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Blind Adaptive Transmitted Reference Receiver Based on Indoor Wireless Propagation

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ABSTRACT

In wireless ultra-wideband (UWB) communication systems, the high data rate propagation is exposed to multiple-users interference (MUI), inter-symbol interference (ISI), and multiple-access interference (MAI), which are influencing the enhanced and performance of the wireless reception systems. In this work, the blind adaptive filtering of mean square error (MSE) adaptive filter in the transmitted reference (TR) receiver was presented with the spread signal by time hopping spread spectrum (TH-SS) technique. The structure of adaptive TR receiver was presented by adjusting the adaptive filter tap weights using constant modulus algorithm (CMA), Godard algorithm (GA), Sato algorithm (SA), and affine projection CM algorithm (APA) to mitigate the multiple interference singles by supporting the weak required signals. The simulation results of symbol error rate (SER) versus signal-to-noise ratio (SNR) are illustrated to show the system performance of the proposed TR receiver.

Keywords: constant modulus algorithm, Sato algorithm, Godard algorithm, transmitted reference receiver, symbol error rate, blind adaptive filter.

1. INTRODUCTION

At reception technique of ultra wideband (UWB) signals, the rake wireless receivers are used to improve the performance of reception system by reducing the symbol error rate (SER) that is related to signal to noise ratio value (SNR) with several correlators (fingers) [1]. In rake receiver architectures espiatioly in case of coherent receivers, synchronization, pulse shape estimation and channel estimation are needed for accurately detection and take full advantage of multi-path diversity [2]. TR reception technique was proposed to avoid the detection complexity by canceling the pulse shape generation and channel estimation processes at the receiver. This cancelation leads to reduce the cost and save extra power on the pilot or reference symbols which are transmitted after or before the desired data symbols [3]. So that, the TR receiver is simplified structure and can be suitable for applications of low data rate system, such as local area networks and sensor networks which constructs the channel template by using part of received pulses that is corresponding to the received reference pulses only. These pulses of low power consumption (-41.3 dBm/MHz) pass through indoor channel models of CM1, CM2, CM3, and CM4 which are represented by [4] with frequency range as shown in Figure (1). In the literature review, one of the generalized TR receiver was proposed by [5] to improve the allocation of energy in data packet with interval length of correlator integration and the result was gained in SNR (signal –to-noise ratio) up to 4.2 dB. In [6] the 4 dB performance gain was optimized with energy allocation between data symbols and reference symbols. The TR receiver was shown in [7] to be more sensitive to SNR than rake receiver but less sensitive to the synchronization error. The TR receiver of frequency shifted reference was proposed by [8] with code shifted reference and the simulated results were improved up to two users. In [9], optimal TR receiver scheme was simulated with two correlators in the coal mine roadway channel model and the results show reducing in interference between several received signals through two fingers which complicated the system.

As known that, the indoor wireless communication for improved systems are daily required to be smaller in size and lower in cost, the blind adaptive filter was chosen in this work to play an important role in digital outdoor and indoor communication fields, such as system identification, noise cancellation, and channel equalization. There are four adaptive filter algorithms were presented (CMA, GA, SA, and APA) to improve the reception system by reducing the SER and enhance the gain in SNR. Additionally, this paper was organized to represent the transmission signal and channel model of wireless propagation in Section 2. Section 3 shows the transmitted reference receiver which is working in time hopping TH-UWB systems. In Section 4, the proposed blind adaptation filtering algorithms are presented to implement TR receiver structure. Performance analysis and simulated results discussion are given in Section 5. Finally, Section 6 appropriates conclusions.

