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BER PERFORMANCE OF AWGN, RAYLEIGH AND RICIAN CHANNEL

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Abstract: MIMO-OFDM is commonly used communication system due to its high transmission rate and robustness against multipath fading. In MIMO-OFDM, channel estimation plays a major role. It refers to estimation of transmitted signal bits using the corresponding received signal bits. Among the different channel estimation methods, Least Square (LS), Least Square-Modified (LS-Mod) and Minimum Mean Square Error (MMSE) methods are commonly used. In this project, AWGN, Rayleigh and Rician channel models are implementing by using LS, LS-Modified and MMSE algorithms. In LS estimation, procedure is simple but it has high Mean Square Error. In low SNR, MMSE is better than that of LS, but its main problem is its high computational complexity and LS-Modified is considered to be the best among the three channel estimation methods. The system is simulated in MATLAB and analysed in terms of Bit Error Rate with Signal to Noise Ratio

Key words: MIMO-OFDM, LS, MMSE, LS-MOD

I.INTRODUCTION

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor while wireless operations permit services, such as long-range communications, that are impossible or impractical to implement with the use of wires. The term is commonly used in the telecommunications industry to refer to telecommunications systems which is to transfer information without the use of wires over both short and long distances. Wireless networking the various types of unlicensed 2.4 GHz WI-Fi devices used to meet many needs [1]. A wireless transmission method is a logical choice to network a LAN segment that must frequently change locations are used to meet many needs. The term "wireless" came into public use to refer to a radio receiver or transceiver, the term is used to describe modern wireless connections such as in cellular networks and wireless broadband Internet.

In MIMO-OFDM channel estimation plays an important role. It refers to the estimation of transmitted signal bits using the corresponding received signal bits. Here, three channel models namely AWGN, Rayleigh and Rician are estimated. It is implemented by using three algorithms namely Least Square (LS), Minimum Mean Square Error (MMSE), Least Square Modified (LS-Mod).The system is simulated in MATLAB and analysed in terms of Bit Error Rate (BER) with Signal to Noise Ratio (SNR).In LS algorithm, estimation procedure is simple but it has high mean square error (MSE).In low SNR, MMSE is better than that of LS, but its main problem is its high computational complexity. In high SNR LS is better than that of MMSE algorithm. LS-Modified is suitable for both low and high values of SNR

Wireless phones use radio waves to enable their users to make phone calls from many locations worldwide. These can be used within the range of telephone required to transmit and receive the radio signals from these instruments. Wi-Fi has become de facto standard for access in private homes, within offices, and at public hotspot. Wireless Mobile Phone Remote Controls, DSRC are used in short-range point-to-point communication [2]. Wi-Fi, WMAN and WiMax used under wireless network category.

II.THEORY OF MIMO-OFDM

Recently, a worldwide convergence has occurred for the use of OFDM as an emerging technique for high data rates. It is a digital multi-carrier modulation scheme. Multi-carrier modulations that use orthogonal waveform for modulating the subcarriers are called OFDM schemes. Since the subcarriers are modulated by orthogonal waveforms. The subcarriers are permitted to have overlapping spectrum and thus achieving higher spectrum efficiency. OFDM solves the problem due to ISI. It can efficiently deal with multipath

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fading and it has enhanced channel capacity [3]. It provides better synchronization of transmitter and receiver. It has robustness against narrow band interference. In particular, the wireless local network systems such as WiMax, Wi-Fi etc and the emerging 4G mobile systems are all OFDM based systems

As shown in fig 1, MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. The terms input and output refer to the radio channel carrying the signal, along with the devices having antennas. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency or to achieve a diversity gain that improves the link reliability [4]

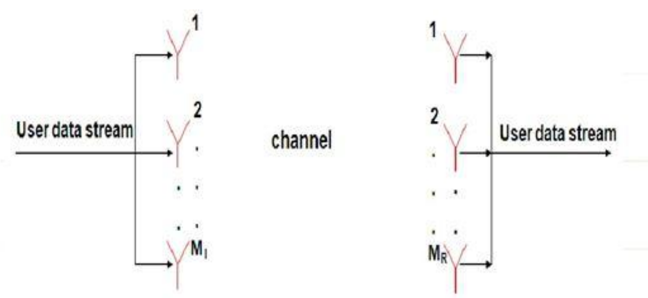

Fig 1. MIMO

Multi-antenna MIMO technology has been developed and implemented in some standards, e.g. IEEE 802.11 products. Some limitations are the physical antenna spacing is selected to be large, multiple wavelength at the base station. The antenna separation at the receiver is heavily space constrained in hand sets, though advanced antenna design[5]. Multi-user MIMO can have a higher potential, practically, the research on multi-user MIMO technology is more active. Spatial multiplexing techniques make the receivers very complex, and therefore these are typically combined with OFDM or with (OFDMA) modulation, where the problems created by a multi-path channel are handled efficiently. MIMO technology can be used in non-wireless communications systems. MIMO system is modeled as

