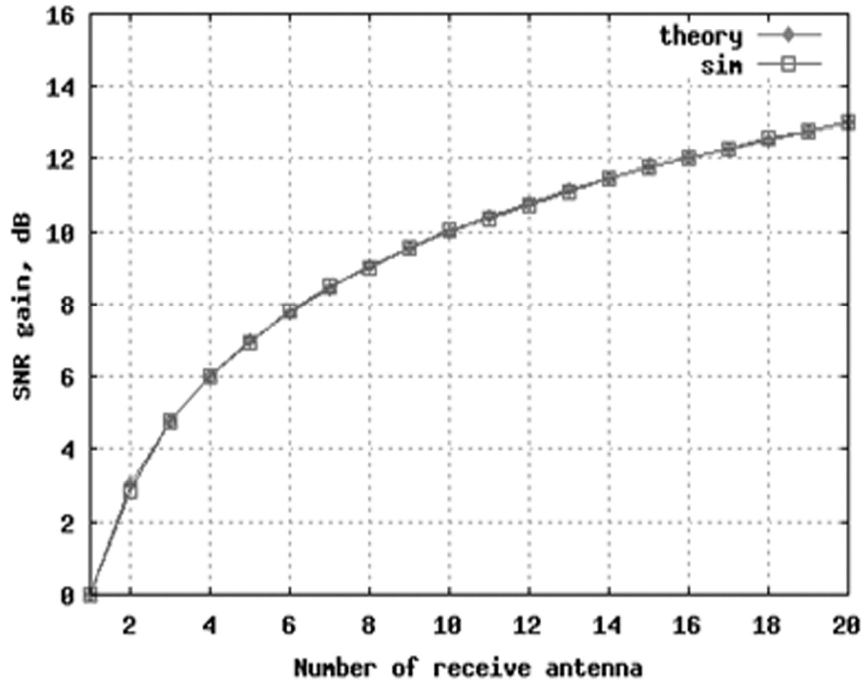

Figure 5: SNR Improved MRC to increase the performance

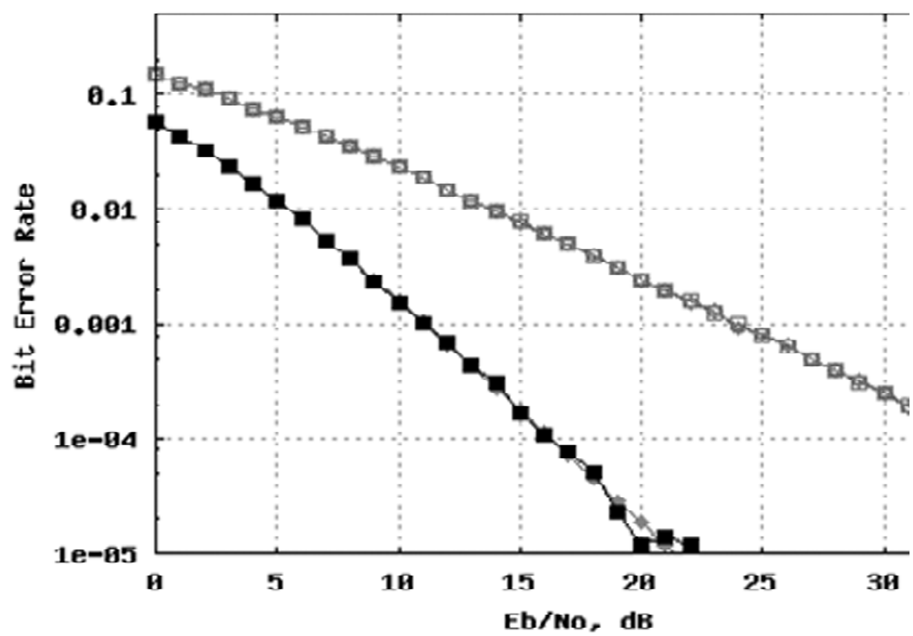

Figure 6: BER-BPSK-MRC Performance

in SRAKE. By changing the number of receiver antennas MRC is verified. Figure-6 shows the performance graph. According to the pulse width, duration and number of bits per frame are investigated with MRC. Also it is observed that the inter-frame interference is not increased.

9. CONCLUSION

The main objective of this paper is to obtain the advantages of UWB application in terms of utilizing rake receivers. It is also examining the performance of rake receivers in any kind of UWB application. In this paper a healthcare application using human body sensor is examined and verified using UWB-IEEE 802.15.3a standard configurations. The examination is carried out by making the sensor in a fixed place, carrying some activity and moving from one location to other location within a restricted area. The energy value is examined whether it is saving the energy due to rake receivers or not. This simulation is carried in MATLAB software and the results are verified. From the obtained results it is clear the rake receivers can provides multipath propagation relay for increasing the efficiency.

From the obtained results it is clear that UWB communication becomes more efficient by selecting a best rake receiver and the modulation techniques. The BER values are measured in terms of MRC an EGC, where the results show that the rake receivers provide outperformance. Similarly the increased number of fingers increases the output and makes the system with less complexity. Hence combining S-RAKE and P-RAKE for UWB communication can provide better performance in terms of BER in any emerging applications.

