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Performance Evaluation of Channel Estimation Techniques in OFDM based Mobile Wireless System

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Abstract

In this modern wireless technology Multicarrier communication is one of the more suitable and reliable communication technique. Orthogonal Frequency Division Multiplexing (OFDM) is used as modulation technique in multicarrier communication. The present paper gives an overview of OFDM and the various Channel Estimation techniques used in OFDM. The results implemented in MATLAB gives the performance of LS and the MMSE channel estimators for an OFDM system based on the parameters of BER and MSE. Paper also describes the Delayed feedback MIMO OFDM channel estimation performance of LS and LMMSE and DFT based channel estimation technique for LS-linear and MMSE estimator. BPSK and 16-QAM modulation techniques are used.

Keywords: *OFDM, BER, MSE, LS, MMSE*

1. Introduction

There are no limit of human desire, so day by day we need much higher data speed to facilitate our need but every physical resource like frequency band, transmit signal strength are finite. Thus wireless communication has benefitted from substantial advances and it is considered as the key enabling technique of innovative future consumer products. For the sake of satisfying the requirements of various applications, significant technological achievements are required to ensure that wireless devices have appropriate architectures suitable for supporting a wide range of services delivered to the users [1]. In the future, the large-scale deployment of wireless devices and the requirements of high bandwidth applications are expected to lead to tremendous new challenges in terms of the efficient exploitation of the achievable spectral resources. Among the existing air-interface techniques, OFDM has shown a number of advantages and has attracted substantial interest.

Orthogonal Frequency Division Multiplexing (OFDM) is adopted as modulation technique in many advance wireless communication technologies because of its advantages like robustness to the multi-path fading, intersymbol interference and high data rate. It has been used in digital audio broadcasting (DAB) systems, digital video broadcasting (DVB) systems, digital subscriber line (DSL) standards, and in wireless LAN [2]. OFDM is an attractive air-interface for next-generation wireless network without complex equalizer. OFDM is designed such a way that it sends data over hundreds of parallel carrier which increases data rate. It has got various advantages like easy and efficient in dealing with multi-path, robust against narrow-band interference, supports various modulation schemes and perfect for MIMO etc.

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 a particular mobile communication system. The estimation channel is mostly done by inserting pilot symbols into all of the subcarriers of an OFDM symbol or inserting pilot symbols into some of the sub-carriers of each OFDM symbol [3].

In [4] author investigates and compares various efficient pilot based channel estimation schemes for OFDM systems. Two major types of pilot arrangement such as block type and comb-type pilot have been focused employing Least Square Error (LSE) and Minimum Mean Square Error (MMSE) channel estimators. In [5] author compares the performance of channel estimation algorithm in terms of Mean square error, Symbol error rate and Bit error rate. The paper highlights the channel estimation technique based on pilot aided block type training symbols using LS and MMSE algorithm and In [6] author makes a study on channel estimation algorithms for OFDM system, and puts forward an improved DFT-based channel estimation algorithm to make a good compromise between accuracy and complexity. The new method chooses significant channel samples based on threshold setting, and suppresses noise inside the cyclic prefix.

The communication channels are the important part of any communication system. There are various types of channels among them wireless channels has unreliable behavior. The state of the channel may change within a very short time span. This stochastic and rapid behavior of radio channels turns wireless data communication into a difficult task [7]. The aim of this paper is to briefly describe the OFDM system model, the various channel estimation techniques, Methodology and simulation result which compares the performance of different channel estimators and finally conclude the result at last.

2. OFDM System Model

Baseband OFDM system based on Pilot channel estimation is given in figure 1. OFDM transmitter maps the message bits into a sequence according to the modulation type in the mapper which will be subsequently converted into N parallel streams. After that pilots are inserted to all the sub-carriers uniformly between the information data sequence with a specific time period.

In practice, Discrete Fourier Transform (DFT) and Inverse DFT (IDFT) processes are useful for implementing these orthogonal signals. The N-point IDFT transforms the data sequence in time domain. Then the guard time is inserted to remove the inter symbol interference (ISI). This guard time includes the cyclically extended part of OFDM symbol in order to eliminate intercarrier interference (ICI). The transmitted signal is passes through the channel. The channel is modeled as an impulse response followed by the complex additive white Gaussian noise (AWGN).

