Performance Evaluation of Block-Type and Comb-Type Channel Estimation for OFDM System

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Abstract: In order to achieve the potential advantages of Orthogonal Frequency Division Multiplexing (OFDM) based systems, the channel coefficients should be estimated with minimum error. Channel estimation plays a vital role in OFDM system. The channel estimation technique for OFDM systems based on block and Comb pilot arrangements are investigated. The Performance comparison of Least Square, Minimum Mean Square and Least Mean Square error estimation algorithm by measuring bit error rate under different modulation techniques like Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM) is carried out both Block and Comb pilot based arrangement. In order to model the effect of a propagation environment under radio signal Rayleigh fading has been considered along with Additive White Gaussian Noise (AWGN). With different modulation schemes and channel estimation algorithm shows better results and improvement in terms of Bit Error Rate (BER).

Keywords: Orthogonal Frequency Division Multiplexing (OFDM); Least Square (LS); Least Mean Square (LMS); Channel estimation; Minimum Mean Square Error (MMSE);*Bit Error Rate(BER.*

1. Introduction

Over the last decade, wireless industries have had a rapid growth so that they can meet the demand of high transmission rates for voice, data, graphical images and videos. More attention has been given to improve the services for mobile wireless telecommunication users rather than wired networks.

Orthogonal Frequency Division Multiplexing (OFDM) has recently been applied widely in wireless communication systems due to its high data rate transmission Capability with high bandwidth efficiency and it robustness to multi-path delay. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions as attenuation of high frequencies, narrowband interference, frequency-selective fading due to multipath etc. without complex equalization filters. OFDM has been adopted as the modulation method of choice for practically all the new wireless technologies being used and developed today. It is perhaps the most spectrally efficient method discovered so far, and it mitigates the severe problem of multipath propagation that causes massive data errors and loss of signal. OFDM systems are attractive for the way they handle ISI, which is usually introduced by frequency selective multipath fading in wireless environment. Each sub-carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. In this way, ISI is diminished. Moreover, if a guard interval between consecutive OFDM symbols is inserted, the effects of ISI can completely vanish. This guard interval must be longer than the multipath delay. Although each-subcarriers operate at a low data rate, a total high data rate can be achieved by using a large number of sub-carriers. ISI has very small or no effect on the OFDM systems hence an equalizer is not needed at the receiver side. Cyclic Prefix (CP) is inserted between two successive symbols as guard interval which not only mitigates Inter Symbol Interference (ISI), but also converts the linear convolution between the transmitted OFDM symbol and channel impulse response to a circular one. At the receiver, the CP corrupted by ISI is generally discarded and the ISI free part of the OFDM symbol is used for channel estimation and data detection. An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM).

The digital source is usually protected by channel coding and interleaved against fading phenomenon, after which the binary signal is modulated and transmitted over multipath fading channel. Additive noise is added and the sum signal is received. A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication systems [2]. The channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol [4]. The objective of Channel Estimation Technique is to compare the performance of LS and LMMSE for block pilot insertion technique using modulation techniques like BPSK, QPSK, and 16-QAM under AWGN noise and Rayleigh fading channel.

2. OFDM System

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that divides a channel with a higher relative data rate into several orthogonal sub-channels with a lower data rate. For high data rate transmissions, the symbol duration Ts is short Therefore ISI due to multipath propagation distorts the received signal, if the symbol duration Ts is smaller as the maximum delay of the channel. To mitigate this effect a narrowband channel is needed, but for high data rates a broadband channel is needed. To overcome this problem the total bandwidth can be split into several parallel narrowband subcarriers. Thus a block of N serial data symbols with duration Ts is converted into a block of N parallel data symbols, each with duration T = N×Ts. The aim is that the new symbol duration of each subcarrier is larger than the maximum delay of the channel, T > Tmax. With many low data rate subcarriers at the same time, a higher data rate is achieved. Different terminologies of OFDm syatem

A. Orthogonality

In OFDM system, the two periodic signals are orthogonal when the integral of their product over a period is equal to zero. This can be represented in continuous time as,

$$\int_0^t \cos(2\pi f_0 nt)\cos(2\pi f_0 mt)\, dt = 0 \qquad (1)$$

In discrete time, it can be represented as,

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right) cos\left(\frac{2\pi km}{N}\right) dt = 0 \qquad (2)$$

B. Sub-Carriers

Each subcarrier in an OFDM system is a sinusoid with a frequency that is an integer multiple of fundamental frequency. Each subcarrier can be expressed as a Fourier series component of the composite signal i.e. an OFDM symbol. The subcarrier waveform can be mathematically expressed as,

$$S(t)=\cos(2\pi fct+\theta k)=an\cos(2\pi nf0t)+bn\sin(2\pi nf0t) \qquad (3)$$

C. Cyclic Prefix

Due to the multipath fading environment, channel causes consecutive OFDM symbols to overlap and introduce symbol interference. This degrades the performance of the overall system and destroys the orthogonality of subcarriers.

