A Novel Training based MIMO-OFDM Channel Estimation in 4G Systems

Prasad Rayi
Associate Professor, Department of E.C.E
Aditya Engineering College
Kakinada, India

Anisetti Shanmuk srinivas
Student, Department of E.C.E
Aditya Engineering College
Kakinada, India

***Abstract*—we proposed channel estimation algorithms for MIMO-OFDM systems based on the least squares (LS) and minimum mean square error (MMSE) algorithms. The presented LS algorithm employs the noise correlation in order to reduce the variance of the LS estimation error by estimating and suppressing the noise in signal subspace. The performance of the MMSE channel estimation algorithm is robust to the number of antennas in transmit and receive sides. The new algorithm attains a significant improvement in performance in comparison with that of the regular channel estimator. Also, with respect to least square error criterion and without using channel statistics, the LS algorithm achieves a performance very close to that of the MMSE estimator in terms of the parameters used in practical MIMO-OFDM systems. The performance of MIMO-OFDM is evaluated on the basis of Bit Error Rate (BER) and Mean Square Error (MSE) level. Further enhancement of performance can be achieved through pilot channel estimation at transmission and reception ends respectively. MMSE estimation has been shown to perform much better than LS but is more complex than LS for the MIMO system using pilot carriers. MATLAB Monte – Carlo simulations are used to evaluate the performance of the studied estimators in terms of Mean Square Error (MSE) and Bit Error Rate (BER) for LTE Downlink systems.**

Keywords-MIMO-OFDM; MMSE; LSE; BER; SNR

I. INTRODUCTION

Modern mobile communication systems transmit bits of information via changes in phase and amplitude of radio waves. In the receiving side of mobile system, amplitude or phase can vary dramatically. This results in degradation of signal strength and system quality since the performance of receiver is highly dependent on the accuracy of estimated instantaneous channel. So channel estimation technique is introduced to improve efficiency of the received signal. In mobile communication systems the radio channels are usually multi path fading channels due to mobility of users, which are producing inter symbol interference (ISI) in the received signal. To separate signal and remove ISI from the signal, many kind of detection algorithms are used at the receiver side [1, 2, and 3]. These detectors should have the knowledge on channel impulse response (CIR), which can be provided by separate channel estimators. The channel estimation process is based on the knowledge of known sequence of bits which are unique for certain transmitter and which is repeated in every transmission burst. Thus the channel estimator method is able to estimate channel impulse response of the channel for each burst separately from the known transmitted bit sequence and corresponding received samples.

Future wireless communication systems require. High speed data-rate and most reliable transmissions with bandwidth efficiency To meet these requirements Multiple-input multiple-output (MIMO) system have been implemented in which multiple antennas are used in both transmitter and receiver sides is an emerging method that is potentially able to provide high data- rate communications with efficient spectrum utilization. Also orthogonal frequency division multiplexing (OFDM) scheme, which uses data symbols with a cyclic prefix inserted between them, overcomes the ISI phenomenon that is one of main challenging issues in reliable wireless transmissions at high data-rate. In addition, several standards such as the IEEE 802.11a, the IEEE 802.16a, d ig ital audio broadcasting (DAB) and terrestrial digital video broadcasting (DVB-T) have already adopted the OFDM technique. Thus, a combination o f the MIMO scheme and the OFDM technique termed MIMO-OFDM that exploits space and frequency diversities is a good candidate transmission system for next generation wireless systems [1,2].

Next-generation wireless systems are mainly focusing on the of multiple-input multiple-output (MIMO) channels [7] with orthogonal frequency-division multiplexing (OFDM) [8] providing MIMO-OFDM systems [9]. Iterative receivers [5] have shown to be very attractive from complexity-performance point of view, and have been designed [4, 5, 6] such to perform also pilot-assisted channel estimation [2]. I n this paper we focus on channel estimation for MIMO-OFDM systems to be performed within the loop of an iterative receiver.

