RESEARCH ARTICLE OPEN ACCESS

Significant Implementation of LS and MMSE Channel Estimation for OFDM Technique

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ABSTRACT
During the last few years, the progress in wireless communication is widely increasing to mitigate the ever increasing demand of higher data rates. OFDM (Orthogonal Frequency Division Multiplexing) techniques using more densely packed carriers, thus achieving higher data rates using similar channels. This paper discusses the channel estimation in OFDM and its implementation using MATLAB for pilot based block type channel estimation techniques by LS and MMSE algorithms. This paper starts with comparisons of OFDM using BPSK and QPSK on different channels, followed by modeling the LS and MMSE estimators on MATLAB. In the end, results of different simulations are compared to conclude that LS algorithm gives less complexity but MMSE algorithm provides comparatively better results.
Keywords: OFDM, Channel Estimation, LS, MMSE

I. INTRODUCTION:

OFDM is the most commonly employed in wireless communication systems because of the high rate of data transmission potential with efficiency for high bandwidth and its ability to combat against multi path delay. It has been used in wireless standards particularly for broadband multimedia wireless services. An important factor in the transmission of data is the estimation of channel which is essential before the demodulation of OFDM signals since the channel suffers from frequency selective fading and time varying factors for particular mobile communication systems [1]. As we know, the channel estimation is mostly done by inserting pilot symbols into all of the subscribers of an OFDM symbol or inserting pilot symbols into some of the subcarriers of each OFDM symbol. The first method is called as the pilot based block type channel estimation and it has been discussed for a slow fading channel. This paper discusses the estimation of the channel for this block type pilot arrangement which is based on LS estimator and MMSE estimator [2]. The MMSE estimator has been shown to give higher SNR for the same MSE of channel estimation over LS estimator [3].

This paper aims to compare the performance of the pilot based block type channel estimation by using BPSK modulation scheme in a slow fading channel. In section-II, the basic system model of an OFDM is discussed. In section-III, the estimation of the slow fading channel is performed based on block type pilot arrangement. In section-IV, the simulation parameters and results are discussed. Section-V concludes which is found.

II. SYSTEM DESCRIPTION FOR OF OFDM:

The OFDM system based on pilot channel estimation is given in fig.1.

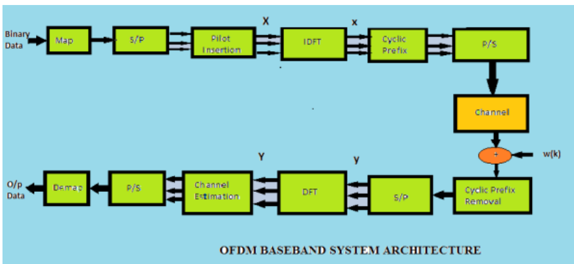

Fig. 1: Baseband OFDM system

The binary information is first grouped or collected and mapped according to the modulation in signal mapping. After inserting pilots either to all subcarriers with a specific period or uniformly between the information data sequence IDFT block is used to transform the data sequence of length N{X(k)} into time domain signal {x(n)}. Following IDFT block, guard time, which is chosen to be larger than the expected delay spread, is inserted to prevent ISI (Inter Symbol Interference). This guard time includes the cyclically extended part of OFDM symbol in order to eliminate ICI (Inter Carrier Interference).

The transmitted signal $x_f(n)$ will pass through the frequency selective time varying fading channel with additive white Gaussian noise. At the receiver side, after passing to discrete domain through A/D and LPF, guard time is removed and y (n) is sent to DFT block [4]. Following DFT block, the pilot signals are extracted and the estimated channel H_e(k) for the data sub channel is obtained in channel estimation block. After the estimation of the transmitted data by:

$$\mathrm{Y}(k) = X(k)H(k) + N(k) \quad \dots\dots\dots (1)$$

$$X_e = \frac{Y(k)}{H(k)}, \quad k=0, 1, 2\dots, N\text{-}1 \quad \dots\dots (2)$$

The input binary information data is obtained back in signal demapper block. This way data information is transferred using OFDM system.

III. Description on Channel Estimation for OFDM

The OFDM system for pilot based block type channel estimation is shown in figure 2.