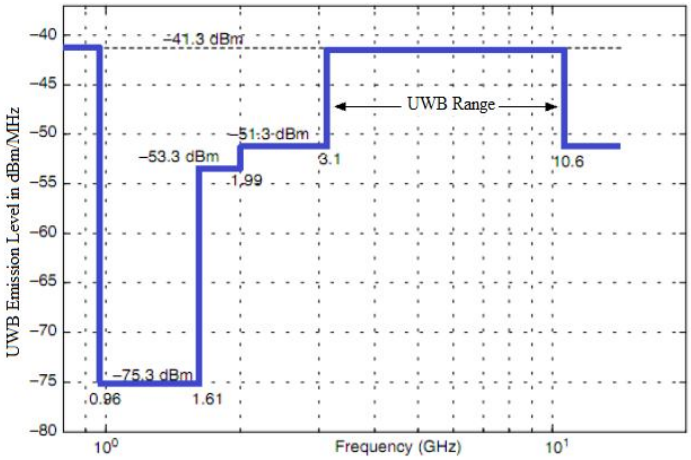

Figure 1. Ultra-wideband frequency range approved by FCC for indoor propagation [10].

2. TRANSMISSION SIGNAL AND CHANNEL MODEL

We consider a TH-UWB system with pulse position modulation (PPM). The information bits are generated randomly by binary source in the transmitter and the Gaussian monocycle pulses doublet pulse are shown in Figure (2) that can be expressed by the Gaussian function {g(t)} bellow [11]:

$$g(t) = ke^{-(\frac{t}{\tau})^2} \tag{1}$$

where k is defined as the factor to maintain the signal energy after each deviation and τ defines the pulse duration.

$$g^{//}(t) = k\frac{-2t}{\tau^2}(1-2\frac{2t^2}{\tau^2})e^{-(\frac{t}{\tau})^2} \tag{2}$$

a train of previous generated pulses are modulated by PPM modulation technique as:

$$W_{PPM}(t) = \sum_{n=-\infty}^{\infty} g(t - nT_f - T_c - D\delta) \tag{3}$$

where T_f is known as the pulse repetition time or frame duration, D defines the binary data of [0, 1], $\boldsymbol{\delta}$ is the pulse position modulation index, T_c is the chip time or the pseudo random shift delay for binary sequence which is applied in spreading the pulses by TH-UWB technique.

Figure (3) shows the TH-UWB signals to verify wide band division in to programmed several blocks and each block is subdivided into several wanted frames. Each frame contains number of chips that depends on the number of users and each T_f with one pulse for transmission process. In a spread spectrum using TH approach, generated data is modulated by PPM technique to allow changing the pulse position along the frame. The T_f duration should be long in order to overcome the channel delay spread and normally ordered of hundreds of nanoseconds to avoid the interference that caused by delayed and reflected pulses in wireless propagation through indoor environment. The process gain of TH-PPM technique conception is achieved by time shift for excuse of more than one monocycle per data symbol that is used to carry a single data bit and the time shift is expressed as a modulation index for this pulse position modulation scheme. The N_s (number of monocycles) is used for modifying the R_s (symbol rate) at constant frame time and can be described bellow as reviewed by [12]:

$$R_s = \frac{1}{T_s} = \frac{1}{N_s T_f} \tag{4}$$

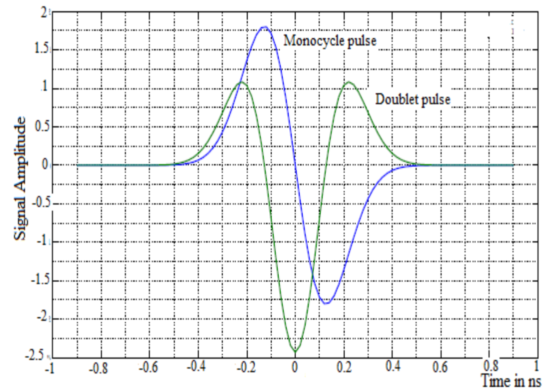

Figure 2. Gaussian pulses [11].

