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Research Article

Improved Successive Interference Cancellation for MIMO/UWB-Based Wireless Body Area Network

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In body area networks, various sensors are attached to clothing or on the body or even implanted under the skin. The sensors measure such as heart beat, the record of prolonged electrocardiogram, blood pressure, and so on. In this paper, an improved Successive interference cancellation (SIC) scheme based on zero correlation zone sequences is proposed. Here ZCZ is used as a random code for TH PPM UWB system. Nodes in a WBAN are connected through wireless communication channel within a very close range. The decrease in internode distance leads to interference between devices. To reduce this interference, an enhanced successive interference cancellation scheme based on ZCZ with optimal ordering is adopted. Because of zero correlation property of ZCZ, the performance of TH PPM UWB system through WBAN channel with ZCZ sequences outperforms performance of existing zero correlation duration code. In this paper, performance of UWB system for various modulation schemes are compared. Performance of UWB/MIMO (2×2) system employing SIC with optimal ordering using ZCZ codes also compared with pseudorandom (PN) and ZCD codes. Simulation results are obtained using sample biological functions as input to the proposed TH PPM UWB/MIMO (2×2) system with m-ZCZ codes in WBAN environment with multiple devices.

1. Introduction

Monitoring of physiological conditions of a patient who is in remote is possible nowadays with the help of wireless medical telemetry [1–3]. This enhances the quality of patient care and the efficiency of hospital administration capabilities. It also helps to reduce healthcare costs because it permits the remote monitoring of several patients simultaneously. The development of this technology leads to wireless body area network (WBAN) [4] where smart wireless medical sensors measuring, for example, electrocardiogram (ECG), noninvasive blood pressure, and the blood oxygen saturation placed in and around the body can communicate with the outside world using wireless networks and provide medical information. The realtime information can be forwarded to a physician.

Ultrawideband (UWB) communication has strong advantages quite promising for WBAN applications [5] because it offers a low-power high data rate technology with large bandwidth signals that provides robustness to jamming and has low probability of interception [6]. UWB low transmit power requirements, which are mainly used in low data rate networks with low duty cycles, allow longer battery life for body worn units [4]. Moreover, UWB can be used to monitor vital parameters such as respiration and heart rate [4]. In addition, UWB gives good penetrating properties that could be implemented to imaging in medical applications [7].

In the WBAN, radio propagations from devices that are close to or inside the human body are complex and distinctive comparing to the other environments since the human body has a complex shape consisting of different tissues with their own permitivity and conductivity.

The UWB system with the help of multiple-input-multiple-output (MIMO) scheme employs features such as spatial diversity and spatial multiplexing, leading to higher system throughput. However, in UWB/MIMO systems, the

performance degradation may be caused by the effects of multiple access interference (MAI) and multipath fading. In the literature [7], successive interference cancellation (SIC) scheme has been proven to work well for interference cancellation of outdoor communication and other multimedia transmission systems. Therefore, SIC scheme can be one of the promising solutions to mitigate interference effects on the performance of WBAN.

Bae et al. show that interference mitigated due to MAI by introducing optimal SIC for UWB/MIMO using zero correlation duration code as spreading code for UWB system in a multidevice environment. Performance comparison of ZF-OSIC, MMSE-OSIC is analyzed [7].

In our previous paper [8], BER performance of CDMA system was found using ZCZ sequences. ZCZ sequences have both autocorrelation side lobes, cross-correlation function are zero, and sequence length is flexible [8].

In this paper, improved interference cancellation schemes for UWB/MIMO-based wireless body area network using m-ZCZ sequences are proposed. In this work, TH PPMUWB system with zero correlation zone code is used as a spreading code which has robust MAI capability. The system performance is analysed in terms of BER.

The paper deals with the following WBAN channel is explained in Section 2. The proposed UWB/MIMO system model is described in Section 3. Performance analysis is given in Section 4. Simulation Results are presented in Section 5. Conclusion is given in, last section.

2. WBAN Channel Model

Figure 1 shows the possible communication links for WBAN. WBAN channel are classified into two categories according to the field of applications [7]. The first category is a nonmedical application where the user is using the wireless connection between his MP3 player and headset. The other category is medical application related to patient health care domain. In latter case, a patient can wear communication equipment with the smart sensors that can constantly measure the patient biological information such as blood pressure, heart rate, electrocardiogram (ECG), electroencephalogram (EEG), respiration, and so on. According to location of equipment, there are three types: in-body, on-body, and off-body. Moreover, speed is categorized as low, moderate, and high. Table 1 gives the Classification of the WBAN systems for various criteria [7].

The distance between the external devices is typically considered to be a maximum of 5 meters. Table 2 shows the parameters of WBAN Channels for different direction of body [7].

In WBAN channel, the complex impulse response $h_i(t)$ for the ith device is given by [7] as following:

$$h_i(t) = \sum_{m=0}^{m-1} \alpha_m^i \delta\left(t - \tau_m^i\right), \tag{1}$$

where m is the number of total arrival paths and modeled as passion random variables with mean value of 400, m is the mth arrival path of the signal and α_m^i is the magnitude of mth path;

$$\left|\alpha_m^i\right|^2 = L_0 \exp\left(-\frac{\tau_m^i}{\Gamma} - F_k[1-\delta(m)]\right)\beta, \tag{2}$$

where L_0 is a path Loss, Γ is an exponential decay factor, β is a log random variable, τ_m^i is described as path arrival time, d is the distance between mth device and the receiver, and F_k is an effect of the K-factor in nonline sight that can be calculated as

$$F_k = \frac{\Delta k \ln 10}{10}. \tag{3}$$

Table 1: Classification of WBAN channel.

