International Journal of Research in Advent Technology, Vol.5, No.5, May 2017
E-ISSN: 2321-9637
Available online at www.ijrat.org

Performance evaluation of MMSE channel estimator for different modulation schemes in MIMO-OFDM systems

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Abstract- MIMO-OFDM technology is a finest technology which meets the requirements of today's high-speed wireless world. When data is transmitted from transmitter to receiver by multiple antennas then because of the transmission channel some noise or distortions are added in the signal. To overcome these distortions channel estimation is used. In this paper, channel estimation is performed by using MMSE channel estimator. The main attention is on the block type method of channel estimation by using MMSE estimator for the PSK and QAM modulation techniques. Various modulation orders of QAM and PSK are compared for better system performance. Comparison of different modulation orders of QAM and PSK is performed for different values of subcarriers and best suitable M-ary modulation is obtained for transmission of subcarriers.

Index Terms- OFDM, MIMO-OFDM, MSE, QAM, PSK, MMSE, channel estimation.

1. INTRODUCTION

Wireless technology has emerged as a pioneering technology, which is being used in our everyday life. In today's world, broadband services are providing excessive data rates. Due to these larger data rates problem of fading is taking place. Fading is an important factor for signal degradation in OFDM systems. Fading is mainly caused by two reasons, one is multipath and another one is shadowing. Multipath propagation is when signal takes multiple paths to reach the receiver and then multiple signals are arrived at different times on the receiver, this cause the interference and signal loss. Shadowing is occurred when there are tons of obstacles in the path of radio waves and because of the shadows of these objects the signal will be eliminated completely [1]. To reduce the problem of multipath it is necessary to use modulation techniques. Modulation techniques are used for the purpose of sending information or data signals up to long distances [2]. In OFDM [3,4,5] as its name suggest Orthogonal frequency division multiplexing, frequency is divided orthogonally among various subcarriers. It is a technique in which data is carried by many sub-carriers after isolating the channel into various smaller and narrower subchannels, this is done to improve data rates and to reduce the problem of ISI [6]. MIMO-OFDM system is a system in which OFDM signal is carried out by using multiple antennas. MIMO-OFDM is a system in which advantages of OFDM and MIMO are combined with each other for better performance and for higher data rates without increase in the extra bandwidth slot.

Channel estimation is a method which is performed by the receiver for recovering the contents of original signal from the distortions created by the channel. In this paper, we will focus on channel estimation based on MMSE method by using various M-ary modulation techniques like QAM and PSK.

2. MIMO-OFDM

The first element of this system is OFDM which is a modulation technique for transmitting information from source to destination by making use of its orthogonality property and by dividing data into various smaller sub streams and then transmitting that data by using various frequencies at same time. The second element for making MIMO-OFDM system is MIMO which uses numerous antennas at its both ends. MIMO have three features i.e. precoding, diversity and spatial multiplexing. In precoding beamforming is performed at transmitter by sending same signals from several antennas to receiver. This increase gain and reduce consequence of multipath [8]. In spatial multiplexing a higher order signal is broken down into various lower order signals and each signal is transmitted using different antenna at the identical time at same frequencies. It gives higher SNR which in turn increases the channel capacity. In diversity, the single stream of data is transmitted by means of space time coding. In diversity coding, there is no information of the transmitter [9]. When MIMO is used with OFDM it provides better quality of signal and higher information rates it also reduces the effects caused by multipath i.e. fading and ISI [7]. OFDM have multiple transmission carriers which are orthogonal respectively, we prefer OFDM in place of single carrier modulations because single carriers produce higher ISI when higher data tariffs are needed and they are only suited for giving low data rates as data is transmitted serially on them. In MIMO-OFDM system the first part is transmitter in which firstly input data is encoded and then pilots are added in the input signal and then the incoming sequential data is changed into parallel form for further transmission, after that IFT is performed and subcarriers are modulated. Then again parallel data is converted into serial form and cyclic prefix is inserted to avoid the effect of ISI at the transmitter. After adding CP data is transmitted by via several antennas through wireless channel. The second part is receiver section where operations are performed on received signal. The data is received by numerous antennas at the receiver and CP is removed. Then the signal or data is again converted into parallel form for more processing. By using FFT demodulation of data subcarriers is performed and then data is given to parallel to serial convertor. Then channel estimation is performed to get back the desired signal from the received signal, then signal decoding is performed.

