Pilot Based Channel Estimation Technique in MIMO-OFDM System

Pragati Ojha, ECE department, Maharana Pratap Engineering college, Kanpur, India,

Abstract—Through OFDM, an effective and low complexity technique of eliminating inter symbol interference for transmission over frequency selective fading channels can be obtained. This technique of eliminating inter symbol interference has a wide area of interest in mobile communication research as the radio channel is usually frequency selective and time variant. Channel estimation information can be reliably estimated by transmitting pilot carriers along with data symbols. In this paper, we investigate the various efficient pilot based channel estimation schemes for MIMO-OFDM systems.

Keywords—Least Square estimation (LSE), Multiple input multiple output (MIMO), Minimum Mean Square estimation (MMSE), Orthogonal frequency division multiplexing (OFDM).

I. INTRODUCTION

Radio transmission has allowed people to communicate without any physical connection for more than hundred years. Today, the progress in semiconductor technology has made it possible, not to forget affordable, for millions of people to communicate on the move all around the world. During the past few years, there has been explosion in wireless technology. This growth has opened a new dimension to future wireless communications whose ultimate goal is to provide universal, personal and multimedia communication without regard to mobility or location, with high data rates. To achieve such an objective, the next generation personal communication networks will need to be support a wide range of service which will include high quality voice, data, facsimile, still pictures and streaming video. These future services are likely to include applications which require high transmission rates of several Megabits per second (Mbps). Wireless communications is an emerging field, which has seen enormous growth in recent years. In the current and future mobile communications systems, data transmission at high bit rates is essential for many services such as video, high quality audio and mobile integrated service digital network. When the data is transmitted at high bit rates, over mobile radio channels, the channel impulse response can extend over many symbol periods, which lead to inter symbol interference (ISI). OFDM is one of the promising candidate to mitigate the ISI. In an OFDM symbol, the bandwidth is divided into many narrow sub-channels which are transmitted in parallel. Each sub-channel is typically chosen narrow enough to eliminate the effect of delay spread. The research on wireless communication systems with high data rate, high spectrum efficiency and reliable performance is a hot-spot. There are several advanced communication technologies or protocols proposed recently, including orthogonal frequency division multiplexing (OFDM)[1], multiple input multiple output (MIMO)[2], ultra wide band (UWB) technology[3], cognitive radio[4], world interoperability for OFDM is an efficient high data rate transmission technique for wireless communication. OFDM presents advantages of high spectrum efficiency, simple and efficient implementation by using the fast Fourier transform (FFT) and inverse fast Fourier transform (IFFT), mitigation of inter symbol interference (ISI) by inserting cyclic prefix (CP) and robustness to frequency selective fading channels. MIMO is the use of multiple antennas at both the transmitter and receiver to improve the communication performance. It is one of the several forms of smart antenna technology. MIMO technology has attracted attention in wireless communication because it increases in data throughput without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability. The combination of MIMO with OFDM technique is a promising technique for next generation wireless communication. In this paper, we investigate the various efficient pilot based channel estimation schemes for MIMO-OFDM system.

II. METHODOLOGY

The channel estimation can be performed by either inserting pilot tones into all sub carriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbols. In this study, two major types of pilot arrangements Block type pilot arrangement and Comb type pilot arrangement have
been focused employing two types of channel estimators i.e. Least square error channel estimator (LSE)[5] and Minimum mean square error channel estimator (MMSE)[6]. Block type pilot sub carrier are especially suitable for slow fading radio channels whereas Comb type pilot sub carrier are suitable for fast fading radio channels. The channel estimation algorithm is divided into two i.e. pilot signal estimation and channel interpolation. Pilot signal estimation is based on LSE and MMSE criteria together while Linear and spline interpolation techniques are used for channel interpolation. The Bit Error Rate performance (BER) of MIMO OFDM system for both Comb type and Block type pilot subcarrier is presented in this paper.