Channel estimation is a crucial and challenging issue in coherent modulation and its accuracy has a significant impact on the evaluation of communication system. The channel estimation in MIMO systems becomes more complicated in comparison with single-input single-output systems due to simultaneous transmission of signals from different antennas that cause co-channel interference. This issue highlights that developing channel estimation algorithm with high accuracy is an essential requirement to achieve the full potential performance of the MIMO-OFDM systems.

The MIMO- OFDM channel estimation methods proposed in literature can be categorized into two g groups. In the first one, it is assumed that the sub channel impulse responses are unknown and a non-statistical criterion such as *least squares* (LS) is employed to estimate the channel [1]-[4]. In this group the performance of estimation algorithm has been enhanced based on knowing the maximum sub channel impulse interval responses at the channel are no longer than the cyclic prefix interval. In the second category, it is assumed that the sub channel impulse responses are random processes and estimation algorithm has been d eve lo p e d based on a statistical criterion such as *minimum mean square error* (MMSE) by using the known or estimated statistical parameters of the sub channel impulse responses [9]-[13].

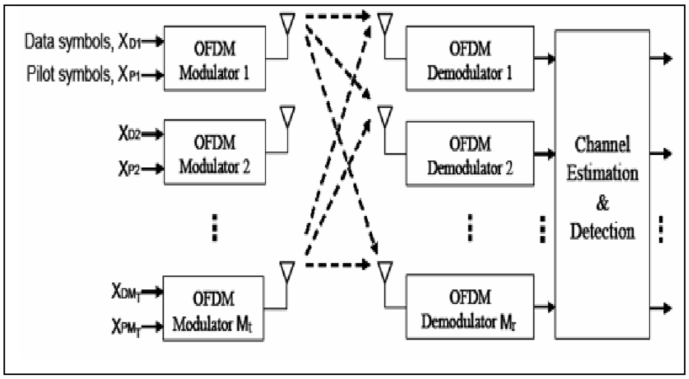

Figure-1: MIMO-OFDM Channel estimation system model

A channel estimation algorithm has been proposed in [6] based o n a LS type algorithm by considering some significant taps. A simplified version of the algorithm derived in [6] has been proposed in [8] by using optimum training sequences and canceling co-channel interferences. A cyclic comb-type training symbol structure has been proposed in [10] f or MIMOOFDM systems in order to reduce the mean square error (MSE) of the edge sub channel estimations. By exploiting the channel correlation in frequency domain and using pilot tones, an iterative least squares algorithm has been proposed in [2,9] for MIMO-OFDM channel estimation. Considering all sub channels of MIMO channel to have the same delay profile and approximating it b y averaging over the power of the initial estimated sub channel impulse responses, MIMO-OFDM channel estimation is enhanced in [11]. Standard paper components have been specified for three reasons: (1) ease of products and (3) conformity of style throughout a conference proceeding. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronics.

II. MIMO - OFDM SYSTEM

In this section we presented MIMO–OFDM system model for easy of understanding. We considered The block diagram of MIMO-OFDM system is shown in Figure.1, for simplicity and easy analysis, MIMO–OFDM system is implemented with two transmitting and two receiving antenna's .The received signal at the receiver is given by

$$\Psi_{\kappa+} H_{\kappa,}+\zeta_{\kappa,} \quad \kappa=1,.,K \qquad (1)$$

Where H_k MIMO channel matrix, and k represents the number of transmitting and receiving signals. We assume the total number of sub carriers is N. clearly the MIMO-OFDM transmitter has *Nt* parallel transmission propagation paths and each path performing serial-to-parallel conversion, pilot insertion, *N*-point IFFT and cyclic prefix extension before the final transmit signals are up converted to RF amplify signal and transmitted. The channel encoding and digital modulation can also be done per branch, where the modulated signals are space-time coded using the Alamouti space time block coding algorithm before transmitting from multiple antennas at the transmitter. At the receiver, the reverse strategy has been implemented that the CP is removed and *N*-point FFT is performed per receiver branch and then the operations like digital demodulation and decoding are done. Finally all the input binary data are recovered with desired BER. more efficiently and effectively.

