Performance Evaluation of MMSE and LS Channel Estimation in OFDM System

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***Abstract*— Since from last two decade Orthogonal Frequency Division Multiplexing (OFDM) got lots interest in mobile communication systems. In OFDM system, the radio channels which we use are frequency selective and vary with time for wireless wideband mobile communication system. The transfer function of these radio channels is unequal in time as well as in frequency domain, due to which a dynamic estimation of these channels should required at the demodulation point of OFDM. In this research work, we use Pilot-aided Least Square (LS) and Minimum Mean- Square Error (MMSE) estimator for estimating the channel of OFDM system with different modulation techniques i.e. 16-PSK, 4-QAM, 8-QAM,16-QAM. In simulation, we compare the performance of both estimators with proposed modulation schemes, which results that LS has preferred performance with low complexity while MMSE has best performance with one drawback i.e. it has high complexity.**

***Keywords*--OFMD, Communication Channel, MMSE, LS, PSK, and QAM.**

I.INDRODUCTION

Current and future broadband wireless communication systems aim to provide high data rate services. As a result, multipath fading becomes a major concern as systems with high data rate are more liable to inter symbol interference (ISI) due to the increase in the normalized delay spread. It is hence interesting to use modulation schemes that were robust to multipath fading. Orthogonal Frequency Division Multiplexing (OFDM), because of the division of a high rate data stream into a parallel of lower rate data streams, provides the much needed resistance to multipath fading and has attracted increasing interest in past decade.

Due to the some characteristics of OFDM i.e. high data rate transmission, high bandwidth efficiency and its robustness to multipath delay, it is applied to the wireless communication systems. OFDM is also used in the wireless LAN standards and in multimedia wireless services i.e. Japanese Multimedia Mobile Access Communication. Due to the frequency selective nature and time varying nature of the radio channels used in OFDM system, channel estimation is required before the modulation of OFDM [1].

OFDM enables simple equalization of frequency selective finite impulse response (FIR) channels. It is the blessing of the Inverse fast Fourier Transform (IFFT) pre-coding and Cyclic Prefix (CP) of having length greater than that of the length of channel memory at the transmitter end. In each block the CP consists of redundant symbols before the IFFT. At the transmitter the combination of IFFT and CP with FFT at receiver converts the frequency selective channels into parallel flat faded sub-channels, each one with different sub-carriers. These flat fades can be removed by dividing each sub-channel output with channel attenuation at the prospective sub-carrier.

In OFDM system, the estimation channel can be done either by adding pilot tones with all symbols having specific period. The two basic technique used for estimating the channel are Block type pilot channel and comb type pilot channel estimation, in which the pilots are inserted in frequency and time direction respectively. LS is used to arrange the block type pilot based scheme under the assumption that the channel is slow faded, while the transfer function of channel is considered as stationary for OFDM data. The transfer function of previous channel is used as the transfer function of present channel. Practically, the channel transfer function of a wideband radio channel may have significant changes even within one OFDM block. Hence, the channel estimation is required at every block of the OFDM symbol.

Firstly, the features of OFDM system are introduced including modulation based on Fast Fourier Transform (FFT), the system structure of OFDM and its mechanism used to counteract frequency-selective fading. In this research work we compare the LS and MMSE under the influence of different modulation techniques in MATLAB emulator.

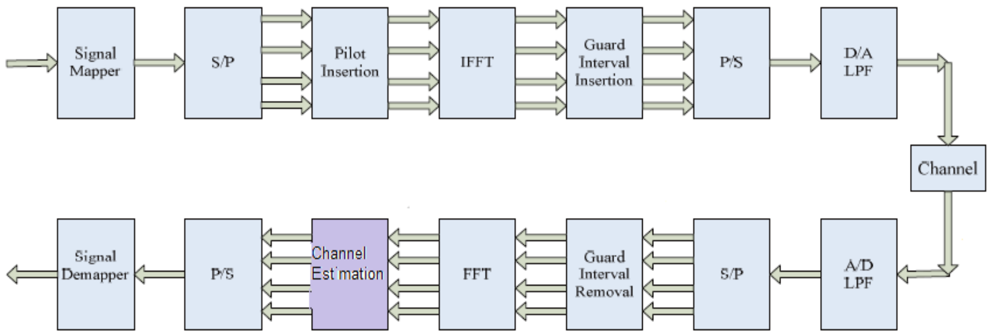

Fig.1 Baseband OFDM system

II. SYSTEM DESCRIPTION

The pilot based channel estimation based OFDM system is shown in fig.1. The binary information is firstly grouped according to modulation in ''signal mapper.'' After adding pilots either to all sub-carriers with specific time period between the information data sequence. IDFT block in base band OFDM system is used to transform the data sequence of length $L\{U(x)\}$ into time domain signal $\{s(v)\}$ with the following equations:

$$s(v) = IDFT\{U(x)\} \qquad v=0,1,2,\ldots\ldots,L-1$$

$$= \sum_{x=0}^{L-1} U(x) e^{j(2\pi x v/L)}$$

Where, L is 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:

$$s_f(v) = \begin{cases} s(L+v), & v = -L_g, -L_g+1, \ldots, -1 \\ s(v), & v = 0, 1, \ldots\ldots, L-1 \end{cases}$$

Where, L_g is the length of the guard interval. The transmitted signal $s_f(v)$ will pass through the frequency selective time varying fading channel with additive noise. The received signal is given by:

$$y_f(v) = s_f(v) \otimes h(v) + w(v)$$

Where, $w(v)$is Additive White Gaussian Noise (AWGN) and $h(v)$is the channel impulse response. The channel response h can be represented by [2]

$$h(v) = \sum_{i=0}^{r-1} h_i e^{j(2\pi/L) f_{Di} T_v} \delta(\lambda - \tau_i) \qquad 0 \le v \le L-1$$

Where, r is the total number of propagation paths, $h_i$is the complex impulse response of the ith path, $f_{Di}$is the ith path Doppler frequency shift, λ is the delay spread index, T is the sample period and τ_i is the ith path delay normalized by the sampling time. At the receiver, after passing to the discrete domain through A/D and low pass filter, guard time is removed:

$$y_f(v) \qquad for -L_g \le v \le L-1$$

$$y(v) = y_f(v + L_g), \quad v = 0,1, \ldots\ldots L-1$$

Then $y(v)$ is sent to DFT block for the following operation:

$$Y(x) = DFT\{y(v)\} \quad x = 0,1,2 \ldots . L-1$$

$$= \frac{1}{L} \sum_{v=0}^{L-1} y(v) e^{-j(2\pi x v/L)}$$

Let us considered that there is no ISI [3], shows the relation of the resulting Y(x) to H(x) = DFT {h(v)}, I(x) that is ICI because of Doppler frequency and W(x) = DFT {w(v)}, with the following equation [4]:

$$Y(x) = U(x)H(x) + I(x) + W(x)$$

$$x = 0,1 \dots . L-1$$

Following DFT block, the pilot signals are extracted and the estimated channel $H_e(x)$ for the data sub-channel is obtained in channel estimation block. Then the transmitted data is estimated by:

$$U_e = \frac{Y(x)}{H_e(x)} \qquad x = 0,1, \dots L-1$$

Then the binary information data is obtained back in ‘’signal demapper’’ block.

III. CHANNEL ESTIMATION

The different types of channel estimators considered in our research work. After channel estimation process at pilot subcarrier position, the channel responses at the rest of data sub-carrier are estimated by interpolation. Firstly, interpolation at time domain which has two symbols time spacing. In our research work we use linear interpolation for time domain interpolation because it is sufficient for small time spacing.

III.1. LS Channel Estimation

In the simple case, the channel estimates, are found by straight forward multiplying the received pilot by the inverse of known transmitted pilot. This method is also known as Least Square (LS) estimator, [5]:

$$\hat{H}_{Pi,LS} = X_P^{-1}Y_p = \left[\frac{Y_{Pi}(1)}{X_{Pi}(1)}\frac{Y_{Pi}(2)}{X_{Pi}(2)}\cdots\frac{Y_{Pi}(N_{Pi})}{X_{Pi}(N_{Pi})}\right]^T$$

Without using any knowledge of statistics of the channels. The LS Estimator has very low complexity, but they suffer from a high mean-square error.

