Linear and Non Linear Estimators For Efficient Channel Estimation with Filtering in OFDM System

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Abstract - Estimation of the channel in OFDM wireless system is the need to improve the system performance and make changes in the designs to prepare system for the immunity against noises. The information sent from source is delivered to the destination with minimum attenuation in the information. Every wireless communication system has a major influence by the information transferring media (channel). The behavior of wireless channel is quite varying in nature so that the predictions of noises disturbing signals is very crucial task. So the estimation of channel play a very important role make wireless communication system better. Here the channel estimation is done and the mean square error(MSE) is calculated for proposed methodology using 4-QAM Modulation and Filter. The system outperformed with the use of MMSE and LS estimators.

Keywords - Channel Estimation, Median Filter, MSE, 4-QAM and BPSK.

I. INTRODUCTION

MIMO technology has attracted attention in wireless communications, because it increases in data throughput without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability or diversity. The combination of MIMO with OFDM technique is a promising technique for the next generation wireless communication. A new protocol draft employing the MIMO-OFDM as the physical layer technology, IEEE 802.11n, as an amendment to IEEE 802.11 standards has been proposed. Wireless LAN technology has seen rapid advancements and MIMO-OFDM has gradually been adopted in its standards. The following table shows the existing IEEE 802.11 WLAN protocols.

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). 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 the inverse Fast Fourier Transform (IFFT), mitigation of inter-symbol interference (ISI) by inserting cyclic prefix(CP) and robustness to frequency selective fading channel. MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology.

Wireless Channel:

Since there exist reflections, scattering, and diffraction in the transmission of electromagnetic wave, the spatial environments such as the landscape of a city, obstructions and so on will make complicated impacts on the transmission of electromagnetic wave. There are two kinds of propagation, including the large-scale propagation and the small scale propagation. The signal variations due to path loss or shadowing occur over relatively large distances, this variation is referred to as the large scale propagation effects. Path loss is a major component in the analysis and design of the link budget of a telecommunication system. The small scale propagation refers to the phenomena that the amplitude of the received wireless signal varies very fast in a short time period or a short distance. The sources of small scale propagation include the Doppler shift effect and multi-path effect. We begin with the introduction of the large scale propagation.

II. DIFFERENT ESTIMATORS

For wide-band wireless communication systems, the channel is time varying and dispersive fading, which will distort the transmitted signal. Thus, the accurate and real-time estimation of channel is a challenging task in OFDM systems. The present channel estimation methods generally can be divided into two kinds. One kind is based on the pilots and the other is blind channel estimation which does not use pilots. Blind channel estimation methods do not use pilots and have higher spectral efficiency. However, they often suffer from high computation complexity and low convergence speed since they often need a large amount of receiving data to obtain some statistical information such as cyclostationarity induced by the cyclic prefix. Blind channel estimation methods are not suitable for applications with fast varying fading channels.

Least square (LS) estimator:

The LS estimator minimizes the following cost function.

$$\min_{\hat{h}} (\boldsymbol{Y} - \boldsymbol{X}\hat{\boldsymbol{h}})^H (\boldsymbol{Y} - \boldsymbol{X}\hat{\boldsymbol{h}})$$

, where *[.]*^{H} is the Hermitian (conjugate) transpose operator. Then, the LS estimation of *h* is given by

$$\hat{\boldsymbol{h}}_{LS} = \frac{\boldsymbol{Y}}{\boldsymbol{X}} = \left[\frac{Y_k}{X_k}\right]^T$$

, where *[.]*^{T} is the transpose operator and k = 0, 1, . . . , N-1. This LS estimator is equivalent to what is also referred to as the zero-forcing estimator [22, 30] since it can also be obtained from the time domain LS estimator with no assumption on the number of CIR taps or length. That is,

$$\hat{\boldsymbol{h}}_{LS} = \boldsymbol{F}\boldsymbol{Q}_{LS}\boldsymbol{F}^{\boldsymbol{H}}\boldsymbol{X}^{\boldsymbol{H}}\boldsymbol{Y}$$

, where

$$\boldsymbol{Q}_{LS} = (\boldsymbol{F}^{\boldsymbol{H}}\boldsymbol{X}^{\boldsymbol{H}}\boldsymbol{X}\boldsymbol{F})^{-1}$$

Note that this simple LS estimator does not exploit the correlation of channel across subcarriers in frequency and across the OFDM symbols in time. Without using any knowledge of the statistics of the channel, the LS estimator can be calculated with very low complexity, but it has a high mean-square error since it does not take into account of the effect of noise on the signal.