$$Y = Hx + n \qquad (1)$$

where,

Y and x are the receiver and transmit vectors, respectively. H and n are the channel matrix and the noise vector, respectively.

III.CHANNEL ESTIMATION

In telecommunication and computer networking, a communication channel, or channel, refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey the information signal, for example a digital bit stream from one or several senders to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bit per second. The term channel refers to the medium between the transmitting antenna and the receiving antenna[6]

The characteristics of wireless signal changes as it travels from the transmitter antenna to the receiver antenna. These characteristics depend upon the distance between the two antennas, the paths taken by the signal and the environment around the path. In general, the power profile of the received signal can be obtained by convolving the power profile of the transmitted signal with the impulse response of the channel. Convolution in time domain is equivalent to multiplication in the frequency domain. Therefore, the transmitted signal x, after propagation through the channel becomes y[7]

$$y(f)=H(f)x(f)+n(f) \qquad (2)$$

Here H(f) is channel response, and n(f) is the noise. Note that x, y, H, and n are all functions of the signal frequency f. The objects located around the path of the wireless signal reflect the signal. Some of these reflected waves are also received at the receiver. Since each of these reflected signals takes a different path, it has a different amplitude and phase. Channel estimation can be performed in three ways. They are training-based channel estimation, blind channel estimation and semi blind channel estimation [8].

In training-based channel estimation, known symbols are transmitted specifically to aid the receiver's channel estimation algorithms [9]. Here, training symbols or pilot tone that are known a priori to the receiver, are multiplexed along with the data stream for channel estimation.

In a blind channel-estimation method, the receiver must determine the channel without the aid of known symbols. The blind channel estimation is carried out by evaluating the statistical information of the channel and certain properties of the transmitted signals. Although higher-bandwidth efficiency can be obtained in blind techniques due to the

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lack of training overhead, the convergence speed and estimation accuracy are significantly compromised. Blind Channel Estimation has its advantage in that it has no overhead loss. It is only applicable to slowly time-varying channels due to its need for a long data record.

Semi-blind channel technique is hybrid of blind and training technique, utilizing pilots and other natural constraints to perform channel estimation. For this reason, training-based channel-estimation techniques are more reliable, more prevalent, and supported by the WiMAX standard.

IV.PILOT BASED CHANNEL ESTIMATION

Pilot provides coherent data detection to decrease error. Receiver performs channel estimation based on received pilot symbols. It is used for synchronization, continuity. The pilots will be inserted to all subcarriers uniformly between the information data sequence which is shown in Fig 2. The training-based method channel estimation can be performed by either block type pilots where pilot tones are inserted into all frequency bins within periodic intervals of OFDM blocks or by comb pilots where pilot tones are inserted into each OFDM symbols with a specific period of frequency

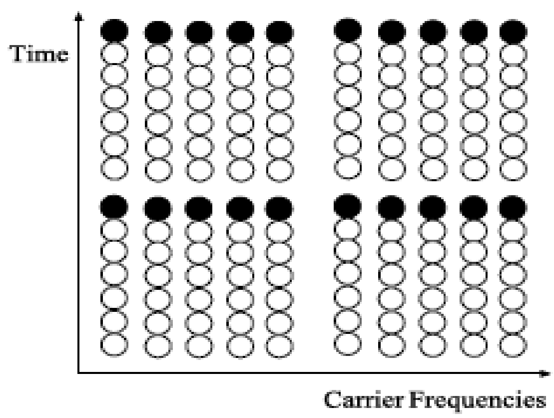

Fig 2. Block Type Pilot Channel Estimation

In training based channel estimation algorithms, training symbols or pilot tones that are known to the receiver are multiplexed along with the data stream for channel estimation. The idea behind these methods is to exploit knowledge of transmitted pilot symbols at the receiver to estimate the channel. For a block fading channel, where the channel is constant over a few OFDM symbols, the pilots are transmitted on all subcarriers in periodic intervals of OFDM blocks. This type of pilot arrangement, depicted in Figure 2 is called the block type arrangement.

