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Design of Adaptive Channel Equalizer for LTE-Advanced System

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Abstract

This paper presents design of Adaptive channel equalizer and performance of LTE-Advanced (LTE-A) System using multiple input multiple output (MIMO) and orthogonal division frequency modulation (OFDM). MIMO with Orthogonal Frequency Division Multiplexing is a key feature of LTE-A system. In this paper channel equalizer based on combination of LMS and RLS filter is used. Performance of proposed model for different communication modulators like QAM (16-QAM, 64 -QAM), BPSK, QPSK is done in term of BER, Scatter plot, Minimum mean square error.

***Keywords*:-** *Adaptive Filter, LMS Filter, RLS Filter, BER,LTE-A, Rayleigh Fading channel, Gaussian channel, OFDM, MMSE, Scatter plot*

1. INTRODUCTION

Wireless communication technology is to provide high quality data services for its users. In multicarrier modulation techniques Orthogonal frequency division multiplexing (OFDM) has become the most popular technique for transmission of signals over wireless channels. OFDM technology transmits the signals using sub channels of various frequencies in parallel mode. The sub channel frequencies satisfies orthogonality principle to avoid interference with each other. This principle allows simultaneous transmission of multiple signals in overlapping frequency channels which reduces bandwidth considerably. OFDM technology offers various advantages like high spectral efficiency, robustness to frequency selective fading, low computational complexity and ease of implementation. Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) is the prominent air interface technology for 4G and 5G broadband wireless communication systems. It combines multiple input, multiple output (MIMO) technology, which multiplies capacity by transmitting different signals over multiple antennas, and orthogonal frequency division multiplexing (OFDM). The combination of MIMO and OFDM is most practically suited for high data rate applications offering highest spectral efficiency, capacity and data throughput. Channel Equalization is a necessity of the communication system for reducing the inter symbol interface (ISI) and noise present in channel. The channel estimation involves examination of channel behavior and prediction of channels response and the equalization process involves equalizing those predicted effects by altering the channel response. Channel equalizer senses the channel activities and generates the responses regarding channels estimates. [6]

Traditionally, inter symbol interference problem is resolved by channel equalization. A channel equalizer is an important component of a communication system. The equalizer depends upon the channel characteristics. The recent digital transmission systems impose the application of channel equalizers with short training time and high tracking rate. These requirements turn attention of researcher to channel equalization algorithms. The channel will affect the transmitting signal because of the channel noise and dispersion which are leading to the Inter symbol Interference (ISI) phenomenon, so it is to pass the received signal at the receiver through an equalizing filter to minimize the channel effect. The adaptive equalizer and the decision device at the receiver compensate the ISI created by the channel. [2]

The paper is organized as follows: Section II briefly describes the concept of channel Equalizer. In Section III presents the Adaptive Equalizer for LTE-Advanced system. Section IV presents the experimental results and minimum BER analysis of the proposed model. Section V concludes the paper.

2. CONCEPT OF CHANNEL EQUALIZER

In the MIMO-OFDM systems the signals are orthogonal to each other, but this orthogonality is lost when the channel is varying fastly with time. The reason is that in the wireless environment the channels which fades continuously with time causes the change in the properties of the signal envelope covering the MIMO-OFDM symbol period, which results in the overlapping of sub-carriers and loss of orthogonality known as inter channel interference (ICI) or inter symbol interference (ISI) due to drop in power among MIMO-OFDM subcarriers. This causes delays and decrement in the error rate performance of the system. It is an iterative process of reducing the mean square error and could be performed in both domains of time and frequency. [4] Unlike normal digital filters most of the Adaptive Filters are able to work in recursive manner which helps to reduce the computational complexity on the basis of particular application. The key goal of working with
Adaptive filters is to minimize the MSE as minimum as possible. Figure 1 shows the basic process required for channel equalization using adaptive filter. The equalizer plays an important role for providing the equalized input to the receiver. **[**2]. The Equalizer is placed before the receiver so the aim of the equalizer is to produce an output for which the receiver can take appropriate action because the equalizer is the most expensive component of a data demodulator.

