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Adaptive Equalization for UWB communication System based on ANFIS

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Abstract—Ultra-wideband (UWB) communication systems cover enormous bandwidths that have strongly low-power spectral densities. At UWB communication system with high data rate, owing to multipath propagation, the spread delay in inter symbol interference (ISI) will raise the bit error rate (BER) considerably. ISI which is formed via the UWB channels can be removed by equalization, which is one of the most significant signal processing techniques. Furthermore, LMS algorithm represents a very efficient tool for determining adaptive equalizer coefficients values in communication systems, in spite of that, the LMS adaptive equalizer encounters response diminishing besides slow convergence rate. The current paper adopts an adaptive equalizer based adaptive neuron-fuzzy inference system (ANFIS). The simulation outcomes reveal that the convergence rates as well as accuracy of identification of ANFIS based algorithm are surpass the traditional LMS algorithm, moreover, simulation outcomes prove that ISI is effectively limited and the performance of the system is clearly improved.

Keywords- UWB communication, adaptive equalizer,LMS, ANFIS.

I. INTRODUCTION

According to the prosperity of modern communication technologies and demands of their prospective applications, the requirements of short range with high speed data transmission are vastly desired. In view of its numerous benefits, Ultra-wideband (UWB) technology has been become as a solving key of indoor high speed data transmission, and occupies one of the most vital recent wireless communication researches [1-4]. UWB signal transmission employs the nanosecond or sub-nanosecond narrow pulse; consequently, it will have an extreme wide bandwidth. The key feature of UWB is its rising transmission rate, space amounting which provides more network users, low power consumption, and low cost. However, although the UWB technology is broadly spread, it still exposed to a number of technical and theoretical problems. One of these problems; the distortion of data transmission in UWB communication system via the channel, which produces the inter symbol interference (ISI). In order to get over the effect of ISI, the equalizer can be utilized at the receiver end [5-6]. An efficient and simple technique to get coefficients' values for adaptive equalizer is the least mean square (LMS) method. However, the essential drawback of LMS adaptive equalizer is response diminishing besides slowness of convergence rate [7-9].

On the other hand, Adaptive Neuron-Fuzzy Inference System (ANFIS) which is implemented through incorporating neural network with fuzzy inference aiming to own the advantages of both of these techniques. The fuzzy technique accommodates the procedures of fuzzification and fuzzy inference, whereas the neural network accommodates the consequent part of fuzzy inference [10-12]. In view of the fact that the ANFIS can manipulate nonlinear functions through fast convergence rate with reasonably slight convergence error, the present paper utilize the ANFIS to enhance and explore the efficiency and convergence rate of adaptive equalizer in UWB communication system.

II. U LTRA-WIDEBAND SYSTEM MODEL

Considering a UWB model which transmits a Binary Phase-shift keying (BPSK) modulated signal [13-14]:

$$s(t) = \sum_{i=-\infty}^{\infty} d[i]p(t - iT_s) \qquad (1)$$

Where $d[i]$ signifies the bit stream of BPSK $\{d[i]\} \in \{-1,1\}$, while $p(t)$ represents the pulse of UWB with a duration of $T_s = NT_c$, and

$$p(t) = \sum_{j=0}^{N-1} c[j] g(t - jT_{c)} \quad (2)$$

While $\{c[i]\} \in \{1,0\}$ denotes the spreading code *j*th chip with length N, whereas T_c represents the duration of the chip. Furthermore, $g\{t\}$ represents either a first or second derivative Gaussian pulse.

On the other hand, The IEEE P802.15.3a multipath channel is considered in this paper, which is derived from Saleh-Valenzuela model with little amendment of L clusters and K rays [15]:

$$h_i(t) = X_i \sum_{l=0}^{L} \sum_{k=0}^{K} \alpha_{k,l}^i \, \delta(t - T_l^i - \tau_{k,l}^i) \quad (3)$$

In which, X_i signifies the shadowing of log-normal, and *i* represents the *i*th realization, while $\alpha_{k,l}^i$ represent the coefficients of the multipath gain, whereas T_l^i denotes the lth cluster delay, while $\tau_{k,l}^i$ represents the *k*th multipath component delay relative to the *l*th cluster arrival time (T_l^i), and $\delta(.)$ represents the Dirac delta function.

