Wireless Body Area Network's Mitigation Method Using Equalization

Savita Sindhu, Shruti Vashist

Abstract**—**A wireless body area sensor network (WBASN) is composed of a central node and heterogeneous sensors to supervise the physiological signals and functions of the human body. This overwhelmimg area has stimulated new research and calibration processes, especially in the area of WBASN's attainment and fidelity. In the era of mobility or imbricated WBASN's, system performance incomparably degrades because of unstable signal integrity. Hence, it is mandatory to define mitigation techniques in the design to avoid interference. There are various mitigation methods available e.g. diversity techniques, equalization, viterbi decoder etc. This paper presents equalization mitigation scheme in WBASNs to improve the signal integrity. Eye diagrams are also given to represent accuracy of the signal. Maximum no. of symbols is taken to authenticate the signal which in turn results in accuracy and increases the overall performance of the system.

Keywords**—**Wireless body area network, equalizer, RLS, LMS.

I. Introduction

A wireless sensor network (WSN) comprises of short range, low power and sensors with variable data rate put within on, or around human body to visualize anatomical signals and other functions [3]. Various anatomical signals can be temperature, blood pressure, electrocardiography (ECG), electroencephalography (EEG), electromyography, and heart. Sensors which aggregate and propagate the signal to the coordinator node can either be mounted on body or may be placed inside the human body. The collected data can then be sent to a hospital for medical purposes.

The Wireless Body Area Sensor Network applications [11], [12] can be illustrated in two major areas: (1) medical applications which include telemonitoring of patient before and after recovery/treatment; (2) applications apart from medical applications which include commitment, achievement and robustness, biometrics, and notification management of the system [4]. As far as wireless body area sensor network's medical and healthcare applications are considered; the quality and continuity of signals are very important. Due to human body movement, different human tissues may be affected differently by proliferation of biosensor signals. It is clearly shown [5] that as channel model proliferates in the vicinity of human body, there is coetaneous transformation in the signal's quality. It was shown also that the effect of different kinds of human tissues to lossy signals had frequency range in between 10 kHz and 1 GHz.

Savita is research scholar and Dr. Shruti Vasisth is Professor in Electronics and Communication Engineering Department, Manav Rachna International Institute of Research ans Studies, Faridabad, Haryana, India (phone: 91-129-425 9000 , fax: 91-129-425 9000, e-mail: savita.fet@ mriu.edu.in, shruti.fet@ mriu.edu.in).

The range of estimated applications, which span from the scientific area (e.g., essential signs and symptoms tracking, automatic drug shipping, and many others.) to the entertainment, gaming, and ambient intelligence areas, creates a set of technical requirements with an extensive version in terms of expected overall performance metrics, as throughput or put off, consequently bendy architectures and protocols are wanted [13]. The foremost conversation well known solutions considered as reference are: IEEE 802.15.four [14], IEEE 802.15.6 [15], and Bluetooth Low energy [16] The most important problem to be taken into consideration is the outage occurrence due to coexistence with other Wi-Fi networks working within the same frequency band. Because it may be remarked later within the paper, many preferred answers for WBAN operate within the license-unfastened business clinical and medical (ISM) band targeted at 2.45 GHz and this results in coexistence issues with different networks running within the equal band (e.g., Wi-Fi IEEE 802.11).[13]

Bit Error Ratio (BER) of a signal is one of the most important criteria to determine the quality of a digital transmission system. The BER is defined by comparing the sequence of bits transmitted to the bits received and counting the number of errors. BER is computed by dividing number of bits having error to the total number of bits received. There are many factors like signal to noise, distortion, and jitter etc. which can affect BER. It is given as:

$$BER=\frac{N_{err}}{N_{Bits}} \quad (1)$$

The acquainted system to calculate BER is robustly sending bits thru the gadget and computes BER. This is analytical process. The measured BER approaches the actual BER as the number of bits tested approaches infinity. Mostly, BER is tested less than a predefined threshold. Required confidence stage and BER threshold are the two parameters which are required in accomplishing BER. The confidence level is defined as the percentage of tests that the system's true BER is less than the specified BER. When error occurs it is not possible to predict the result with certainty and hence the confidence level is below 100%.