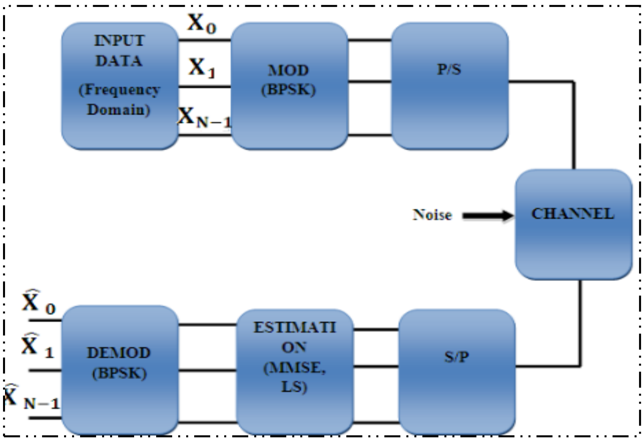

Fig.2: Channel Estimation using LS/MMSE techniques

In block type, pilot based channel estimation each subcarrier in an OFDM symbol is used in such a way that all subcarriers are used as pilots. The estimation of the channel is then done using LS estimator and MMSE estimator (5, 6).

$$\mathrm{y} = DFT_N(IDFT_N(x) \times \frac{h}{\sqrt{N}} + \tilde{n}) \quad \dots\dots (3)$$

Where, H_k is frequency response of h is given by,

sin39c functions,

$$h_k = \frac{1}{\sqrt{N}} \sum_{m=0}^{N} i_m e^{\frac{-j\pi}{N}(k+(N-1)\tau_m)} \frac{\sin(\pi\tau_m)}{\sin\frac{(\pi(\tau_m - k))}{N}} \dots\dots\dots (4)$$

$$\mathrm{Y}(k) = X(k)H(k) + N(k) \quad \dots\dots (5)$$

For simplicity, we may rewrite above equation as following:

$$\mathrm{Y{=}XFh + n} \quad \dots\dots\dots\dots (6)$$

Where F is the DFT matrix

X= diag$\{x_0, x_1, \dots, x_{N-1}\}$
Y= $[y_0, y_1, \dots, y_{N-1}]$
w= $[w_0, w_1, \dots, w_{N-1}]$
h=$[h_0, h_1, \dots, h_{N-1}]$

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

F is the matrix of DFT with corresponding weights given as:

$$W_N^{nk} = \frac{1}{\sqrt{N}} e^{-j2\pi\frac{nk}{N}} \quad \dots\dots (7)$$

If the channel vector g is Gaussian and it is not correlated with the noise of the channel w, then the MMSE estimates of g becomes [6].

$$H_{MMSE} = \widehat{FR}_{hy} R^{-1}{}_{yy}\, y \quad \dots\dots (8)$$

Where, $R_{hy} = E\{hy^h\} = R_{hy} F^H X^H$

$R_{yy} = E\{yy^H\} = \mathrm{X F} R_{hh} F^H X^H + \sigma_n^2 I_N$

Here, R_{hy} is the cross correlation matrix between h and y, R_{yy} is the auto correlation matrix of y with itself and R_{hh} is the auto correlation matrix of the h with itself. Since σ_n^2 denotes the noise variance [4].

The R_{hh} and σ_n^2 are assumed to be known parameter. The LS estimate of the channel is given as:

$$\widehat{h_{LS}} = X^{-1}Y = Y/X \quad \dots\dots (9)$$

This minimizes $(y - XFh)^H(y - XFh)$.

Both above estimators suffer from different drawbacks. The MMSE usually suffers from a high complexity than LS, but where here LS estimator suffers from MSE which is high. The MMSE estimator requires to calculate an N× N matrix which results in a high complexity when N becomes large value [5].Here keep in mind that both these estimators are derived under the assumption [4] of known channel correlation and noise variance, σ_n^2 .