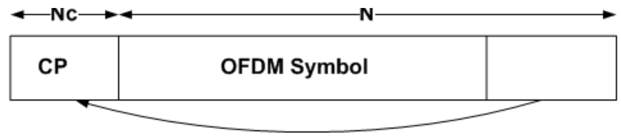

Figure 1: Cyclic Prefix adding process in OFDM symbol

To prevent ISI and to preserve the orthogonality, a guard interval is used in every OFDM. This type of guard interval is called cyclic prefix (CP).The Cyclic Prefix (CP) or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of symbol in a transmitter, and is removed at the receiver before demodulation. It acts as a repetition of the end of the symbol, thus allowing the linear convolution of a frequency–selective multipath channel to be modeled as circular convolution which in turn may be transformed to the frequency domain using a discrete Fourier transform.

D. Inter-Carrier Interference (ICI)

Presence of Doppler shifts and frequency and phase offsets in an OFDM system causes loss in orthogonality of the subcarriers. The loss of orthogonality introduces interference between subcarriers. This phenomenon is known as inter carrier interference (ICI). Due to ISI, OFDM systems become very sensitive to frequency offsets and degrade the achievable Bit Error Rate (BER) performance. Frequency offsets correction for OFDM system can be done by using data aided technique where Cknown bit patterns or pilot tones are inserted in OFDM system

E. Inter Symbol Interference (ISI)

In many wireless systems, multiple channels create problems when the transmitted signal reflects from several objects. As a result, multiple delayed versions of the input signal arrive in the receiver at different time spans. Due to the multiple versions of the input signal, received OFDM symbol becomes distorted by the previously transmitted OFDM symbols. This problem is called as Inter Symbol Interference. This is an unwanted phenomenon as the previous symbols have similar effect as noise; thus, making the communication less reliable. Therefore, in the design of transmitting and receiving filters, the objective is to minimize the effects of ISI and; thereby, deliver the digital data to its destination with the smallest error rate possible.

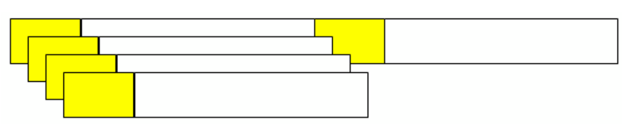

Figure 2: Example of inter-symbol interference

First few samples of an OFDM symbol are distorted by inter-symbol interference. This problem can be minimized by adding extra guard interval in front of every OFDM symbol. These effects cause the signal to be spread in any transformed domains as time, frequency and space.

3. Channel Estimation and Interpolation Techniques

In any communication systems, channel estimation is a most important and challenging problem, especially in wireless communication systems. Usually, the transmitted signal can be degraded by many detrimental effects such as mobility of transmitter or receiver, scattering due to environmental objects, multipath and so on. There are many channel estimation methods that can be used in multicarrier communication systems but the especial properties of multicarrier transmission systems give an additional perspective which forces to developing new techniques to channel estimation in wireless communication systems. Pilot Symbol Assisted Modulation is used to achieve reliable channel estimates by transmitting pilots along with data symbols.

A. Pilot Based Channel Estimation

Pilot based channel estimation can be of two types Block Pilot insertion and Comb Pilot Insertion. In pilot based channel estimation known symbol called pilots are transmitted. Channel state varies continuously so channel state information needs to be estimated on short term basis. An approach of inserting training sequence (or pilot sequence), where a known signal is transmitted and the channel matrix H is estimated using the combined knowledge of the transmitted and received signal.

Let the training sequence be denoted by P1…PN

Where the vector Pi is transmitted over the channel as:

$$Yi = Hpi+ni \qquad (4)$$

By combining the received training signals yi for i = 1,….., N total training signaling becomes:

$$Y= [y_1………..y_N] = Hp+N \qquad (5)$$

With the training matrix P = $[p_1……..p_{N]}$ and the noise matrix:

$$N = [n_1……… n_N] \qquad (6)$$

With this notation, channel estimation means that H should be recovered from the knowledge of Y and P. In order to estimate the channel at receiver side using the transmitted symbol of pilot two types of estimation techniques is used. The block-type refers to that the pilots are inserted into all the subcarriers of one OFDM symbol with a certain period. The block-type can be adopted in slow fading channel, that is, the channel is stationary within a certain period of OFDM symbols. The comb-type refers to that the pilots are inserted at some specific subcarriers in each OFDM symbol. Assuming that inter symbol interference is dropped by guard interval, we write output Y (k) as:

$$Y = Xh+nY \qquad (7)$$

Where Y is the received vector, X is a matrix containing the transmitted signaling points on its diagonal, h is a channel attenuation vector, and n is a vector of i.i.d. Complex, zero mean, Gaussian noise with variance σ_n^2. It's assumed that the received OFDM symbol contains data known to the estimator - either training data or receiver decisions.