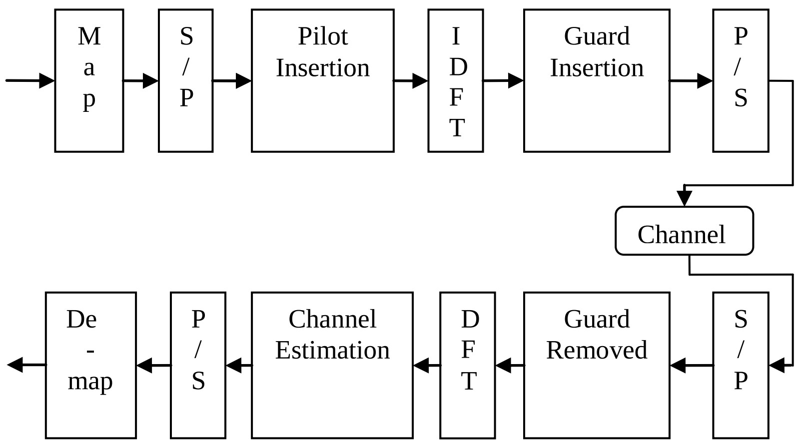

Figure 1. Baseband OFDM System [8]

At the receiver side, guard time is removed and after passing through DFT block the pilot signal gets extracted and the estimated channel for the data sub-channels is obtained in channel estimation block. Lastly, the binary information data is obtained back after the demapping [8].

2.1. Channel Estimation

In wireless communication, the channel is usually unknown a priori to the receiver. Therefore to do the channel estimation, a pilot symbol aided modulation is used, where known pilot signals are periodically sent during the transmission. In general, the performance of channel estimation depends on the number, the location, and the power of pilot symbols inserted into OFDM blocks [6]. This paper describes the three types of estimators least square (LS), minimum mean square (MMSE) and linear minimum mean square (LMMSE). In least squares the parameters to be estimated must arise in expressions for the means of the observations. When the parameters appear linearly in these expressions then the least squares estimation problem can be solved in closed form, and it is relatively straightforward to derive the statistical properties for the resulting parameter estimates. But LS estimator suffers with high mean square error, thus the MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error. MMSE more specifically refers to estimation in a Bayesian setting with quadratic cost function.

In many cases it is not possible to determine a closed form expression for the conditional expectation required to obtain the MMSE estimator. Direct numerical evaluation of conditional expectation is computationally expensive, since they often require multidimensional integration usually done by Monte Carlo methods thus Linear MMSE estimators are chosen in practice because they are simpler and retain the MMSE criterion. Here the constraint on the estimator is assumed to be linear. LMMSE channel estimation requires knowledge of the channel frequency correlation and the operating SNR. As the operating SNR varies, the inverted matrix should be changed for reliable estimation. On this point of view, the LMMSE channel estimation needs the matrix inversion and complex multiplication in an efficient implementation [9].

The DFT-based channel estimation has received close attention for its good performance and easy implementation. The traditional DFT- based algorithm set the points outside the CP to zero and consider all the samples inside it as informative ones. However there are still some samples which contain only noise without any information of the channel inside the CP. Therefore it is necessary to reduce the noise inside the CP. Thus DFT-based channel estimation technique has been derived to improve the performance of LS or MMSE channel estimation by eliminating the effect of noise outside the maximum channel delay [10].

3. System Methodology

According to the analysis in previous section the various channel estimators like LS, MMSE, LMMSE and DFT based channel estimator has been compared. Methodology steps related to the work are as follows:

Flow chart on the technique of LS and the MMSE channel estimators for an OFDM system based on the parameters of Bit error rate (BER) is shown in fig. 2.