IV. IMPLEMENTED SIMULATION AND RESULTS

In this section discussing the results of the implemented simulation that were performed based on the information and mathematics discussed in above and based on this simulation, comparing both channel estimation techniques. For the simulation this OFDM system, we should have following parameters as shown in table below:

Parameters	Specifications
FFT size	64
Subcarriers, N	256
No. of Pilots	32
Pilot Position Interval	8
OFDM symbols	500
Modulation	BPSK,QPSK
Channel Length	16
Channel	AWGN

V. SIMULATION RESULTS:

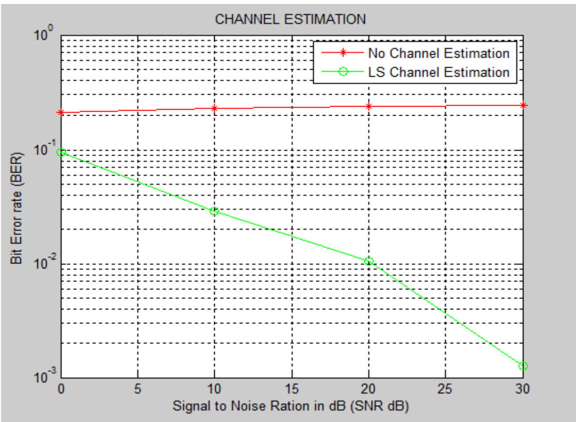

Fig.3: Comparison of BER for No channel estimation and LS Channel estimation

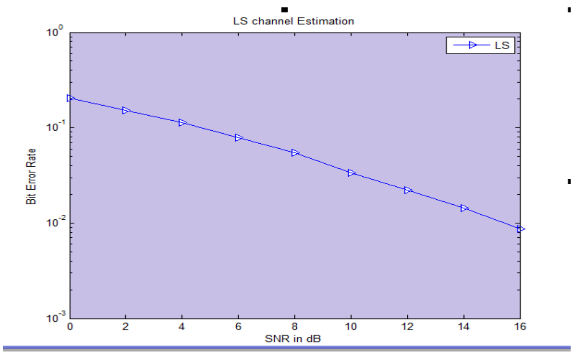

Fig.4: LS Channel Estimation

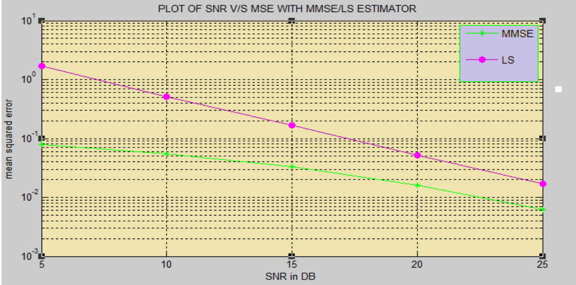

Fig.5: Plot of SNR Vs MSE with MMSE/LS Estimator

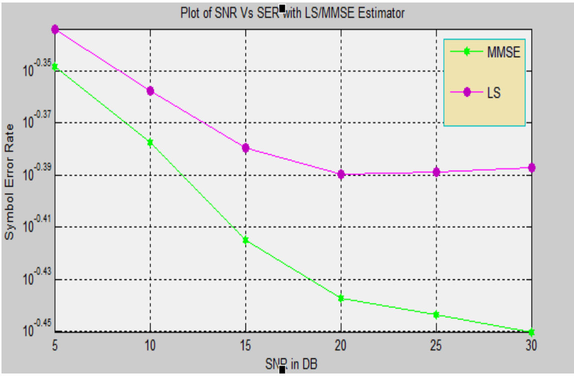

Fig.6: Plot of SNR Vs SER with LS/MMSE Estimator

The fig. shows the MSE Vs SNR for the LS and MMSE estimators. For low SNRs channel noise effect is higher than the approximation effect, while it becomes dominant for large SNRs. BER curves based on the MSE of the channel estimation. For the calculation of BER, the simulation makes use of the formulae calculated earlier.

In the simulation we first transmitted the training symbols just to estimate the behavior of the channel so that these results can be used again for the actual transmission in the simulation code.

VI. CONCLUSION

The paper describes the channel estimation technique based on pilot aided block type training symbols using LS and MMSE algorithm. The channel estimation is one of the fundamental key of OFDM system design, which shows the added noisy signal with the transmitted signal and goes many effects such reflection, refraction and diffraction. So due to these channel estimation techniques, calculate received signal and these added noisy signals must be eliminated to recover the original signal at the receiver side.

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