Criterion	WBAN channel mode		
Field of application	Nonmedical	Medical	
Location	In-body	On-body	Off-body
Speed	Low	Middle	High

Table 2: Parameters of WBAN channel for different direction of body.

Direction of body in degrees	Γ in ns	F_k	σ (dB)
0	44.6346	5.111	7.3
90	54.2868	4.348	7.08
180	53.4186	3.638	7.03
270	83.9635	3.983	7.19

3. Proposed System Model

Figure 2 shows the block diagram of Proposed UWB/MIMO system using m-ZCZ codes.

The data from devices are transmitted by using TH PPM UWB modulator. As a spread code of TH PPM UWB systems, the zero correlation zone code with robust MAI is employed for random hopping. Then the signal is fed into UWB MIMO (2×2) encoder and it is fed through WBAN channel with the channel parameters shown in Table 2. At the receiver side, incoming data is processed by MMSE equalizer and is followed by SIC scheme with optimal ordering in order to mitigate the interference.

The Channel impulse response in the WBAN channel with multipath propagation can be expressed as

$$h(t) = \sum_{m=0}^{k-1} \alpha(m)\delta\left(t - mT_p\right), \tag{4}$$

where k is the total number of multipath components, $\alpha(m)$ is a fading coefficient of the m path. $\delta(t)$ is dirac delta unction. T_p is the minimum multipath resolution.

The received signal $Y_p(t)$ at the Pth receive antenna is given as

$$Y_p(t) = \sum_{n=1}^{N}\sum_{m=0}^{K} h_{p,n}(k)x_n\left(t - kT_p\right) + n_k(t), \tag{5}$$

where $h_{p,n}(k)$ represents a fading coefficient of mth path for the signal from nth transmit Antenna to the pth receive antenna. $n_k(t)$ is the additive white Gaussian noise.

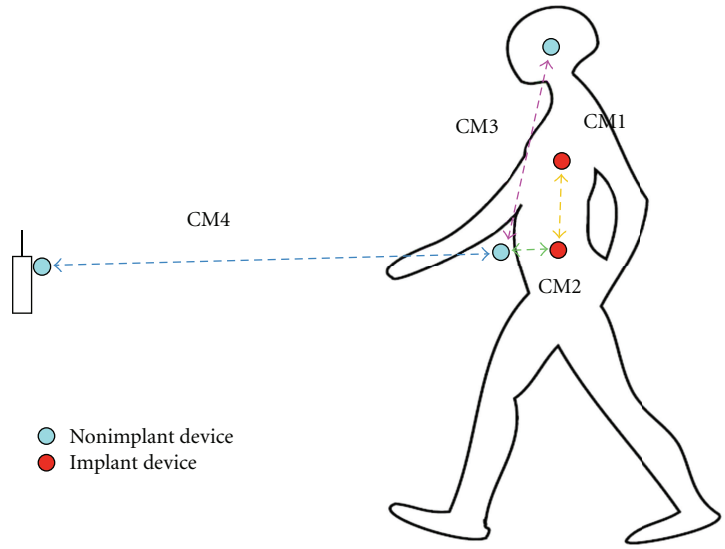

Figure 1: Possible communication links for WBAN.

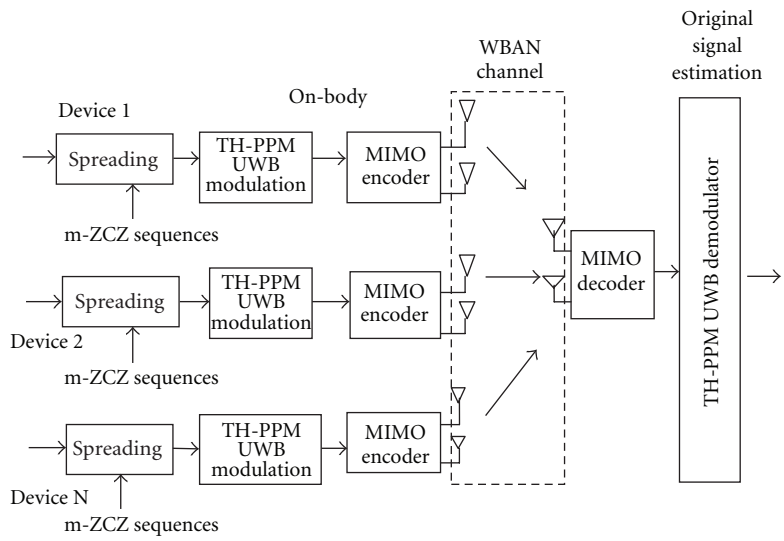

Figure 2: Proposed UWB/MIMO system using m-ZCZ codes.

3.1. ZCZ Sequences. The m-ZCZ code set is denoted as m-ZCZ$(C_L, S, W_{\min}) = \{(z_{i1}, z_{i2})\}$, where $i = 0, 1, \ldots, S-1$, and C_L represents code length, S is set size of the code set, and $W_{\min}$ is minimum length of one-side ZCZ.