III. INTRODUCTION TO OFDM

OFDM is very similar to the well known and used technology of frequency division multiplexing (FDM). OFDM uses the principle of FDM to allow multiple messages to be sent over a single radio channel. It is however in a much more controlled manner, allowing an improved spectral efficiency. OFDM is different from FDM in several ways. In conventional broadcasting each radio station transmits on a different frequency, effectively using FDM to maintain a separation between the stations. There is however no coordination between each of these stations. With an OFDM transmission, the information signals from multiple stations is combined into single multiplexed stream of data. This data is then transmitted using an OFDM ensemble that is made up from a dense packing of many subcarriers. All the subcarriers within the OFDM signal are time and frequency synchronized to each other, allowing the interference between the subcarriers to be carefully controlled. These multiple subcarriers overlap in the frequency domain, but do not cause inter symbol interference due to the orthogonal nature of the modulation. Typically with FDM, the transmission signals need to have a large frequency guard-band between channels to prevent interference. This lowers the overall spectral efficiency. However with OFDM, the orthogonal packing of the subcarriers greatly reduces this guard-band, improving the spectral efficiency. OFDM is simply defined as a form of multi-carrier modulation where the carrier spacing is carefully selected so that each subcarrier is orthogonal to other sub carriers. Two signals are orthogonal if their dot product is zero. That is, if you take two signals multiply them together and if their integral over an interval is zero, then two signals are orthogonal in that interval. Orthogonality can be achieved carefully selecting carrier spacing, such as letting the carrier spacing be equal to the reciprocal of the useful symbol period.

As the sub carriers are orthogonal, the spectrum of each carrier has a null at the centre frequency of the other carriers in the system. This result in no interference between the carriers, allowing them to be spaced close as theoretically possible. Mathematically, suppose we have a set of signals Ψ then,

\[ \int_0^T \Psi_p(t)\Psi_q'(t) = k \text{ for } p = q \]
\[ = 0 \text{ for } p \neq q \]

(1)

Where \( \Psi_p \) and \( \Psi_q \) are the \( p \)th and \( q \)th elements in the set and \( T \) is the symbol period.

IV. DESCRIPTION OF BASEBAND OFDM SYSTEM

The binary information is first grouped and mapped ac-cording to the modulation in “signalmapeer”. After inserting pilots either to all sub-carriers with a specific period or uniformly between the information data sequence, IDFT block is used to transform the data sequence of length into time domain signal with the following equation

\[ x(n) = \text{IDFT}[X(k)] \]
\[ n = 0,1,2 \ldots N - 1 \]

(2)

\[ = \sum_{k=0}^{N-1} X(k) e^{j2\pi kn/N} \]

Where \( N \) is the DFT length. Following IDFT block, guard time, which is chosen to be larger than the expected delay spread, is inserted to prevent inter-symbol interference. This guard time includes the cyclically extended part of OFDM symbol in order to eliminate inter-carrier interference (ICI). The resultant OFDM symbol is given as follows
\[ X_i(n) = x(N + n), \quad n = -N_g-N_e+1,\ldots\ldots,-1 \]
\[ = x(n) \quad (3) \]

where \( N_g \) is the length of the guard interval.

The transmitted signal \( x(n) \) will pass through the frequency selective time varying fading channel with additive noise. The received signal is given by:

\[ Y_f(n) = x_f(n) \otimes h(n) + w(n) \quad (4) \]

where \( w(n) \) is Additive White Gaussian Noise (AWGN) and \( h(n) \) is the channel impulse response. The channel response can be represented by

\[ h(n) = \sum_{i=0}^{r-1} h_i e^{j(\frac{\pi}{T}) f_{d,i} n} \delta(\lambda - \zeta_i), \quad 0 \leq n \leq N-1 \quad (5) \]

where \( r \) is the total number of propagation paths, \( h_i \) is the complex impulse response of the \( i \) th path, \( f_{d,i} \) is the \( i \) th path Doppler frequency shift, \( \lambda \) is delay spread index, \( T \) is the sample period and \( \tau_i \) is the \( i \) th path delay normalized by the sampling time. At the receiver, after passing to discrete domain through A/D and low pass filter, guard time is removed:

\[ y_f(n) \quad \text{for} \quad (-N_g \leq n \leq N-1) \]
\[ y(n) = y_f(n+N_g) \quad n=0,1,\ldots\ldots,N-1 \quad (6) \]