Minimum Mean-Square Error Estimator:

The minimum mean-square error is widely used in the OFDM channel estimation since it is optimum in terms of mean square error (MSE) in the presence of AWGN [7]. In fact, it is observed in [15] that many channel estimation techniques are indeed a subset of MMSE channel estimation technique. The MMSE estimator employs the second-order statistics of the channel, channel correlation function, and the operating SNR.

Let us define $\boldsymbol{R_{gg}}$, $\boldsymbol{R_{hh}}$, and $\boldsymbol{R_{YY}}$ as the autocovariance matrix of ***g, h***, and $\boldsymbol{Y}$, respectively. We also define $\boldsymbol{R_{gY}}$ as the cross covariance matrix between g and $\boldsymbol{Y}$. Assuming the channel vector, ***h***, and the noise vector, ***n***, are uncorrelated, we derive that

$$\boldsymbol{R_{hh}} = E\left\{\boldsymbol{H}\boldsymbol{H}^H\right\} = E\left\{(\boldsymbol{F}\boldsymbol{g})(\boldsymbol{F}\boldsymbol{g})^H\right\} = \boldsymbol{F}\boldsymbol{R_{gg}}\boldsymbol{F}^H$$

$$\boldsymbol{R_{gY}} = E\left\{\boldsymbol{g}\boldsymbol{Y}^H\right\} = E\left\{\boldsymbol{g}(\boldsymbol{X}\boldsymbol{F}\boldsymbol{g}+\boldsymbol{n})^H\right\} = \boldsymbol{R_{gg}}\boldsymbol{F}^H\boldsymbol{X}^H$$

, and

$$\boldsymbol{R_{YY}} = E\left\{\boldsymbol{Y}\boldsymbol{Y}^H\right\} = \boldsymbol{X}\boldsymbol{F}\boldsymbol{R_{gg}}\boldsymbol{F}^H\boldsymbol{X}^H + \sigma_{\boldsymbol{n}}^2\boldsymbol{I}_N$$

where σ_n^2 is the noise variance,$E\{|n|^2\}$, and IN is the NxN Identity matrix. Assuming the channel correlation matrix, Rhh, and the operating SNR, σ_n^2 , are known at the receiver, the MMSE estimator of g is given by [2].

$$\hat{\boldsymbol{g}}_{MMSE} = \boldsymbol{R_{gY}}\boldsymbol{R_{YY}^{-1}}\boldsymbol{Y}$$

Finally, combining the above equations, the frequency domain MMSE estimator can be calculated by

$$\begin{aligned}
\hat{\boldsymbol{h}}_{MMSE} &= \boldsymbol{F}\hat{\boldsymbol{g}}_{MMSE} \\
&= \boldsymbol{F}[(\boldsymbol{F}^H\boldsymbol{X}^H)^{-1}\boldsymbol{R_{gg}^{-1}}\sigma_{\boldsymbol{n}}^2 + \boldsymbol{X}\boldsymbol{F}]^{-1}\boldsymbol{Y} \\
&= \boldsymbol{F}\boldsymbol{R_{gg}}[(\boldsymbol{F}^H\boldsymbol{X}^H\boldsymbol{X}\boldsymbol{F})^{-1}\sigma_{\boldsymbol{n}}^2 + \boldsymbol{R_{gg}}]\boldsymbol{F^{-1}}\hat{\boldsymbol{h}}_{LS} \\
&= \boldsymbol{R_{hh}}[\boldsymbol{R_{hh}} + \sigma_{\boldsymbol{n}}^2(\boldsymbol{X}\boldsymbol{X}^H)^{-1}]^{-1}\hat{\boldsymbol{h}}_{LS}.
\end{aligned}$$

The above MMSE estimator yields much better performance than LS estimator, especially under the low SNR scenarios. However, a major drawback of the MMSE estimator is its high computational complexity, since the matrix inversion of size NxN is needed each time data in X changes.