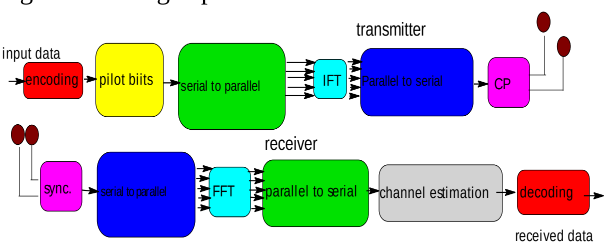

Fig.1 MIMO-OFDM system

3. MODULATION

Modulation is a process in which any one or more than one characteristics of a continuous signal is changed as modulating signal changes its shape. If this modulating is analog in nature then it is called analog modulation and if this modulating signal is digital in nature then it is called digital modulation. Modulation is done to transmit the signal through long distances [12]. Multiple modulation schemes like PSK and QAM are used with the MMSE estimators. In PSK phase changes in accordance with modulating signal. While using PSK its M-ary techniques like BPSK, QPSK,8PSK and 16PSK are used. In QAM amplitude changes in accordance with modulating signal. With QAM its M-ary techniques like 4-QAM, 8-QAM and 16-QAM is used. Larger order modulations give higher constellation points, so transmission is more suitable as order modulation increases [13].

4. CHANNEL ESTIMATION

In MIMO-OFDM system, at the transmitter section information or data is modulated and converted into PSK or QAM and then it is converted from frequency domain signal to time domain signal and then this time domain signal is transmitted by the antenna through a wireless channel. The wireless channel creates some distortions and add some noise in the signal. So, the signal received by the receiver is full from noisy components and distortions. It will decrease the performance of the system and because of these distortions it is not conceivable to process this signal further with distortions inside it. So, we need to form back the original signal which is transmitted by the receiver for its further transmission for achieving larger data rates and good strength. For this purpose, channel estimation is used. The receiver compensates the effect of distortions formed by the transmission channel if a pilot symbol is known to the transmitter as well as to the receiver. Pilot symbols are added in the data by using two techniques one is block type and second is comb type.

In block type method of injecting pilot symbols in the data, each and every subcarrier is used as a pilot and all the symbols are communicated periodically [10]. Block type method is used to estimate the channel with the support of pilot symbols by using or by not using the knowledge of characteristics of channel. In block type arrangement, the received data is decoded inside the block unless the next pilot symbol is arrived. This type is appropriate for slow fading conditions. LS and MMSE are the two techniques used for channel estimation by using block type pilot arrangement method.

In comb type method, some particular subcarriers are chosen and then pilot symbols are introduced in every symbol of those chosen subcarriers. The transmission of signal is not periodic like block type arrangement and it is very delicate towards frequency selective fading as compare to the previous method. It has an advanced re-transmission degree so it is appropriate for fast fading conditions [1].

This paper concentrates on MMSE estimator for block type arrangement by using PSK and QAM.

5. MMSE ESTIMATOR

Signal arrives in the distorted form at the receiver due to the distortions originated by the channel. So, to recover back the original transmitted signal channel estimation operation is performed. These types of compensations are performed by making use of MMSE estimators. These types of estimators are used for minimizing mean square error. Inversion of matrix is required for every time when data changes so it have very complex mathematical computations. Auto covariance is used for minimizing squared error [11].

If x is transmitted over a channel h then the output signal can be written as

$$Y=xh \tag{1}$$

And error is given as

$$e=y''-y \tag{2}$$

Mean square error is given as

$mean\{(y''-y)^2\}$ (3)

$E\{(y''-y)\}$ where E is the operator for expected value

For finding the channel response expected values and correlation are used

D_{gg}= autocovariance matrix of g

D_{yy}= autocovariance matrix of y

D_{gy}=cross covariance matrix of g and y

The estimated channel H_{mmse} can be found by equation

$$H_{mmse}=F*(D_{gy}*D_{yy}^{-1}*y) \quad (4)$$

Where F is the noise matrix

$$D_{gy}=D_{gg}*F'*X' \quad (5)$$

$$D_{yy}=x*F*D_{gg}*F'*x'+\text{ variance of noise*identity matrix} \quad (6)$$

6. SIMULATIONS AND RESULT

For the simulation of MMSE estimator by using different modulation schemes MATLAB R(2009a) is used. It is a software that is used for the purpose of technical computing. Code for MMSE by making use of various modulation schemes is generated by using this software. PSK and QAM are compared for their various types by using MMSE estimator to minimize mean square error(MSE). Plots for SNR vs. MSE are obtained using MATLAB.