Depending on the arrangement of pilots, two basic 1D channel estimations in OFDM systems:

1) Block Type Pilot Insertion

Block-type pilot channel estimation is developed under the assumption of slow fading radio channel, and it is performed by inserting pilot tones into all subcarriers of OFDM symbols within the specific period. OFDM channel estimation symbols are transmitted periodically in time-domain. The training block contains all pilots channel interpolation in frequency domain is not required. Therefore, this type of pilot arrangement is relatively insensitive to frequency selectivity. If the channel is constant during the block, there will be no channel estimation errors in the pilots are sent at all carriers [7].

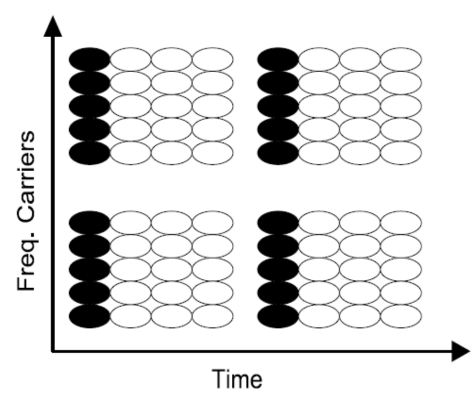

Figure 3: Block Pilot Insertion Method

For block type arrangements, channel at pilot tones can be estimated by using LS, LMS estimation, and assumes that channel remains the same for the entire block. So in block type estimation, we first estimate the channel, and then use the same estimates within the entire block.

2) Comb Type Pilot Insertion

Comb-type pilot channel estimation is best suited for fast fading channels. In this type, every OFDM symbol has pilot tones at the periodically located subcarriers, which are used for a frequency domain interpolation to estimate the channel along the frequency axis. In order to keep track of frequency selective channel characteristics, the pilot symbols must be placed as frequently as coherent bandwidth. This channel estimation technique is introduced to satisfy the need for equalizing when the channel changes even from one OFDM block to the subsequent one [8]. Comb-type pilot insertion has been shown to be suitable for channel estimation in fast fading channels.

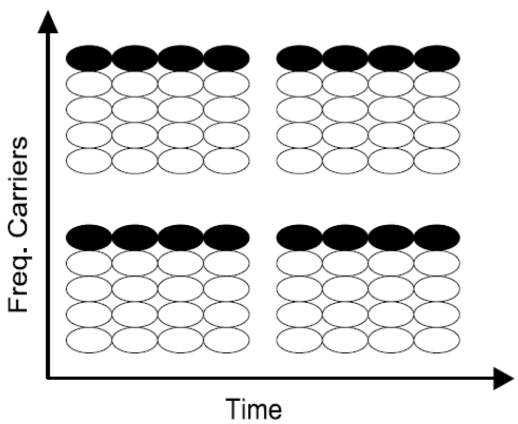

Figure 4: Comb Pilot Insertion Method

It is thus performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers.

B. interpolation techniques

Comb-type channel estimation has been used because of the use of the fast fading Rayleigh channel for performance analysis of the OFDM system. Equi-spaced pilot insertion is adopted because of optimum performance [10]. The channel estimation based on comb type pilot insertion, an interpolation technique is necessary in order to estimate channel at data sub-carriers by using the channel information at pilot sub-carriers. Once the CFR estimates have been obtained at the pilot subcarrier frequencies, they are extended to data subcarriers by interpolation. When the pilot interval is shorter than coherent bandwidth, after the frequency response of pilot sub-channel is estimated, interpolation is used in frequency domain to get the channel estimation. There are two types of interpolators [3].

- One dimensional interpolator
- Two dimensional interpolator

There are different types of one dimensional

Interpolation schemes such as:

1) Linear Interpolation

Linear interpolation is one of the simplest interpolation methods. Linear interpolation is quick and easy, but it is not very precise. Two successive known pilot subcarriers are used in linear interpolation to determine the channel response for data subcarriers that are located in between the pilots. The intermediate estimates are evaluated by the linear sum of the known components on either side. The channel estimation at the data subcarrier k

$mL<k<(m+l)L$

Where mL and (m+l)L are two points

Using linear interpolation is given in [11]

$$H(k)=H(mL+1),\ \ 0<l<L \quad (8)$$

$$H(k)=Hp(m+1)-Hp(m)\left(\frac{m}{L}\right)+Hp(m) \quad (9)$$

2) Spline Cubic Interpolation

The spline cubic interpolation is based on drawing smooth curves through a number of points which produces smooth and continuous polynomial fitted to given data points. The fundamental idea behind spline cubic interpolation is based on draw smooth curves through a number of point's interpolation. The cubic interpolation uses four known points to obtain a third degree polynomial. In case the range of interpolation becomes larger than the range covered by the first four reference points, it is required to obtain a second polynomial using the next four points.

