MIMO OFDM CHANNEL ESTIMATION USING LMS ALGORITHM

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***Abstract*:** The Wireless Communication Technology has developed many folds over the past few years. One of the techniques to enhance the data rates is called Multiple Input Multiple Output in which multiple antennas are employed both at the transmitter and the receiver. These Multiple signals are transmitted from different antennas at the transmitter using the same frequency and separated in space. There are various channel estimation techniques are employed in order to judge the physical effects of the medium present. The Analysis and implementation of various estimation techniques for MIMO OFDM Systems such as Least Mean Squares (LMS), Minimum Mean Square Error (MMSE), Zero Forcing (ZF). These Channel Estimation techniques are therefore compared to effectively estimate the channel in MIMO OFDM Systems.

***Index Terms*- Zero Forcing (ZF); Least Mean Squares (LMS); Minimum Mean Square Error (MMSE); MIMO OFDM**

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing OFDM) has received a broad attention in wireless communication system due to its resistance against multipath fading and high spectral efficiency. For these reasons, it has been accepted by many of the future generation system such as LTE, IEEE802.11 and WIMAX.

At high data rates, channel distortion to data is very significant; therefore channel estimation becomes essential before the demodulation of OFDM signals .In OFDM system, channel estimation methods can be divided into two classes: blind channel estimation and pilot based channel estimation. The blind channel estimation is carried out by using the statistical properties of the received signals . In pilot based channel estimation, pilot tones that are known at priority by the receiver are multiplexed along with the data for channel estimation.

The pilot-based channel estimation can be performed by either inserting pilot tones into all subcarriers of the OFDM symbol with a specific period (block type pilot arrangement) or inserting pilot tones into each OFDM symbols with a specific period of frequency(comb-type pilot arrangement).By now, many channel estimation algorithms are used such as LS estimator and MMSE estimator. The previous performance comparison between the two channel estimation estimators are reported previously . All use the block type pilot arrangement, which is suitable for frequency selective fading. In practice, with the mobility between the transmitter and the receiver, the wireless channel is time varying channel. In order to keep track of the time-varying channel characteristic, it might incur too much pilot tones which causes data reduction. our contribution is to compare the performances of LS and MMSE over time-varying channel using comb-type pilot arrangement. Matlab simulation is used to measure the performance in term of Signal to noise ratio (SNR) and Bit error rate (BER).

MIMO OFDM

The Multiple-input multiple-output of orthogonal frequency-division multiplexing is the dominant air interface for 4G and 5G broadband wireless communications. It combines both multiple-input, multiple-output MIMO technology, which multiplies capacity by transmitting different signals over multiple antennas, and orthogonal frequency-division multiplexing (OFDM), which divides a radio channel into a large number of closely spaced sub channels to provide more reliable communications at highspeeds. The Researches conducted during the mid-1990s showed that while MIMO can be used with other popular air interfaces such as time-division multiple access (TDMA) and code-division multiple access (CDMA), the combination of multiple input multiple output and OFDM is most practical at higher data rates.

The most advanced mobile broadband network and wireless local area network standards based on MIMO-OFDM .It obtains the greatest spectral efficiency and delivers the highest capacity and data throughput. MIMO invented by Greg Raleigh in 1996 when he showed that different data streams could be transmit at the same time on the same frequency by taking advantage of the fact that signals transmit through space bounce off objects (such as the ground) and take multiple paths to the receiver. By using multiple antennas and precoding data, different data streams could be sent over different paths. Greg Raleigh suggest and later prove that the processing required by MIMO at higher speeds would be most manageable using OFDM modulation, because OFDM converts a high-speed data channel into a number of parallel lower-speed channels.