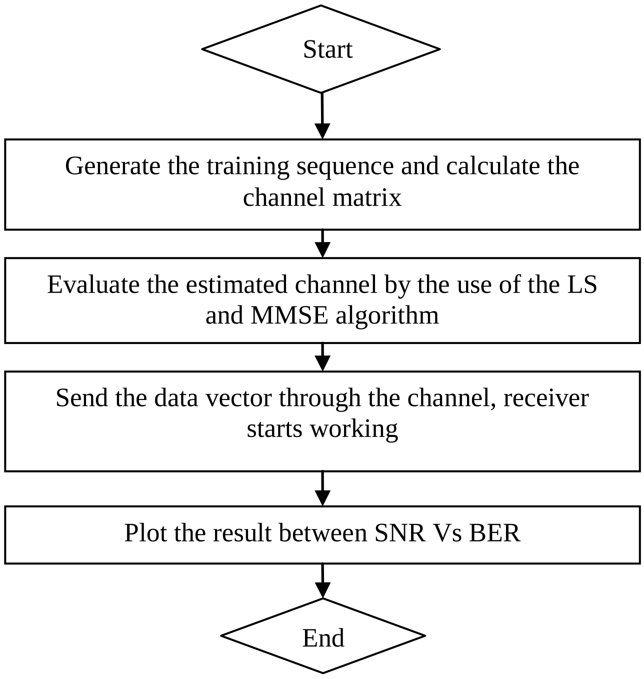

Figure 2.

Algorithm based on the performance of LS and the MMSE channel estimators for an OFDM system based on the parameters of Mean square error (MSE) is shown in fig. 3.

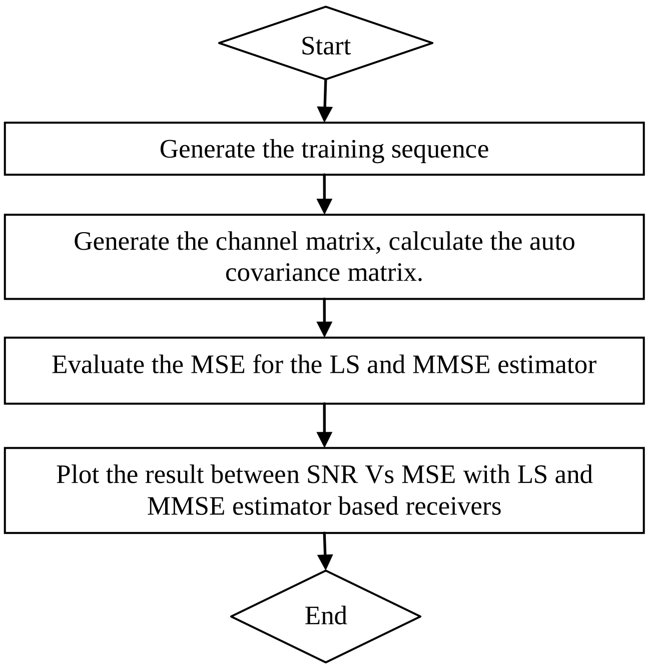

Figure 3.

Fig. 4 shows the algorithm of the Delayed feedback MIMO-OFDM channel estimation technique for the LS and LMMSE estimators.

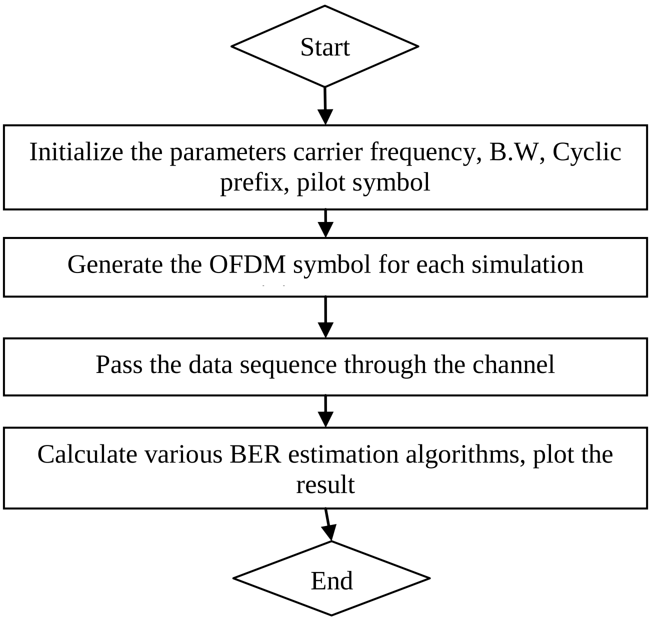

Figure 4.