3) Low-Pass Interpolation

The low-pass interpolation method is performed by inserting zeros into the original sequence and then applying a low-pass finite-length impulse response (FIR) filter, which allows the original data to pass through it without any changing. This method also interpolates such that the mean-square error between the interpolated points and their ideal values is minimized [11].

solutions. We have use estimation and interpolation technique to analyze the performance.

4. System Model

The block diagram of pilot channel estimation based OFDM system shown in figure below:

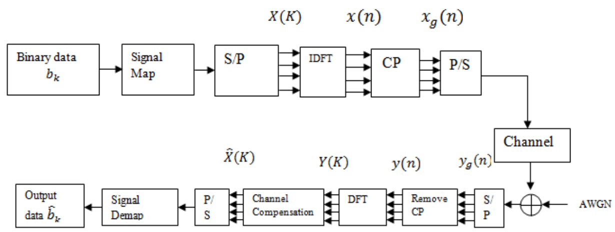

Figure 5: Based band OFDM system

The binary information is first grouped and mapped according to the modulation in signal mapper. Then the pilot is inserted to the mapped signal. After inserting the pilot, IDFT block is used to transform the data sequence of length into time domain signal. Then guard time is inserted to the time domain signal which prevents the inter-symbol interference as well as eliminates the inter-carrier interference. At the receiver, the analog signal received is converted to discrete domain and the guard time is removed. In DFT block, the pilot signals are extracted and the estimated channel for the data sub-channels is obtained in channel estimation block. At last the binary information data is obtained back from signal demapper block. Based on principle of OFDM transmission scheme, it is easy to assign the pilot both in time domain and in frequency domain [8].

5. Methodology

This thesis uses Block type and comb type pilot based channel estimation schemes. The first one, Block type channel estimation, is suitable for slow fading radio channel and symbols are transmitted periodically, in which all sub-carriers use as pilots. The later one, Comb type pilot based channel estimation, is suitable for fast fading radio channel and consists of algorithms to estimate the channel at pilot frequencies and to interpolate the channel. Estimation is performed by using LS, LMS and MMSE algorithms under different modulation schemes. The performance of the OFDM link will be evaluated in terms of BER and SNR plot comparing the different channel estimation technique. The technique which will give less BER vs SNR plot will be the best method for better performance. The analysis can be carried out on MATLAB to simulate and model different problems. MATLAB is a strong mathematical tool which provides help to engineers to solve, model, simulate the problems and find their solutions. We have use estimation and interpolation technique to analyze the performance.

A. Channel Estimation Scheme

Channel state varies continuously so channel state information needs to be estimated on short term basis. An approach of inserting training sequence (or pilot sequence), where a known signal is transmitted and the channel matrix H is estimated using the combined knowledge of the transmitted and received signal.The estimation can be performed by using LS, LMS, MMSE algorithms.

1) Least Square Estimation

When ICI is eliminated by the guard interval, the received signal can be modeled with the following equation:

$$Y = HX + W \tag{10}$$

Where Y is the received signal vector, X is a diagonal matrix of the transmitted signal, Least Square estimator of OFDM signal is given

$$Hls = (XH\ X)^{-1}\ XH\ Y \tag{11}$$

Since X is the diagonal matrix, the estimate is reduced to

$$Hls = X^{-1}\ Y \tag{12}$$

The advantage of LS algorithm is its simplicity, because no consideration of noise and ICI. So, without using any knowledge of the statistics of the channels, the LS estimators are calculated with very low complexity. But obviously it suffers from a high MSE. LS method, in general, is utilized to get initial channel estimates at the pilot subcarriers, which are then further improved via different methods.

2) Least Mean Square Estimation

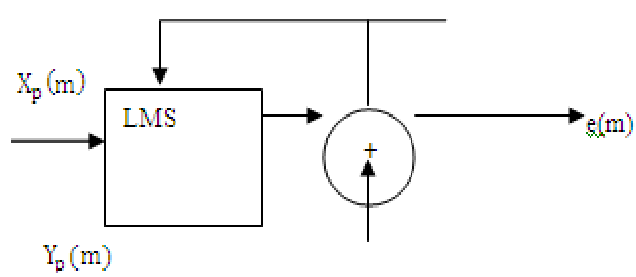

Figure 6: Least Mean Square

The LMS estimator uses one-tap LMS adaptive filter at each pilot frequency. The first value is found directly through LS and the following values are calculated based on the previous estimation and the current channel output. As shown in figure e(m) is the error signal which is formed by taking the difference between the received pilot symbol Y_P (m) and transmitted pilot symbol X_P (m).