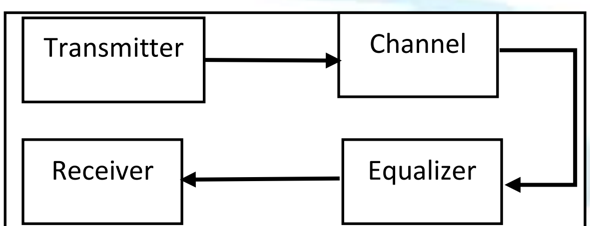


Fig 1: - General block of Channel Equalization [2]

3. PROPOSED ADAPTIV EQUALIZER FOR LTE-A SYSTEM

The operation of signal filtering by definition implies extracting something desired from a signal containing both desired and undesired components.
In Fig.2 the process required for Adaptive equalization is explained Where u(n) is the filter input, y(n) is the filtered output, e(n) is the error between the filtered output and the desired response d(n). The Adaptive filtering means the Adaptive algorithm which is to be able to update the filter coefficients and adjust the filter weights on the basis of error occurred and again this process is repeated to get the optimum output. [2]

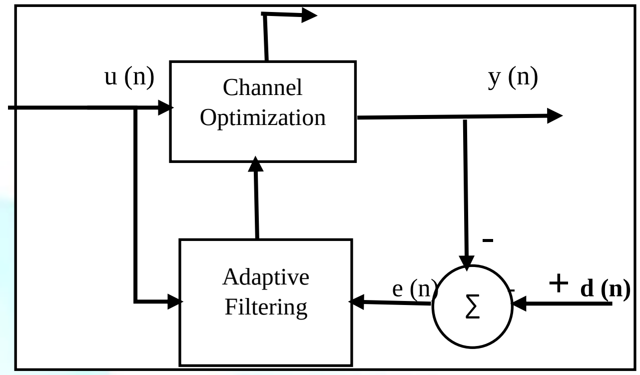


Fig 2 Adaptive Equalization [2]

Adaptive filtering (AF) is proven to be an efficient filter in channel equalization by means of self-adjusting the channel impulse response (CIR) coefficients based on some adaptation algorithm such as least mean squares (LMS), recursive least squares (RLS). [7]
Figure 3 shows the general block diagram of Adaptive filter based Equalizer for LTE-A System.
In this paper combination of LMS and RLS is presented and this combination is applied at the channel parallel. Filter length is taken for both (LMS, RLS) filter is 32. In this input of both equalizer LMS and RLS is feed with common channel input and data of LMS filter is used as reference data for RLS filter. RLS is recursive filter that repeat and repeat the process with the using of reference data which is LMS Filter output. LMS algorithm is generally consisting two procedure first is that filtering that means it compute filter response and equalized output, and other one is that estimated error. It generate estimated error by compare output data with input and produce estimated error and mean square error.
The LMS filter algorithm is defined by the following equations.

$$y(n)=\mathbf{w}^{T}(n-1)\mathbf{u}(n) \quad (1)$$

$$e(n)=d(n)-y(n) \quad (2)$$

$$w(n)=\alpha\mathbf{w}(n-1)+f(\mathbf{u}(n),e(n),\mu) \quad (3)$$

where y(n) is The filtered output at step *n*, *w(n) is* The vector of filter weight estimates at step *n*, *u(n)*

The vector of buffered input samples at step *n* , *e(n) is* The estimation error at step *n* ,*d(n)* The desired response at step *n, α is* The leakage factor (0 < α ≤ 1).