Intersymbol interference is another problem, which affects the efficiency of the communication nowadays. The method in which one symbol interferes with subsequent symbols is a type of distortion commonly known as Intersymbol Interference (ISI). As noise affects on signals so as ISI; simultaneous communication becomes deficient in terms of reliability. Either due to multipath propagation Intersymbol Interference or through the inherent non-linear frequency reaction of a channel; both are the reasons of successive symbols to "blur" collectively. If ISI is present in the system it will lead to errors in the decision device at the receiver output. Therefore, while designing transmitter and receiver filters, the main aim is to minimize the effects of ISI, and thereby digital data are delivered to the destination with the smallest error rate possible. Simultaneously more emphasis may be put to decrease the Intersymbol Interference as much as possible.

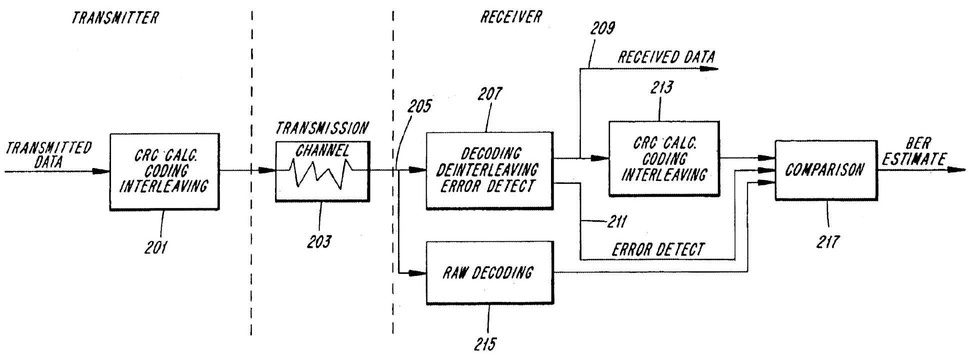

Fig. 1 Estimation of BER

WBASN interference can be categorized into three categories: (1) if intervention takes place among sensor nodes within the same WBASN then it is known as Intra-WBASN; (2) If intervention takes place among WBASNs working at the similar frequency band inter-WBASN; and (3) inter-domain or cross-intervention that occurs between a WBASN and other wireless networks (e.g., Bluetooth, Zigbee, or WiFi) [1]. These forms of interventions should be avoided or mitigated to ensure signal quality in WBASNs [2].

This paper is organized as follows: Section II presents previous work. Section III covers various equalizer techniques on the signal. Section IV gives the analysis of the result based on various equalizers and finally in section V conclusions are drawn.

II. Literature Review

Mahapatro et al. [6] discussed the problem of interference when multiple WBANs come in the proximity of one another. In Wireless Body Area Network (WBAN) various small physiological wearable sensors are mount on the body to monitor its vital signs and then sensor nodes sense physiological information; transmit that data to the on-body coordinator or server through wireless medium in real-time. As the cost of latency per node is increasing; [6] proposed a TDMA-based solution for consistent communication with their sensors without intervention amongst them that creates an ordinary agenda among these WBANs. When adjoined TDMA based WBANs came closer; other interfering WBANs are sensed. They proposed solution with a scheme that defines the time when to exchange their TDMA schedules. That solution was implemented using NS-3 network simulator and observed that percentage of packet delivery needs improvement. Moreover percentage of packet delivery decreased as the speed WBANs increases [6].

Equalization is crucial mitigation mechanics in WBAN channels for ISI issue. Conventional algorithm LMS and RBF do not give adequate results in WBAN channels because of time variable and multipath effect. Reference [7] suggested a hybrid algorithm by joining NFN and RBFN algorithms. In prediction problem of WBAN channels, simulation technique gives good enough output comparative to both NFN and RBFN algorithms [7].

Panigrahi et al. proposed two advanced algorithms by integrating block adaptive filtering techniques with distributed adaptation scheme known as block diffusion least mean square (BDLMS) and block incremental least mean square (BILMS). When compared with conventional diffusion LMS and incremental LMS algorithms; these algorithms show same performance [9].

Reference [10] proposed least mean squares (LMS) and recursive least squares (RLS) equalizers towards the multi-route outcomes since the channels are used in the UWB receiver. Due to use of equalizers and the DSSS Signal to noise ratio (SNR) - BER performances were better.