Let us Suppose pilot signals as *Mpi* with symbols as *Xpi(n), n=0,1,.....,Mpi-1* which are uniformly inserted into *X(m)* data signals. The OFDM signal modulated on the M^{th} subcarrier can be expressed as:

$$(K)= X((nLs + i)) \quad (13)$$

$$= \begin{cases} Xpi(n), i = 0 \\ Source\ data, i - 1,2,3, \dots\dots, Ls - 1 \end{cases} \quad (14)$$

When the total *M* subcarriers are divided into *Mpi* groups, each with $L_s = M / M_{pi}$ adjacent subcarriers. The estimate of pilot signals based on least squares (LS) criterion is given by [11].

$$\widehat{H}pi = Xpi\text{-}1Ypi \quad (15)$$

$$Hpi = [Hpi(0) Hpi(1) \dots\dots.. Hpi(Mpi - 1)]T \quad (16)$$

The channel frequency response at pilot sub-carriers,

$$Ypi= [Ypi(0) Ypi(1) \dots\dots.. Ypi(Mpi - 1)]^T \quad (17)$$

Received pilot signals vector which can be expressed,

$$Ypi=Xpi.Hpi+Ipi+Wpi \quad (18)$$

$$\text{Where } Xpi= \begin{pmatrix} Xpi(0) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & Xpi(Mpi - 1) \end{pmatrix}$$

Ip and Wp are the inter carrier interference (ICI) vector and Gaussian noise vector in pilot sub carrier, respectively.

3) Minimum Mean Square Error Estimation

Minimum Mean Square Error (MMSE) is linear detection method in which mean squared error (MSE) is minimized between the transmitted signals. The MMSE estimator employs the second-order statistics of the channel conditions to minimize the MSE. MMSE equalizer does not usually eliminate ISI completely but, minimizes the total power of the noise and ISI components in the output [3]. In order to obtain the unknown transmitted signal MMSE use a weight matrix given by:

$$W = (H^H H + N_0 I)^{-1} H^H \quad (19)$$

The performance of MMSE estimator is much better than LS estimator. And MMSE estimator could gain 10-15 dB more of performance than LS. However, because of the required matrix inversions, the computation is very complex when the number of subcarriers of OFDM system increases. Therefore, an important drawback of the MMSE estimator can be the high computational complexity.

B. Algorithm

Step 1: Initialize binary message signal SNR values

Step 2: Declare modulation object

Step 3: Insert pilots, perform IFFT and insert cyclic prefix

Step 4: Transmit signal initialize EbNo=0:20

Step 5: Loop for each SNR values

If count is greater and equal to the length of SNR then plot graph else goto ta step 6.

Step 6: calculate SNR= EbNo+3+10*log2 (M)

Step 7: Declare Rayleigh channel object and add the Additive White Gaussian Noise

Step 8: Remove pilot signal, perform FFT and remove cyclic prefix

Step 9: Use channel estimation technique

Step 10: Perform demodulation

Step 11: Calculate BER

Step 12: Go to the step 5

6. Simulation

The simulated output is the comparison of BER performance over different channel estimation technique like LS and LMS under block type and comb type pilot insertion and also linear, spline cubic and low-pass interpolation technique. On the first step the comparison of BPSK, QPSK, and 16-QAM modulation techniques by using LS and LMS estimation based on bit error rate has been performed in case of Block type as well as comb type pilot insertion. The simulation result using MATLAB gives the clear view of performance analysis. The channel parameters like Doppler shift and delay spread has been considered.

Table 1: simulation setup

Coding and simulation tool	MATLAB
Fading model	Rayleigh
Carrier modulation	OFDM
Sub carrier modulation	BPSK, QPSK,16QAM
Type of pilot insertion	Block, Comb
Estimation technique	LS,LMS,MMSE
Comparison	BER verus SNR

After the transmission of OFDM symbol and estimating the channel using algorithms like LS, LMS and MMSE simulated result has been analyzed. Data for Bit error rate obtained using different condition has been collected and compared to determine the better channel estimation technique

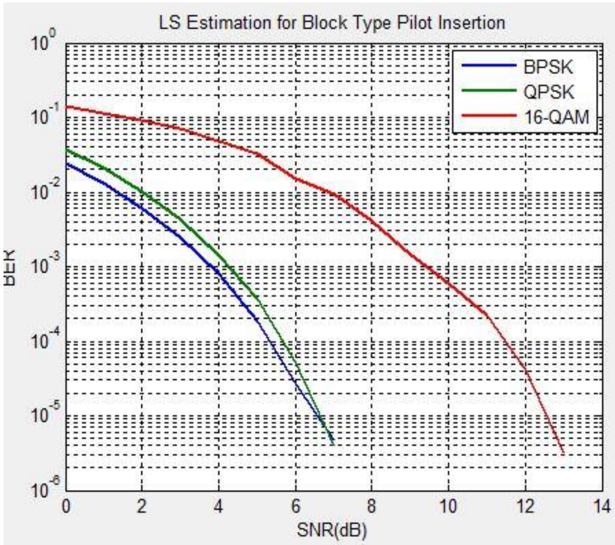

Figure 7: Comparison of modulation technique for Rayleigh Channel under LS estimation Block type pilot

