Performance Comparison of LS and LMMSE Channel Estimation Methods for MIMO-OFDM LTE Downlink System

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Abstract— Orthogonal Frequency Division Multiplexing - LTE downlink system provides higher data rates with the use of MIMO-OFDM techniques. Due to the trade-off between complexity and estimation accuracy, choice of channel estimator is important factor for LTE downlink system. For pilot aided type, Least Square(LS) method exhibits lower complexity & requires implicit channel knowledge. But it suffers from Inter Carrier Interference (ICI). On other side, Linear Minimum Mean Square Error (LMMSE) method performs better than LS with higher computational and circuit complexity. Due to this, optimal design of Channel Estimator is area of ongoing research. As LTE Downlink system is based on a MIMO-OFDMA technology, a Cyclic Prefix (CP) is inserted at the beginning of each transmitted OFDM in order to minimize inter-carrier interference (ICI) and inter-symbol interference (ISI). Usually, the length of the inserted CP is defined to be equal to or longer than the channel length. Here we proposed the performance analysis of two estimation methods. Simulation results show that when cyclic prefix length is equal to or longer than channel length, LMMSE has better performance than LS. In other case if cyclic prefix is shorter than channel length, LMMSE performs better only for lower SNR. As SNR increases, LS shows better performance.

Key words: LTE; MIMO; OFDM; Cyclic Prefix; Channel Length; LS; LMMSE

I. INTRODUCTION

The goal of future wireless communication is to provide high quality wireless multimedia services, and thus high data rate communication must be transmitted reliably. For higher data rate, more bandwidth is required. Orthogonal frequency division multiplexing (OFDM) has high spectrum efficiency. One of the advantages of OFDM systems is to convert the frequency selective channels to several flat sub channels. In OFDM transmission, the problem of intersymbol interference is avoided by the addition of cyclic prefix. Multiple transmit and receive antennas, which are usually referred to MIMO systems, enhances diversity gain by developing a special space time coding and increases the information capacity of wireless communication systems by applying interference cancellation technique. The combination of MIMO and OFDM is a strong candidate for the recent wireless communications systems. Space time block code help increasing reliability over wireless communications, and they can achieve full diversity gains with simple linear processing at the receiver[1].

Channel estimation is a crucial and challenging issue in coherent modulation and its accuracy has a significant impact on the overall performance of communication system. The channel estimation in MIMO systems comes more complicated in comparison with single-input single-output systems due to simultaneous transmission of signals from different antennas that cause cochannel interference. This issue highlights that developing channel estimation algorithm with high accuracy is an essential requirement to achieve the full potential performance of the MIMO-OFDM systems [2].

The MIMO-OFDM channel estimation methods proposed in literature can be categorized into two groups. In the first one, it is assumed that the sub channel impulse responses are unknown and a non-statistical criterion such as least squares (LS) is employed to estimate the channel. In this group the performance of estimation algorithm has been enhanced based on knowing the maximum sub channel impulse responses interval that is not longer than the cyclic prefix interval. In the second category, it is assumed that the sub channel impulse responses are random processes and estimation algorithm has been developed based on a statistical criterion such as minimum mean square error (MMSE) by using the known or estimated statistical parameters of the sub channel impulse responses [2].

Designing efficient channel estimation for wireless communication system is always a challenge. There are many factors involved in the analysis of a system. Single Carrier - Frequency Division Multiple Access (SC-FDMA) & Orthogonal Division Multiple Access (OFDMA) are a major part of future mobile communication standards like Long Term Evolution (LTE), LTE-Advanced and Ultra Mobile Broadband (UMB). OFDMA is well utilized for achieving high spectral efficiency in communication systems, used in downlink. SC-FDMA was recently introduced and has become handy candidate for uplink multiple access scheme[3].

In LTE physical layer downlink, OFDMA is used as multiple access technique. The channel estimation is difficult due to the noise and interferences included by multipath propagation. The basic channel estimation technique includes Least Square (LS) and Minimum Mean Square Error (MMSE). LS estimation is very simple to implement and reduces the square distance between the received signal and the original signal. But it has poor performance like high mean square error (MSE). In order to reduce the effect of channel noise that increases the MSE, MMSE estimation technique is evolved which provides better efficient channel estimation but has high complexity to implement due to the use of inversion matrix and channel correlation matrix[3].