According to MIMO signaling technique, *Nt* different signals are transmitted simultaneously over *Nt* X *Nr* transmission propagation paths and each of those *Nr* received signals is a combination of all the *Nt* transmitted signals and the distorting additive noise. It improves in the diversity gain for enhanced system capacity. Hence the channel estimation and symbol detection is more complex due to the more number of channel coefficients at receiver. The data stream from each antenna undergoes OFDM Modulation. The Space Time Block Coding (STBC) is designed for encoding purpose and the encoding matrix is given as

$$X = \begin{bmatrix} X_1 & -X_2^* \\ X_2 & X_1^* \end{bmatrix} \qquad (2)$$

Where input vector coefficients are given by

$$X1 = X[0] \quad -X^*[1] \quad X[2] \quad -X^*[3] \ldots\ldots \quad -X[N-1] \qquad (3)$$

$$X2 = X[1] \quad X^*[0] \quad X[3] \quad X^*[2] \ldots\ldots \quad X[N-2] \qquad (4)$$

The vectors *X*1 and *X*2 are transmitted performing the Inverse Fast Fourier Transform (IFFT) and a CP code is added between two input data symbols. Thus, this converts linear convolution into a circular convolution.

It acts as a guard time interval among data symbols. . Then two modulated signals *Xg*1 and *Xg*2 are transmitted by the transmitting antennas. Assuming that the guard time interval is more than the expected largest delay spread of a multi path channel to avoid inters symbol interference. The antenna at the receiving side receives the incoming signal which will be the convolution integral of the channel and the transmitted signal. This motivates to avoid ISI more effectively between data symbols. At the receiver, the CP is removed first from the received signal. Then FFT is performed and the demodulated signal can be represented by the equation (5).

$$\begin{bmatrix} Y_1 \\ Y_{N_R} \end{bmatrix} = \begin{bmatrix} H_{1,1} \ldots & H1_{1,N_T} \\ H_{N_{R,1}\ldots} & H_{N_R,N_T} \end{bmatrix} \begin{bmatrix} X_1 \\ X_{N_T} \end{bmatrix} + \begin{bmatrix} W_1 \\ W_{N_T} \end{bmatrix} \quad (5)$$

Where [*W1*, *W2*……*WNT*] represents additive white Gaussian noise(AWGN). Which is zero mean circularly symmetric complex Gaussian white noise (ZMCSCG) and *H Nt* X *Nr* is the MIMO-OFDM channel gain between the r'th receiver antenna and t'th transmitter antenna. For simplicity of analysis, two transmitting and two receiving antennas are considered. By Knowing the channel state information at the receiver perfectly, Maximum Likelihood (ML) detection technique is used for decoding the received information. It can be represented by equation (6) & (7).

$$\widetilde{S}[2k] = \sum_{i=1}^{N_R} H^*{}_{i,1}[2k]Y_i[2k] + H_{i,2}[2k]Y_i^*[2k+1] \quad (6)$$

$$\widetilde{S}[2k+1] = \sum_{i=1}^{N_R} H^*{}_{i,2}[2k+1]Y_i[2k] - H_{i,1}[2k+1] * Y_i^*[2k+1] \quad (7)$$

Where $k = 0,1,2\ldots\ldots(N/2)-1$

We assume that the channel gains between two adjacent Sub channels are approximately equal to equation (8) & (9)

$$H_{i,1}[2k] = H_{i,1}[2K+1] \quad (8)$$

$$H_{i,2}[2k] = H_{i,2}[2K+1] \quad (9)$$

III. MIMO-OFDM CHANNEL ESTIMATION

In this section we proposed simple signal model for MIMO-OFDM .we mainly focused on training based channel estimation algorithms, in the generalization of training symbols or pilot tones that are perfectly known to the receiver are multiplexed along with the data stream for channel estimation strategy. Thus, the receiver should have the knowledge of pilot tones for the estimation of channel more efficiently at the receiver side. A block fading channel is modeled by which is constant response over a few OFDM symbols. This channel is modeled based on the knowledge of pilot tones, which are transmitted on all sub carriers in periodic intervals of OFDM blocks. This type arrangement pilot of is shown in Fig. 2(b), is commonly called as block type arrangement.