2. OFDM SYSTEM

OFDM system model block diagram in Fig1 can be described as follow: at beginning the binary is mapped according to modulation followed by serial to parallel conversion. After that, pilot sub-carriers are multiplexed with data sub-carriers, which give $X(k)$ samples. Then IFFT is performed on $X(k)$ sample that transform frequency domain samples $X(k)$ into time domain $x(n)$, which can be shown as

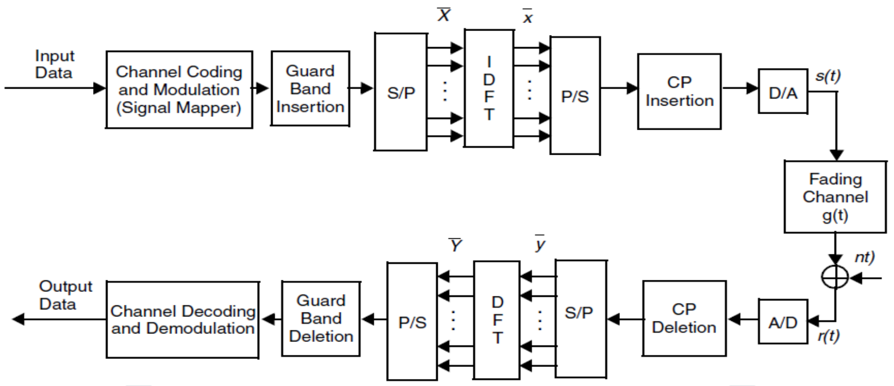

Figure 1 Basic OFDM system

After the symbol mapping process, a K-point IFFT is applied to the complex data symbols where K represents the number of orthogonal sub-carrier frequencies used. We can represent the complex baseband equivalent signal by

The channel is modeled as an impulse response g(t) followed by the complex additive white Gaussian noise (AWGN) n(t), where α_m is a complex values and $0 \le \tau_m \mathrm{T}_s \le \mathrm{T}_G$.

$$g(t) = \sum_{m=1}^{M} \alpha_m \delta(t - \tau_m \mathrm{T}_s) \qquad (1)$$

Let denote the input data of IDFT block at the transmitter and the output data of DFT block at the receiver, respectively. Let the sampled channel impulse response and AWGN, respectively. Define the input matrix and the DFT-matrix,

$$F = \begin{bmatrix} W_N^{00} \cdots & W_N^{0(N-1)} \\ W_N^{(N-1)0} \cdots & W_N^{(N-1)(N-1)} \end{bmatrix} \qquad (2)$$

Where $W_N^{i,k} = (1/\sqrt{N})^{-j2\pi(ik/N)}$

Also define $\bar{\mathrm{H}} = DF\mathrm{T}_N(\bar{g}) = F\bar{g}$, and $\bar{N} = F\bar{n}$.

Under the assumption that the interferences are completely eliminated, you can derive:

$$\bar{Y} = DF\mathrm{T}_N(IDF\mathrm{T}_N(\bar{\mathrm{X}}) \otimes \bar{g} + \bar{n}) = \mathrm{X}F\bar{g} + \bar{N} = \mathrm{X}\bar{\mathrm{H}} + \bar{N} \qquad (3)$$

After the symbol mapping process, a K-point IFFT is applied to the complex data symbols where K represents the number of orthogonal sub-carrier frequencies used. We Represent the complex baseband equivalent signal by

$$\tilde{s}(t) = \frac{1}{K} \sum_{K=0}^{K-1} \tilde{A}_k(t) e^{j2\pi k \Delta f t} \qquad (4)$$

Where f(Δ) is the frequency separation between each sub-carrier pair and is the complex amplitude for the k^{th} sub-carrier. The term $\frac{1}{k}$ in Equation (1) is inserted for convenience. Supposing that the total symbol period is T_s seconds by sampling $\tilde{s}(t)$ every $\frac{T_s}{K}$ seconds, we obtain a block of K data points defined as

$$x_n = \tilde{s}\left(\frac{nT_s}{K}\right) = \frac{1}{K}\sum_{k=0}^{k-1} A_k e^{\tilde{j}2\pi kn\Delta fT_s/k}, n = 0,1,2.....,K-1 \tag{5}$$

Choosing $\Delta fT_s = 1$ for orthogonality yields

$$x_n = \frac{1}{K}\sum_{k=0}^{k-1} A_k e^{\tilde{j}2\pi kn/K}, n = 0,1,2.....,K-1 \tag{6}$$

Equation (6) is equivalent to the inverse discrete Fourier transform (IDFT) operation, and it shows modulation of the data $\tilde{A}_k$ by the sub-carriers with digital frequencies $\frac{k2\pi}{K}$.In our simulations, we used a 128-point fast Fourier transform (FFT). The length of the IFFT output is called the OFDM symbol time, denoted as T_s.