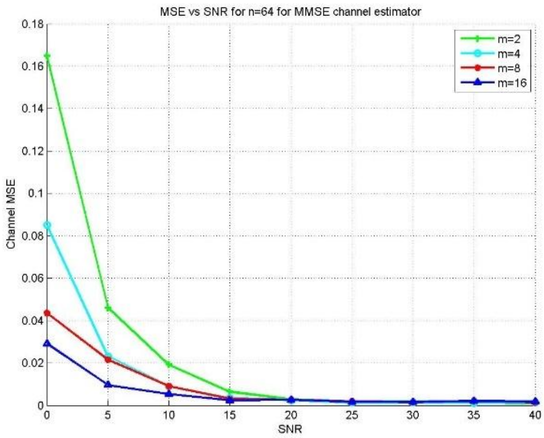

Fig.2. SNR vs channel MSE for n=64 by using QAM modulation

Table 1. for N=64

SNR	M=2QAM	M=4QAM	M=8QAM	M=16QAM
0	0.165	0.085	0.0435	0.0291
5	0.0543	0.0259	0.0234	0.0118
10	0.0186	0.0092	0.0064	0.0458
15	0.0065	0.0035	0.0032	0.0024
20	0.0030	0.0022	0.0023	0.0022
25	0.0014	0.0016	0.0015	0.0019
30	0.0016	0.0014	0.0018	0.0014
35	0.0012	0.0015	0.0016	0.0015
40	0.0012	0.0012	0.0019	0.0021

This graph shows the comparison of 2QAM, 4QAM, 8QAM and 16QAM when no. of subcarriers(n)=64. It is illustrated that 2QAM is giving greater mean square error at lower values of SNR. As the SNR increases MSE starts decreasing. When SNR reaches at 20 then 2QAM gives almost constant value of MSE, there is very small change in the MSE after SNR reaches to 20. 4QAM gives better performance than 2QAM, at SNR=0 there is a difference of 0.08 in the MSE of 2QAM and 4QAM. 4QAM is giving 0.08 less error as compare to 2QAM. When SNR increases, the channel MSE starts decreasing and it decrease up to 0.0012 which means there is a decrease of 0.0838 in the MSE. When SNR reaches to 20 then it also shows constant MSE like 2QAM. MSE of 8QAM is 0.0415 times less than that of 4QAM at SNR=0. At SNR=40 MSE reaches at 0.0019 which means there is a decrease of 0.0416.16QAM is giving the better performance because it has a very minor value of MSE at SNR=0 and SNR= 40. 16QAM also gives constant performance after SNR reaches to 20. So 16QAM is best suited for the transmission of N=64.

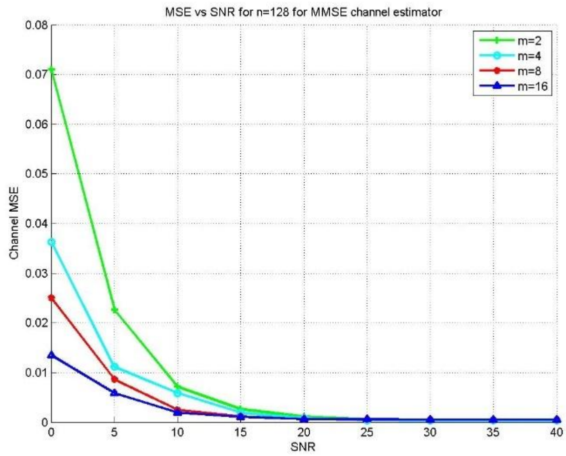

Fig.3. SNR vs channel MSE for n=128 by using QAM modulation

Table 2. for N=128

SNR	M=2QAM	M=4QAM	M=8QAM	M=16QAM
0	0.0710	0.0363	0.0250	0.0135
5	0.0236	0.0154	0.0082	0.006
10	0.0082	0.0052	0.0029	0.0022
15	0.003	0.0016	0.0012	0.0010
20	0.0011	0.0007	0.0005	0.0006
25	0.0005	0.0004	0.0005	0.0005
30	0.0003	0.0003	0.0005	0.0004
35	0.0003	0.0002	0.0004	0.0004
40	0.0003	0.0003	0.0005	0.0004