We assume a fast fading channel has channel impulse response changes more rapidly within symbol duration and the channel varies between adjacent OFDM symbols. In this fast fading model, the pilots are modulated at all times but with an even spacing on the sub carriers, representing noel channel estimation i.e., a comb type pilot placement which is shown in Fig. 2(a) .The channel estimates and computes from the pilot subcarriers are interpolated to estimate the channel perfectly at the data subcarriers

An efficient way of estimating the channel more perfectly based on the knowledge of pilot tones presented with a Least square (LS) channel estimation for MIMO-OFDM System .while the LS estimate of MIMO-OFDM channel analyzed between t'th transmitter and r'th receiver antenna is given by the equation (10).

$$\hat{H}_{LS}^{(r,t)} = \left(X^{(t)}\right)^{-1} Y^r \quad (10)$$

$$X = diag\{X(0), X(1),\ldots\ldots X(N-1)\} \quad (11)$$

Assuming the channel is constant over the symbol duration which results minimum mean square estimation (MMSE) channel estimation for MIMO-OFDM System among t'th transmitter and r'th receiver antenna is

$$\hat{H}_{MMSE}^{(r,t)} = FR_{hY} R_{YY}^{-1} Y^{(t)} \quad (12)$$

$$R_{hY} = R_{hh}^{t,r} F^H \left(X^{(r)}\right)^H \quad (13)$$

$$R_{yY} = x^{(r)} F R_{hh}^{(r,t)} F^H \left(X^{(r)}\right)^H + \sigma^2 I_N \quad (14)$$

where the matrices F,H,W are represented by:

$$F = \begin{bmatrix} W_N^{00} & \ldots & W_N^{0(N-1)} \\ . & . & . \\ W_N^{(N-1)0} & \ldots. & W_N^{(N-1)(N-1)} \end{bmatrix} \quad (15)$$

$$H = [H(0), H(1),\ldots\ldots H(N-1)]^T \quad (16)$$

$$W = [W(0), W(1),\ldots\ldots W(N-1)]^T \quad (17)$$

Where σ^2 noise variance of ZMCSCG, I_N is N X N identity matrix. t = 1, 2….NT, r = 1, 2….NR and NT, NR are the numbers of transmit and receive antennas, respectively in MIMO-OFDM channel. X (n) is an N X N diagonal matrix whose diagonal elements are corresponding to the pilots of the t'th transmit antenna and Y(t) is N length received vector at receiver antenna r.

IV. SIMULATION RESULTS

A. System Parameters

In this section we presented simulation results for pilot type and comb type with LS estimation and MMSE estimation. First we employed different system parameters for a Rayleigh fading channel model. MIMO-OFDM system evaluated in the channel simulation scheme's are shown below with FFT Size -128; No. of sub carriers -128 ; CP length -32;Modulation –QPSK, number of transmitter antenna's Ntx=2,Nrx=2; Pilot type–Block & Comb pilot. Initially we assumed that proper synchronization is maintained across the transmitter side &receiver side. In order to avoid ISI, the guard interval value should have as high as length of the channel.