In section II LTE downlink system is given with physical layer specification and system model explanation. Section III will contain channel estimation methods namely LS and LMMSE with their mathematical equation. Lastly, section IV contains simulation results and section V ended with final conclusion of this work.

II. LTE DOWNLINK SYSTEM

A. LTE PHYSICAL LAYER SPECIFICATION

LTE downlink frame is of 10ms duration. Each frame is divided into 2 sub frame each of 0.5ms. This sub frame consists of 7 or 6 OFDM symbols depending on cyclic prefix i.e Normal or Extended. Here 12 consecutive subcarriers are combined into one group called Physical Resource Block(PRB) which has duration of 1 time slot.so, there are 84 resource elements in one PRB for normal CP and 72 for extended CP.

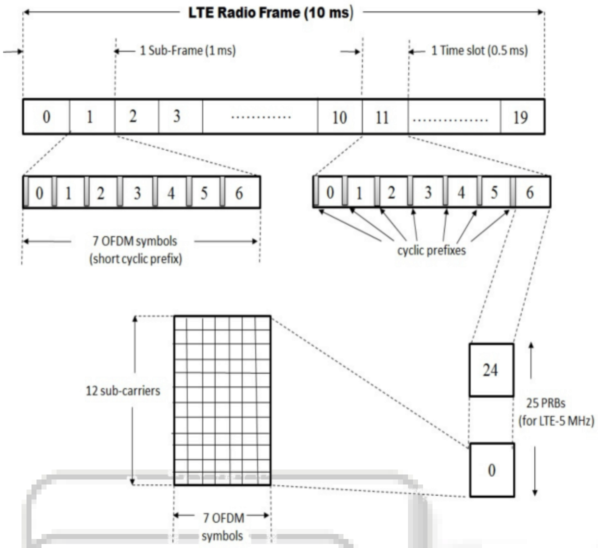

Fig. 1: LTE Radio Frame Structure[4]

B. LTE DOWNLINK SYSTEM MODEL

LTE Downlink system is a MIMO-OFDM based system. The system model is given in Figure 2. We consider a MIMO system with MT transmit antennas and MR antennas. LTE Downlink systems uses OFDMA scheme for multiple access. OFDMA is a multiple access scheme based OFDM modulation technique. OFDMA allocates a number of time/frequency resources to different users. Its objective is to split the data stream to be transmitted onto narrowband orthogonal subcarriers by the means of the inverse discrete Fourier Transform (IDFT) operation, which allows for an increased symbol period. A cyclic prefix with the length of L_{CP} is appended at the beginning of each OFDM symbol. The CP consists of a repetition of the last part of an OFDM symbol. In order to avoid degradations due to inter-symbol interference (ISI) and intercarrier interference (ICI), the inserted CP is generally equal or longer than the maximum excess delay of the channel [4].

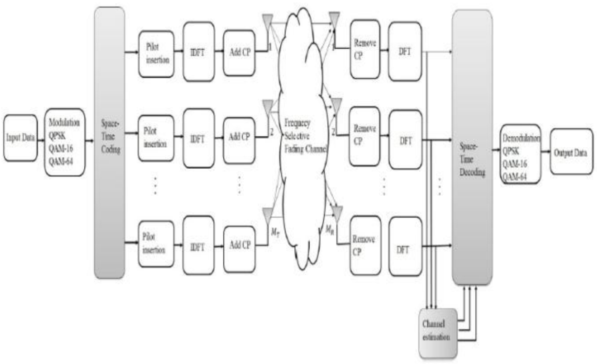

Fig. 2: LTE Downlink System Model[4]

III. CHANNEL ESTIMATION

A. Least Square (LS):

The least square (LS) channel estimation is a simple estimation technique with very low complexity. It does not require any prior knowledge of the channel statistics. It is widely used because of its simplicity. However, it suffers from a high mean square error. The LS estimation channel frequency response ($\hat{H}_{LS}$) is obtained by minimizing the squared distance between received and original signal. It can be obtained by following equation[5]:

$$\hat{H}_{LS} = X^{-1}Y \quad (1)$$

Where, X represents input symbol vector and Y represent received symbol vector

B. Linear Minimum Mean Square Error (LMMSE):

The minimum mean square error (MMSE) channel estimation is an estimation technique with very high computational complexity. It requires prior knowledge of the second order channel statistics. The MMSE estimation channel frequency response ($\hat{H}_{LMMSE}$) is obtained by minimizing the mean square error (e) between the actual channel (H) and the raw estimated channel ($\hat{H}$).