Furthermore, the received signal through a matched filter of an impulse response *p*(-*t*) followed by a DFE is given by [3],

$$r(t) = \sum_{i=-\infty}^{\infty} d[i] \sum_{m=0}^{M-1} h_m \, w(t - iT_s - \tau_m) + n'(t) \quad (4)$$

Where $w(t) = p(t) * p(-t)$ and $n'(t) = n(t) * p(-t)$n'(t) = n(t) * p(-t) , and $n(t)$ represents the additive white Gaussian noise (AWGN) with zero mean and variance $N_0/2$, while m represents the number of channel paths. To combat distortions, an adaptive equalizer is used at receiver, and these equalizer coefficients can be estimated during the training data transmission. Furthermore, conventional least mean square (LMS) is utilized to adapt the receiver side equalizer, in which, its output is given through [16]:

$$z(k) = \mathbf{W}^T(k) \, \mathbf{r}(k) \quad (5)$$

Where $\mathbf{W}(k)$ is weight vector and expressed as

$$\mathbf{W}(k) = [\, w_1(k),\ w_2(k), \dots\dots, w_N(k)\,]^T \quad (6)$$

These weights are calculated utilizing least mean square algorithm depending on Minimum Squared Error (MSE) principles, then weight coefficients are adjusted according to the equation

$$\mathbf{W}(k+1) = \mathbf{W}(k) + \mu e^*(k) \, \mathbf{X}(k) \quad (7)$$

Where μ represents step size and $e(k)$ is the error signal that utilized in order to adjust the adaptive system using weight vector optimization as

$$e(k) = d(k) - y(k) \quad (8)$$

while $d(k)$ represents the reference signal.

And finally, the detected symbols is obtained simply by means of *z*(*k*) sign.

$$x(k) = sgn(z(k)) \quad (9)$$

III. ANFIS ARCHITECTURE

The ANFIS is a framework that able to map the inputs' characteristics to a single output or decision through a fuzzy inference that is essentially obtained based on the users' interpretation of the variables' characteristics of the model. Moreover, the inference rule is constructed based on IF_THEN representation, THEN part in Takagi– Sugeno (T-S) model is a combination of linguistic variables with their determinable coefficients that is suitable for the algorithm learning purpose. Fuzzy systems essentially work on normalized values that are obtained through membership functions (MFs).

Based on functional characteristics, ANFIS or synthetic Neuro-Fuzzy network is similar to radial function basis network neural network below some specific constrictions. Learning techniques involve the integration of back-propagation gradient besides least squares algorithms in order to train the MF parameters on behalf of emulating the giving training data set [17-18].

To build the ANFIS network, it is not necessary to own a pre-specified model depending on the variables' characteristics of the system, and only an input/output data collection is vital. More specifically, ANFIS will be able to determine both MF parameters besides THEN part coefficients using input–output data based on learning algorithms [19-20].

IV. PROPOSED MODEL

The adopted model of adaptive equalizer system based on ANFIS is illustrated in Fig (1). The primary process of the adopted system can be summarized as follows. Initially, the original signal s(k) is transmitted through the UWB communications channel , then forced with noise n(k). Afterward, the received signal y(k) is functioned to ANFIS adaptive equalizer and error e(k) is computed by comparing the output of the equalizer z(k) with the desired signal d(k).

In the final step, the ANFIS adaptive equalizer output z(k) is forced to slicer; which is actually a quantizer; and the slicer output will be the quantized signal.

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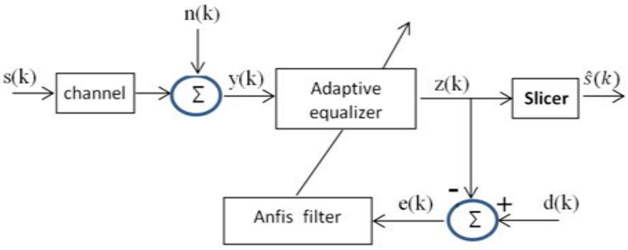
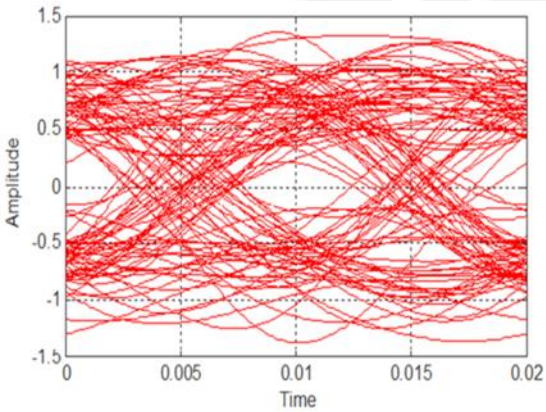


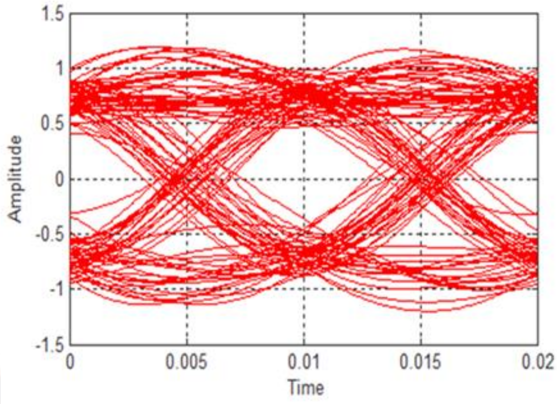
Figure 1. Structure of the Proposed Model.