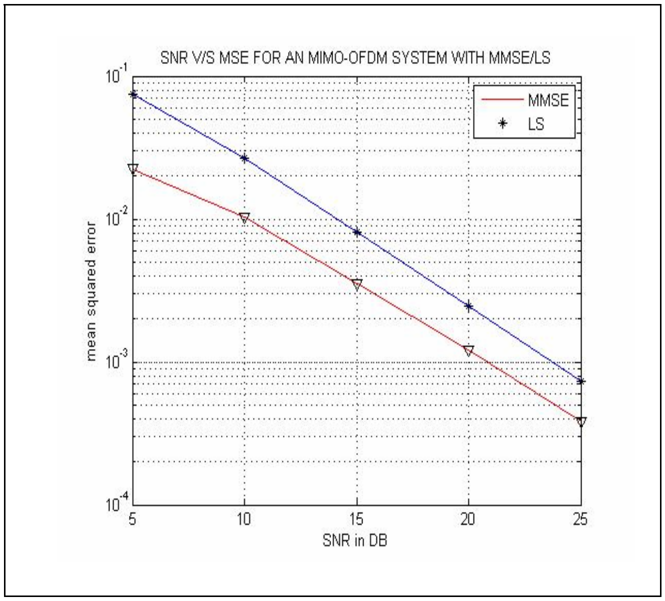

Figure - 2 SNR VS Mean Squared Error.

While compared the mean square error(MSE) of LS channel estimation ,the MMSE channel estimation dramatically decreases MSE shown in Figure.2.which improves the perfect estimate of CSI .which results an efficient and effective channel estimation of MIMO-OFDM systems for current wireless applications. we considered the channel estimate with. We simulated the results shown in Figure.2 with SNR=20dB,which results MSE is equal to 10^{-3} for MMSE, thus LS estimate provides in-between 10^{-2} to 10^{-3}.

We observed that the variation of power (dB) versus subcarrier index for true channel and estimated channel is represented in Figure.3 and Figure.4 with a an FFT size of 128.which employs MMSE performs superior than the LS-Linear, LS-spline. We presented simulated the results shown in Figure.5 with SNR=20dB,which results Symbol Error Rate is equal to $10^{-1.6}$ for MMSE, thus LS estimate provides only $10^{-1.4}$.

As presented in . figure.2and figure.4 the two proposed schemes performs outperform in-terms of MMSE estimate of the channel as well as MSE .compared with the LS channel estimation ,the MMSE based channel estimation with comb type pilot scheme achieves about 10^{-3} reduce BER. However two methods have different computational complexity i.e., designing of MMSE channel estimation algorithm requires multiple iterations than the LS channel estimation. For which results MMSE employed with superior complexity.

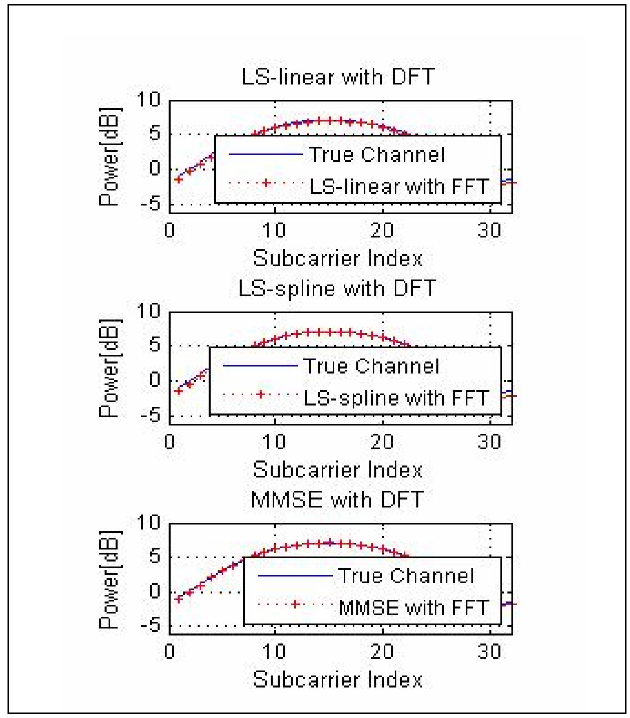

Figure – 3 Sub Carrier Index VS Power [dB]