It has been introduced in case where the channel changes even in one OFDM block. The comb-type pilot channel estimation consists of algorithms to estimate the channel at pilot frequencies and interpolation is used to find the channel at signal frequencies. The interpolation of the channel for comb-type based channel estimation can be depend on linear interpolation, low-pass interpolation and spline cubic interpolation.

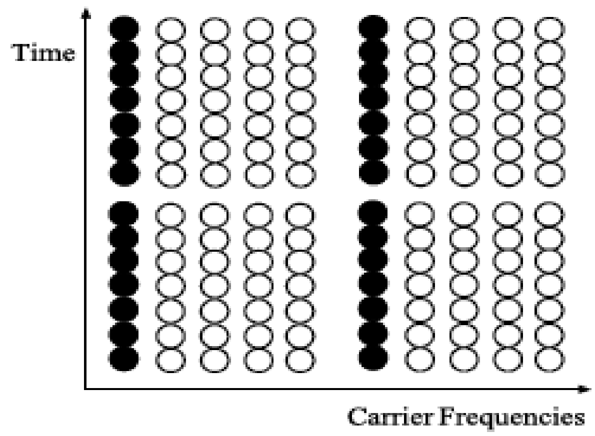

Fig 3. Comb Type Pilot Channel Estimation

For a fast fading channel, where the channel changes between adjacent OFDM symbols, the pilots are transmitted at all times but with an even spacing on the subcarriers, representing a comb type pilot placement, Figure 3. The channel estimates from the pilot subcarriers are interpolated to estimate the channel at the data subcarriers. Further, this signal model is transformed into a linear form suitable for the LS and MMSE estimation algorithm. MMSE has been shown to perform much better than LS but more complex than LS optimal low rank MMSE estimator is used to reduce complexity. And finally we can conclude that MMSE is an optimal channel estimator in the sense of achieving the minimum MSE

A bit error rate (BER) calculation represents the percentage of bit errors occurring in a digital data stream, such as Internet or digital telephone signals. Bit errors occur due to noise or distortion in some part of the circuit that causes a "1" to be received as a "0" and vice versa. The existence of bit errors requires that error-checking methods be built into communication systems to detect such problems. Digital transmission-stream quality can be evaluated by comparing the number of bits transmitted per second and the percentage of those bits that must be retransmitted due to errors. Ongoing monitoring of the BER remains an important task in maintaining high quality digital communications

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TABLE I. SIMULATION PARAMETERS

Parameter	Specification
Number of sub carrier	64
FFT size	64
Modulation type	BPSK
Channel model	AWGN, Rayleigh and Rician
Number of pilots	8
Guard interval	16
Encoder	Trellis
Decoder	Viterbi

Table I represents various OFDM system parameters to assume to have perfect synchronization since the aim is to observe channel estimation performance. Simulations are carried out for different signal-to noise (SNR) ratios.

V.TYPES OF CHANNEL MODEL

The profile of received signal can be obtained from that of the transmitted signal if we have a model of the medium between the two. This model of the medium is called channel model. The estimation of the channel is done using the following three channel models namely, Additive White Gaussian Noise (AWGN), Rayleigh and Rician. It is done by implementing LS, MMSE and LS-Modified channel estimation algorithms.

ADDITIVE WHITE GAUSSIAN NOISE CHANNEL

Additive White Gaussian Noise (AWGN) is a channel model in which only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. This model does not account for fading, frequency selectivity, interference, non-linearity or dispersion. AWGN is common to every communication channels, which is statistically random radio noise characterized by a wide frequency range with regards to a signal in communication channel. The assumptions are noise is additive, white and noise samples have a Gaussian distribution.

RAYLEIGH CHANNEL MODEL

In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. Signal weakening can cause the main component not to be noticed among the multipath components, originating Rayleigh model. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Rayleigh fading is the specialized model for stochastic fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalized concept of Rician fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution. The requirement that there be many scatters present means that Rayleigh fading can be a useful model in heavily built-up city centers where there is no line of sight between the transmitter and receiver and manybuildings and other objects attenuate, reflect, refract and diffract the signal.