RLS is selected, recursively computes the least squares estimate (RLS) of the FIR filter weights. The System object estimates the filter weights or

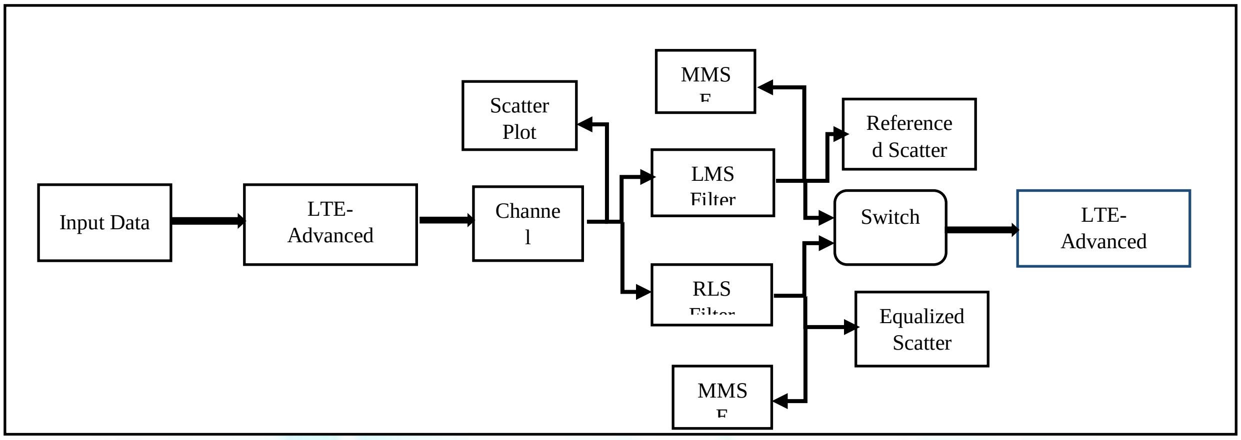


Fig 3 Block diagram of Adaptive Filter based Equalizer for LTE-A System

Coefficients, needed to convert the input signal into the desired signal. The input signal can be a scalar or a column vector. The desired signal must have the same data type, complexity, and dimensions as the input signal.

$$k(n) = \frac{\lambda^{-1}P(n-1)u(n)}{1+\lambda^{-1}u^{H}(n)P(n-1)u(n)} \quad (4)$$

$$y(n) = w^{T}(n-1)u(n) \quad (5)$$

$$e(n) = d(n) - y(n) \quad (6)$$

$$w(n) = w(n-1) + K(n)e(n) \quad (7)$$

$$P(n) = \lambda^{-1}P(n-1)\lambda^{-1}K(n)u^{H}(n)P(n-1) \quad (8)$$

Where n is current time index, u(n) is vector of buffered input samples at step n, P(n) is inverse correlation matrix, K(n) is gain vector, w(n) is vector of filter tap estimate, y(n) is filtered output, e(n) is estimated error, d(n) is desired response, λ is forgetting factor.

4. EXPERIMENTAL RESULTS

In this paper random binary generator with probability of zero and probability of one both are equal to 0.5 and number of samples per frame is equal to20 and sample time is taken 4ms with using a turbo code generator of rate 1/3 with different modulators like BPSK, QAM (16QAM, 64QAM), QPSK applied as an input to the Rayleigh channel. In this paper Adaptive filter based Equalizer is used. MMSE, Scatter plot, Spectrum of power spectral density, BER comparison for different modulators BPSK, QAM, QPSK is shown.

4.1 Performance of Adaptive Equalizer

In this Adaptive Equalizer based on combination of LMS & is Filter is designed. Output data of LMS Filter is taken as reference for the input of RLS and then performance has been done for differentmodulators (BPSK, QAM, and QPSK) for various parameters.
The model is experimented for three categories.
(I).Performance of Adaptive Equalizer in term of MMSE, Scatter Plot, Spectrum.
(II). BER Analysis of LTE-A System.
(III). Comparison with existing system.
Study of Different modulator based system for the combination of LMS & RLS filter is done and performance in term of MMSE, Constellation diagram is shown. Minimum Mean Square error (MMSE) is most common criteria used in Adaptive Filtering.
Formula for MMSE is given by

$$MMSE = E[|e_0|^2] \quad (9)$$

Where e_0 is the optimum error between the measured output y (n) and desired signals d (n).