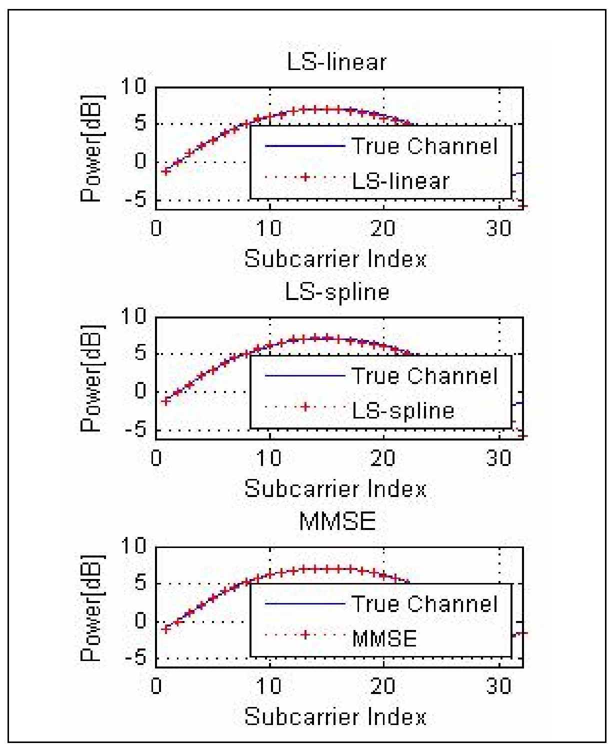

Figure – 4.Power Vs Subcarrier index for True channel

LS-linear,LS-spline,MMSE

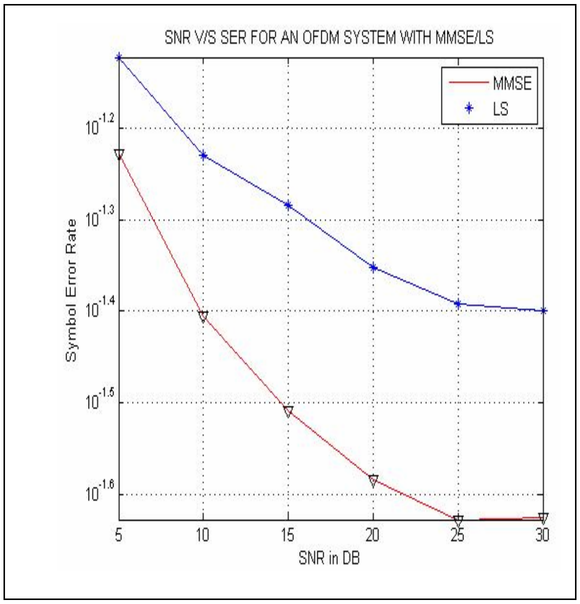

Figure.5 SNR in DB VS symbol Error Rate

B. MIMO-OFDM system Modeling & Simulation

In the training based channel estimation demonstrated with Multi path fading channel model for 2 X 2 MIMO-OFDM system with sampling interval Ns is described by the following equations.

$$h_{11}(n)=\delta(n)+\delta(n-0.5N_S)+\delta(n-3.5N_s)$$
$$h_{12}(n)=\delta(n)+\delta(n-0.4N_S)+\delta(n-1.1N_s)$$
$$h_{13}(n)=\delta(n)+\delta(n-0.4N_S)+\delta(n-0.9N_s)$$
$$h_{22}(n)=\delta(n)+\delta(n-0.6N_S)+\delta(n-2.2N_s) \quad (19)$$

The performance of the system is evaluated based on the knowledge of Bit Error rate(BER) information with Energy over Bit to the noise power spectral density i.e. Eb/No. We observed that the variation of Bit Error Rate versus Eb/No for no channel estimation, LS estimated channel and MMSE channel estimations represented in Figure.5 with a an FFT size of 128 and SNR=20dB.which employs MMSE performs superior than the no channel estimation and LS estimated channel. We presented simulated the results shown in Figure.5 with SNR=20dB,which results Bit Error Rate is equal to $10^{-5}$for MMSE, thus LS estimate and no channel provides in-between 10^{-2} to 10^{-3} .

The MIMO-OFDM system performance is evaluated by means of performing simulation between Mean Square Error (MSE) and Bit Error Rate (BER) analysis which is shown in Figure.3 & Figure.4. Block-type and comb type pilot based channel estimation using LS and MMSE algorithms are employed to model the Rayleigh fading channel of MIMO-OFDM system. The instantaneous Mean Square Error (MSE) is defined as the average error within an OFDM block and that can be expressed as Where k is the index of the sub carrier and He(k) is estimated by effect of channel attenuation the value.