The first subcode of the ith code is $z_{i1} = a^{i \cdot w \min}$ with the length of N, where a^0 is an m-sequence with its period N, and $a^{i \cdot w \min}$ stands for the sequence generated by cyclically leftward shifted a^0 with $i \cdot W_{\min}$ chips. This can be represented as

$$a_n^{i \cdot w \min} = a^o_{(n+i \cdot w \min)} \bmod N, \tag{6}$$

where $n = 0, 1, \ldots, N-1$, and n is the chip index.

The second subcode $z_{i2} = \{+1\}$ contains only one "+1" chip. The congregated code length is $C_L = N + 1$. The set size of the code is $S = [N/W_{\min}]$.

The periodic autocorrelation function (ACF) of an m-ZCZ code and periodic cross-correlation function (CCF) of any two m-ZCZ codes can be calculated as follows [8]:

$$\begin{aligned} R_{i,j}(k) &= \sum_{n-0}^{N-1} a_n^{i \cdot w \min} a_{n+k}^{j \cdot w \min} + z_{i2} z_{j2} \\ &= \sum_{n=0}^{N-1} a^0_{(n+i \cdot w \min)} \bmod N a^0_{(n+1+j \cdot w \min)} \\ &\quad \times \bmod N + z_{i2} z_{j2} \end{aligned}$$

$$= \begin{cases} N+1 & i=j,\ k=0 \\ -1+1 & i=j,\ 0<|k|<w_{\min}, \\ & \text{or } i\neq j,\ |k|<w_{\min} \end{cases}$$

$$= \begin{cases} C_L & i=j,\ k=0 \\ 0 & i=j,\ 0<|k|<w_{\min}, \\ & \text{or } i\neq j,\ |k|<w_{\min}, \end{cases} \tag{7}$$

where integer k denotes the relative time shift.

From (7), it is seen that the ACF of any m-ZCZ code is zero when $0 < |k| < W_{\min}$ and the CCF between any two codes is zero $|k| < W_{\min}$. Thus, there exists a ZCZ with minimum one-side length being wmin. The wmin can be flexibly controlled by adjusting the number of cyclic shifted chips.

3.1.1. Example. Given $L = 64$ and $w_{\min} = 30$, a set of m-ZCZ codes are denoted by (64, 2, 30) containing $J = [63/30] = 2$ codes as

$$(z_{01}, z_{02}) = \begin{pmatrix} -1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & 1, \\ -1 & -1 & -1 & -1 & -1 & -1 & 1 & -1 \\ 1 & -1 & -1 & -1 & 1 & -1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & -1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \end{pmatrix},$$

$$(z_{11}, z_{12}) = \begin{pmatrix} -1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & 1, \\ -1 & -1 & -1 & -1 & -1 & -1 & 1 & -1 \\ 1 & -1 & -1 & -1 & 1 & -1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & -1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \end{pmatrix}. \tag{8}$$

3.2. MMSE Equalizer for 2 × 2 MIMO Channel. In the first time slot, the received signal on the first receive antenna is

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = [h_{1,1}h_{1,2}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1. \tag{9}$$

The received signal on the second receive antenna is

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1}h_{2,2}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2, \tag{10}$$

where y_1 and y_2 are the received symbols on the first and second antennas, respectively,

$h_{1,1}$ is the channel from 1st transmit antenna to 1st receive antenna;

$h_{1,2}$ is the channel from 2nd transmit antenna to 1st receive antenna;

$h_{2,1}$ is the channel from 1st transmit antenna to 2nd receive antenna;

$h_{2,2}$ is the channel from 2nd transmit antenna to 2nd receive antenna;

x_1, x_2 are the transmitted symbols and n_1, n_2 is the noise on 1st, 2nd receive antennas.

Assuming that the receiver knows $h_{1,1}$, $h_{1,2}$, $h_{2,1}$, $h_{2,2}$, and y_1, y_2 the matrix representation of the above equation is

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}. \tag{11}$$

Equivalently,

$$y = Hx + n. \tag{12}$$

The minimum mean square error (MMSE) algorithm is used to find a coefficient "w" which minimizes the error criterion. The decoding matrix is given by [7]

$$W = \left[H^H H + N_0 I\right]^{-1} H^H, \tag{13}$$

where W is equalization matrix and H is channel matrix. This matrix is known as the pseudoinverse for a general $m \times n$ matrix and $N_0 I$ is the noise term, where

$$\begin{aligned} H^H H &= \begin{bmatrix} h_{1,1}^* & h_{2,1}^* \\ h_{1,2}^* & h_{2,2}^* \end{bmatrix}\begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \\ &= \begin{bmatrix} |h_{1,1}|^2 + |h_{2,1}|^2 & h_{1,1}^* h_{1,2} + h_{2,1}^* h_{2,2} \\ h_{1,2}^* h_{1,1} + h_{2,2}^* h_{2,1} & |h_{1,2}|^2 + |h_{2,2}|^2 \end{bmatrix}. \end{aligned} \tag{14}$$

The MMSE algorithm is used to counteract the interference by varying decoding matrix according to SNR. It also prevents the amplification of noise component.