Another drawback of this estimator is that it requires one to know the correlation of the channel and the operating SNR in order to minimize the MSE between the transmitted and received signals. However, in wireless links, the channel statistics depend on the particular environment, for example, indoor or outdoor, Line-Of-Sight (LOS) or Non-Line-Of-Sight (NLOS), and changes with time [12]. Therefore, MMSE estimator may not be feasible in a practical system.

III. PROPOSED METHODOLOGY

The wireless communication system is the best to estimate for lower mean square error and for such aim we need the efficient technique to improve system. The same aim considered here to make system better by estimating the channel performance and minimizes the MSE.

In below figure the proposed system is explained in major blocks in which the system is divided. The major blocks are in the sequence i.e. modulation, OFDM Modulation, Channel Part, OFDM Demodulation, proposed technique i.e. LS/MMSE Estimation and Median Filtering.

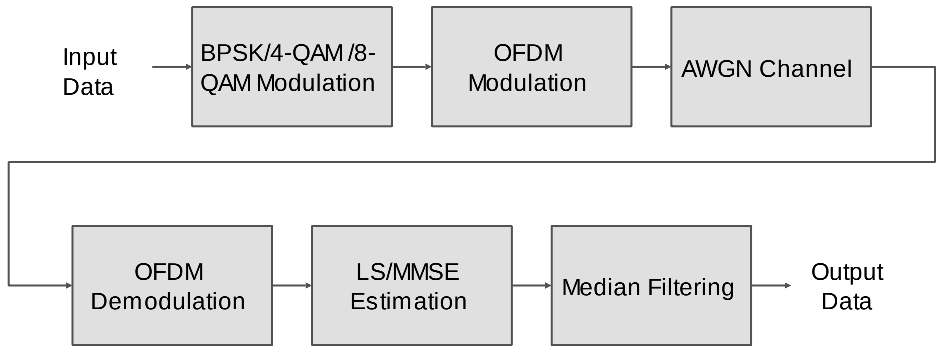

Fig. 3.1 Block Diagram of proposed methodology

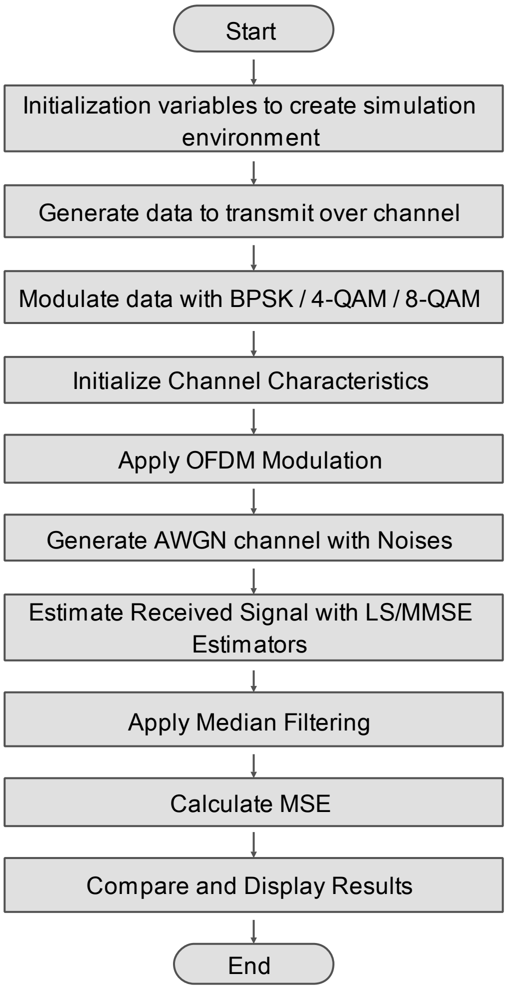

Fig. 3.2 Flow chart of proposed methodology

The above system is implemented on simulation tool and the flow of execution of algorithm is shown in below figure.