3. CHANNEL ESTIMATION

ZERO FORCING

The zero forcing algorithm (ZF) is used, where multiplier matrix W is an inverse or pseudo inverse (PI) matrix of the channel matrix H, namely:

$$\begin{aligned} W &= \mathrm{H}^{-1} && for\ M = N \\ W &= \left(\mathrm{H}^{\mathrm{H}}\mathrm{H}\right)^{-1}\mathrm{H}^{\mathrm{H}} && for\ M \neq N \end{aligned} \tag{7}$$

With $^{\mathrm{H}}$ is complex conjugate transpose matrix H.

We have to use Least Square channel estimation technique and Zero Forcing symbol detection method in this study due to more emphasis on analysis of channel characteristic that influence on the capacity of the system with known channel that compared to the systems with estimated channel.

MMSE Estimation

The MMSE estimator employs the second-order statistics of channel conditions to minimize the mean square error. Denote by $\underline{R}_{gg}, \underline{R}_{HH}, \underline{R}_{YY}$ and the auto covariance matrix of $\overline{g}, \overline{H}, \overline{Y}$, and Respectively, and by $\underline{R}_{gY}$ the cross covariance matrix between $\overline{g}$ and $\overline{Y}$. Also denote by σ_N^2 the noise variance $E\left\{\left|\overline{N}\right|^2\right\}$. Assume that the channel vector $\overline{g}$ and the noise $\overline{N}$ are uncorrelated, it is derived that

$$\underline{R}_{HH} = E\left\{\overline{H}\,\overline{H}^H\right\} = E\left\{(\underline{F}\overline{g})^H\right\} = \underline{F}\,\underline{R}_{gg}\,\underline{F}^H \tag{8}$$

$$\underline{R}_{gY} = E\left\{\overline{g}\,\overline{Y}^H\right\} = E\left\{\overline{g}(\underline{X}\,\underline{F}\,\overline{g}) + \overline{N}^H\right\} = \underline{R}_{gg}\,\underline{F}^H\,\underline{X}^H \tag{9}$$

$$\underline{R}_{YY} = E\left\{\overline{Y}\,\overline{Y}^H\right\} = \underline{X}\,\underline{F}\,\underline{R}_{gg}\,\underline{F}^H\,\underline{X}^H + \sigma_N^2\underline{I}_N \tag{10}$$

Assume $\underline{R}_{gg}$ (thus $\underline{R}_{HH}$) and σ_N^2 are known at the receiver in advance, the MMSE estimator of $\overline{g}$ is given by $\hat{g}_{MMSE} = \underline{R}_{gY}\,\underline{R}_{YY}^{-1}\overline{Y}^{HH}$ [2–5]. Note that if $\overline{g}$ is not Gaussian $\hat{g}_{MMSE}$ is not necessarily a minimum mean-square error estimator, but it is still the best linear estimator in the mean-square error sense. At last, it is calculated that

$$\hat{H}_{MMSE} = \underline{\hat{F}}_{g\,MMSE} = \underline{F}\left[(\underline{F}^H\,\underline{X}^H)^{-1}\underline{R}_{gg}^{-1}\sigma_N^2 + XF\right]^{-1}\overline{Y} \tag{11}$$

$$= \underline{F}\,\underline{R}_{gg}\left[\left(\underline{F}^H\,\underline{X}^H\,\underline{X}\,\underline{F}\right)^{-1}\sigma_N^2 + \underline{R}_{gg}\right]\underline{F}^{-1}\,\hat{H}_{LS}$$

$$= \underline{R}_{HH}\left[\underline{R}_{HH} + \sigma_N^2\left(\underline{X}\,\underline{X}^H\right)^{-1}\right]^{-1}\hat{H}_{LS} \tag{12}$$

Hence, MMSE estimator yields much better performance than LS estimators, especially under the low SNR scenarios. The major drawback of the MMSE estimator is its high computational complexity, especially if matrix inversions are needed each time the data in $\underline{X}$ changes.