III.2. MMSE Channel Estimation

The MMSE channel estimator obeys the second order statistics of channel condition to minimize the mean-square error the major drawback of MMSE estimator is its high complexity, which grow exponentially with observative samples. The frequency domain MMSE estimate of channel response is given as [6]

$$\hat{H}_{Pi,MMSE} = R_{H_{Pi}H_{Pi}}\left(R_{H_{Pi}H_{Pi}} + \sigma_v^2(X_{Pi}X_{Pi}^H)^{-1}\right)^{-1}\hat{H}_{Pi,LS}$$

Where, $\hat{H}_{Pi,LS}$ is LS estimate of channel condition at the pilot position, σ_v^2 is variance of noise, $X_{Pi}$is a matrix having transmitted pilot on its diagonal, and $R_{H_{Pi}H_{Pi}}$ is channel autocorrelation matrix which is given by

$$R_{H_{Pi}H_{Pi}} = E\left(H_{Pi}{H_{Pi}}^H\right)$$

For this given case, the correlation function between channel frequency response values is given as [7]

$$E\{H_m H_V^*\}\begin{cases}1, & m = v\\ \dfrac{1-e^{-j2\pi(N_g(m-v)/L)}}{j2\pi\left(N_g(m-v)/L\right)} & m \neq v\end{cases}$$

From above equation we get $R_{H_{Pi}H_{Pi}}$MMSE interpolation for all sub-carrier can be performing by modifying the MMSE estimator at equation to get all data sub-carrier’s channel responses.

$$\hat{H}_{MMSE} = R_{H_{Pi}}\left(R_{H_{Pi}} + \sigma_v^2(X_{Pi}X_{Pi}^H)^{-1}\right)^{-1}\hat{H}_{Pi,LS} = Q\hat{H}_{Pi,LS}$$

The MMSE estimator uses a known knowledge of σ_v^2 and $R_{H_{Pi}H_{Pi}}$, and is optimal when these statistics of channel are known. The values of SNR are predefined: higher target SNRs are easy to obtain more accurate estimates. The robustness estimator design requires account for worst correlation of multipath channel, namely when channel power-delay profile (PDP) is uniform in nature [8].

IV. SIMULATION AND EXPERIMENT

This section, tells about the performance of channel estimation by LS and MMSE for OFDM system under the influence of different modulation techniques, in the terms of channel MMSE and E_b/N_o. For simulation we set length of IFFT to 64 and length of cyclic prefix (CP) is 8.

In our research work and simulation result we compare the performance of LS in frequency domain and MMSE in frequency and time domain. In fig.2 we use 4-QAM with the bit of per symbol is 2. In fig.3 we use 8-QAM having bit per symbol is 3. In fig.4 we are using 16-QAM with the bit per symbol is 4. In fig.5 we are using 8-PSK with the bit per symbol 3 and in fig.6 we are using 16-PSK with the bit per symbol equal to 4. Fig.2-fig.6 is shown below in perspective order.

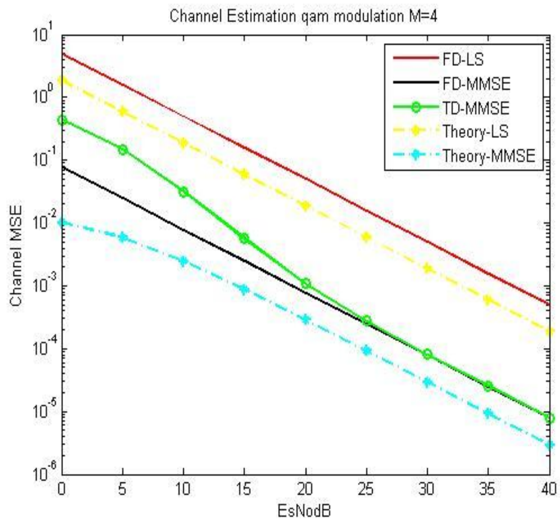

Fig.2.Channel estimation by LS and MMSE using 4-QAM

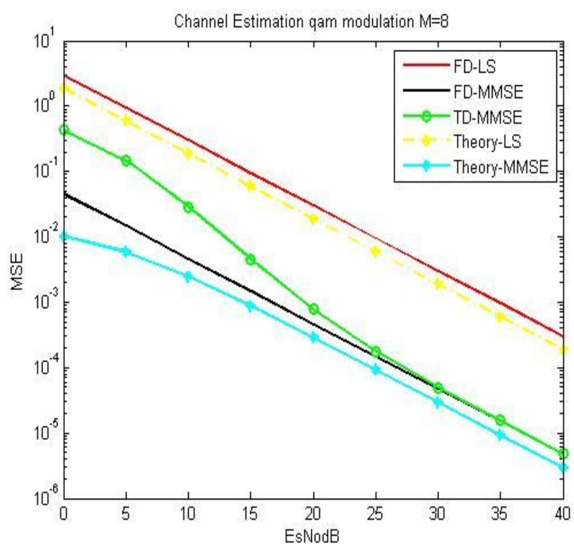

Fig.3. Channel estimation by LS and MMSE using 8-QAM.