RICIAN CHANNEL MODEL

When there is a dominant stationary signal component present, such as a line-of-sight propagation path, the small-scale fading envelope distribution is Rician. In such a situation, random multipath components arriving at different angles are superimposed on a stationary dominant signal. At the output of an envelope detector, this has the effect of adding a dc component to the random multipath.

Rayleigh channel model is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself the signal arrives at the receiver by several different paths multipath interference and at least one of the paths is changing. Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution

VI.CHANNEL ESTIMATIONALGORITHMS

LEAST SQUARE ALGORITHM

It is a standard approach to the approximate solution of over determined system. It means that the overall solution minimizes the sum of the squares of the errors made in the results of every single equation.

$$H_{LS^{\wedge}} = XY \qquad (3)$$

where,

X = Input
Y = Output
$H_{LS^{\wedge}}$ = Channel matrix for LS algorithm

MINIMUMMEANSQUARE ERROR ALGORITHM

MMSE estimator describes the approach which minimizes the Mean Square Error (MSE), which is a common means of estimator quality. MMSE channel model is estimated using the equation given below

$$MSE = E\{(H - H_{LS})^{\wedge}H(H - H_{LS})\} \qquad (4)$$

where,

H = Channel matrix
$H_{LS^{\wedge}}$ = Channel matrix for LS algorithm
MSE = Mean Square Error

LEAST SQUARE MODIFIED ALGORITHM

This approach finds the most important application in data fitting. The best fit in the least-squares sense minimizes the sum of squared residuals, a residual being the difference between an observed by a model

$$H_{est(i)} = \frac{H_{est1(i)} + H_{est1(i+1)}}{2} \qquad (5)$$

$$H_{est} = [H_{est} H_{est(end)}]$$

where,

$H_{est(i)}$ = Estimated channel matrix for i^{th} value
$H_{est(i+1)}$ =Estimated channel matrix of $i+1^{th}$value
H_{est} = Estimated channel matrix

STEPS TO CALCULATE BER FOR CHANNEL

Step 1: Initialize the various parameters such as number of subcarriers, number of pilots, guard interval and SNR.
Step 2: Generate G matrix by using formula.
Step 3: Generate OFDM symbols for random input data and encode it by using trellis algorithm.
Step 4: Modulate the encoded data by BPSK modulation technique.
Step 5: For AWGN channel, add the complex Gaussian noise to the data.
Step 6: Take variance of noise and add data to the noise.
Step 7: The channel is estimated by evaluating the mean square error (MSE) and Bit Error Rate(BER) using LS, LS-Modified, MMSE algorithms.
Step 8: Finally the received data is demodulated and decoded by using viterbi algorithm.
Step 9: Plot the graph for BER and end the process.

The MIMO-OFDM is an efficient wireless system. It has the efficient use of available bandwidth since the sub channels are overlapping. The performance of the MIMO-OFDM system is optimized with minimum bit error rate. OFDM with multiple transmit and receive antennas form a MIMO system to increase system capacity The same algorithm can be applied to the Rayleigh and Rician channel models. Then comparing the BER value for different low and high SNR value. are implemented by using LS, MMSE, LS-Mod algorithms.

VII.RESULTS

AWGN Channel

AWGN Channel for N=64 and Pilot=8

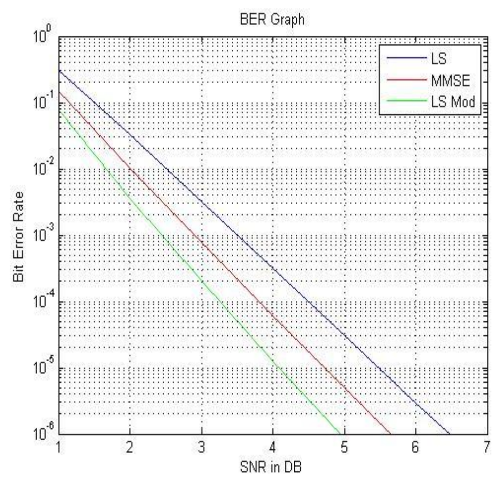

Fig 4. BER Graph for LS, MMSE, LS-Modified Algorithms

Figure 4 represents the SNR vs BER graph for AWGN channel using LS, MMSE, LS-Modified algorithms. From the graph it is inferred that LS-Modified algorithm has low BER value.