$$e_0(n) = y(n) - d(n) \quad (10)$$

CASE STUDY I: - BPSK Based System

(i) Minimum Mean Square Error (MMSE):-

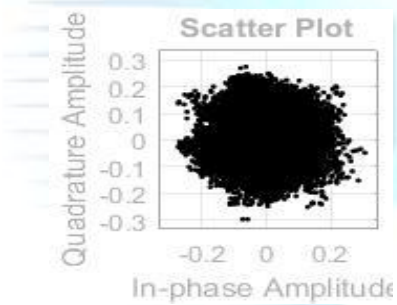
MMSE is calculated for BPSK Modulator system is the error between measured output and desired signal

MMSE for LMS = 0.1218
MMSE for RLS = 0.01313

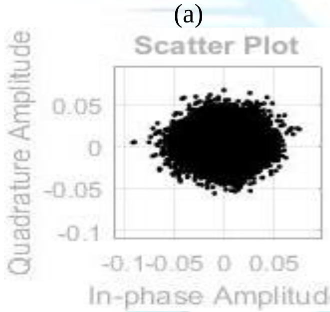
(ii) Scatter Plot for BPSK: -

Figure 4 shows the Scatter Plot for BPSK modulator based system.

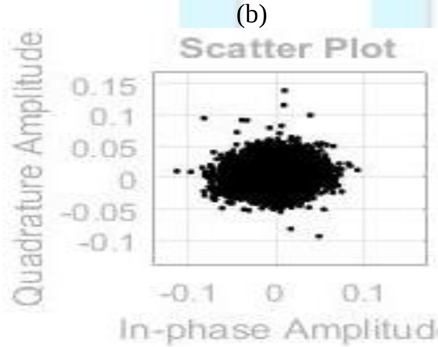
Figure (a) represent the scatter plot before equalization process and figure (b) is represent as referenced equalized scatter plot and figure (c) represent equalized scatter plot for system.



(a)



(b)



(c)

Fig 4 Scatter plot for BPSK (a)Before Equalizer (b) Reference output (c) Equalized output

(iii) SPECTRUM FOR BPSK

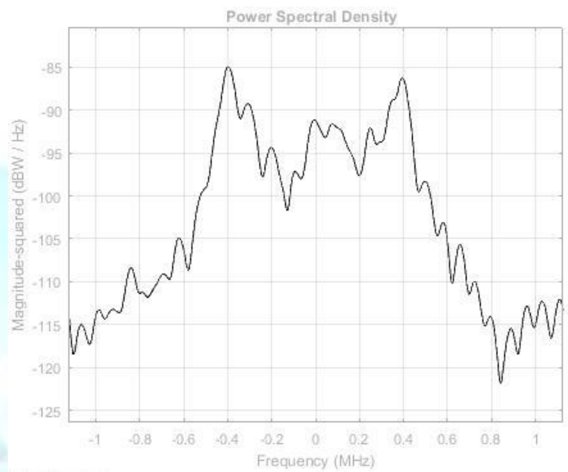


Fig5 Spectrum for BPSK at receiver side

CASE STUDY II: - QAM Based System

QAM based system performance is done for two QAM Modulators (16 QAM,64 QAM).