LMS Estimation

Channel estimation is based on standard LMS techniques. We can write the transmitted and the received signals in vector form as

$$r[n] = \left[r[n,0], r[n,1], \ldots.., r[n,k-1]\right]$$
$$s[n] = \left[s[n,0], s[n,1], \ldots.., s[n,k-1]\right] \qquad (13)$$

where $r[n]$ and $s[n]$ are the vectors containing samples $r[n,k]$ and $s[n,k]$ respectively for $k = 0,1,\ldots.,k-1$, and K is the total number of sub-carriers in an OFDM symbol. By simply dividing $r[n,k]$ and $s[n,k]$ we get the frequency response of the channel plus some noise. In this way, we can express the estimated channel frequency response by

$$\hat{H}[n,k] = \frac{r[n,k]}{s[n,k]}, \quad for\ k = 0,1,\ldots,K-1 \qquad (14)$$

Since the transmitted signal QPSK with unit magnitude

$$\frac{1}{s[n,k]} = s^{*}[n,k] \qquad (15)$$

and we can rewrite Equation (15) as

$$\hat{H}[n,k] = r[n,k]s^{*}[n,k], \quad for\ k = 0,1,\ldots,K-1 \qquad (16)$$

LMS has low computational complexity as compared to other channel estimators**.**

4. PROPOSED METHOD

A block type pilot arrangement depicted in Figure 2. In this time type, OFDM symbols with pilot at all subcarriers are transmitted periodically for channel estimation. Using these pilots, a time-domain interpolation is perform to estimate the channel along the time axis. Let *t s* denote the period of pilot symbols in time. In order to keep track of the time varying channel characteristic, the pilot symbols must be placed as frequently as the coherence time is. As the coherence time is given in inverse form of the Doppler frequency Doppler fin the channel, the pilot symbol period must satisfy the following inequality

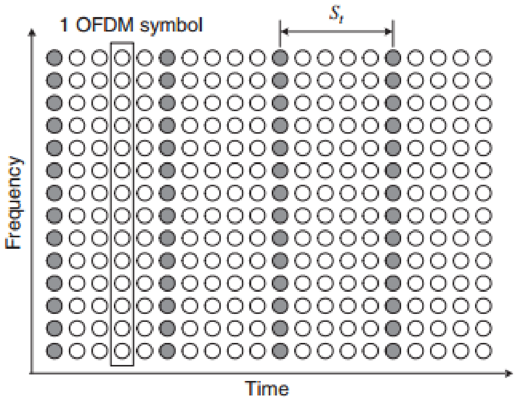

Figure 2 Block -type pilot arrangement

Aiming at this disadvantage, we propose to multiplex the pilot tones with data at each time but at specific subcarriers (Figure3). The channel is estimated at pilot subcarriers using the LS and MMSE estimators. With Interpolation techniques of the channel estimation at data subcarrier can be obtained using channel estimation at pilot subcarriers. The Np pilot signals are uniformly inserted into the subcarriers *X* (*k*) according to the following equation

$$X(k) = X(iL+l) \quad l=0,1,2,\ldots\ldots L-1$$
$$= \begin{cases} X_p(k) & l=0 \\ \text{Data} & l=1,2,\ldots\ldots L-1 \end{cases}$$

Where L = number of subcarriers (N)/number of pilots (Np) ,
i = pilot carrier index.

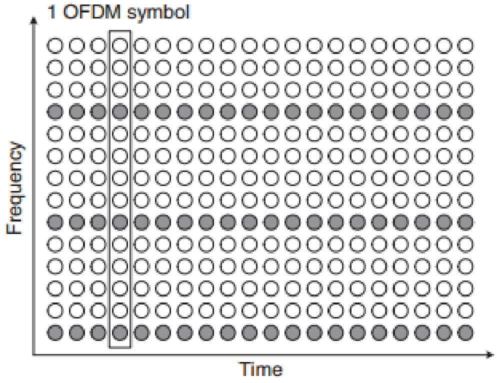

Figure 3 Comb-type pilot arrangement

5. SIMULATION AND RESULTS

This section discusses the results of the simulation using MATLAB that were performed based on the channel estimators discussed in the section III. For the basic OFDM system simulation, we used the following parameters as shown in Table.