The flowchart of proposed approach is given in the figure below. The steps are as follows:

a. Start of simulation
b. The system need to be initialized before starting of simulation
c. For system analysis data is generated
d. Modulate signal with BPSK / 4-QAM / 8-QAM
e. Characteristics of the channel is initialize
f. Applying OFDM Modulation
g. Transmitting through AWGN channel with adding Noises
h. Now signal is estimated with LS and MMSE estimators
i. In addition with estimators median filtering is applied to improve the performance
j. Calculation of MSE
k. Compare and display results
l. End of simulation

IV. SIMULATION RESULTS

The proposed system is explained in the previous system implemented with the help of simulation tool and outcomes of the methodology is shown in below figures. In Fig. 4.1 the proposed methodology with system is evaluated with LS estimator and MMSE estimator and BPSK modulation to enhance the performance of system error with filtering.

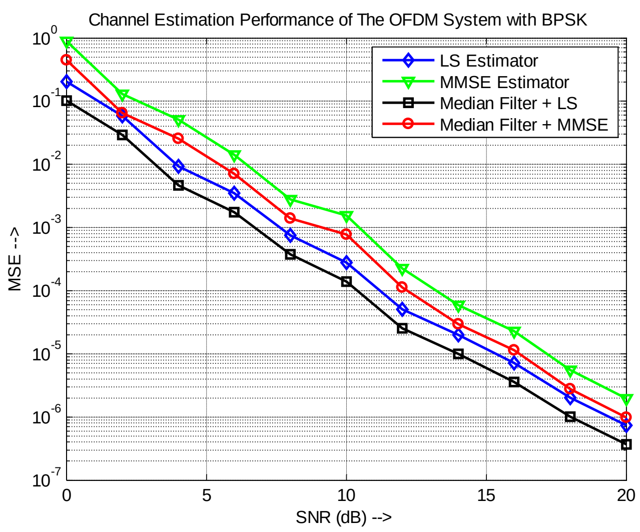

Fig. 4.1 Simulation results of Mean Square Error (MSE) with BPSK Scheme and Median Filter

By the use of median filter the performance of the system using least square estimation and minimum mean square error is improved. The below results are obtain by applying BPSK modulation technique. From the results it can be observed that the black graph i.e. least square with median filtering is optimum performance in terms of mean square error(MSE).

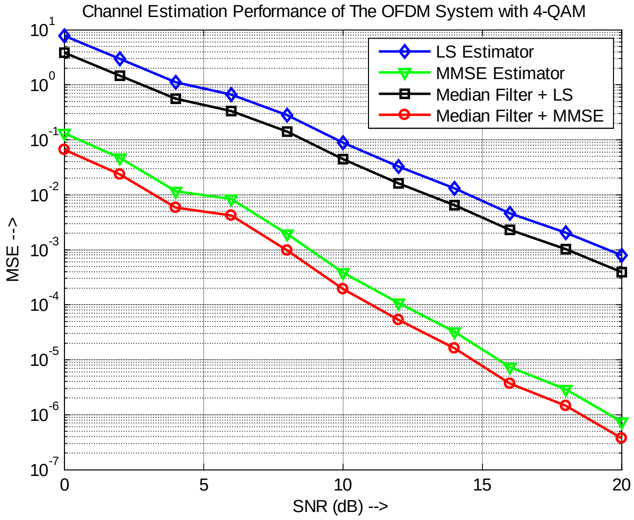

Fig. 4.2 Simulation results of Mean Square Error (MSE) with 4-QAM Scheme and Median Filter

In fig. 4.2 the proposed methodology with system is evaluated with LS estimator and MMSE estimator and 4-QAM modulation to enhance the performance of system error with filtering.