Fig.3 shows graph of SNR vs. channel MSE for N=128. The graph shows that 2QAM is giving poorest performance at smaller SNR in comparison to other three modulations because it has the highest MSE at SNR=0 but the MSE starts decreasing as SNR starts increasing. At higher SNR 2QAM gives very small

MSE of 0.003, but gives larger errors at SNR=0,5,10,15 and 20 as compare to others. At SNR=30,35,40 it gives constant performance and gives very small value of MSE.4QAM gives a little bit better results than 2QAM at low SNR's. As SNR increase 4QAM also gives constant performance of 0.0003, means at high SNR's 2QAM and 4QAM acts almost same. There is a difference of 0.0113 between the MSE of 4QAM and 8QAM at SNR=0, means 8QAM gives 0.0113 smaller error as compare to 4QAM but at SNR=25,30,40 it gives more error as compare to 4QAM,2QAM and 16QAM.At lower SNR 16QAM performs best instead of other three modulation orders, it decrease the mean square error up to 0.0004 but at higher SNR's it gives moderate performance.

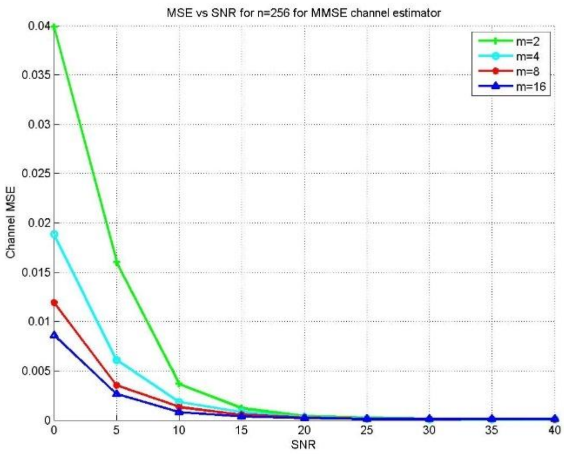

Fig.4. SNR vs channel MSE for n=256 by using QAM modulation

Table 3. for N=256

SNR	M=2QAM	M=4QAM	M=8QAM	M=16QAM
0	0.0398	0.0188	0.0119	0.0086
5	0.01604	0.006	0.0035	0.0026
10	0.0036	0.0018	0.0013	0.0009
15	0.0012	0.0008	0.0005	0.0003
20	0.00039	0.00032	0.00025	0.00020
25	0.00022	0.00015	0.00013	0.00012
30	0.00011	0.00009	0.00012	0.00013
35	0.000079	0.00010	0.00011	0.00011
40	0.000089	0.000079	0.00010	0.00012

Fig. 4 shows that 16QAM is giving the finest performance until SNR reaches to 30. When SNR reaches at 30 then 4QAM gives the lesser MSE of 0.00009 among 2QAM,8QAM,16QAM. At SNR=35 2QAM gives less SNR among all and at SNR=40, 4QAM gives lesser MSE. At SNR=35 and 40 MSE of 8QAM and 16QAM is almost same. In case of 2QAM we observe that at lower SNR'S 2QAM is giving worst performance among all but as SNR increases, performance of 2QAM also increases and it gives the less number of errors with increase in SNR. It means performance of 2QAM increases and give us lesser no. of errors at larger value of SNR. In case of 4QAM,8QAM and 16QAM similar thing happens.