Table 2: BER result for Rayleigh Channel under Block type LS estimator

SNR DB	BPSK	QPSK	16QAM
0	0.0238	0.0370	0.1442
2	0.0131	0.0210	0.1157
4	0.0025	0.0043	0.0695
6	1.9063e-04	3.6484e-04	0.0327
8	4.6875e-06	3.9063e-06	0.0092
10	0	0	0.0014
12	0	0	2.2344e-04
14	0	0	3.1250e-06

Table 3: BER result for Rayleigh Channel under Comb type LS estimator

SNR DB	BPSK	QPSK	16QAM
0	0.0390	0.0591	0.2328
2	0.0130	0.0204	0.1851
4	0.0026	0.0043	0.1335
6	2.0313e-04	3.5703e-04	0.0833
8	3.1250e-06	1.0156e-05	0.0417
10	0	0	0.0153
12	0	0	0.0033

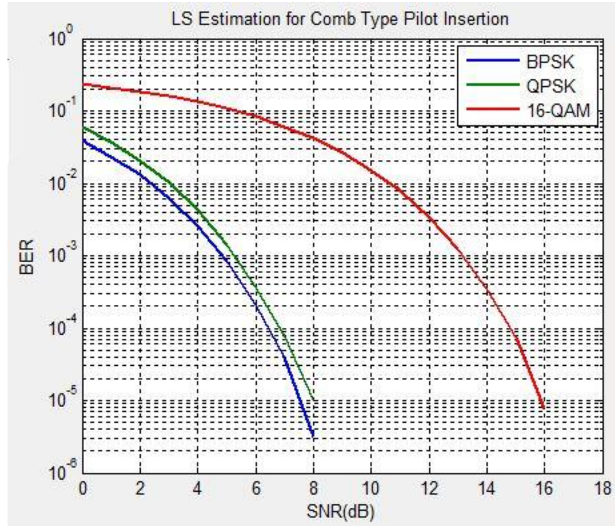

Figure 8: Comparison of modulation technique for Rayleigh Channel under LS estimation Comb type pilot

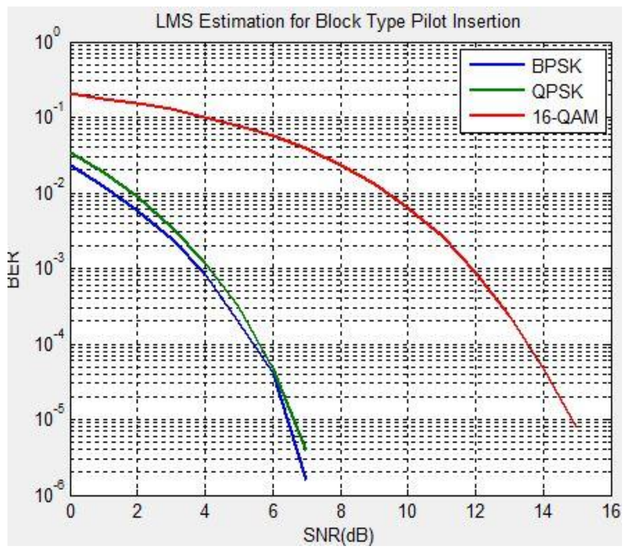

Figure 9: Comparison of modulation technique for Rayleigh Channel under LMS estimation Block type pilot

Table 4: BER result for Rayleigh Channel under Block type LMS estimator

SNR DB	BPSK	QPSK	16QAM
0	0.0229	0.0343	0.2042
2	0.0060	0.0090	0.1527
4	8.2813e-04	0.0012	0.1019
6	4.0625e-05	4.6875e-05	0.0565
8	0	0	0.0235
10	0	0	0.0064
12	0	0	8.9336e-04
14	0	0	4.6484e-05
15	0	0	7.8125e-06

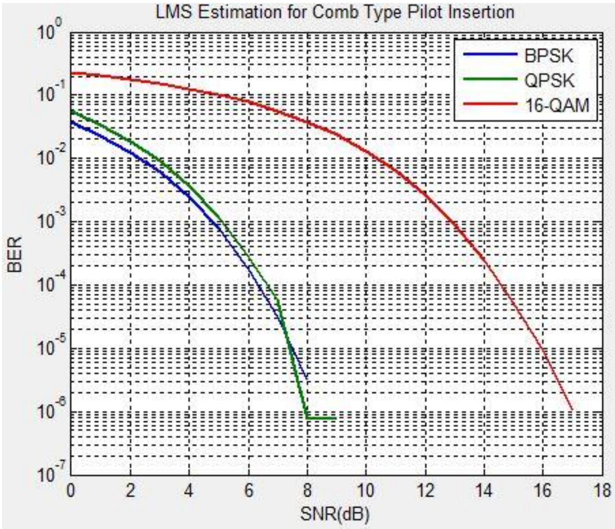

Figure 10: Comparison of modulation technique for Rayleigh Channel under LMS estimation Comb type pilot