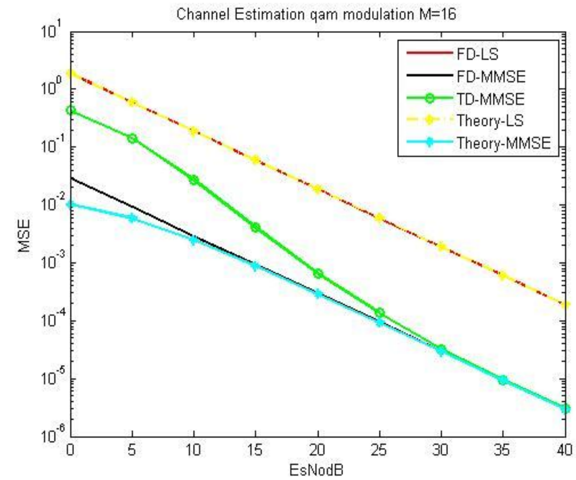

Fig.4. Channel estimation by LS and MMSE using 16-QAM

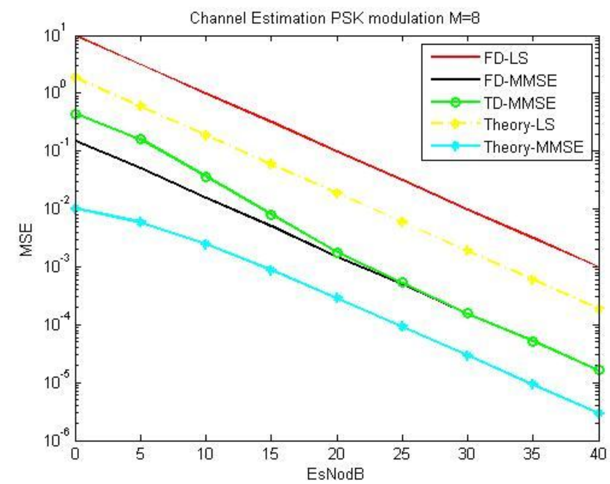

Fig.5. Channel estimation by LS and MMSE using 8-PSK

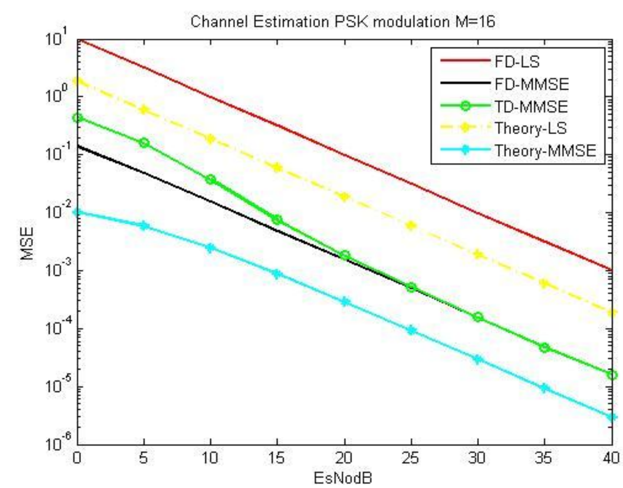

Fig..6. Channel estimation by LS and MMSE using16-PSK

VI. CONCLUSION

The result of our research work that, mean square error is continuously improved as the SNR increases to its maximum value i.e. 40 dB. When we compare the LS and MMSE in terms of mean square error later one gives better performance than former. Furthermore, MMSE works much better in frequency domain than time domain at the higher value of SNR. When we use, 16-QAM as a modulation technique in OFDM system the channel estimation result is very much improved in comparison of 4-QAM, 8-QAM, 8-PSK, and 16-PSK.

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