3.3. SIC with Optimal Ordering. The interference cancellation technique SIC is used after linear equalization to mitigate the effect of MAI. In conventional successive interference cancellation, the receiver arbitrarily takes one of the

estimated symbols (e.g., $\overline{x_2}$) and subtract its effect from the received symbol y_1 and y_2. If the previous decision is incorrect and error occurs then next decision also could be incorrect [7].

To eliminate the error propagation, SIC with optimal ordering is adopted. SIC with optimal ordering has more intelligence in choosing the effect of $\overline{x_1}$ first or $\overline{x_2}$ first and then subtracts corresponding $\overline{x_1}$ or $\overline{x_2}$ from the received signal. In this scheme, the strongest signal is cancelled out first followed by the second strongest, and so forth.

The received power at the both the antennas corresponding to the transmitted symbol x_1 is

$$P_{x1} = |h_{1,1}|^2 + |h_{2,1}|^2. \tag{15}$$

The received power at both antennas corresponding to the transmitted symbol x_2 is

$$P_{x2} = |h_{1,2}|^2 + |h_{2,2}|^2. \tag{16}$$

If $P_{x1} > P_{x2}$, then the receiver decides to remove the effect of $\overline{x_1}$ from the received vectors y_1 and $y_2\overline{x_2}$. Then $\overline{x_2}$ is reestimated as

$$r_2 = Hx_2 + n, \tag{17}$$

where r is the reestimated signal.

Else if $P_{x1} \leq P_{x2}$ the receiver decides to subtract effect of $\overline{x_2}$ from the received vectors y_1 and y_2. Then $\overline{x_2}$ is reestimated as

$$r_1 = Hx_1 + n. \tag{18}$$

The SIC with optimal ordering guarantees the reliability of the signal decoded first so that signal has minimum error probability.

3.4. Pseudocode for the Proposed System

(i) Generate random binary sequence of +1's and −1's.

(ii) Binary sequence is spread using m-ZCZ sequences and groups them into symbols.

(iii) Spreaded symbols are converted into UWB pulses. It is modulated using TH PPM modulation (PPM TH-ZCZ).

(iv) The symbols are transmitted through BAN channel.

(v) Equalize the received symbols with minimum mean square error criterion.

(vi) Do successive interference cancellation by both classical and optimal ordering approach.

(vii) Perform maximal ratio combining for equalizing the new received symbol.

(viii) Perform hard decision decoding and count the bit errors.

(ix) BER performance has been compared with PPM-TH, PAM DS-PN, and PAM-DS-ZCD [7].

Table 3: Simulation parameters.

Modulation	TH PPM
MIMO scheme	2 by 2
Spreading code	ZCZ
Channel model	WBAN (CM4)
Equalizer	MMSE
Interference cancellation	SIC with
Scheme	Optimal ordering

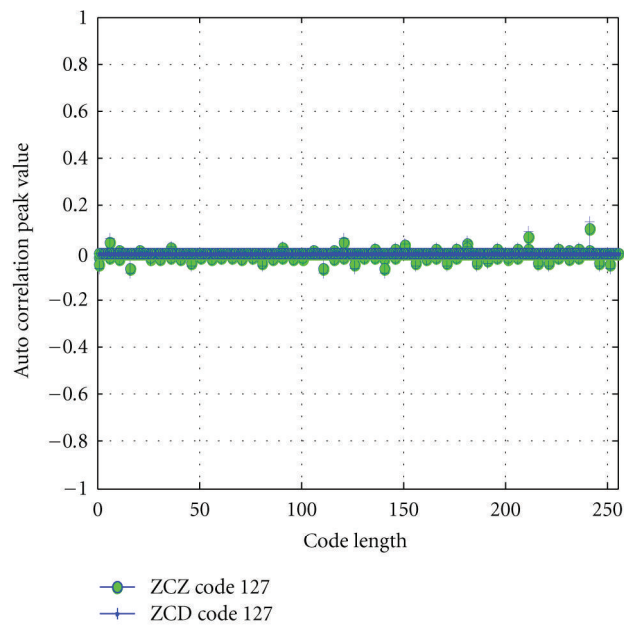

Figure 3: Performance of autocorrelation function.

4. Results and Discussion

The performance of the proposed UWB/MIMO system using ZCZ sequences combined with successive interference cancellation scheme is simulated in the WBAN Environment.

In this section, the performance of UWB system for various modulation schemes using ZCZ codes is simulated using Monte Carlo simulations in the WBAN environment. BER performance has been compared with UWB/MIMO (2×2) system employing SIC with optimal ordering for different codes. Table 3 gives the simulation parameters.

Figures 3 and 4 show the performance of the correlation function of ZCD and ZCZ code. It is seen that performance evaluated in terms of correlation peak value. The energy of the side lobes is higher in case of ZCD for the autocorrelation function almost approaches zero in case of ZCZ code and ZCD has comparatively high peak values. Because of good autocorrelation and cross-correlation properties, ZCZ code shows better performance than that of ZCD code.