(A) 16 QAM Based System

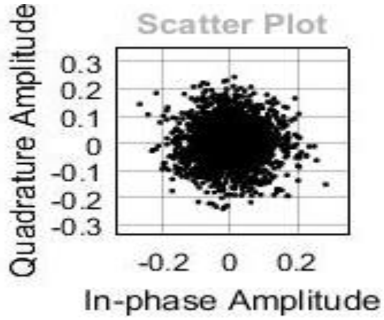
(i) Minimum Mean Square Error (MMSE):-

MMSE is calculated for 16QAM Modulator system is the error between measured output and desired signal

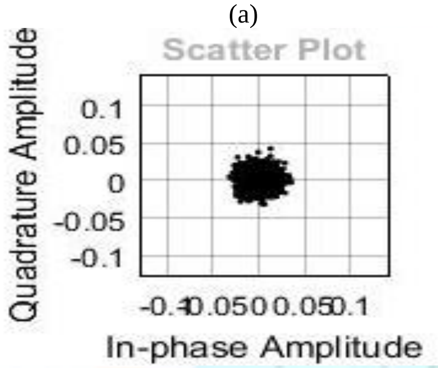
MMSE for LMS = 0.000284
MMSE for RLS = 0.000444

(ii) Scatter Plot for 16QAM

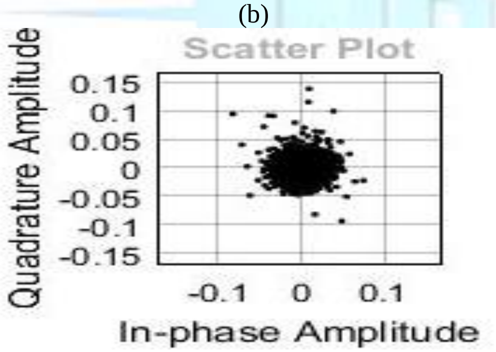
Figure 6 shows the Scatter Plot for 16 QAM modulator based system. Figure (a) represent the scatter plot before equalization process and figure (b) is represent as referenced equalized scatter plot and figure (c) represent equalized scatter plot for system.



(a)



(b)



(c)

Fig 6 Scatter plot for 16 QAM (a)Before Equalizer (b) Reference output (c) Equalized Output

(iii) SPECTRUM FOR 16 QAM

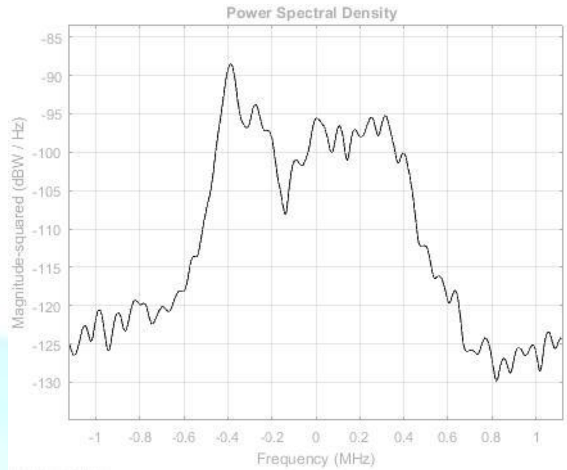


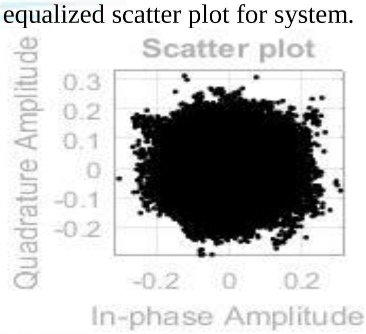
Fig 7 Spectrum for 16 QAM at receiver side

(B) 64 QAM Based System

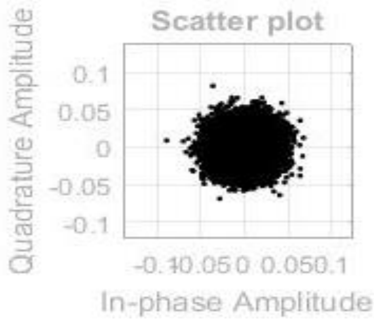
(i) Minimum Mean Square Error (MMSE):-
MMSE is calculated for 64 QAM Modulator system is the error between measured output and desired signal

MMSE for LMS = 0.0064
MMSE for RLS = 0.0059

(ii) CONSTELLATION DIAGRAM FOR 16QAM
Figure 8 shows the Scatter Plot for BPSK modulator based system. Figure (a) represent the scatter plot before equalization process and figure (b) is represent as referenced equalized scatter plot and figure (c) represent equalized scatter plot for system.