TABLE2 BER VALUES FOR LS, MMSE, LS_MODIFIED ALGORITHMS

E_b/N_o	BER-LS	BER-MMSE	BER-LS-MOD
1	3.2166	2.9375	3.2166

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2	03141	0.1484	0.0785
3	0.0324	0.0104	0.0036
4	0.0032	$7.793e^{-4}$	$2.0068e^{-4}$
5	$3.1600e^{-4}$	$6.1500e^{-5}$	$1.2600e^{-5}$
6	$3.0417e^{-5}$	$4.965e^{-6}$	$8.4491e^{-7}$
7	$2.9643e^{-6}$	$4.1582e^{-7}$	$6.0495e^{-8}$
8	$2.9062e^{-7}$	$3.5742e^{-8}$	$4.541e^{-9}$
9	$2.6611e^{-8}$	$3.1327e^{-9}$	$3.5322e^{-10}$
10	2.625e-9	$2.767e^{-10}$	$2.825e^{-11}$

Table II represents the BER values for different values of SNR using LS, MMSE, LS-Modified algorithms for AWGN channel

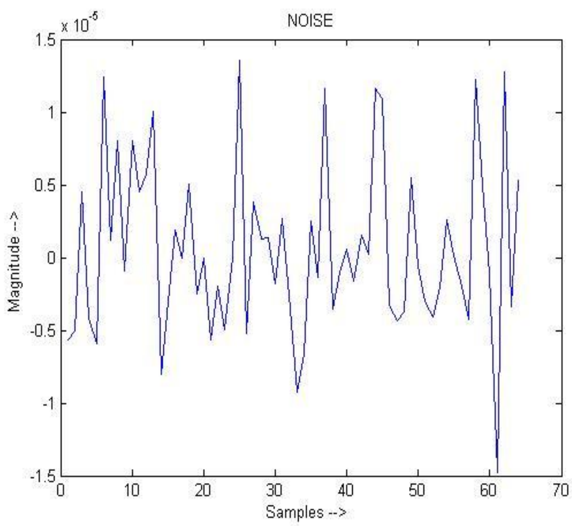

Fig 5. Noise Signal

Figure 5 represents the noise level in AWGN channel during the transmission of the signal.

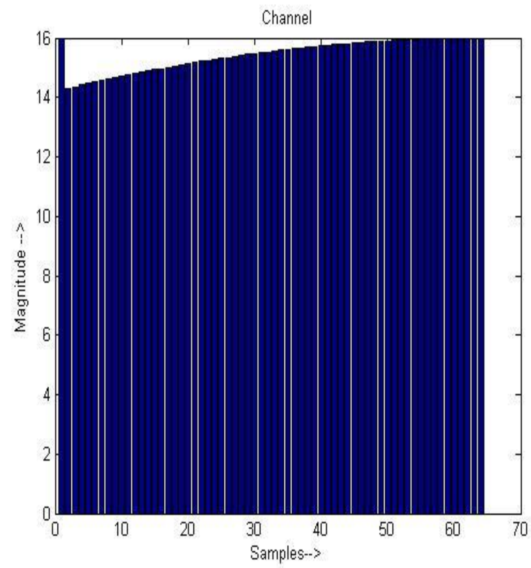

Fig 6 Channel Matrix

Figure 6 represents the channel matrix plotted between Samples and Magnitude values for AWGN channel.

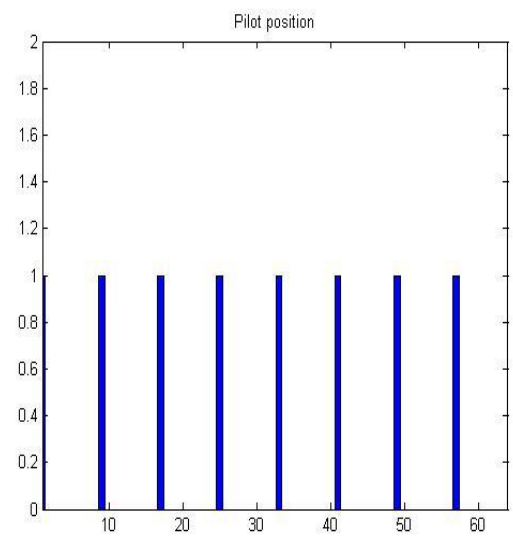

Fig 7. Pilot Position Representation

Figure 7 represents the position of pilot inserted for every 8 bits for synchronization