Figure 5 compares the performance of PN, ZCD, and the proposed ZCZ code with different code lengths for SIC with optimal ordering. Since ZCZ has robust MAI characteristics the ZCZ code showed better performance than that of existing PN and ZCZ codes. When $E_b/N_0 = 8$ dB, BER of

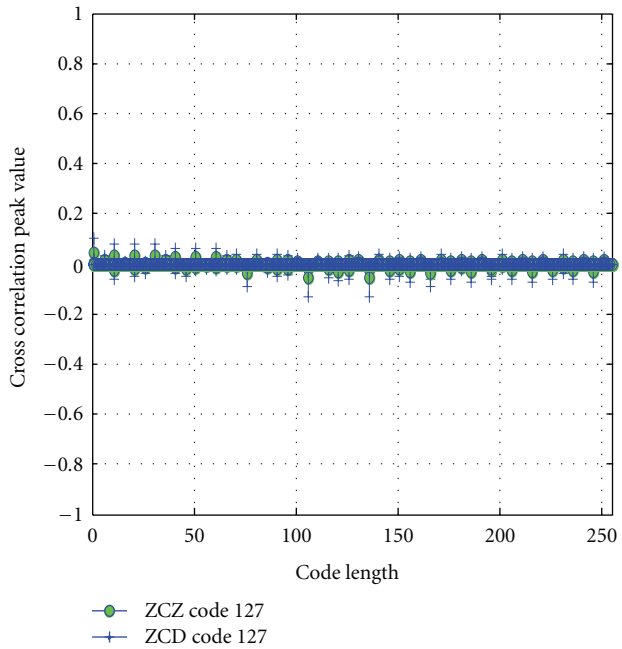

Figure 4: Performance of cross-correlation function.

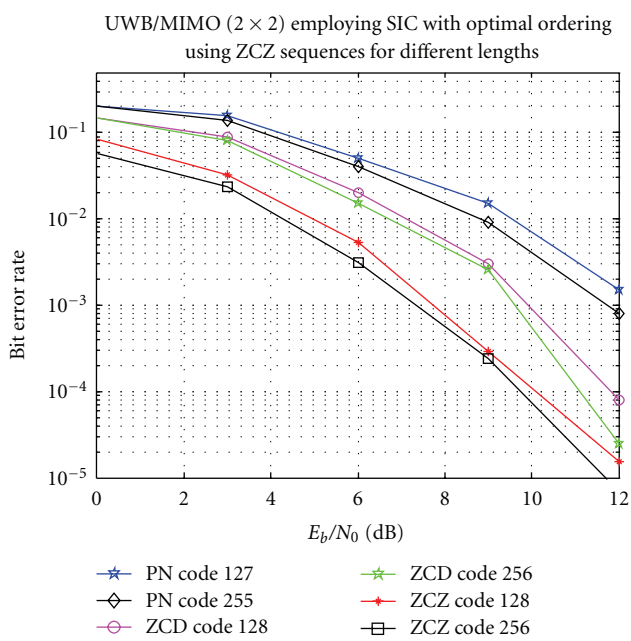

Figure 5: Performance of UWB/MIMO (2 × 2) system employing SIC with optimal ordering using ZCZ sequences for different sequence lengths.

ZCZ code is $\sim 10^{-4}$ and for ZCD code BER value is increased to $\sim 10^{-3}$ and $\sim 10^{-2}$ PN code. From the figure, it is seen that when SNR increases BER of UWB/MIMO system decreases.

Figure 6 shows the performance comparison of UWB system in WBAN for PPM TH [7], PPM TH-ZCZ (proposed), PAM DS-PN [7], and PAM DS-ZCD [7] systems.

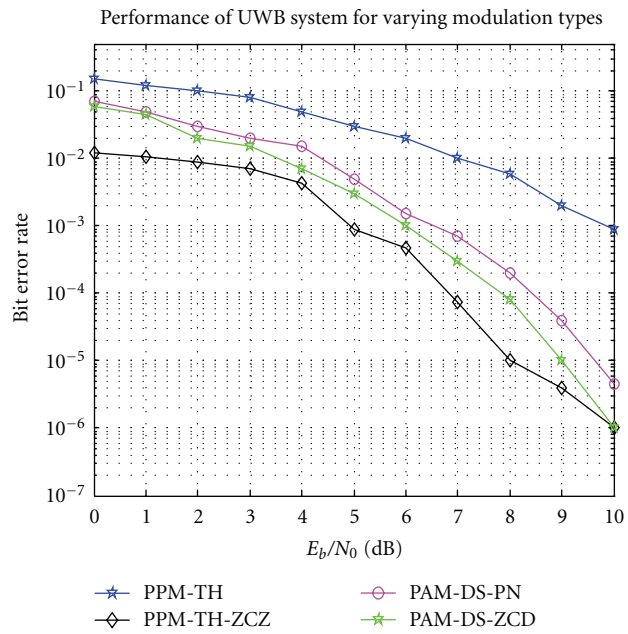

Figure 6: Performance of UWB system employing for varying modulation types.

It shows that proposed system with PPM TH-ZCZ outperforms all the other three. In Figure 4, When $E_b/N_0 = 8$ dB, BER value of PPM-TH-ZCZ code is $\sim 10^{-5}$. PAM-DS-ZCD system for same dB the BER is increased to $\sim 10^{-4}$ [7]. In PPM TH system without ZCZ code, BER value is increased to $\sim 10^{-2}$. At 8 dB, it can be seen that PPM TH-ZCZ shows 10% improvement of BER compared with PAM DS-ZCD [7] for the same dB.