Assuming that the channel statistics, namely the auto-covariance (R_{HH}) of the channel and the noise variance (σ_N^2) are known at the receiver, the MMSE estimated channel can be given as[5],

$$\hat{H}_{LMMSE} = R_{HH}(R_{HH} + \sigma_N^2(X\,X^H)^{-1})\hat{H}_{LS} \quad (2)$$

Though MMSE channel estimation yields a much better performance than LS channel estimation, it has very high computational complexity. It is observed from equation (2) that every time the input signal changes, complex matrix inversion operation is required. Thus, the Modified MMSE estimated channel can be simplified to [5],

$$\hat{H}_{LMMSE} = R_{HH}\left(R_{HH} + (\frac{\beta}{SNR})I\right)\hat{H}_{LS} \quad (3)$$

β is constant only depending on the signal constellation β=1 for QPSK and 17/9 for 16QAM

IV. SIMULATION RESULTS

LTE bandwidth	5 MHz
Cyclic Prefix	16
Number of used subcarriers	300
Number of Transmit antenna	2
Number of Receive antenna	2
Number of transmitted frames	100
Channel model	Rayleigh
Modulation used	QPSK

Table 1: Simulation Parameters

1) Case-1: $L \leq L_{CP}$

Here, cyclic prefix is longer than the channel length. So, ISI and ICI can't be present. Results show that LMMSE performs better than LS continuously. Simulation results in terms of BER and MSE are shown in the following figures.

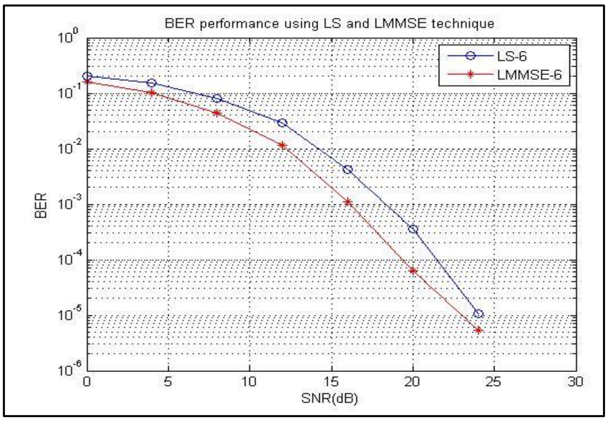

Fig. 3: BER Vs SNR For L=6

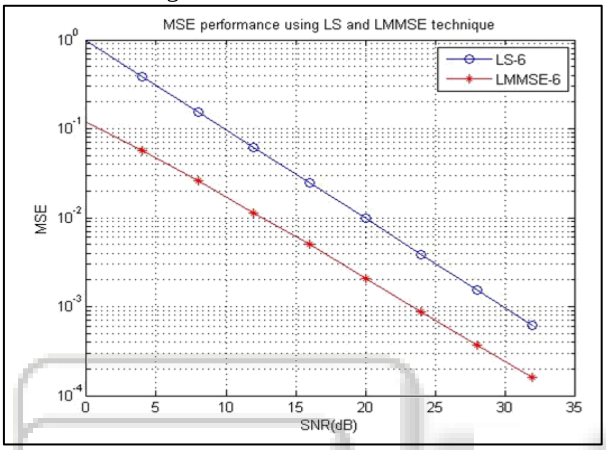

Fig. 4: MSE Vs SNR for L=6

2) *Case-2: L > L_{CP}*

In this case inserted cyclic prefix is shorter than the channel length. So, it will create the ISI and ICI. Following results shows that as channel length increases than cyclic prefix, performance degrades more and more in terms of BER. For MSE, results shows that LMMSE gives better performance only for lower values of SNR. As SNR increases, LMMSE performance degrades as compared to LS. This is clearly shown in figure-6 & 8