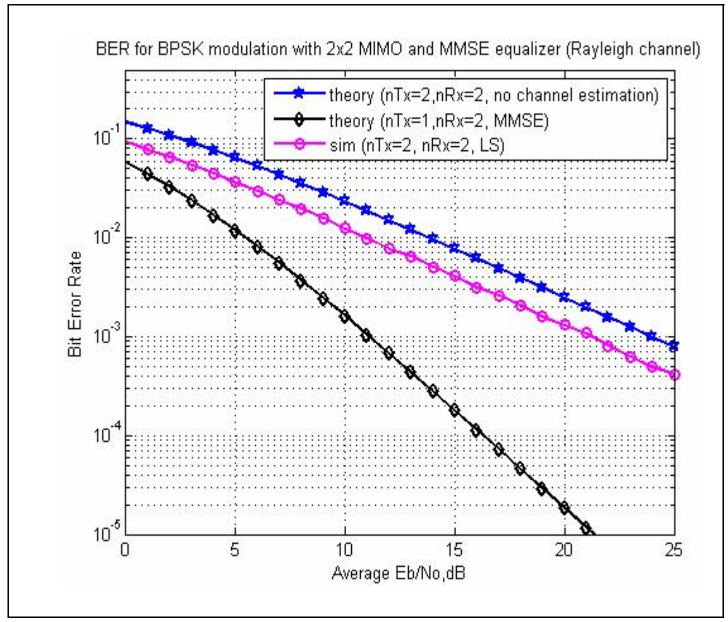

Figure.6 Bit Error Rate VS Rate Eb/No in dB

Figure.3 shows the Mean Square Error (MSE) for the LS and MMSE channel estimation algorithms of MIMO- OFDM systems. We observed that from the MMSE channel estimation strategy has low Mean Square Error against LS channel estimation algorithm.

$$\text{M}\Sigma\text{E} = \frac{1}{N}\sum_{K=1}^{N}\left|H(K)-H_e(K)\right|^2 \quad (20)$$

Finally, we described that the BER plot of the MIMO-OFDM system with LS/MMSE Estimators shown in Figure.4. It is observed that bit error rate (BER) is high without any channel estimation, which is represented in the plot. While estimation of channel is introducing, the BER is drastically reduced. It is observed from the simulated figure, Minimum Mean Square Error (MMSE) Estimator has lower BER than LS Estimator. In the simplicity of evaluating channel estimation with block and comb type pilot carriers, shown in Figure 5.The BER plot of MIMO-OFDM system It is assumed that channel is known to the receiver.

By comparing both block type and comb type carrier estimation, Comb type carrier estimation has lower bit error rate and better performance than the pilot type channel estimation. Thus considering, from the most analysis of our knowledge MMSE channel estimation performs better than the LS channel estimation.

V. CONCLUSION

In this paper we presented channel estimation schemes for MIMO-OFDM systems. for a Rayleigh fading channel model is analyzed. Two methods of pilot allocation for LS and MMSE in MIMO-OFDM have been proposed. The two different algorithms such as LS channel estimation & MMSE channel estimation algorithms are employed and simulation also performed. As compared with traditional LS estimate of the channel, MMSE based channel estimation can effectively improve the spectral efficiency of MIMO-OFDM system with marginally larger computationally complexity. Monte carlo simulation results presented that two channel estimation techniques produce better performance in-terms of the SER, MSE of the channel estimate as well as BER in MIMO-OFDM systems. Thus the second proposed method has superior to the first one considering less MSE and BER. The simulation observed that the channel estimation using comb type pilot carrier has lower BER than block type pilot carrier. So MMSE channel Estimator has better performance than LS channel estimator.