REFERENCES

[1] M. K. A. Rahim, T. Masri, H. A. Majid, O. Ayop, F. Zubir, Design and Analysis of Ultra-Wide BandPlanar Monopole Antenna, WSEAS Trans. Comm., Vol.10, No7, Jul 2011, pp. 212-221.

[2] C. H. Cheng, G. J. Wen, Y. F. Huang, Hopfield Neural Network for UWB MultiuserDetection, WSEAS Trans. Comm., Vol.8,No7, Jul 2009,pp. 578-587.

[3] M. Renzo, and D. Leonardis, Timing Acquisition Performance Metrics of Tc–DTR UWBReceivers over Frequency–Selective Fading Channels with Narrow–Band Interference,Wireless Commun, Mar. 2010.

[4] J. R. Foerster, M. Pendergrass, and A. F. Molisch, "A channel model for Ultrawideband indoor communication", "In International Symposium on Wireless Personal Multimedia Communication", Oct. 2003

[5] Y. Ishiyama, and T. Ohtsuki, Performance evaluation of UWB-IR and DS-WB with MMSE-frequency domain equalization (FDE), In Global electro communications Conference, IEEEGLOBECOM'04, Vol. 5, Nov. 2004, pp. 3093-3097.

[6] Hämäläinen M., Pirinen P., Shelby Z. (2007) Advanced Wireless ICTHealtcare Research. Mobile and Wireless Communication Summit, 1-5July 2007. 16th IST, Budapest, Hungary.

[7] Cramer R. J-M., Scholtz R. A., Win M. Z., (2002) Evaluation of anUltra-Wide-Band Propagation Channel. IEEE Transactions onAntennas and Propagation, Vol. 50, No. 5, May 2002.

[8] Taparugssanagorn A., Pomalaza-Raez C., Tesi R., Isola A., HämäläinenM., Iinatti J. (2009) UWB Channel for Wireless Body Area Networksin a Hospital Environment. The 12th International Symposium onWireless Personal Multimedia Communications (WPMC'09), Sendai,Japan, Sep. 7-10, 2009.

[9] Fort A., Desset C., Ryckaert J., De Doncker P., Van Biesen L.,Wambacq P. (2006) Characterization of the Ultra Wideband Body AreaPropagation Channel. IEEE International Conference on Ultra-Wideband, ICU 2005, Zurich, Switzerland, September 5-8, 2005.

[10] Zasowski T., Meyer G., Althaus F., Wittneben A. (2005). PropagationEffects in UWB Body Area Networks. IEEE International Conferenceon Ultra-Wideband, ICU 2005, Zurich, Switzerland, September 5-8,2005.

[11] Cassioli D., Win M.Z., Vatalaro F., Molisch A.F. (2007) LowComplexity Rake Receivers in Ultra-Wideband Channels. IEEETransactions on Wireless Communications, Vol. 6, No. 4, April 2007.

[12] IEEE Standard 802.15.4a: Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), Amendment 1: Add Alternate PHYs. IEEE Computer Society, IEEE Std 802.15.4a–2007 (Amendment to IEEE Std 802.15.4 –2006), NY, USA. 187p.

[13] Taparugssanagorn A., Pomalaza-Raez C., Tesi R., Isola A., Hämäläinen M., Iinatti J. (2009) UWB Channel for Wireless Body Area Networks in a Hospital Environment. The 12th International Symposium on Wireless Personal Multimedia Communications (WPMC'09), Sendai, Japan, Sep. 7-10, 2009.

[14] R. Fontana, A. Ameti, E. Richley, L. Beard, and D. Guy, "Recent advances in ultra-wideband communications systems," in IEEE Conf. UWB Systems and Technologies Dig., 2002, pp. 129-133.

[15] R.A. Scholtz and M.Z. Win, "Impulse radio," in Wireless Communications: TDMA vs.CDMA, S.G. Glisic and P.A. Leppänen, Eds. Norwell, MA: Kluwer, 1997, pp. 245-264.

[16] M.Welborn, T. Miller, J. Lynch, and J. McCorkle, "Multi-user perspectives in UWB communications networks," in IEEE Conf. UWB Systems and Technologies Dig., 2002, pp. 271-275.

[17] R. Fleming, C. Kushner, G. Roberts, and U. Nandiwada, "Rapid acquisition for ultra-wideband localizers," IEEE Conf. UWB Systems and Technologies Dig., 2002, pp. 245-249.

[18] M. Ho, L. Taylor, and G.R. Aiello," UWB architecture for wireless video networking," in Proc. IEEE Int. Conf. Consumer Electronics, 2001, pp. 18-19.

[19] Wireless Communications and Networks, William Stallings, Second Edition

[20] Wireless Communications Principles and Practice, Theodore S. Rappaport, SecondEdition

[21] "Performance of Coherent UWB RAKE Receivers with Channel Estimators", BartoszMielczarek, Matts-Ola Wessman and Arne Svensson, Chalmers University of Technology.