Algorithm of DFT based channel estimation technique which compares the LS-linear interpolation with MMSE estimator is given in fig. 5

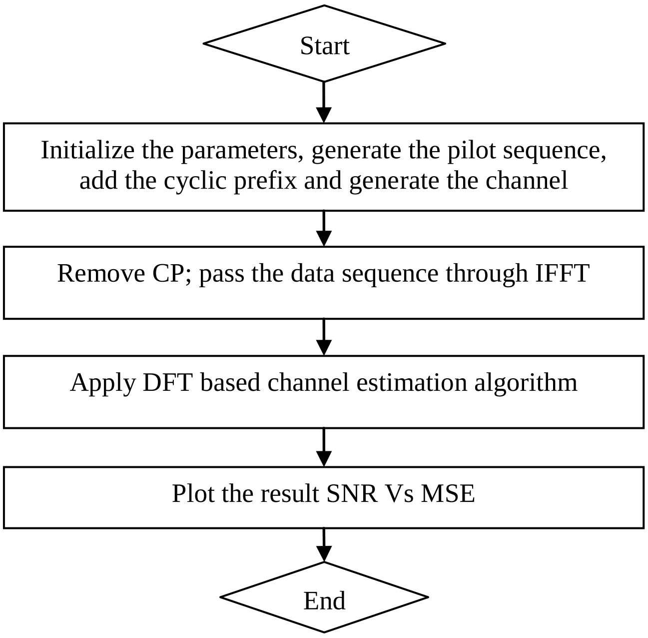

Figure 5.

4. Simulation Result and Discussion

This section discusses the results that were performed based on the theoretical information described in the above section.

The Fig. 6 and Fig. 7 Shows the performance of LS and the MMSE channel estimators for an OFDM system based on the parameters of Bit error rate (BER) and Mean square error (MSE). Fig. 6 show the graph of BER Vs SNR for the LS and MMSE estimators and Fig. 7 show the graph of MSE Vs SNR for the LS and MMSE estimator. The modulation technique used for both is BPSK.

The graph shows that in the case of MMSE the BER decreases gradually as SNR increases but in the case of LS BER remains constant after 25 dB which enhance the performance of MMSE as compared to LS.

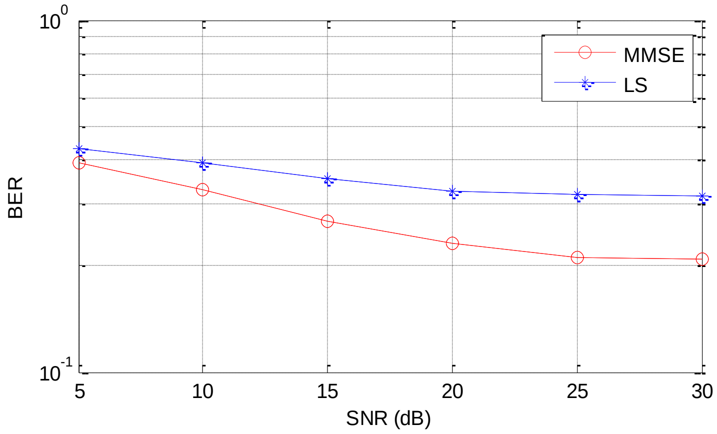

Figure 6. SNR Vs BER

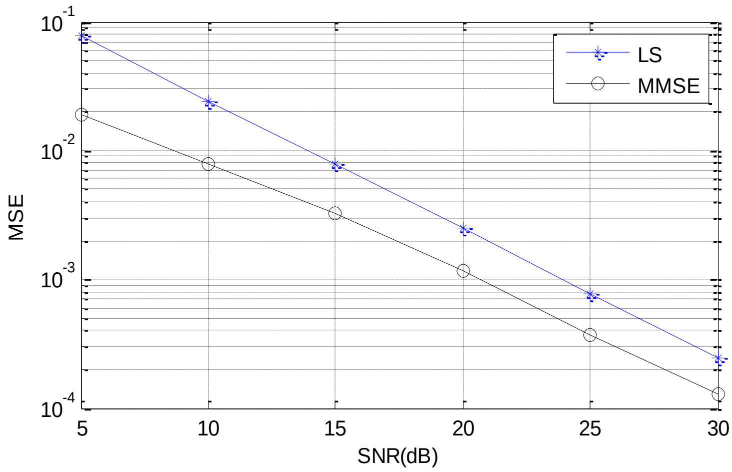

Figure 7. SNR Vs MSE

The simulation result shows that LS requires 6 to 7 dB more power as compared to MMSE to reach the value of 10^{-2} MSE thus MMSE performs better than LS at both low and high SNR value.