5. Validation

In order to vaidate the performance of proposed improved successive interference cancellation for MIMO-based wireless body area network, we have considered several devices in WBAN channel for body surface to external (CM4). For testing, BER results have been obtained with multiple biological functions as the input to the various devices in the system model shown in Figure 2. Samples of biological functions such as ECG and blood pressure are given in Figure 7.

In Figures 7(a)–7(c) show that ECG signal of patient is passed through TH-PPM UWB/MIMO system under WBAN environment (CM4). At the receiver side, the signal is demodulated based on TH-code of each patient, despread, and then decoded to get back the transmitted ECG signal. Similarly, Figures 7(d)–7(f) show that continuous measurement of blood pressure signal of patient is passed through TH-PPM UWB/MIMO system under WBAN environment (CM4). At the receiver side, the signal is demodulated based on TH-code of each patient, despread, and then decoded to get back the original data.

Figure 8 shows the performance of PPM TH-ZCZ UWB/MIMO (2 × 2) system with 10, 5, and 1 devices in WBAN channel, CM4 with inputs such as ECG and blood pressure.

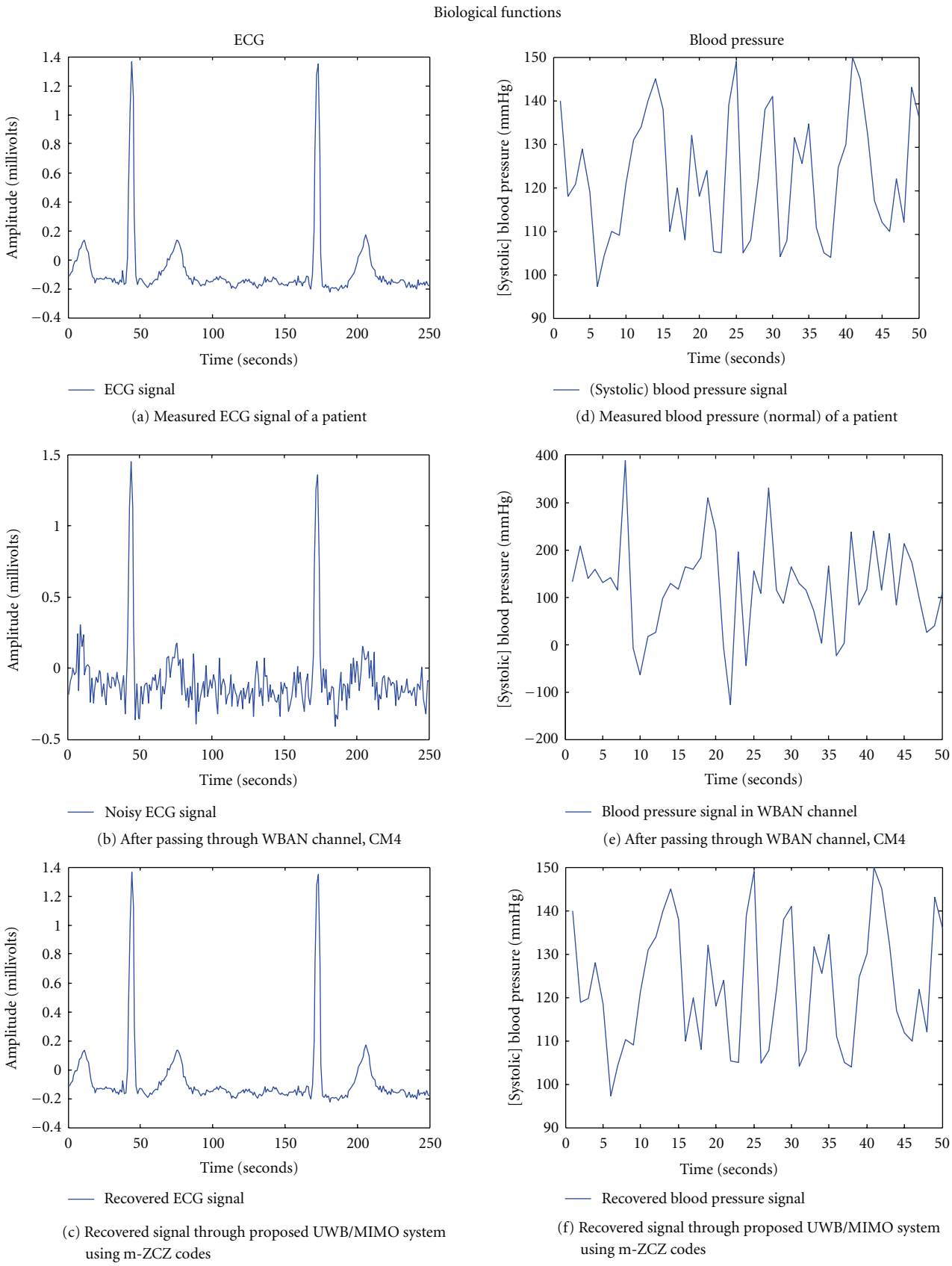

Figure 7: Transmission/reception of sample biological functions of patients through PPM TH-ZCZ UWB/MIMO (2×2) system.