Then \( y(n) \) is sent to DFT block for the following operation:

\[ Y(k) = DFT\{y(n)\} \quad k = 0,1,2\ldots\ldots,N-1 \]
\[ = \frac{1}{N} \sum_{n=0}^{N-1} y(n) e^{-j(\frac{2\pi kn}{N})} \quad (7) \]

Assuming there is no ISI, [7] shows the relation of the resulting \( Y(k) \) to \( H(k) \) = DFT\{\( h(n) \)\}, and \( W(k) = DFT\{w(n)\} \) , with the following equation:

\[ Y(k) = X(k) H(k) + W(k) \quad (8) \]

Following DFT block, the pilot signals are extracted and the estimated channel \( \hat{H}(k) \) for the data sub-channels is obtained in channel estimation block. Then the transmitted data is estimated by:

\[ \hat{X} = \frac{Y(k)}{\hat{H}(k)} \quad (9) \]

Then the binary information data is obtained back in “signal demapeer” block. Based on principle of OFDM transmission scheme, it is easy to assign the pilot both in time domain and in frequency domain.

V. INTRODUCTION TO MIMO SYSTEM

MIMO is an important breakthrough in wireless communication. The MIMO technology has been considered as a strong candidate for next generation wireless communication systems. Using multiple transmitting as well as receiving antennas, a MIMO – OFDM system gives a high data rate without increasing the total transmission power or bandwidth compared to a single antenna system. Recently research suggests that the implementation of MIMO-OFDM is more efficient because of straight forward matrix algebra invoked for processing the MIMO-OFDM signals. It is thus seems to be an attractive solution for future broadband wireless system. The arrangement of multiple antennas at the transmission and reception end results increase in the diversity gain refers the quality of signal and multiplexing gain refers the transmission capacity.

VI. CHANNEL ESTIMATION

For wideband wireless communication systems, the channel is time varying and dispersive fading, which will distort the transmitted signals. Thus, the accurate and real time estimation of channel is a challenging task in OFDM systems. For an OFDM communication system, the channel transfer function at difference of carriers appears unequal in both time and frequency domains. Therefore a dynamic estimation of the channel is necessary. Pilot based approaches are widely used to estimate the channel properties and correct the received signals. We have investigated two types of pilot arrangements. The first kind of pilot arrangement is denoted as Block type pilot arrangement. The pilot signal assigned to a particular OFDM block, which is sent periodically in time domain. This type of pilot arrangement is especially suitable for slow fading radio channels. The second type of pilot arrangement is known as Comb type pilot arrangement. The pilot arrangements are uniformly distributed within each OFDM block. Assuming that the payloads of pilot arrangements are the same, the comb type pilot arrangement has a higher re-transmission rate. Thus, the comb type arrangement provides better resistance to fast fading channels. The comb type pilot arrangement is sensitive to frequency selectivity when compared to the block type pilot arrangement system.

VII. CHANNEL ESTIMATION BASED ON BLOCK TYPE PILOT ARRANGEMENT
In block-type pilot channel estimation, OFDM channel estimation symbols are transmitted periodically, in which all sub-carriers are used as pilots. If the channel is constant during the block, there will be no channel estimation error since the pilots are sent at all carriers. The estimation can be performed by using either LSE or MMSE [5],[6]. If inter symbol interference is eliminated by the guard interval, we write (8) in matrix notation:

\[
Y = XFh + W = XH + W
\]

Where

\[
X = \text{diag}\{X(0), X(1), \ldots, X(N-1)\}
\]

\[
Y = [Y(0), Y(1), \ldots, Y(N-1)]^T
\]