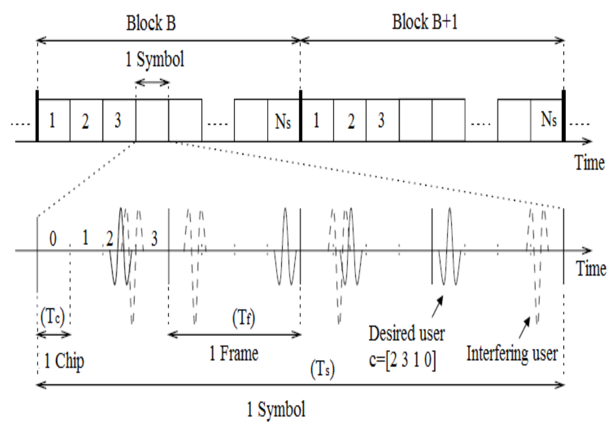

Figure 3. TH-UWB signaling structure.

So that, by using PPM modulation and TH spreading spectrum with low duty cycle pulses, the transmitted signal ($S_{TH}(t)$) can be defined as follows:

$$s_{TH}(t) = \sqrt{\frac{E_s}{N_s}} \sum_{j=-\infty}^{\infty} \sum_{i=0}^{N_c-1} d_j C(i) W_{PPM}(t - jT_f - iT_c - \delta\beta_{\lfloor j/N_s \rfloor} - jT_d) \tag{5}$$

where $d_j \in \{-1, 1\}$ defines the modulated binary data bits, E_s defines the symbol energy, N_s defines the symbol pulses number, $C(i) \in \{-1, 1\}$ is the pseudo-random code (spreading sequence), $\delta\beta_{\lfloor j/N_s \rfloor}$ is used to vary the time positions of the PPM pulses, and T_d is delay time for d_j. The generated and modulated pulses sequence is transmitted over line-of-sight (LOS) through CM1 of up to 15 meters range. These channel models were proposed by IEEE 802-15 with values of main channel parameters. Assuming the wireless channel is time-invariant through the indoor transmission process, so that, the indoor channel impulse response {h(t)} using log-normal shadowing is modeled bellow as reviewed in [4].

$$h(t)=\sum_{k=0}^{K}\sum_{l=0}^{L}\alpha_{k,l}\delta(\tau-T_k-\tau_{k,l}) \qquad (6)$$

where $\alpha_{k,l}$ = multi-path gain coefficients for k-th cluster within the *l*-th multi path ray, T_k = arrival time of the k-th cluster, and $\tau_{k,l}$ is the delay of k-th cluster path within the *l*-th ray. The multi path gain is based on channel coefficients that used to mitigate the effect of path loss or dissipation on UWB spreader signals. Hence, at the input of TR proposed receiver, the wireless received signal {r(t)} is given by:

$$r(t)=S_{TH}(t)*h(t)+n(t) \qquad (7)$$

where * denotes the convolution between channel impulse response and transmitted signal and n(t) is the AWGN (additive white Gaussian noise).

3. THE TRANSMITTED REFERENCE RECEIVER MODEL

The basic principal in TR technique is to transmit un-modulated signals as a reference pulses along the modulated or data pulses and used to define the data at reception technique. Both reference and data pulses are transmitted with delay time between and these pulses are affected equally through the wireless channel. Due to indoor obstacles which are coming from scattering, diffractions and reflections, the wireless signals have different delays and amplitudes. The adaptive TR receiver structure as shown in Figure (4) contains one correlator is feed by blind adaptive filter to support the weak signal by computing the expected error at the output of the proposed receiver. Firstly, the objective required function in adaptive filtering is the MSE process which is defined by [13]:

$$F[e(n)]=\xi(n)=E[e^2(n)-2d(n)x(n)+x^2(n)] \qquad (8)$$

where ξ (n) is the MSE function, d[n] is the reference or desired signal, and e[n] is the deference between the output of TR receiver system and the desired data symbol. The e[n] is needed to be reduced with several frequented iterations to get value of $e[n]^{(n)} < e[n]^{(n+1)}$ and this computation updates the receiver tap weights for obtaining improved system performance by suppressing or cancellation the noise components at many iterations.