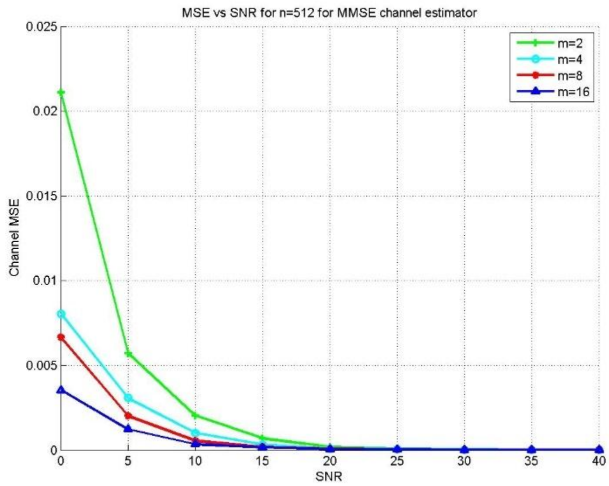

Fig.5. SNR vs channel MSE for n=512 by using QAM modulation

Table 4. for N=512

SNR	M=2QAM	M=4QAM	M=8QAM	M=16QAM
0	0.0210	0.0080	0.0066	0.0035
5	0.0057	0.0030	0.0020	0.0012
10	0.0020	0.0010	0.00055	0.00035
15	0.00069	0.00033	0.00019	0.00016
20	0.00019	0.00010	0.00007	0.00005
25	0.00007	0.00005	0.00004	0.00004
30	0.00005	0.00003	0.00003	0.00003
35	0.00002	0.00002	0.00002	0.00002
40	0.00002	0.00002	0.00003	0.00002

In fig. 5 2QAM is giving the higher MSE at low SNR's and 16QAM is giving the lowest MSE at low SNRs. As SNR increases all the modulation orders are providing almost constant values of MSE after SNR reaches to 25. There is a very tiny difference between the MSE of all modulations. At SNR=0, here is a difference of 0.013 between the MSE of 2QAM and 4QAM, MSE of 8QAM is giving 0.0014 small error as compare to 4QAM. MSE of 16QAM is 0.0035, which is giving smallest error at SNR=0. There is a difference of 0.0031 between the MSE of 16QAM and 8QAM. It means 16QAM is giving supreme performance at SNR=0.Till SNR reaches to 30,16QAM is giving the foremost performance, after that all the modulation orders are giving almost same performances.

In fig. 6 it is shown that at SNR=0, 16PSK is giving the smallest MSE and 2PSK is giving the highest MSE, after 2PSK, 4PSK is giving the 2nd highest MSE and after that 8PSK is giving the third highest MSE.

At SNR=10 8PSK is giving the lesser error as compare to other, but as SNR reaches to 15 again 16PSK is found best. At SNR=20 all modulations give same performance except 16PSK, this time 16PSK gives 0.0001 greater error as compare to others. At SNR=25, 2PSK, 4PSK, 16PSK gives identical performance but 8PSK gives 0.0001 increase in the error. At SNR=30, 2PSK and 8PSK gives almost same performance and gives the highest error among all, here 4PSK gives the healthier performance at SNR=30.At SNR=35, again 16PSK gives smallest error. When SNR reaches to 40 then 2PSK gives lesser error as compare to 16PSK, 8PSK ,4PSK. So, we can say that 16PSK is giving improved performance among all.

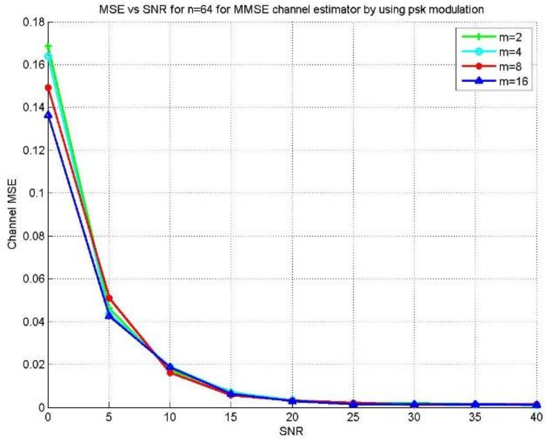

Fig.6 SNR vs channel MSE for n=64 by using PSK modulation

Table 5. for N=64

SNR	M=2PSK	M=4PSK	M=8PSK	M=16PSK
0	0.1618	0.164	0.1492	0.1365
5	0.0524	0.0517	0.0524	0.0516
10	0.02	0.0207	0.0169	0.0174
15	0.0063	0.0058	0.00685	0.0056
20	0.0028	0.0028	0.0028	0.0029
25	0.0017	0.0017	0.0018	0.0017
30	0.00153	0.0013	0.00153	0.0014
35	0.00129	0.00129	0.00131	0.00127
40	0.0012	0.0013	0.0015	0.0014

Fig.7 displays the graph between channel MSE and SNR for different modulation orders of PSK for transmitting N=128. The graph shows that 16PSK is giving highest errors at SNR=0 as compare to others. At SNR=5,10,15, 16PSK gives lesser no. of errors as compare to BPSK, QPSK and 8PSK.at SNR=20 2PSK,4PSK and 16PSK gives same error of 0.0012 and 8PSK gives MSE=0.0011, which is smaller than all. At SNR=25 BPSK gives smallest error, after that 8PSK, then 4PSK and then highest MSE is given by 16PSK.At SNR=30,35 and 40 all the modulation orders are giving smaller and almost constant performances.