(a)



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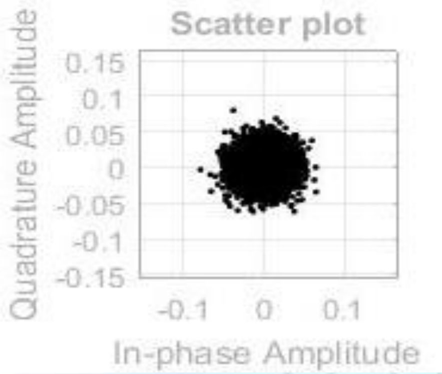


(c)

Fig 8 Scatter plot for 64QAM (a)Before Equalizer (b) Reference Output (c) Equalized Output

(iii) SPECTRUM FOR 64 QAM

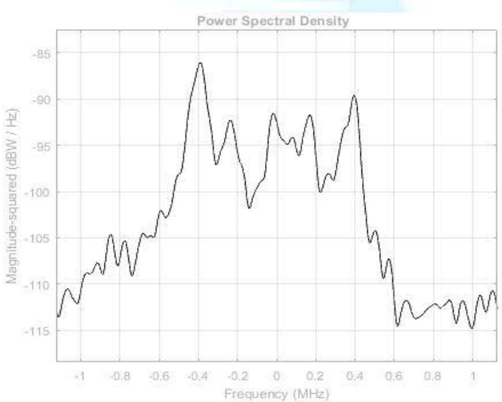


Fig9 Spectrum for 64 QAM at receiver side

CASE STUDY III: - QPSK Based System

(i) Minimum Mean Square Error (MMSE):-

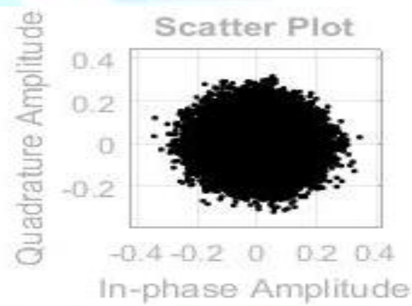
MMSE is calculated for QPSK Modulator system is the error between measured output and desired signal

MMSE for LMS = 0.002202

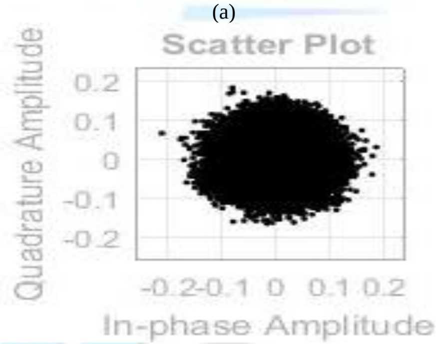
MMSE for RLS = 0.002250

(ii) CONSTELLATION DIAGRAM FOR BPSK

Figure 10 shows the Scatter Plot for QPSK modulator based system. Figure (a) represent the scatter plot before equalization process and figure (b) is represent as referenced equalized scatter plot and figure (c) represent equalized scatter plot for system.

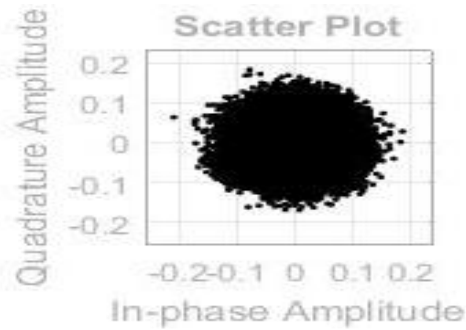


(a)



(b)

Modulator	LMS Filter	RLS Filter
16 QAM	0.000284	0.000444
QPSK	0.002202	0.002250
64 QAM	0.0064	0.005959
BPSK	0.01218	0.01313