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

\[
H = [H(0), H(1), \ldots, H(N-1)]^T = \text{DFT}_{N}\{h\}
\]

\[
F = \begin{bmatrix}
W_{N}^{00} & \cdots & W_{N}^{0(N-1)} \\
\vdots & \ddots & \vdots \\
W_{N}^{(N-1)0} & \cdots & W_{N}^{(N-1)(N-1)}
\end{bmatrix}
\]

\[
W_{N}^{nk} = \frac{1}{N} e^{-j2\pi(n/N)k}
\]

VIII. MINIMUM MEAN SQUARE ERROR (MMSE) ESTIMATION

MSE (Mean square error)

\[
J(\hat{h}) = E[(H - \hat{H})^H (H - \hat{H})]
\]

\[
= E[(H - \hat{H})^H j\mu (H - \hat{H})]
\]

Here \(\hat{H} = MY\) where M is a linear estimator. Invoking the well-known orthogonality principle in order to minimize the mean square error vector \(e = H - \hat{H}\), \(\hat{H}\) has to be set orthogonal by the MMSE equalizer to the estimators input vector Y.

That is \(E[(H - \hat{H}) Y]^H = 0\)

\[
\Rightarrow E[HY]^H - ME[YY]^H = 0
\]

\[
\Rightarrow E[HY]^H - ME[YY]^H = 0
\]

If the time domain channel vector \(h\) is Gaussian and uncorrelated with the channel noise \(W\), then

\[
FR_{YY} = MR_{YY}
\]

Where \(R_{YY} = E[hY]^H\) and \(R_{YY} = E[YY]^H\)

\[
R_{YY} = E[hY]^H = E[h(XFh+w)^H]
\]

\[
R_{YY} = R_{MMSE}(X^H)
\]

Because of \(E[hw]^H = 0\) i.e. \(h\) is uncorrelated with \(w\).

\[
R_{YY} = E[YY]^H = E[(XFh+w)(XFh+w)^H]
\]

\[
R_{YY} = \text{MMSE}(X^H)
\]

Where \(\sigma^2\) is the variance of noise

\[
M = FR_{YY} R_{YY}^{-1}
\]

\[
\hat{H} = FR_{YY} R_{YY}^{-1} Y
\]

The time domain MMSE estimate of \(h\) is given by-

\[
\hat{H}_{MMSE} = FR_{YY} R_{YY}^{-1} Y
\]

IX. LEAST SQUARE ERROR (LSE) ESTIMATION

We have to minimize

\[
J = (Y-XH)^H (Y-XH)
\]

\[
= (Y^H H^H X^H Y - H^H X^H Y + H^H X^H (XH) - (XH) (XH)^H) Y^H
\]

For minimization of J we have to differentiate J with respect to \(H\)

\[
\frac{\partial J}{\partial H} = 0
\]

That is

\[
-2Y^H X - 2 \hat{H}^H X^H \hat{H} = 0
\]

\[
\Rightarrow Y^H X = \hat{H}^H X^H \hat{H}
\]

\[
\Rightarrow Y^H (X^H X)^H = \hat{H}^H (X^H X) (X^H X)^H
\]

\[
\Rightarrow Y^H (X^H X)^{-1} = \hat{H}^H
\]

\[
\hat{H} = [(X^H X)^{-1}]^H Y
\]

\[
\hat{H} = [(X^H X)^{-1}]^H Y = X^H Y
\]

\[
\hat{H} = X^H Y
\]

The time domain LS estimate of \(h\) is given by-

\[
\hat{H} = F^H X^H Y
\]

X. CHANNEL ESTIMATION BASED ON COMB TYPE PILOT ARRANGEMENT

In comb-type based channel estimation, the \(n_p\) pilot signal are uniformly inserted into \(X(k)\) according to following equation:

\[
X(k) = X(mL+1)
\]

\[
= \{X_p(k), l=0, \ldots, L-1\}
\]