Table 5: BER result for Rayleigh Channel under Comb type LMS estimator

SNR DB	BPSK	QPSK	16QAM
0	0.0379	0.0551	0.2279
2	0.0126	0.0186	0.1789
4	0.0025	0.0037	0.1275
6	1.7344e-04	2.6953e-04	0.0778
8	3.1250e-06	7.8125e-07	0.0378
10	0	0	0.0131
12	0	0	0.0026
14	0	0	9.0938e-04
16	0	0	4.8438e-05

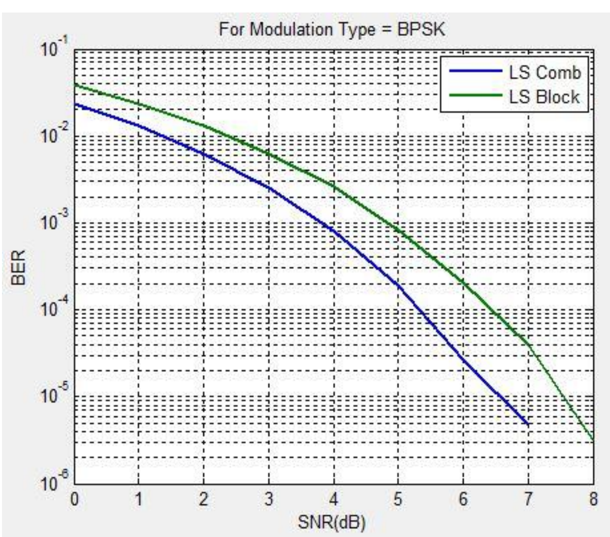

Figure 11: Comparison of BPSK modulation technique for Rayleigh Channel under LS estimation Comb type and Block type pilot

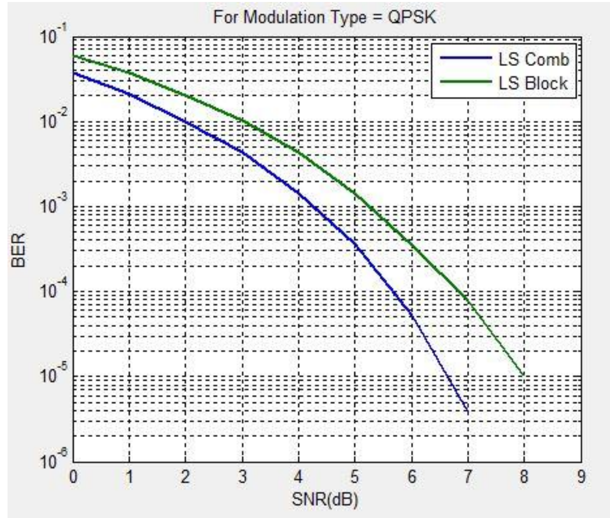

Figure 12: Comparison of QPSK modulation technique for Rayleigh Channel under LS estimation Comb type and Block type pilot

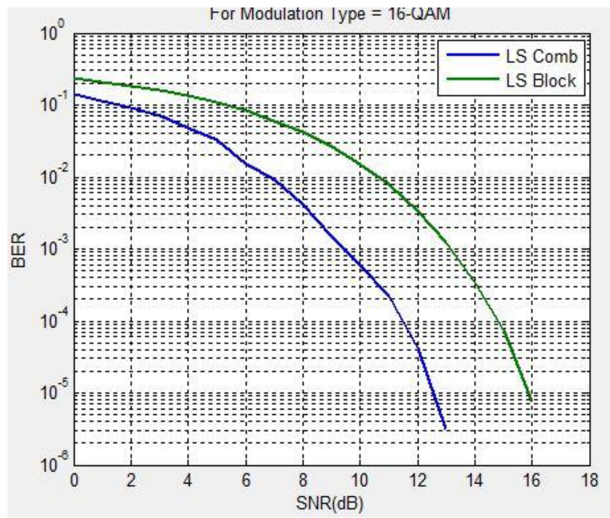

Figure 13: Comparison of 16QAM modulation technique for Rayleigh Channel under LS estimation Comb type and Block type pilot

Among these three comparisons which show the Comb type pilot insertion technique has the better performance than Block type pilot insertion technique. For these comparison different modulation techniques is used for LS estimation. Among BPSK, QPSK and 16QAM modulation, BPSK gives low Bit Error Rate but 16 QAM gives the high data rate.