$$x(n)=\sum_{i=0}^{N}\omega_i(n)y(n)=\omega^T y(n) \qquad (9)$$

where y(n) = [y_0(n), y_1(n), y_2(n)........y_N(n)] is the input signal and ω(n) = [ω_0(n), ω_1(n), ω_2(n)..........ω_N(n)]^T defines the coefficient vectors of adaptive filter. So that the MSE function is given by:

$$\zeta(n)=E[d^2(n)]-2\omega^T(n)E[d(n)y(n)]+\omega^T E[y(n)y^T(n)]\omega(n)$$

(10)

$$\zeta(n)=E[d^2(n)]-2\omega^T p+\omega^T R\omega \qquad (11)$$

Where R is the value of input signal correlation matrix and p is the cross-correlation vector between the input signals and the desired signals.

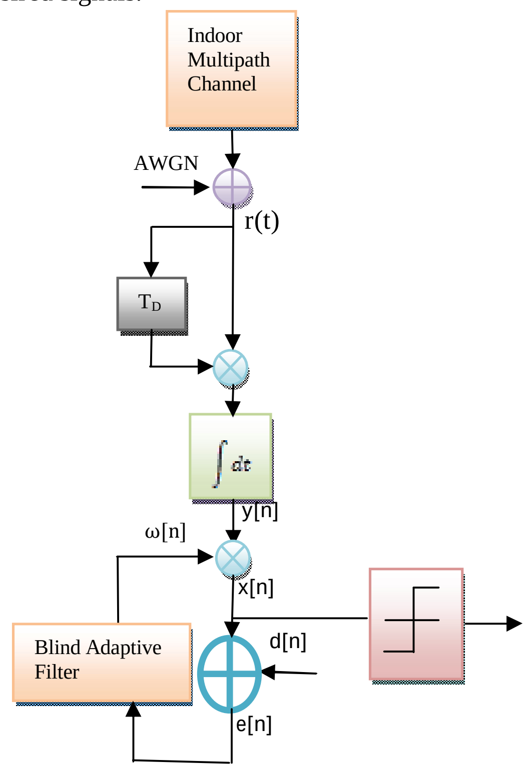

Figure 4. Block diagram of the proposed transmitted-reference receiver.

4. THE PROPOSED BLIND ADAPTIVE FILTERING ALGORITHMS

The *A.* Constant-Modulus Algorithm *(CMA)*

The CMA function can be expressed as bellow [14]:

$$E[e^2_{CMA}(n)]=E[(|\ \omega^H(n)y(n)\ |^2]-q_1)^2] \qquad (12)$$

$$E[e^2_{CMA}(n)]=E[(|\ x(n)\ |^2]-q_1)^2] \qquad (13)$$

where q_1 is the constant value and the updated equation of the used adaptive filter is:

$$\omega(n+1)=\omega(n)-2\mu(|x(n)|^2-q_1)x^*(n)y(n) \qquad (14)$$

$$\omega(n+1)=\omega(n)-2\mu e_{CMA}(n)x^*(n)y(n) \qquad (15)$$

B. Godard Algorithm (GA)

The idea of this algorithm technique is to minimize the expectation error calculation of the adaptive filter for updating requirements [15].

$$E[e^b_{Godard}(n)] = E[(\left| \omega^H(n)y(n) \right|^a] - q_a)^b] \quad (16)$$

$$E[e^b_{Godard}(n)] = E[(\left| x(n) \right|^a] - q_a)^b] \quad (17)$$

Where a and b are positive integers and the value of q_a requires the energy level which [x(n)]a should approach.

$$\omega(n+1) = \omega(n) - \frac{1}{2}\mu ab(\left|x(n)\right|^a - q_a)^{b-1} \left|x(n)\right|^{a-2} x^*(n)y(n)$$

(18)

$$\omega(n+1) = \omega(n) - \mu(x(n) - \text{sgn}[x(n)]q_2)x(n) \quad (19)$$

C. Sato Algorithm (SA)

The objective function of Sato algorithm is defined as bellow and the signals follow the sign of the transmitted symbols [16].