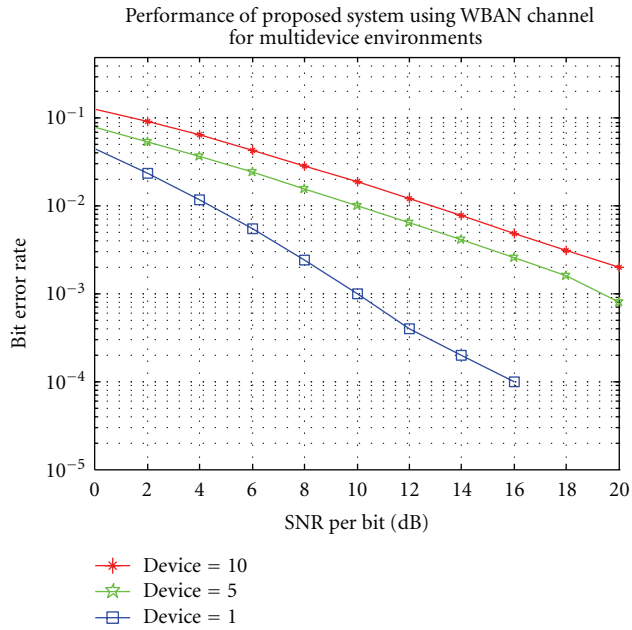

Figure 8: Performance of PPM TH UWB/MIMO (2 × 2) system using m-ZCZ codes for multidevice environments in WBAN channel.

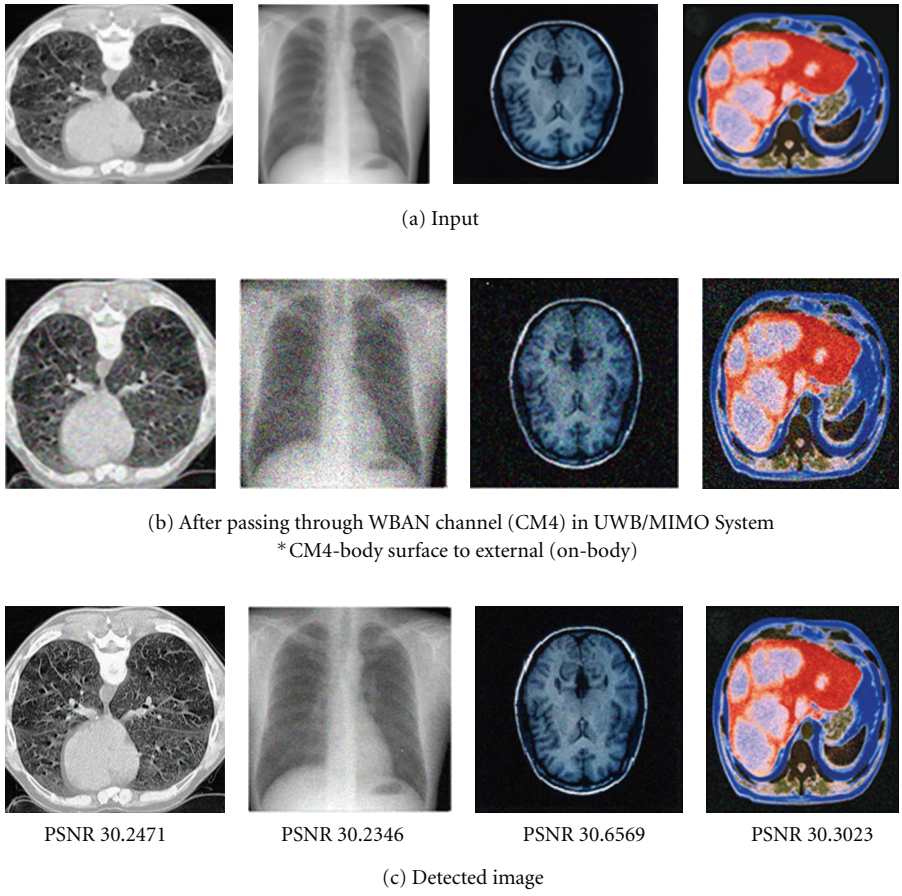

Figure 9: PSNR values of sample biomedical images: sample biological images through PPM TH-ZCZ UWB/MIMO (2 × 2) system.

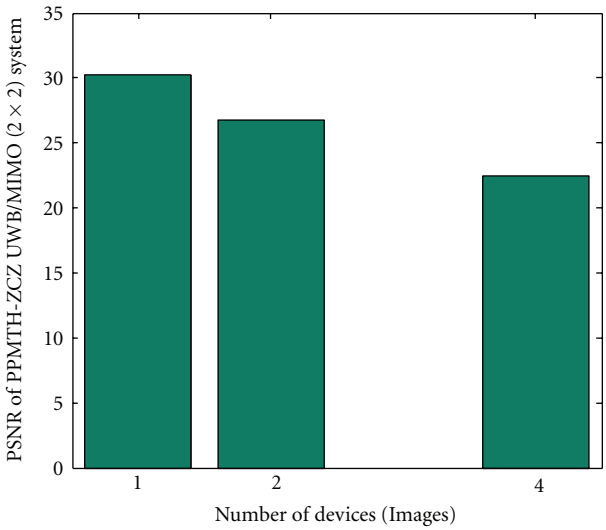

Figure 10: Histogram when input as biomedical image for PPM TH-ZCZ UWB/MIMO (2 × 2) system with multiple devices in WBAN channel (CM4).