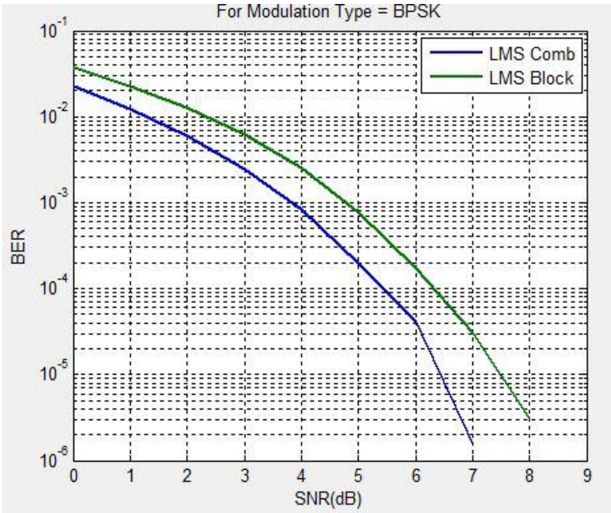

Figure 14: Comparison of BPSK modulation technique for Rayleigh Channel under LMS estimation Comb type and Block type pilot

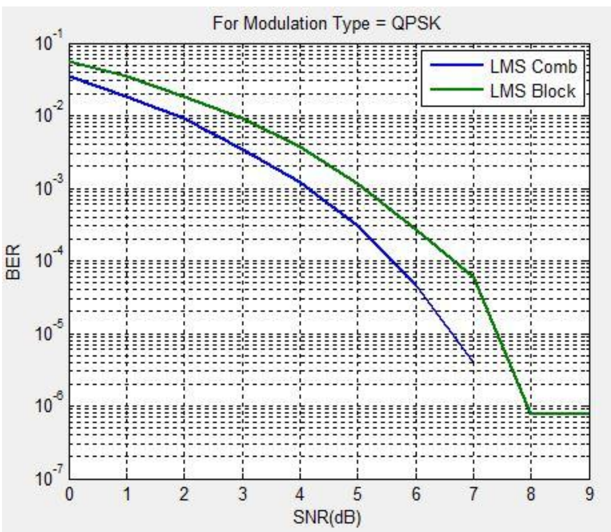

Figure 15: Comparison of QPSK modulation technique for Rayleigh Channel under LMS estimation Comb type and Block type pilot

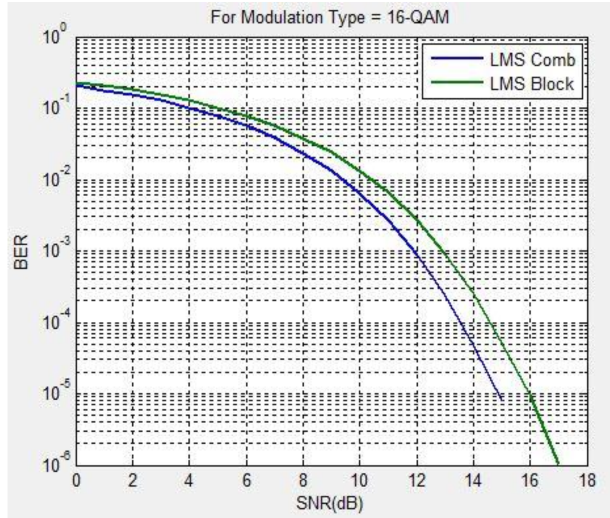

Figure 16: Comparison of 16QAM modulation technique for Rayleigh Channel under LMS estimation Comb type and Block type pilot

Among these three comparisons which show the Comb type pilot insertion technique has the better performance than Block type pilot insertion technique. For these comparison different modulation techniques is used for LMS estimation. These simulation results show the comparison between two different LS and LMS estimation technique between Block and Comb type pilot insertion, LMS gives the better performance than LS estimation due to minimize the errors.

5. Conclusion

Channel estimation based on Comb type pilot arrangement as well as Block type pilot arrangement have been done. Based on Comb type pilot arrangement has been presented by giving channel estimation method at pilot frequencies and then by mean of interpolation the CFR at data frequencies are estimated. Further the performance of OFDM system has been analyzed using least square and LMS techniques using different modulation technique viz. BPSK, QPSK, and 16-QAM. From Bit Error Rate calculation, LMS performance found to be better as compared to LS as SNR value increases. LS estimation algorithm it has been found that Comb type pilot insertion performs better than Block type pilot insertion under 16 QAM modulations. LMS estimation algorithm it has been found that Block type pilot insertion performs better than Comb type pilot insertion under BPSK, QPSK and 16 QAM modulations. The advantage of using Comb type pilot's arrangement is the ability to track the variation of channel in time. However as we go to higher SNR values both the estimation algorithm has similar results. As least square(LS) estimation does not consider SNR so it shows better result at greater SNR values.

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