Sklar [8] presented various mitigation techniques to combat distortion in signal as shown in Table I. The table shows various mitigation methods to remove fading effects. One of the methods is used in this paper.

TABLE I
Mitigation Methods to Combat Distortion

To combat distortion	To combat loss in SNR
Frequency Selective Distortion • Adaptive Equalization • Spread Spectrum • Orthogonal FDM • Pilot Signal	Fast and Slow fading • Error correcting Code • Some type of diversity to get additional uncorrelated estimates of the signal
Fast Fading Distortion • Robust Modulation • Signal redundancy to increase signalling rate • Coding and interleaving	Diversity Types • Time (e.g. Interleaving) • Frequency (e.g. Spread Spectrum with Rake receiver) • Polarization • Spatial (e.g. Spaced Received antennas)

III. Equalizers

A. LMS Algorithm

LMS equalizer is vigorous equalizer in which the coefficients are gradually adjusted to converge to a filter that minimizes the error between the equalized signal and the stored reference. The LMS algorithm seeks to diminish the mean square error. If channel is considered at a specific condition, prediction error will depend on the tap gain W_N, so that mean square error of an equalizer is a function of W_N; where the subscript N denotes the number of delay stages in the equalizer.

If time dispersion parameter is more than propagation hindrance then distortion will not be reduced through the equalizer. Due to step size α, LMS algorithm's convergence rate is slow. This parameter governs the adaptation rate.

B. RLS Algorithm

For determining the coefficients of an adaptive filter, RLS algorithm is used. To estimate the autocorrelation matrix of the input vector, RLS algorithm uses information from all past input samples. A forgetting factor for the influence of each sample is used to decrease the influence of input samples. There are two processes to show how RLS works: 1) Filtering is done and estimation error is generated by RLS using output of a linear filter in response to an input signal. 2) Parameters of the filters are adjusted in accordance with the estimation error.

IV. Set Up and Results

A. Results for LMS Algorithm

1. Waveform for the Error Calculated:

The LMS algorithm firstly calculates the BER for the error cancellation as shown in Fig. 2. The figure gives the graph of desired signal, input signal with noise and the error signal which comes after the use of LMS equalizer. Desired signal will come when error signal is subtracted from input signal.

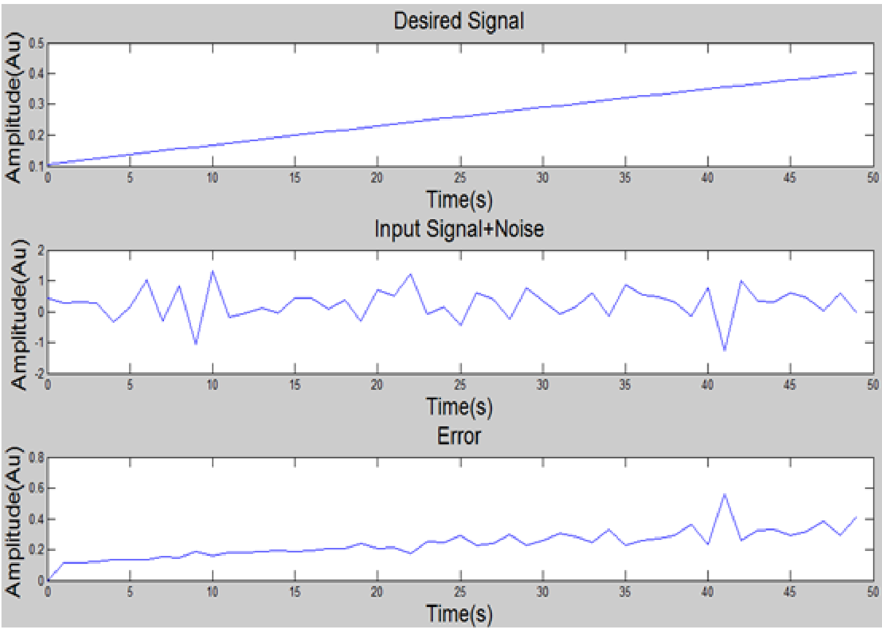

Fig. 2 Desired signal, input signal + noise and the error signal

2. Considerations

The various considerations used in the code for LMS algorithms are shown as in Table II.