Rayleigh Channel

Rayleigh Channel for N=64 and Pilot=8

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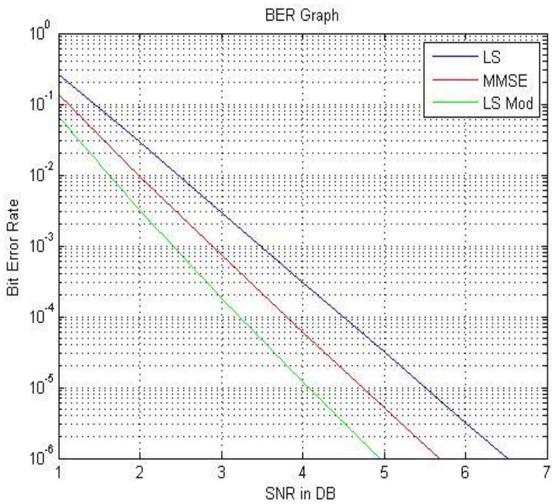

Fig8. BER Graph for LS, MMSE, LS-Modified Algorithms

Figure 8 represents the SNR vs BER graph for Rayleigh channel using LS, MMSE, LS-Modified algorithms. From the graph it is inferred that LS-Modified algorithm has low BER value.

TABLE III. FOR LS BER VALUES, MMSE, LS_MODIFIED ALGORITHMS

E_b/N_o	BER-LS	BER-MMSE	BER-LS-MOD
1	2.7188	2.6875	2.7186
2	0.2664	0.1365	0.0666
3	0.0266	0.0095	0.0032
4	0.0029	$7.2900e^{-4}$	$1.8091e^{-4}$
5	$3.0141e^{-4}$	$6.0625e^{-5}$	$1.2056e^{-5}$
6	$3.1146e^{-5}$	$5.2148e^{-6}$	$8.651e^{-7}$
7	$3.199e^{-6}$	$4.5886e^{-7}$	$6.530e^{-8}$
8	$3.2520e^{-7}$	$4.0784e^{-8}$	$5.0812e^{-9}$
9	$3.316e^{-8}$	$3.6950e^{-9}$	$4.0938e^{-10}$
10	$3.3523e^{-9}$	$3.3609e^{-10}$	$3.3523e^{-11}$

Table III shows the BER values for different values of SNR using LS, MMSE, LS-MOD Algorithms for Rayleigh channel

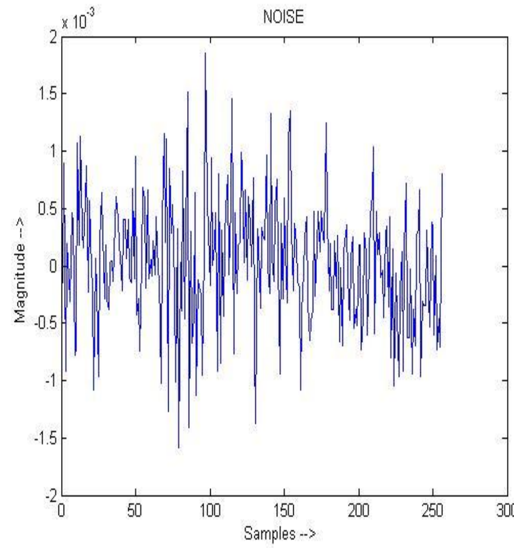

Fig 9. Noise Signal

Figure 9 represents the noise level in Rayleigh channel during the transmission of the signal.

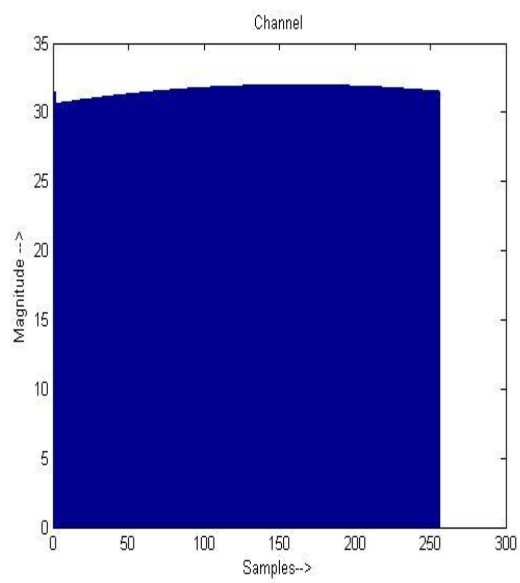

Fig 10. Channel Matrix

Figure 10 represents the channel matrix plotted between Samples and Magnitude values for Rayleigh channel.