Where \(L = \text{number of carriers} / n_p\), and \(L\) are uniformly inserted into \(X(k)\), and length of the cyclic prefix exceeds the channel order. After demodulation the demodulation, the received signal on the nth subcarrier corresponding to pilot symbols can be written as

\[
Y = XFh + W = XH + W
\]
\[ Y[K] = \sqrt{\varepsilon_p} H(k)X(n) + w(k), \quad k \in \mathcal{I}_p \]  \hspace{1cm} [25]

Where \( \mathcal{I}_p \) denotes the set of subcarriers on which the pilot symbols are transmitted, \( e_p \) is the transmitted power per pilot symbol, \( H(k) \) is the channel frequency response on kth carrier \( X(k), k \in \mathcal{I}_p \), is the pilot symbol, and \( w(k) \) is the complex additive white Gaussian noise (AWGN) with zero- mean and variance \( N_0/2 \). The received samples corresponding to information symbols can be expressed as

\[ Y[K] = \sqrt{\varepsilon_p} H(k)X(k) + w(k), \quad k \in \mathcal{I}_i \]  \hspace{1cm} [26]

Where \( e_i \), the transmitted power per information symbol, and \( \mathcal{I}_i \) denotes the set of subcarriers on which the information symbols are transmitted. Suppose that the total number of subcarrier is \( N \), and set of \( \mathcal{I}_p \) is \( |\mathcal{I}_p| = P \). For simplicity, we assume that the size of \( \mathcal{I}_i \) is \( |\mathcal{I}_i| = N-P \), although is possible that \( |\mathcal{I}_i| < N-P \), when null subcarriers are inserted for spectrum shaping. Selecting information symbols from M-PSK constellation, we have also that \( |X(k)| = 1, \forall k \in \mathcal{I}_i \). The frequency selective channel is assumed to be Rayleigh- fading, with channel impulse response \( h = [h(0), \ldots, h(L-1)]^T \) where \( L \) denoting the number of taps; i.e. \( h(l), \forall l \in [0, L-1] \), are uncorrelated complex Gaussian random variables with zero- mean. Channels are normalized so that

\[ \sum_{l=0}^{L-1} \sigma_h^2(l) = 1 \]. Define the \( L \times N \) matrix \( [F]_{k,n} = \exp(2\pi(l-1)(k-1)/N) \), and let \( e_p \) of it. Then the channel is complex Gaussian with zero- mean and unit variance. The average signal-to-noise ratio (SNR) per pilot (Information) symbol is \( e_p/N_0 (e_i/N_0) \). The AWGN variables \( w(k) \) are assumed to be uncorrelated, \( \forall k \).

Suppose that the set of pilot subcarrier is given by \( \mathcal{I}_p = \{k_1, \ldots, k_p\} \). Letting \( h_p := [H(k_1), \ldots, H(k_p)]^T \) contains frequency response on pilot subcarriers, and defining \( F_p := [f_{k_1}, \ldots, f_{k_p}] \), we can relate the fast Fourier transform (FFT) pair via: \( H_p = F_p h \). Let the \( P \times 1 \) vector \( Y := [Y(k_1), \ldots, Y(k_p)]^T \) consist of the received pilot samples per block, and define \( X_p := [X(k_1), \ldots, X(k_p)]^T \), and \( w := [w(k_1), \ldots, w(k_p)]^T \),

\[ Y = \sqrt{\varepsilon_p} D(X_p)H_p + w = \sqrt{\varepsilon_p} D(X_p)F_p h + w \]  \hspace{1cm} [27]

on pilots from only one block to estimate the channel on a per block basis. This is particularly suitable for packet data transmission, where the receiver may receive different blocks with unknown delays.

\[ \hat{h} = R_{yy}^{-1}R_{yx}y \]  \hspace{1cm} [28]

With knowledge of channel statistics, channel estimation in MMSE [6] way can be written as

\[ R_{yy} := \text{E}[yy^H] = e_p D(X_p)F_p h_p D(X_p)^H + N_0 I_p \]

\[ R_{yx} := \text{E}[yx^H] = \sqrt{\varepsilon_p} D(X_p)H_p + w = \sqrt{\varepsilon_p} D(X_p)F_p h + w \]