$$e_{Sato}(n) = x(n) - \text{sgn}[x(n)]q_2 \quad (20)$$

$$\omega(n+1) = \omega(n) - \mu(x(n) - \text{sgn}[x(n)]q_2)y(n) \quad (21)$$

$$\omega(n+1) = \omega(n) - \mu e_{Sato}(n)y(n) \quad (22)$$

D. Afine Projection Algorithm (APA)

The aim of this algorithm is to find the solution when the convergence speed is not acceptable [17].

$$\omega(n+1) = \omega(n) - \mu y(n)(y^H(n))^{-1}\{\text{sgn}[y^H\omega(n)] - y^H(n)\omega(n)\}$$

(23)

5. PERFORMANCE ANALYSIS AND SIMULATED RESULTS DISCUSSIONS

MATLAB simulation software was used to show the simulation results of the wireless proposed TR receiver which is modified by blind adaptive filter CMA, GA, SA, and APA algorithms. Indoor CM1 channel of short range was based in simulation process with spreading spectrum signal by TH-UWB and modulated by PPM modulation technique. The proposed system parameters were taken for eight users with 0.5 ns chip duration (T_c) and 0.4 ns pulse duration (T_p). The simulation results evaluate the SER through CM1 of second derivative Gaussian signals against SNR at the output of the reception system. Presentation and comparisons of results are illustrated in the following figures using blind adaptive filter algorithms of MSE adaptive technique:

Figure (5) shows the behavior of SER verses SNR at TH-UWB system that is established in IEEE-UWB of CM1 channel model with TR receiver of single correlator. The application of MSE algorithm in the blind adaptive filter was used to support the output of correlator or integrator to avoid the signal weakness that happen by weak received signal from the reflected paths. The simulation results in this figure describe the obtained gain in SNR when using CMA algorithm which is 5 dB and reducing the computational complexity of the adaptive filter that leads to better noise cancellation than MSE algorithm used.

Figure (6) provides the system performance by reducing SER when using GA algorithm for adaptive TR wireless receiver under CM1 channel parameters. The SER against SNR curves are clearly shown the gain of using GA algorithm over MSE algorithm by adaptive filter and the gain is 6 dB in the presence of eight user interfacing. This algorithm technique is used to minimize the expectation SER error of the adaptive filter for updating requirements.

Figure (7) represents the comparison simulated results between MSE and SA algorithms that used in adaptive filter and the gained SNR is 5 dB. The SER is zero at 40 dB SNR that's mean no symbol error are provided in the system when SNR more than 40 dB. The computational process of blind adaptive filter using Sato algorithm is less than that using the other previous algorithms which leads to reduce system complexity.

Figure (8) shows the improved system performance with blind adaptive filter using APA algorithm over MSE algorithm through indoor CM1 channel model. The SER is zero at 35 dB SNR that's mean no symbol error are provided in the system when SNR more than 35 dB which reduces the reception system complexity.

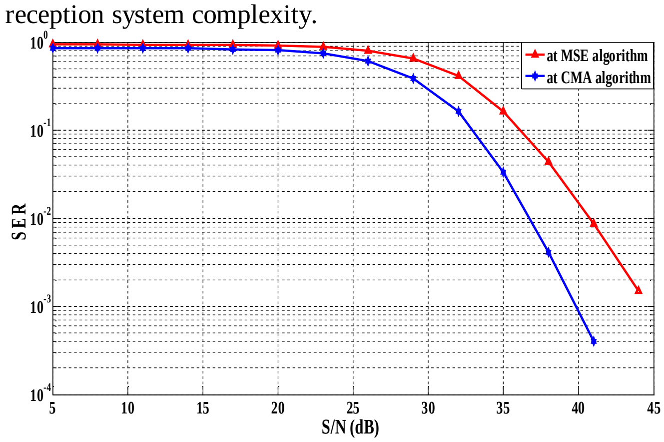

Figure 5. Comparison of SER at MSE and CMA algorithms.