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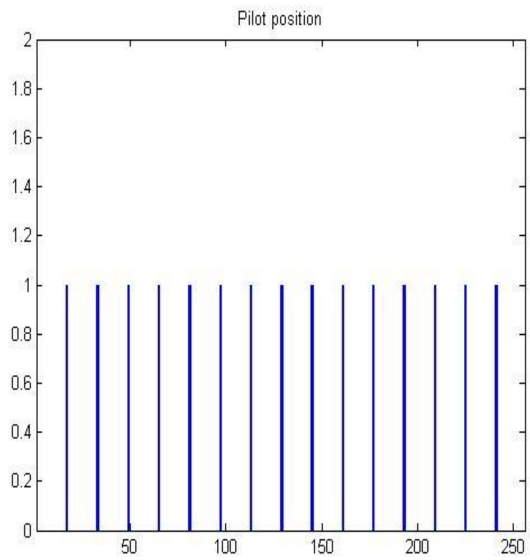

Figure 11. Pilot Position Representation

Figure 11 represents the position of pilot inserted for every 8 bits for synchronization

Rician Channel

Rician Channel for N=64 and Pilot=8

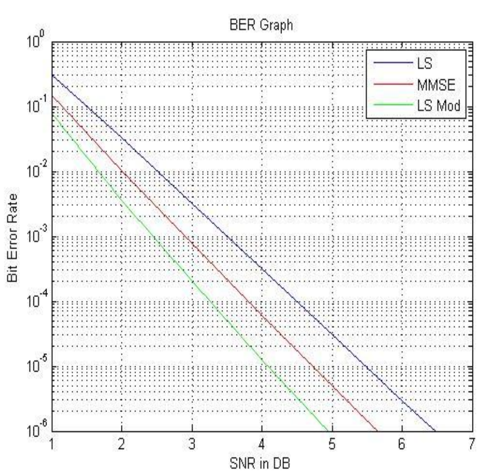

Figure 12 BER Graph for LS, MMSE, LS-Modified Algorithms

Figure 12 represents the SNR vs BER graph for Rician channel using LS, MMSE, LS-Modified algorithms.From the graph it is inferred that LS-Modified algorithm has low BER value

TABLE IV. BER VALUES FOR LS, MMSE, LS_MODIFIED ALGORITHMS

E_b/N_o	BER-LS	BER-MMSE	BER-LS-MOD
1	3.1094	3.0156	3.1094
2	0.3070	0.1516	0.0768
3	0.0310	0.0102	0.0034
4	0.0030	$7.5000e^{-4}$	$1.8921e^{-4}$
5	$3.0594e^{-4}$	$6.0750e^{-5}$	$1.2238e^{-5}$
6	$3.0026e^{-5}$	$4.974e^{-6}$	$8.3406e^{-7}$
7	$2.9665e^{-6}$	$4.2156e^{-7}$	$6.0541e^{-8}$
8	$2.9082e^{-7}$	$3.6182e^{-8}$	$4.5441e^{-9}$
9	$2.8628e^{-8}$	$3.1674e^{-9}$	$3.5344e^{-10}$
10	$2.8266e^{-9}$	$2.8156e^{-10}$	$2.8266e^{-11}$

Table IV shows the BER values for different values of SNR using LS, MMSE, LS-MOD Algorithms for Rician channel

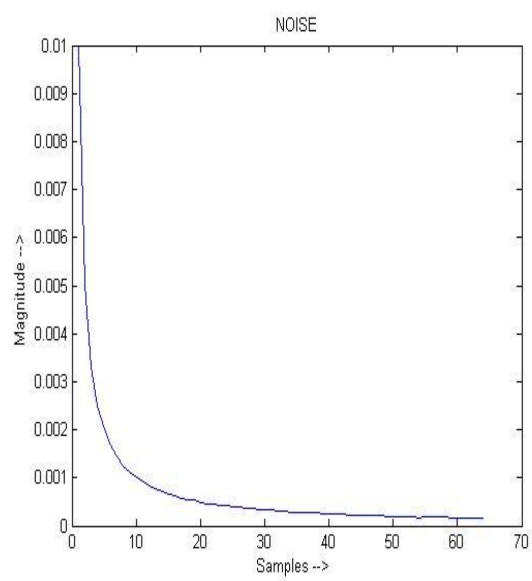

Figure 13. Noise Signal

Figure 13 represents the noise level in Rician channel during the transmission of the signal