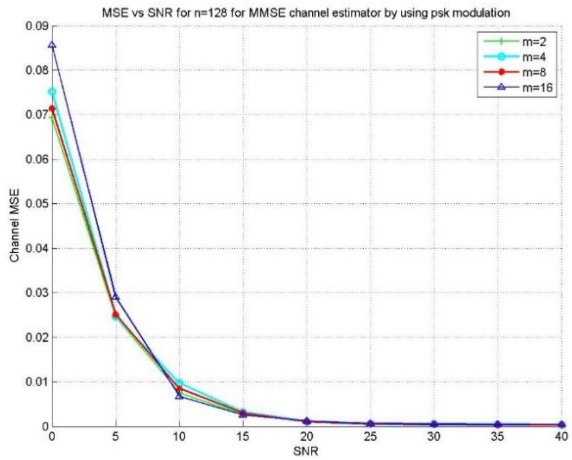

Fig.7 SNR vs channel MSE for N=128 by using PSK modulation

Table 6. for N=128

SNR	M=2PSK	M=4PSK	M=8PSK	M=16PSK
0	0.0693	0.07519	0.07139	0.08569
5	0.025	0.02867	0.02706	0.02599
10	0.0083	0.00886	0.00877	0.00788
15	0.0032	0.0028	0.00271	0.00271
20	0.0012	0.001287	0.001109	0.00126
25	0.00055	0.00062	0.00058	0.00071
30	0.00035	0.00040	0.00032	0.00039
35	0.00035	0.00032	0.00041	0.00038
40	0.00032	0.00037	0.00031	0.00035

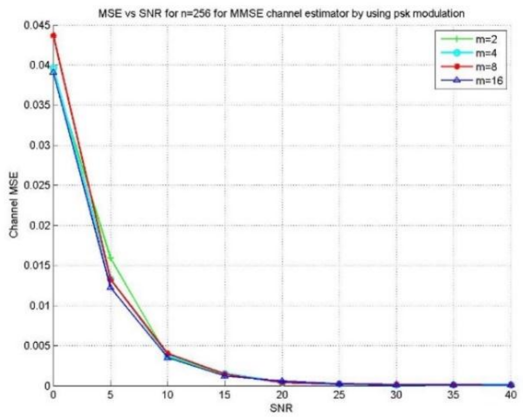

Fig.8 SNR vs channel MSE for n=256 by using PSK modulation

Fig.8 shows the graph between channel MSE and SNR for different modulation orders of PSK for transmitting N=256. Here at SNR=0, 8PSK is giving the highest no. of errors whereas there is a very small difference in the MSE of 2PSK, 4PSK and 16PSK.2PSK and 16PSK are giving the same value of MSE at SNR=0. If we study the overall graph then 16PSK is giving the best performance, but when we see the case when SNR=40 then BPSK is giving the smallest value of MSE.2nd best suited modulation is 8PSK, third best is 4PSK and the worst is 2PSK. 2PSK is considered worst because it is giving larger MSE as compare to others.

Table 7. for N=256

SNR	M=2PSK	M=4PSK	M=8PSK	M=16PSK
0	0.03908	0.03963	0.04367	0.03908
5	0.01432	0.01318	0.01362	0.01217
10	0.00400	0.00468	0.00428	0.00402
15	0.00144	0.00151	0.00135	0.00146
20	0.00051	0.00045	0.0005	0.00044
25	0.00021	0.00023	0.00020	0.00018
30	0.00015	0.00012	0.00011	0.00012
35	0.00010	0.00009	0.00008	0.00091
40	0.00007	0.00011	0.00009	0.00009

Fig.9. shows the graph between channel MSE and SNR for different modulation orders of PSK for transmitting N=512. Here we can see that 16PSK is giving better performance at SNR=0,5,10,20,25,35,40 by giving less value of MSE, whereas at SNR=15, 2PSK and 4PSK are giving similar value of MSE by giving the lowest value of MSE, their value is very near to the value of 16PSK, there is a difference of 0.00005 between them. At SNR=30, 4PSK is giving the minimum value of MSE.