TABLE II
Various Considerations Used in the Code

Name of Parameter	Value
Sampling Frequency	10000
Symbol Rate	40
SamplesPer Symbol	250
Symbols Per Trace	2
Step Size	.08
Modulation Technique	FSK

3. Output Waveforms

In this, the outputs of LMS algorithm have been shown for different number of symbols. Different no. of symbols is indicated by N here.

Now after observing the eye diagrams of LMS at different number of N, the error is compared before and after equalization.

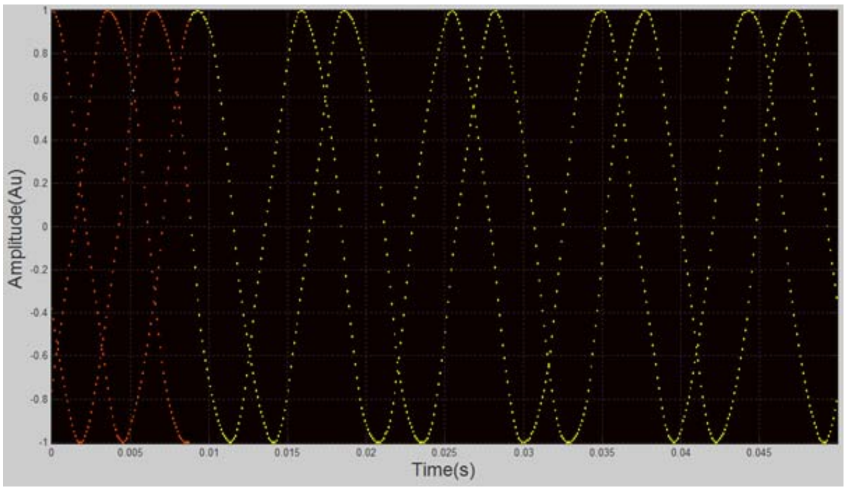

Fig. 3 Eye diagram at output of equalizer with N=32

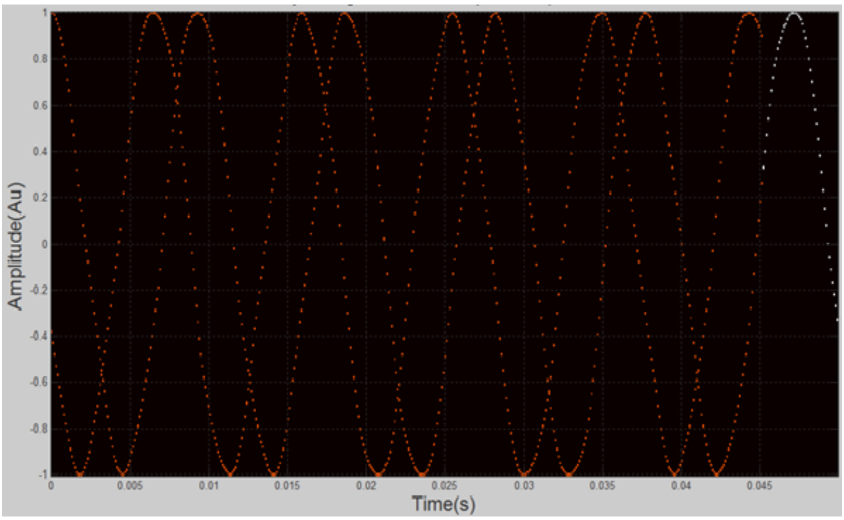

Fig. 4 Eye diagram at output of equalizer with N=28

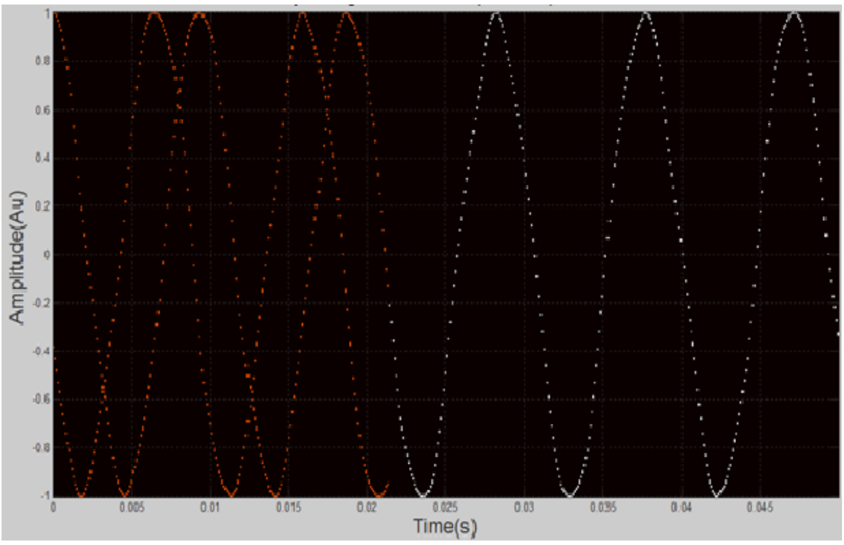

Fig. 5 Eye diagram at output of equalizer with N=21

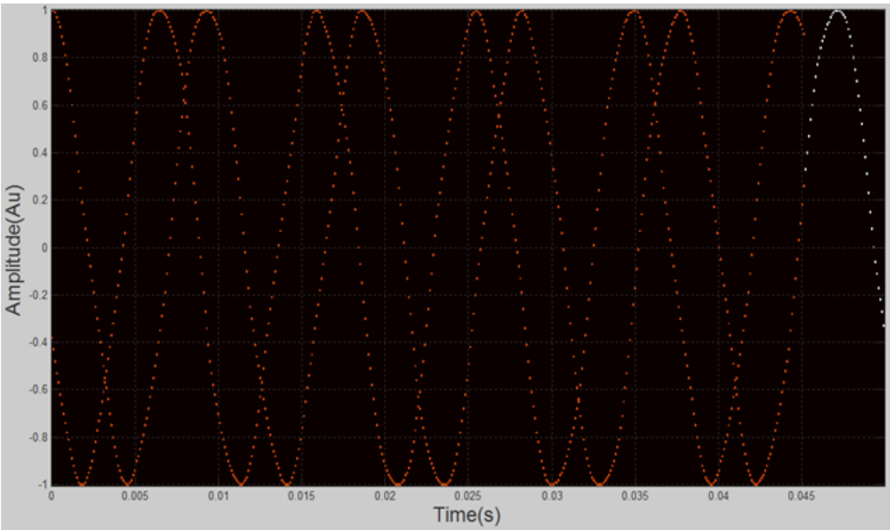

Fig. 6 At output of Equalizer Eye diagram with N=50

Fig. 7 Comparison of error before and after equalization

4. Comparison Table

TABLE III
COMPARISON OF ERRORS BEFORE AND AFTER EQUALIZATION

Symbol Number	10	20	30	40	50	60
Bit Error Rate before equalization	0.157	0.221	0.315	0.411	0.235	0.492
Bit Error Rate after equalization	0.002	-.001	-0 .005	-0 011	-0 .013	-0.001

Fig. 6 shows that after applying LMS qualizer, system became more prone to the errors.

B. Results for Recursive LMS Algorithm

1. Considerations

Table IV shows various parameters used for generating output waveforms.

TABLE IV
VARIOUS CONSIDERATIONS USED IN THE CODE

Name of Parameter	Value
Sampling Frequency	10000
Symbol Rate	40
Samples Per Symbol	250
Symbols Per Trace	2
Forgetting Factor	.90
Modulation Technique	FSK

2. Output Waveforms

Here the outputs of RLS algorithm have been observed for different number of symbols, which are again indicated by N. The outputs are observed at various N, because the comparison with other equalizers becomes easy to do. It also shows how the pairing of symbols is done while transmitting the symbols.