And \( R_{hh} := \text{E}[hh^H] = \text{diag}(\sigma_h^2(0), \sigma_h^2(L-1)) \)

The channel estimator is given by \( e = h \hat{H} \) which is Gaussian distributed with zero-mean, and covariance \( R_s := \text{E}[e e^H] = (R_s + e_p F_p h_p / N_0)^{-1} \) where \( \sigma_h^2(l) \neq 0, \forall l \), so that \( R_{hh} \) is invertible. The estimated channel frequency response on \( n \)th carrier can be obtained as-

\[ \hat{H}(k) = f_k^H \hat{h} = H(k) * (k) \]  \hspace{1cm} [29]

The estimator \( \hat{H}(k) \) is Gaussian distributed with zero mean. Since the orthogonality principle renders \( e \) uncorrelated with \( h, e(k) \) and \( \hat{H}(k) \) are uncorrelated.

\[ \text{XII. LEAST SQUARE ERROR (LSE) ESTIMATION} \]

If we define

\[ G : (\varepsilon_p F_p F_p^H (X_p) D(X_p) F_p^H)^{-1} (\sqrt{\varepsilon_p} D(X_p) F_p^H)^H \]  \hspace{1cm} [32]

then the least square error (LSE) estimate of channel impulse response is given by

\[ \hat{h} = G y = h + \eta \]  \hspace{1cm} [29]

Where \( \eta \approx G w \).

Using the fact that \( D^H(X_p)D(X_p) = I_p \), it follows that

\[ \eta \sim CN(0, (F_p F_p^H)^{-1} N_0 / e_p) \]

The estimated channel frequency response on the \( k \)th subcarrier can be obtained as

\[ \hat{H}(k) = f_k^H \hat{h} = H(k) + \nu(k) \]  \hspace{1cm} [27]

Where

\[ \nu(n) \sim CN(0, \sigma^2_{\nu(k)}) \]  \hspace{1cm} [27]

with \( \sigma^2_{\nu(k)} := f_k^H (F_p F_p^H)^{-1} f_k N_0 / e_p \)

\[ \text{XIII. CHANNEL ESTIMATION BASED ON INTERPOLATION TECHNIQUES} \]

Without going back to time domain channel frequency response for each subcarrier can be found by using interpolation techniques. In comb-type pilot based channel estimation, an efficient interpolation technique is necessary in order to estimate channel at data sub-carriers by using channel information at
pilot sub-carriers. The estimated transfer function at pilot frequencies will be

\[ \hat{H}_p(k) = \frac{Y(k)}{\sqrt{\hat{P}_p}(k)} \quad \text{for} \quad k \in \mathbb{N} \tag{30} \]

XIV. LINEAR INTERPOLATION

In the linear interpolation algorithm, two successive pilot sub-carriers are used to determine the channel response for data sub-carriers that are located in between the pilots. The channel estimation at data-carriers \( k, mL < k < (m+1)L \), is given by:

\[ H(n) = H_d(n) = H_d(mL+1) - H_p(m+1) - H_p(m) \tag{31} \]

XV. SPLINE INTERPOLATION

Spline interpolation are done by using “interp1” function of MATLAB. Spline interpolation produce a smooth and continuous polynomial fitted to given data points. Spline interpolations works better than linear interpolation for comb pilot arrangement.

XVI. RESULTS

The model allows for the signal to noise ratio and multipath to be controlled. The signal to noise ratio is set y adding a known amount of white noise to the transmitted signal.