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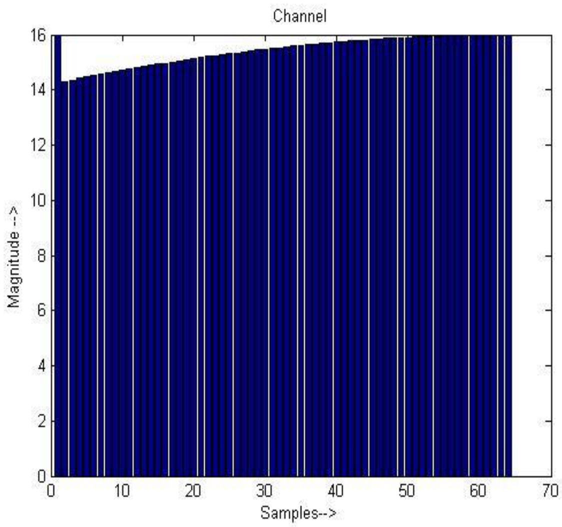

Figure 14 Channel Matrix

Figure 14 represents the channel matrix plotted between Samples and Magnitude values for Rician channel.

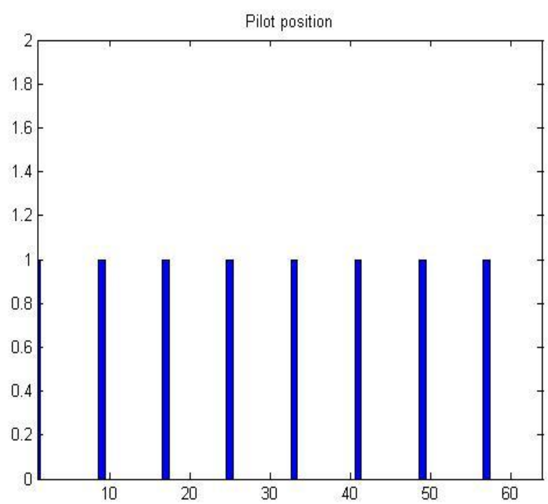

Figure 15. Pilot Position Representation

Pilot provides coherent data detection to decrease error. Receiver performs channel estimation based on received pilot symbols. It is used for synchronization continuity. Figure 15 represents the position of pilot inserted for every 8 bits for synchronization.

Comparison of BER

For N=64 and SNR=2dB

TABLE V COMPARISON OF BER FOR LOW VALUE OF SNR

Channel model	LS Algorithm	MMSE Algorithm	LS-Modified Algorithm
AWGN Channel	0.3141	0.1484	**0.0785**
Rayleigh Channel	0.2664	0.1385	**0.0666**
Rician Channel	0.3070	0.1516	**0.0768**

Table V shows that, at low SNR value MMSE is better than LS but, LS-Modified is better among LS, MMSE, LS-Modified algorithms

For N=64 and SNR=30dB

TABLE VI COMPARISON OF BER FOR HIGH VALUE OF SNR

Channel model	MMSE Algorithm	LS Algorithm	LS-Modified Algorithm
AWGN Channel	$6.0157x10^{-13}$	$3.567x10^{-13}$	**$3.632x10^{-14}$**
Rayleigh Channel	$6.142x10^{-13}$	$3.962x10^{-13}$	**$3.852x10^{-14}$**
Rician Channel	$6.996x10^{-13}$	$2.625x10^{-13}$	**$3.665x10^{-14}$**

Table V shows that, at high SNR value LS is better than MMSE but, LS_ Modified is better among LS, MMSE, LS_ Modified algorithms.

VIII. CONCLUSION

The MIMO-OFDM is an efficient wireless system. It has the efficient use of available bandwidth since the sub channels are overlapping. The performance of the MIMO-OFDM system is optimized with minimum bit error rate. OFDM with multiple transmit and receive antennas form a MIMO system to increase system capacity. Thus the three channels are estimated using three algorithms. From the graph it is inferred that in low SNR, MMSE is better than that of LS, its main problem is its high computational complexity, but LS_ Modified Algorithm is suitable. In our

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proposed system, we have estimated the AWGN, Rayleigh and Rician channel models using LS,MMSE and LS_ Modified algorithms. This project can be further extended by estimating the three channels using RLS and NLMS algorithms and to compare their bit error rate performances.

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