Total number of sub channels	256
Total number of Pilots	32
Total number of data sub channels	224
guard interval length	64
modulation	2
pilot position interval	8
channel length	16
number of iteration	500
energy in pilot symbols	2
No of channel taps	3

Table1 Simulation parameters

The original channel is multiplied by the data symbols from the both transmitter including a pilot symbols. The estimated channel which is obtained by using Least Square method is called as initial estimated channel. It said the initial estimated, because only a few channel characteristics are known at the receiver, based on pilot symbols by subcarrier. Furthermore, based on the initial estimated channel, we can obtain all the overall channel estimation through the use of channel information before, in all subcarriers with no pilot symbols. Thus, Channel estimation performance is also measured based on the value of Bit Error Rate (BER). The greater the SNR is given than the smaller the BER values obtained. We also compare the BER performance in the system that use original channel and system that use estimated channel. The results showed that BER on system using the original channel are better than that using the estimated channel. The System performance can also be analyzed based on channel capacity.

The result of channel estimation is being affected by the SNR value. Larger the SNR value higher the accuracy of the estimation will be present. It relates to selection of channel estimation and detection techniques. The estimation results also affect the value of BER that would be decrease by increasing the value of SNR.

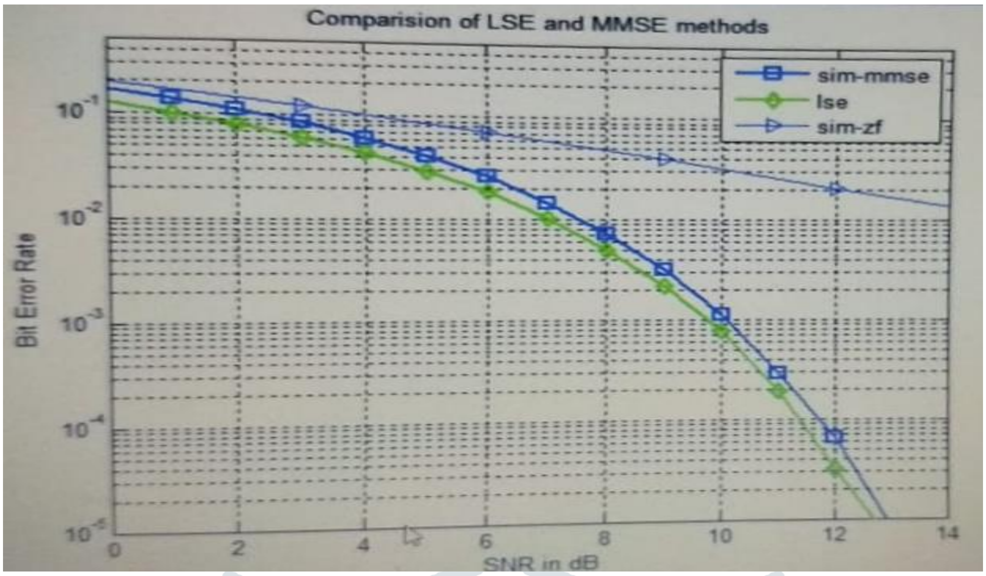

Figure 4 Comparison of LSE, MMSE and ZF methods

6. CONCLUSION

This paper highlights the comparative performance study between LS and MMSE estimators over time varying Channel using comb-type pilot arrangement. The channel estimation is one of the most fundamental issues of OFDM system design. The transmitted signal under goes many effects such reflection, refraction and diffraction. Also due to the mobility, channel response can change rapidly over time. At the receiver these channel effects must be cancelled to recover the original signal. From the present simulation based comparative study, it can be concluded that MMSE estimator provides better performance to track the time-varying channel.

7. FUTURE SCOPE

The computational complexity and stability problem increases in an algorithm as the authors tried to reduce the mean squared error. LMS is the favorable choice for the most of industries due less computational complexity and fair amount of noise reduction. All of these algorithms are worked on different parameters to remove Noise but these Algorithms use input signals as sinusoidal with random noise signal. As a future work, the same work is going to be extend in real time environment like recorded speech with different background noise and compare their performances with the different Channel estimation algorithms i.e., LMS, ZF and MMSE to achieve high convergence rate. The performance is analyzed with different parameters and length of input signal.

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