1. In the block type arrangement BPSK & QPSK modulation scheme are used for a 64- subcarrier OFDM system with a two ray multipath channel. The channel impulse response \( h(t) \) is a time limited pulse train in the form of

\[ h(t) = \sum_m \alpha_m \delta(t - \tau_m T_s) \]

Where the amplitudes \( \alpha_m \) are complex valued, \( \tau_m \) is m th path delay and \( T_s \) is sampling time. Guard time \( T_G \) is taken such that \( 0 \leq \tau_m T_s \leq T_G \). The above continuous time relationship can be represented as a discrete time version having discrete channel impulse response \( h(n) \) as:

\[ h(n) = \sum_m \alpha_m e^{-\frac{\pi}{N} (n + (N-1)\tau_m)} \frac{\sin(\pi)}{\sin\left(\frac{\pi}{N} (\tau_m - n)\right)} \]

In the simulation for block type pilot arrangement we have taken two ray multipath channels.

\[ h(t) = \delta(t - 0.5T_s) + \delta(t - 3.5T_s) \tag{2} \]

2. In comb type pilot arrangement we have considered Rayleigh- fading channel. The frequency selective channel is assumed to be Rayleigh-fading, with channel impulse response \( h(l) = [h(0), \ldots, h(L-1)]^T \), where \( L=40 \) is the number of taps are uncorrelated complex Gaussian random variables with zero mean . We adopt an exponential power profile delay for taps.

XVII. SIMULATION RESULTS FOR BLOCK TYPE PILOT ARRANGEMENT

Fig. 4. BER for LSE estimation with Linear interpolation.

Fig. 5. BER for MMSE estimation with Linear interpolation.
XIX. CONCLUSION

In this work, we have studied LSE and MMSE estimators for both block type and comb type pilot arrangement. The estimators in this study can be used to efficiently estimate the channel in an OFDM system given a certain knowledge about channel statistics. The MMSE estimators assume a priori knowledge of noise variance and channel covariance. Moreover, its complexity is large compare to the LSE estimator. For high SNRs the LSE estimator is both simple and adequate. The MMSE estimator has good performance but high complexity. The LSE estimator has low complexity, but its performance is not as good as that MMSE estimator basically at low SNRs.

In comparison between block and comb type pilot arrangement, block type of pilot arrangement is suitable to use for slow fading channel where channel impulse response is not changing very fast. So that the channel estimated, in one block of OFDM symbols through pilot carriers can be used in next block for recovery the data which are degraded by the channel modulation. Here 64 numbers of carriers are used in one OFDM block. We calculated BER and MSE in channel estimation for different SNRs in simulation. Comb type pilot arrangement is suitable to use for fast fading channel where the channel impulse response is changing very fast even if one OFDM block. So comb type of pilot arrangement can not be used in this case. We used both data and pilot carriers in one block of OFDM symbols. Pilot carriers are used to estimate the channel impulse response. The estimated channel can be used to get back the data sent by transmitter certainly with some error. We also have compared performance of LSE with MMSE estimator. MMSE estimation is better that LSE estimator in low SNRs where at high SNRs performance of LSE estimator approaches to MMSE estimator. We also used interpolation techniques for channel estimation. simulation we have also calculated MSE for estimation of channel with number of pilot arrangement. MSE decreases when number of pilots increase. But we have to limit the number pilots when mean square error comes constant.

XX. FUTURE WORK

Following are the areas of future study which should be considered for further research work.

1. Implementation of other interpolation techniques for channel estimation: In this work we have considered only two type interpolation techniques. We can extend this work for other interpolation techniques such as second order, low-pass etc.

2. We have investigated pilot allocation for MIMO-OFDM systems with a small number of subcarriers. However, the complexity of searching the optimum pilot pattern for the large number of subcarriers is
still very high. A lower complexity method is also required for WiMAX, LTE and LTE-A, which have hundreds of subcarriers in OFDM systems. Besides, the multi-user MIMO-OFDM systems have not been taken into account. This is because the channel estimation is more complicated. It is worth to study further on dynamic pilot allocation with other channel estimation techniques.

ACKNOWLEDGMENT
On the submission of my paper, I would like to extend my gratitude & my sincere thanks to my supervisor Mr.Sharad kumar Gupta, Asst. Professor, Department of Electrical Engineering for his constant motivation and support. I truly appreciate and value his esteemed guidance and encouragement from the beginning to the end of this paper.

REFERENCES