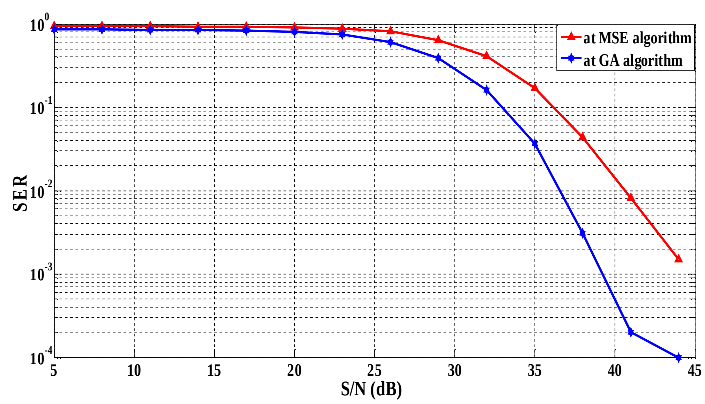

Figure 6. Comparison of SER at MSE and GA algorithms.

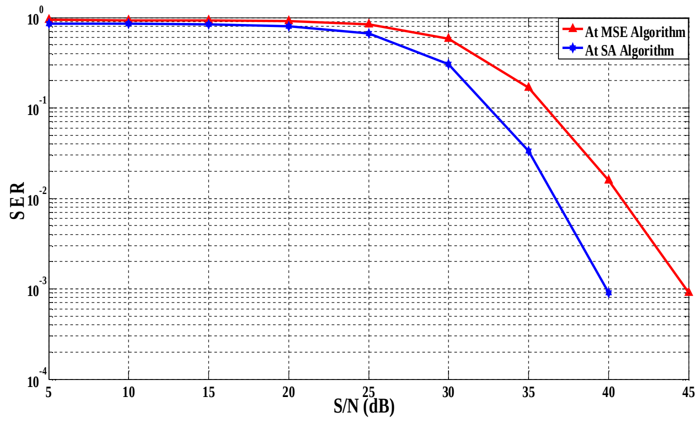

Figure 7. Comparison of SER at MSE and SA algorithms.

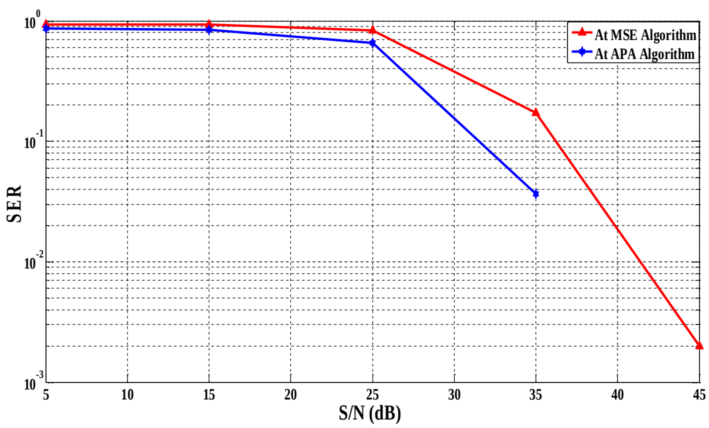

Figure 8. Comparison of SER at MSE and APA algorithms.

6. CONCLUSIONS

In this work, four adaptive algorithms CMA, GA, SA, and APA are applied in the blind filter over MES algorithm to show the indoor wireless system performance. These algorithms are shared to optimize the noise cancellation and to reduce the interferences between several received signals. The above simulation results discover the comparison of each algorithm with MSE application to show the SER performance over SNR values. The behavior of algorithms in adaptation analysis is seemed to reduce the complexity of computation in the process of adaptation. From the simulation results, the four blind adaptive algorithms are more suitable in implementation of adaptive filter than that use MSE algorithm and APA is the best in implementation because no symbol error detection at 35 dB SNR.

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