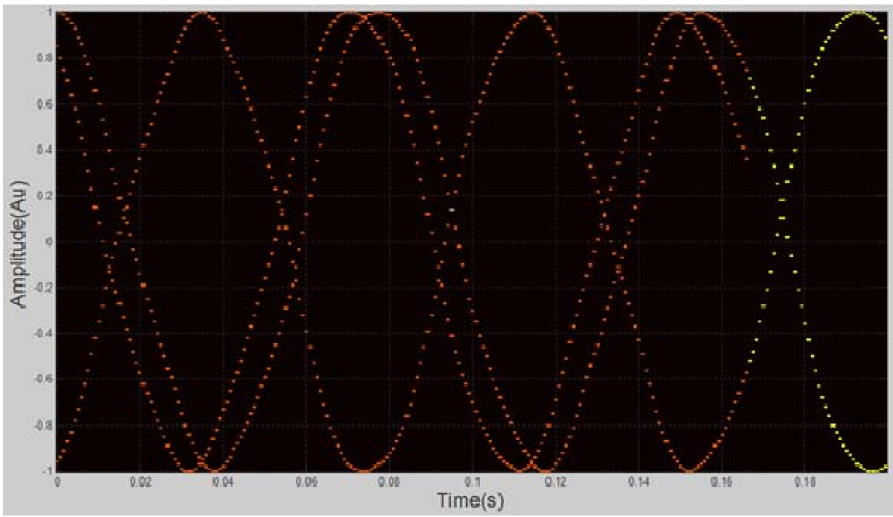

Fig. 8 Eye diagram at output of equalizer with N=20

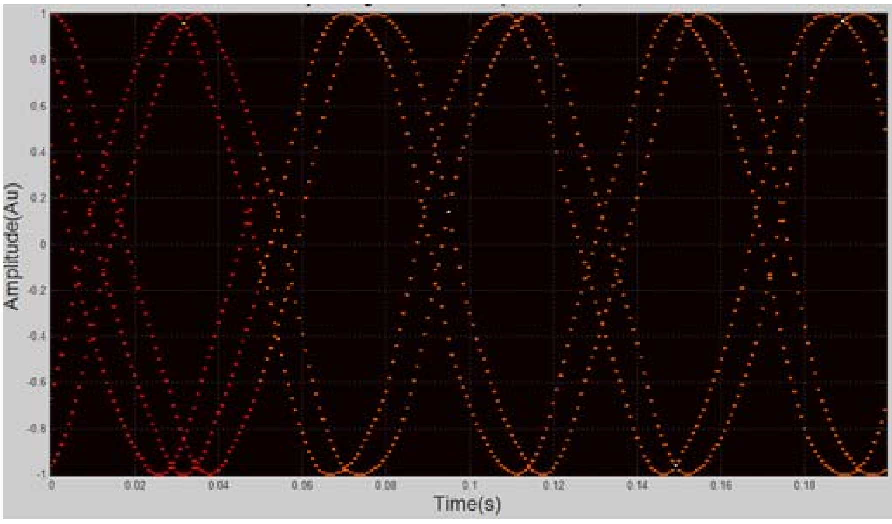

Fig. 9 Eye diagram at output of equalizer with N=30

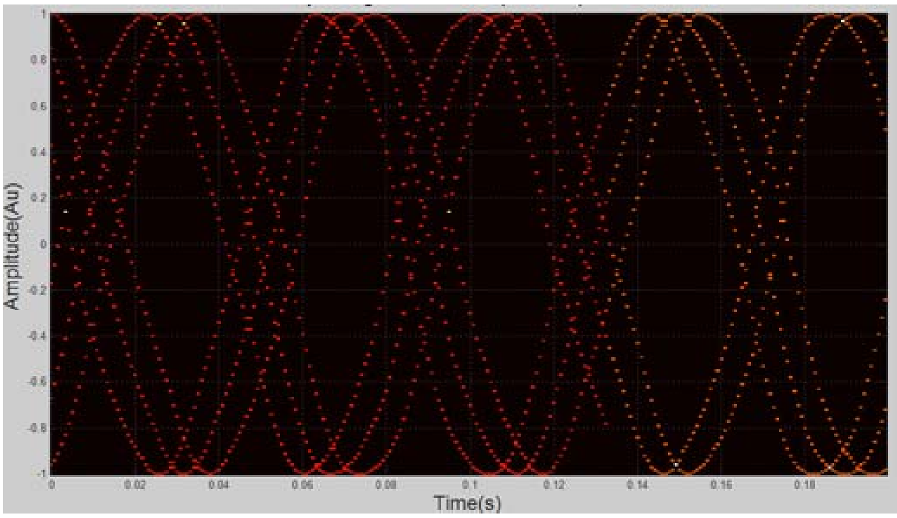

Fig. 10 Eye diagram at output of equalizer with N=40

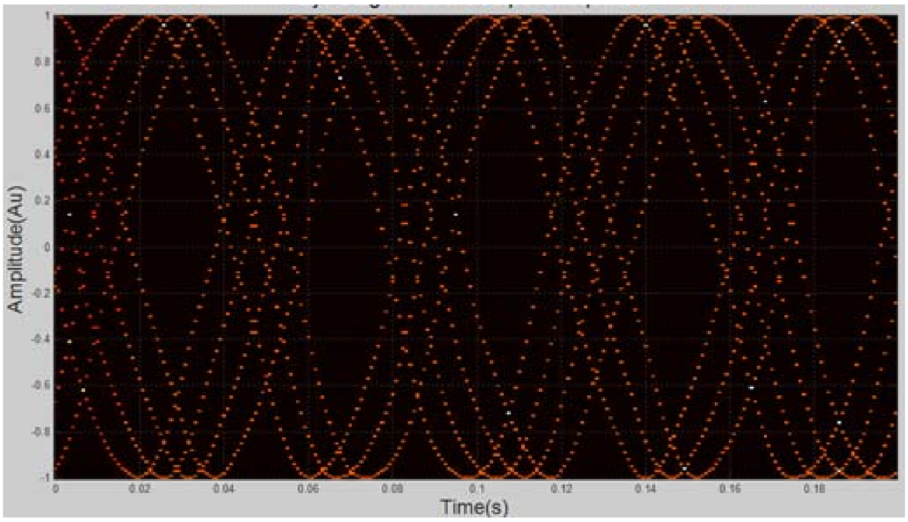

Fig. 11 Eye diagram at output of equalizer with N=50

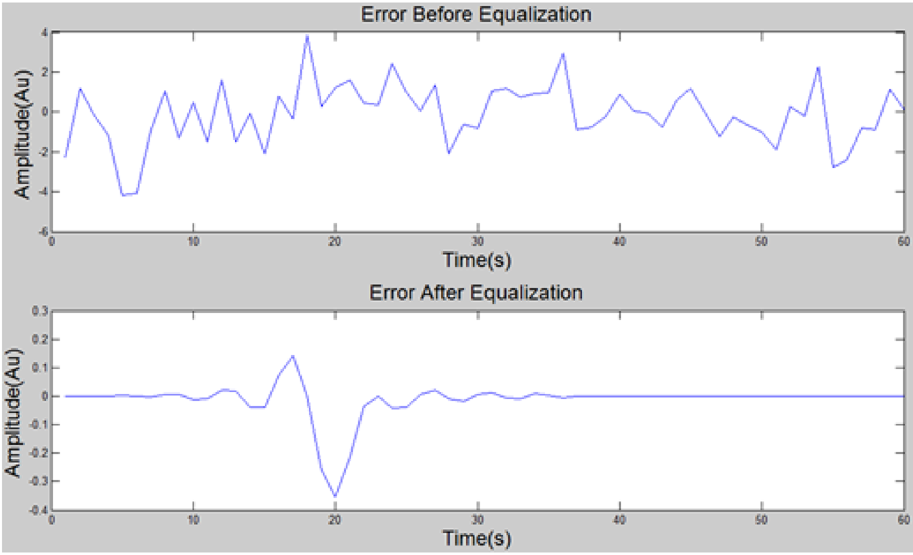

Fig. 12 Comparison of errors before and after equalization

Fig. 12 shows comparative study of errors before and after equalizer used.

3. Table of Comparison

TABLE V
COMPARISON OF ERRORS BEFORE AND AFTER EQUALIZATION

Symbol Number	10	20	30	40	50	60
Bit Error Rate before equalization	0.5077	1.2336	-0.8086	0.8927	-1.0154	0.0777
Bit Error Rate after equalization	-0.0122	-0.3527	0.0064	-0.0010	0.0000	0.0000

It has been observed from Table V that errors are generated less in no. after the use of equalizer. As the no. of symbol rate increases error decreases simultaneously

V. CONCLUSION

In this paper the implementation and results of various linear equalizers have been shown. Equalizer is one of the mitigation method used for fading. Also the error has been compared before and after equalization. No. of symbol rates are also varied to show accuracy in eye diagrams. As the number of symbol rate increases; simultaneously error decreases. The comparison of errors with different symbol rates is shown in different tables, which makes comparison easy. Moreover modulation technique's was taken here. As a future scope, different types of modulation schemes could be taken to improve the equalizer performance.

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