Fig. 8 shows the performance of the Delayed feedback MIMO-OFDM channel estimation for the LS and LMMSE estimators. The graph shows the BER performance of MIMO-OFDM. The modulation technique used is 16-QAM. The simulation result shows that for the low SNR value LMMSE performs better than the LS estimator. But as SNR increases both LS and LMMSE estimators behaves same. Thus there is no need to use such a complex system (LMMSE) at high SNR which is not giving any improvement.

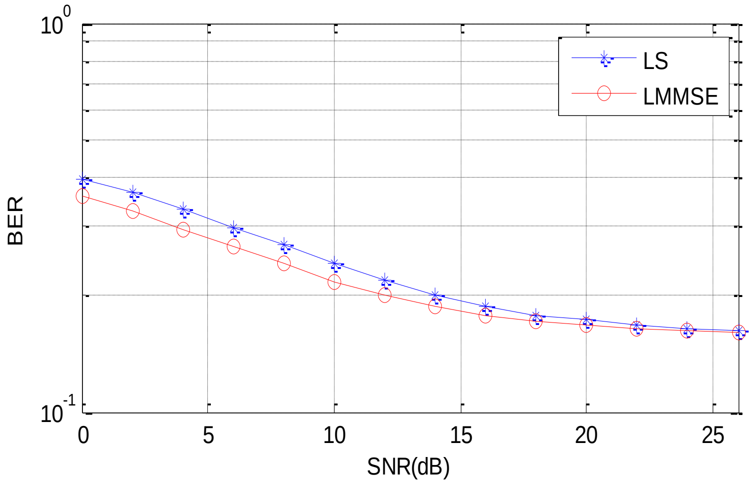

Figure 8. SNR vs BER

Fig. 9 shows the performance of LS-linear and MMSE with DFT technique with 16QAM. DFT-based channel estimation method can reduce the leakage energy efficiently. Thus DFT technique gives better result. Fig. reveals that at $10^{-0.5}$ the LS-linear require 5dB more power with respect to MMSE and with more increase in SNR MMSE performs better where as LS becomes constant at the value 10^{-1}.

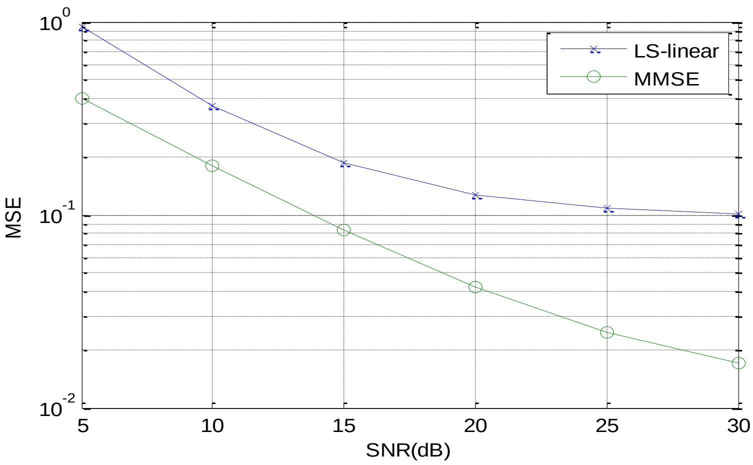

Figure 9. SNR vs MSE

Table 1.

MSE	LS-linear (SNR in dB)	LS (SNR in dB)	MMSE (SNR in dB)
10^{-1}	28	-	14
10^{-2}	-	14	8
10^{-3}	-	24	20

Table 1 justifies that the performance of LS-linear, LS and MMSE for MSE which shows MMSE has lower MSE as compared to LS-linear and LS. As the MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error thus we can say that the performance of MMSE is better than LS-linear and LS especially under the low SNR scenarios.

5. Conclusion

The Channel estimation is one of the fundamental issues of OFDM system design. Thus the paper fully reviews the channel estimation strategies of OFDM. The last section shows the simulation results implemented in MATLAB. The performance of the two types of estimators LS and MMSE based on the parameters of BER and MSE has been compared. The result shows that MMSE performs better, but the only drawback of MMSE is its complexity. On the other hand LS is simple than MMSE. The paper also compared the Delayed feedback MIMO OFDM channel estimation technique for LMMSE and LS which shows that for low SNR LMMSE performs better and results for DFT based channel estimation technique shows LS-linear require 5dB more power than MMSE thus MMSE performs better than LS-linear.

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