Table 5.1 Comparison of Mean Square Error(MSE)

SNR	Existing System	Proposed (Our)		
		BPSK	4-QAM	8-QAM
0	1.5 x 10^{-1}	8.69x10^{-2}	1.19x10^{-1}	1.81x10^{-2}
2	9.01 x10^{-2}	3.32x10^{-2}	2.07x10^{-2}	5.86x10^{-3}
4	5.11 x10^{-2}	2.19x10^{-2}	1.18x10^{-2}	1.78x10^{-3}
6	2.31 x10^{-2}	3.98x10^{-3}	1.88x10^{-3}	4.92x10^{-4}
8	1.15 x10^{-2}	6.70x10^{-4}	6.21x10^{-4}	1.39x10^{-4}
10	6.51 x10^{-3}	2.32x10^{-4}	1.06x10^{-4}	3.57x10^{-5}
12	4.51 x10^{-3}	7.40x10^{-5}	2.61x10^{-5}	1.66x10^{-5}
14	2.31 x10^{-3}	1.54x10^{-5}	2.11x10^{-5}	3.76x10^{-6}
16	1.21 x10^{-3}	5.01x10^{-6}	5.82x10^{-6}	7.20x10^{-7}
18	7.51 x10^{-4}	1.31x10^{-6}	1.11x10^{-6}	2.43x10^{-7}
20	4.91 x10^{-4}	7.59x10^{-7}	4.38x10^{-7}	9.16x10^{-8}

In fig. 4.2 the proposed methodology with system is evaluated with LS estimator and MMSE estimator and 8-QAM modulation to enhance the performance of system error with filtering.

By the use of median filter the performance of the system using least square estimation and minimum mean square error is improved. The below results are obtain by applying 8-QAM modulation technique. From the results it can be observed that the black graph i.e. minimum mean square error with median filtering is optimum performance in terms of mean square error(MSE).

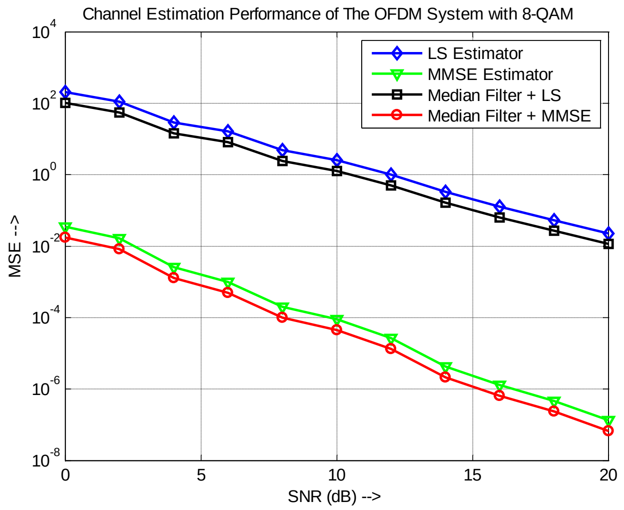

Fig. 4.3 Simulation results of Mean Square Error (MSE) with 8-QAM Scheme and Median Filter

V. Conclusion and Future Scope

The OFDM based wireless communication system is channel estimated and after studying of various effective techniques, here least square(LS) and minimum mean square error(MMSE) are taken into consideration for estimation of channel and to reduce the mean square error (MSE) median filtering(MF) is used followed by LS and MMSE estimators. After analysis of the system using BPSK and 8-QAM modulation techniques it is found that the when MMSE is used with 8-QAM the MSE is better and if LS is used with 8-QAM than also MSE is better. Now with the less complex modulation technique i.e. BPSK is preferred over other. So that BPSK is best with LS estimator and median filtering.

In the future more effective estimators make great change in the system with proposed median filtering technique and more efficient modulation enhance the system performance and reduce mean square error(MSE).

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