REFERENCES

[1] Pierluigi SalvoRossi RalfR.M¨uller , OveEdfors, "Linear MMSE estimation of time–frequency variant channels for MIMO-OFDM systems" Signal Processing 91 (2011) 1157.,

[2] Kala Praveen Bagadi, Prof. Susmita Das ‘‘MIMO OFDM channel estimation using pilot carriers’’,International Journal of computer applications, vol 2,no.3,May 2010

[3] A. Petropulu, R. Zhang, and R. Lin, "Blind OFDM channel estimation through simple linear pre-coding", IEEE Transactions on Wireless Communications, vol. 3, no.2,March 2004, pp. 647-655

[4] Osvaldo Simeone, Yeheskel Bar-Ness, Umberto Spagnolini,"Pilot-BasedChannel Estimation for OFDM Systems by Tracking the Delay-Subspace",IEEE Transactions on Wireless Communications, Vol. 3, No. 1, January 2004.

[5] Siavash M. Alamouti, "A Simple Transmit diversity Technique for Wireless Communications", IEEE Journal on Select Areas in Communications, Vol. 16, No. 8, October1998

[6] J.-J. van de Beek, O. Edfors, M. Sandell, S. K. Wilson, andP. O. Borjesson,"On channel estimation in OFDM systems,"in Proc. IEEE *45th Vehicular Technology Conf., Chicago,IL, Jul. 1995, pp. 815–819.*

[7] *Ezio Biglieri, Robert Calderbank, Robert Calderbank,AnthonyConstantinides, Andrea Goldsmith, Arogyaswami Paulraj, H. Vincent Poor, "MIMO WirelessCommunications", Cambridge Press*

[8] *Pan Pei-sheng, Zheng Bao-yu, "Channel estimation in space and frequency domain for MIMO-OFDM systems" ELSEVIER journal of China Universities of Posts and Telecommunications, Vol. 16, No. 3, June 2009,*

[9] *] Mohammad Torabi, "Antenna selection for MIMO-OFDM Systems"*

[10] I. Barhumi, G. Leus, and M. Moonen, "Optimal training design for MIMO OFDM systems in mobile wireless channels," *IEEE Trans. Signal Process.*, vol. 51, no. 6, pp. 1615–1624, Jun. 2003.

[11] J. Yu and Y. Lin, "Space–time-coded MIMO ZP-OFDM systems: Semiblind channel estimation and equalization," *IEEE Trans. Circuits Syst. I,Reg. Papers*, vol. 56, no. 7, pp. 1360–1372, Jul. 2009.

[12] F. Wan, W.-P. Zhu, and M. N. S. Swamy, "A signal-perturbation-free transmit scheme for MIMO-OFDM channel estimation," *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 57, no. 8, pp. 2208–2220, Aug. 2010.

[13] C. Qi and L. Wu, "A hybrid compressed sensing algorithm for sparse channel estimation in MIMO OFDM systems," in *Proc. IEEE Int. Conf.Acoust., Speech, Signal Process.*, May 2011, pp. 3488–3491

[14]

AUTHORS PROFILE

Mr. Prasad Rayi obtained his B.Tech. Degree from Nagarjuna University, Nagarjuna Nagar, Guntur District, Andhra Pradesh, India in the year 2004. He obtained his M.Tech from Andhra University, Visakhapatnam, India in the year 2010.Presently he is working as an Associate Professor in the department of Electronics and Communication Engineering, Aditya Engineering College, Surampalem, Kakinada. He has published 13 papers in various International Journals and conferences. He is interested in the fields of wireless communication, Digital signal processing, Image and video processing. Mail Id: prasadrayi@gmail.com

Mr.A.Shanmuk Srinivas obtained his B.Tech. Degree from Pragati engineering college, Kakinada affiliated to JNTU Kakinada, East Godavari District, Andhra Pradesh, India in the year 2011. Now he is pursuing M.Tech. (Final year) from Aditya Engineering College, Kakinada, affiliated to JNTU Kakinada, India. He is interested in the fields of Embedded Systems, Wireless communication. Mail Id:shanmukha.sri4u@gmail.com