(c)
Fig 10 Scatter plot for QPSK (a)Before Equalizer (b) Reference output (c) Equalized output

(iii) SPECTRUM FOR QPSK

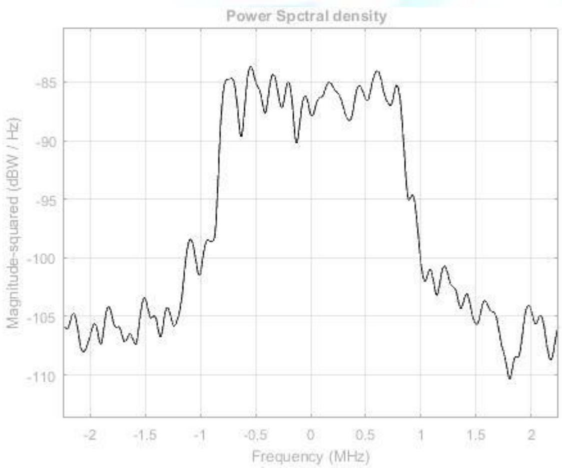


Fig9 Spectrum for QPSK at receiver side

4.2 BER Analysis for proposed System

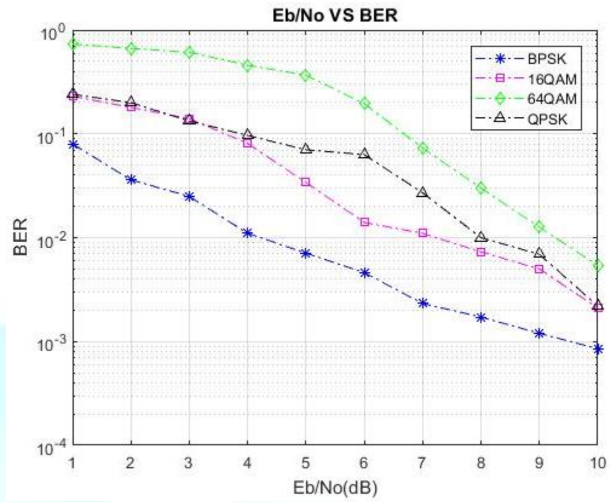


Fig 13 Eb/No Vs BER for different modulators

4.3 MMSE for proposed System

Table 1 shows the Minimum Mean Square Error (MMSE) for different modulators like BPSK, QPSK, and QAM. Table shows that MMSE is minimum for 16 QAM system for LMS it is equal to 0.000284 and for RLS system it is 0.000444.

Table 1 MMSE for Different Modulator

4.3 Comparison of Proposed Model with Existing System

The performance evaluation for the Adaptive filter Based equalizer for LTE-A System with different modulation is experimented and compared with reference model [1]. The proposed model is designed for 20 samples per frame and using a turbo code generator of rate 1/3 with Rayleigh channel and observed better BER of 0.0071 at 5db SNR for BPSK and BER of 0.0050 at 9db SNR for 16QAM and BER of 0.27 at 7db SNR for QPSK as shown in Table 2.

Table2 Minimum BER Comparison

Modulator	Eb/No	BER	
		Reference Model [1]	Proposed Model
BPSK	5	0.0092	0.0071
QPSK	7	0.05	0.027
16QAM	9	0.0065	0.0050
64 QAM	10	-	0.0054

5. CONCLUSION

This paper concludes with the successful implementation of Adaptive filter Based Equalizer for LTE-A System. Bit Error Rate (BER) and MMSE is calculated for measuring performance. Scatter plot before Equalizer and after Equalizer is shown above for different modulator BPSK, QAM (4 QAM, 16 QAM, and 64 QAM), QPSK based system, this concludes that after equalizer transmitted data can be recovered. Experimental results shows better performance for BPSK, 16QAM, QPSK at 5db, 9db, 7db. MMSE is minimum for 16 QAM System and it is

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