From the figure, it can be seen that when one device is used, BER value is $\sim 10^{-3}$ at $E_b/N_0 = 10$ dB and for the same E_b/N_0 BER is increased to $\sim 10^{-2}$ when the number of devices is increased to five. Thus increase in number of devices causes increase of multiaccess interference power which leads to increase of BER. Thus, we have validated that an increase in the number of devices induces the performance degradation of PPM TH-ZCZ UWB/MIMO system in WBAN environment.

We have considered images as input to the proposed system shown in Figure 2 which can be used in telemedicine application. Figure 9(a) shows the inputs of biomedical Image which are given to the proposed system. Figure 9(b) shows noisy images obtained after passing through WBAN channel. Figure 9(c) shows the detected images using improved sucessive interference cancellation for MIMO/UWB-based body area network with m-ZCZ codes.

Figure 10 shows the histogram when biomedical images are given for PPM TH-ZCZ UWB/MIMO (2 × 2) system with 4, 2, and 1 devices in WBAN channel (CM4). From the figure, it can be seen that when one device is used, PSNR value is 30.2 and for the four devices PSNR value decreases to 22.5. Thus as number of devices increases, the PSNR value decreases due to increase in multiaccess interference.

6. Conclusion

In this paper, an improved successive interference cancellation scheme for MIMO/UWB-based wireless body area network is proposed. Proposed system utilizes ZCZ sequences as a spreading sequence. To mitigate interdevice interference in body area network successive interference cancellation with optimal ordering is used. TH PPM modulation followed by MMSE equalization is employed. From the simulation results, it can be seen that TH PPM-ZCZ UWB system gives better BER performance than that of existing TH PPM without ZCZ, PAM-DS-PN, and PAM-DS-ZCD because of good cross-correlation properties. Also ZCZ codes have been compared with various other codes such as PN, ZCD codes for UWB/MIMO (2 × 2) system for different code lengths. Finally simulation results are validated using sample biological functions as input to the proposed TH PPM-ZCZ UWB/MIMO (2 × 2) system in WBAN environment with multiple devices.

Acronyms

3GPP:	Third generation partnership project
BAN:	Body area network
BER:	Bit error rate
ECG:	Electrocardiogram
EEG:	Electroencephalogram
MIMO:	Multiple input multiple-output
MAI:	Multiple access interference
PAM:	Pulse amplitude modulation
PPM:	Pulse position modulation
SIC:	Successive interference cancellation
SNR:	Signal-to-noise ratio
ZCD:	Zero correlation duration
UWB:	Ultrawide band
ZCZ:	Zero correlation zone
ZF-OSIC:	Zero forcing-optimal successive inteference.

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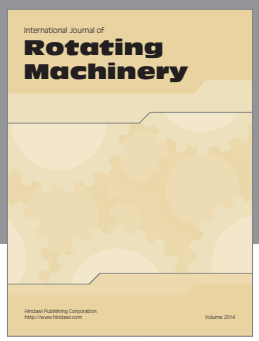

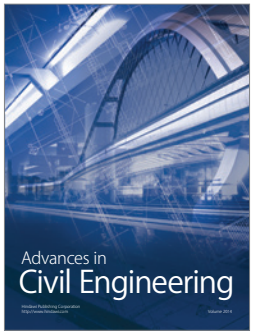

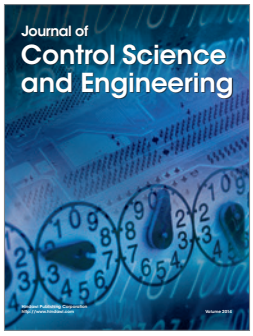

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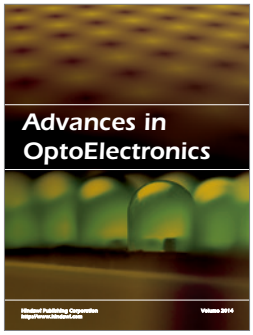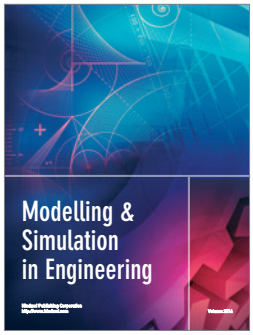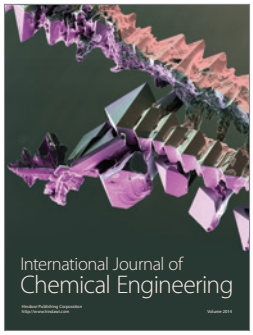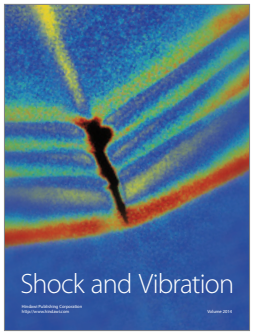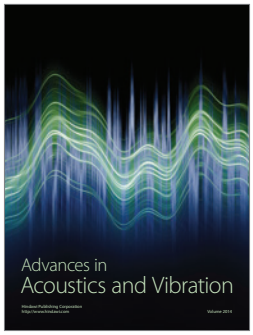
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