V. SIMULATION AND RESULTS

To evaluate the performance of the adaptive equalizer based on above proposed model and the conventional LMS algorithm in a UWB channel, a computer simulation has been built using Matlab 2020 to accommodate the characteristics of a channel model of IEEE802.15.3a standard mode, with BPSK modulation at a SNR of 15 dB. The equalizer comprises N=31 taps and step size ($\mu = 0.0001$) for LMS algorithm. The parameters of the ANFIS algorithm that are used in the proposed model include training epoch number of 10, MFs for each input was 4, the initial step size, step size increase rate, and step size decrease rate were 0.1, 1.1, and 0.9 respectively. In this work, the success degree of the adaptive equalization could be viewed under "eye pattern". The results of the conventional LMS algorithm and the proposed model with SNR of 15 dB are displayed in Fig (2), In LMS algorithm, the eye pattern as demonstrated in Fig (2a) is close, un-sharp and not clear. While the pattern of the proposed model as presented in Fig (2b) is open, sharp and clear. On the other hand, Fig (3) illustrates the performance of the LMS algorithm and proposed model with a convergence rate at a SNR of 15 dB, the convergence of the proposed model is clearly faster than LMS algorithm. Finally, Fig. 4 shows the bit error rates performance of the LMS algorithm and proposed model, as shown in the figure, the proposed model gives better BER as compared to LMS algorithm.



(a)



(b)

Figure 2. Eye diagram for a) LMS algorithm b) proposed model

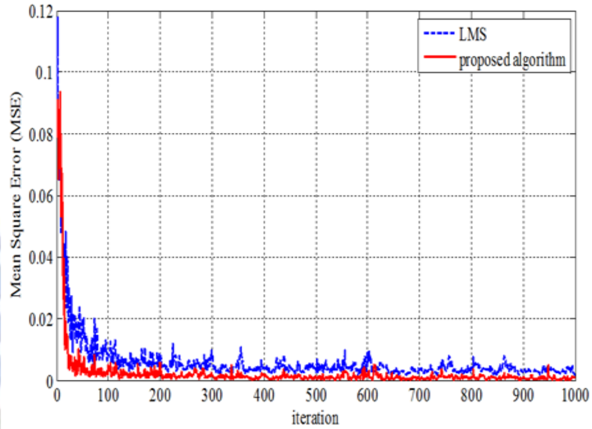


Figure 3. MSE performance comparison of the proposed algorithm and LMS logarithm

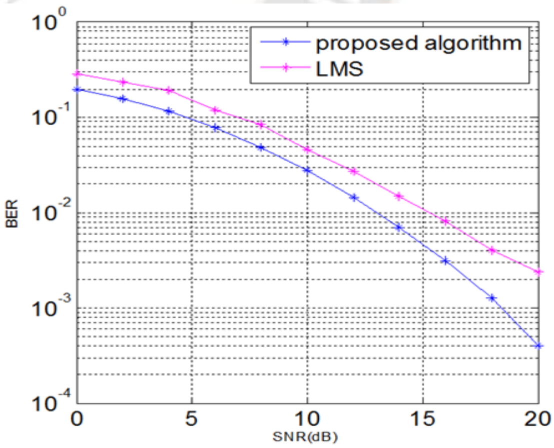


Figure 4. BER versus SNR for the proposed algorithm and LMS logarithm

VI. CONCLUSION

AISI represents a critical factor that limits the performance of high-speed UWB communication systems. Even though the LMS algorithm can be used to equalize ISI, its performance is seriously affected by the ISI. In this paper, a new system for adaptive equalizer based ANFIS network is proposed for UWB communication systems. Through simulation and analysis, this proposed system reveals four benefits over the traditional LMS algorithm. Firstly, it is more efficient to degrade the ISI. Secondly, it demonstrates clearly faster convergence time. Thirdly, it offers obvious BER performance improvement. And finally, it effectively improves the reliability and validity of the UWB communication system.

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