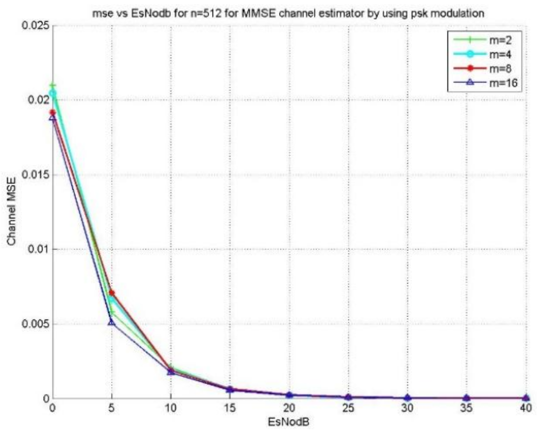

Fig.9 SNR vs channel MSE for n=512 by using PSK modulation

Table 8. for N=512

SNR	M=2PSK	M=4PSK	M=8PSK	M=16PSK
0	0.2095	0.02046	0.01916	0.01878
5	0.00648	0.00672	0.00686	0.005533
10	0.002134	0.00209	0.00207	0.001872
15	0.00061	0.00061	0.00076	0.000661
20	0.00021	0.00021	0.00021	0.00021
25	0.000095	0.000088	0.000090	0.000083
30	0.000041	0.000038	0.000042	0.000041
35	0.000031	0.00029	0.000029	0.000027
40	0.000024	0.000022	0.000023	0.000022

CONCLUSION

From above simulations, it is concluded that PSK performs well than QAM because PSK gives smaller errors as compared to QAM. Channel MSE decreases with the increase in the SNR which gives us good system performance. It is also shown that as number of subcarriers increase in MMSE estimator 16PSK is best suited for transmission because it gives comparatively smaller errors. If we study QAM, then 16QAM is best suited for transmission of N no. of subcarriers.

REFERENCES

[1] Pathak, S.; Sharma, H; (2013): Channel Estimation in OFDM Systems, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 3
[2] Singh, A.; Gupta, V. (2014): Performance Evaluation of MMSE and LS Channel Estimation in OFDM System International Journal of Engineering Trends and Technology (IJETT) – Volume 15 Number 1
[3] Mohamedian, M.; Maaly, I.; Elrahman, A.; Osman, I. (2007): Performance of Orthogonal Frequency Division Multiplexing (OFDM) under the effect of Wireless Transmission System Drawback, Sudan Engineering Society Journal, Volume 52 No. 49.
[4] Haykin, S. (1988): Digital Communications, Wiley Publications Ltd, Singapore.
[5] Schiller, J. (2003): “Mobile Communications”, Pearson Education Ltd, Singapore.
[6] Zhe, W; Fan, B; Zhanjun, J. (2010): A Simplified Training Pattern for MIMO-OFDM Channel Estimation Technology, International Conference on Computer Application and System Modeling.
[7] Payal; Taneja, A. (2016): Review on channel estimation for MIMO-OFDM system, International Journal of Innovations in Engineering and Technology(IJIET), Volume 6, Issue 4, ISSN: 2319- 1058.
[8] Sarmadi, S; Shahbazpanahi, S.; Gershman, A. (2009): Blind channel Estimation in Orthogonally

coded MIMO-OFDM Systems: A Semi Definite Relaxation Approach IEEE Transaction on Signal Processing, vol.57, No.6, pp.2354-2364

[9] Salihath, P.; Nandakumar, P. (2016): Channel Estimation Techniques in MIMO-OFDM, International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 3, Issue 5.

[10] Chouhan, S. (2014): Channel estimation using LS and MMSE estimators, IJSR - international journal of scientific research, Volume 3, Issue 8, ISSN NO: 2277-8179.

[11] Sahu, A.; Khare, A. (2014): A Comparative Analysis of LS and MMSE Channel Estimation Techniques for MIMO-OFDM System, International Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 4, Issue 6(Version 6), pp.162-167

[12] Jethva, B.; Porwal, M.; Trivedi, A. (2013): Performance Analysis for Different Modulation Schemes in MIMO for LTE and WLAN, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 5

[13] Sharma, S.; Singh, H. (2016): Comparison of Different Digital Modulation Techniques in LTE System using OFDM AWGN Channel: A Review, International Journal of Computer Applications (0975 – 8887) Volume 143 – No.3.