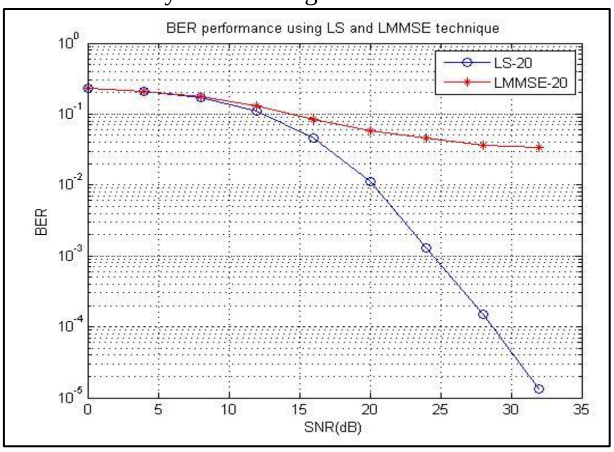

Fig. 5: BER Vs SNR for L=20

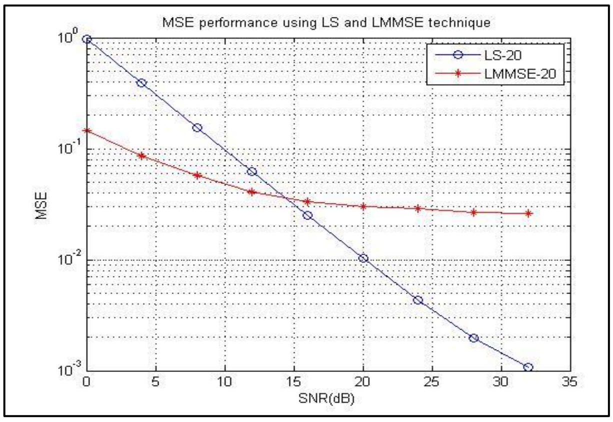

Fig. 6: MSE Vs SNR for L=20

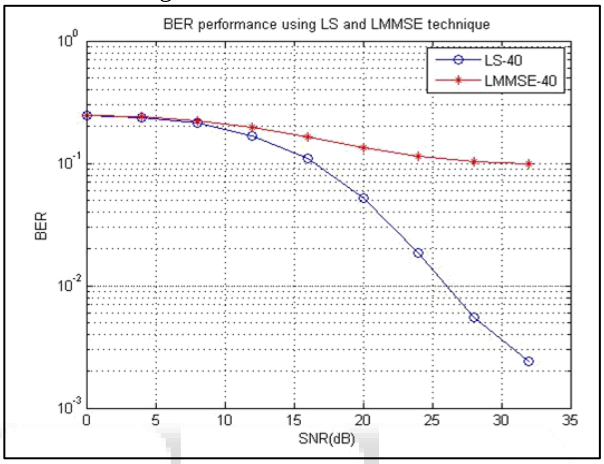

Fig. 7: BER Vs SNR for L=40

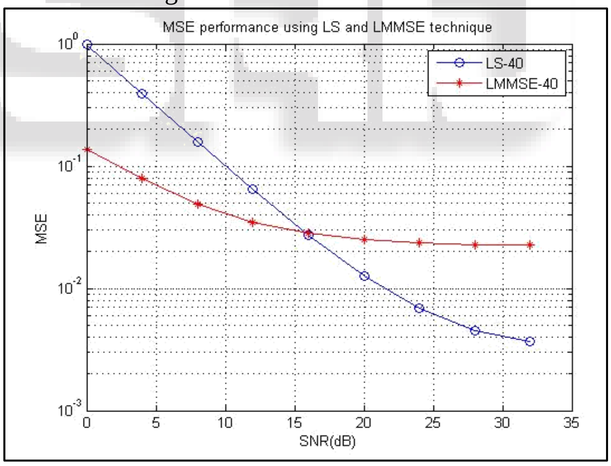

Fig. 8: MSE Vs SNR for L=40

V. CONCLUSION

In this paper, performance of LS and LMMSE channel estimation is compared for LTE downlink system. Studies show that to overcome the effect of ICI and ISI, cyclic prefix is inserted at the beginning of each OFDM symbol. Generally, Length of cyclic prefix is chosen to be greater or equal to the channel length. But in some cases it can be seen that channel length is larger than cyclic prefix. Simulation results show that for cyclic prefix larger than channel length, LMMS performs better than LS. When cyclic prefix is shorter than channel length, LMMSE shows better performance only for lower range of SNR. As SNR increases, LMMSE performance is degraded and LS shows better performance

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