Performance Enhancement of Channel Estimation in MIMO-OFDM for LTE Downlink Systems

Kunjesh S. Patel[1] Prof Hitesh L. Desai[2]
[1]PG Student [2]Assistant Professor
[1,2]Department of Electronics & Communication
[1,2]Sankalchand Patel College of Engineering, Visnagar, India

Abstract— The main purpose of this paper is to study the performance of two linear channel estimators for LTE Downlink systems, the Least Square Error (LSE) and the Linear Minimum Mean Square Error (LMMSE). LTE is a MIMO-OFDM based system and cyclic prefix is inserted at the beginning of each transmitted OFDM symbol in order to completely suppress both inter-carrier interference (ICI) and inter-symbol interference (ISI). Usually, the cyclic prefix is equal to or longer than the channel length but in some cases and because of some unforeseen channel behavior, the cyclic prefix can be shorter. Therefore, we propose to study the performance of the two linear estimators under the effect of the channel length. Computer simulations show that, in the case where the cyclic prefix is equal to or longer than the channel length, LMMSE performs better than LSE but at the cost of computational complexity. In the other case, LMMSE continue to improve its performance only for low SNR values but it degrades for high SNR values in which LS shows better performance for LTE Downlink systems. MATLAB Monte – Carlo simulations are used to evaluate the performance of the studied estimators in terms of Mean Square Error (MSE) and Bit Error Rate (BER) for 2x2 LTE Downlink systems.

Key words: MIMO, OFDM , LTE, Pilot based Channel Estimation, Least square, Linear Minimum Mean Square Error, Inter Symbol Interference, and Inter carrier Interference

I. Introduction

Over the last few decades, due to the increasing demand for high speed data and widespread network access in mobile communications, there has been tremendous ongoing research in the field of cellular communications which has resulted in achieving significant developments. Among them, the multiple-input multiple-output (MIMO) represents the most interest research results. The researches based on MIMO technologies have leading to improve high system capacity without additional bandwidth. Multipath propagation causing selective frequency channels may causes serious problems for mobile .Therefore, Multicarrier modulation (MC), especially Orthogonal Frequency Division Multiplexing (OFDM) which is used to combat the effect of frequency selective fading.

OFDM consists of converting a frequency-selective fading channel into parallel flat-fading sub-channels. The propagation over the radio-frequency channel is characterized by a spread of the signal in time due to Doppler Effect. So, there will be an Inter Symbol Interference and Inter Carrier Interference introduced. So to mitigate that effect cyclic prefix is used in beginning of every OFDM symbol. Cyclic prefix is sometimes shorter and longer than the channel length. LTE is a fourth generation combination of MIMO-OFDM system. In this paper we focus on the LTE downlink System.

LTE Downlink system adopts Orthogonal Frequency Division Multiple (OFDM) as an access technique in Downlink system.LTE Downlink provides a data rate of 100 Mbps for 2*2 MIMO systems. Channel estimation is critical in LTE Downlink MIMO- OFDM system. At many research works they assume that length of the cyclic prefix should be greater than the channel length. But sometimes because of the channel behavior cyclic prefix can be shorter than the channel length. At that condition channel estimation is difficult because of ISI and ICI introduced. In this paper, we are using the two estimator technique LS and LMMSE for Block type pilot based channel estimation of LTE Downlink.

II. Overview of MIMO-OFDM

Recently, a worldwide convergence has occurred for the use of OFDM as an emerging technique for high data rates. It is a digital multi-carrier modulation scheme. Multi-carrier modulations that use orthogonal waveform for modulating the subcarriers are called OFDM schemes. Since the subcarriers are modulated by orthogonal waveforms. The subcarriers are permitted to have overlapping spectrum and thus achieving higher spectrum efficiency. OFDM solves the problem due to ISI. It can efficiently deal with multipath dm is becoming the preferred modulation scheme for both high bit rate and broadband fading and it has enhanced channel capacity.

It provides better synchronization of transmitter and receiver. It has robustness against narrow band interference In particular, the wireless local network systems such as WiMax, Wi-Fi etc and the emerging 4G mobile systems are all OFDM based systems

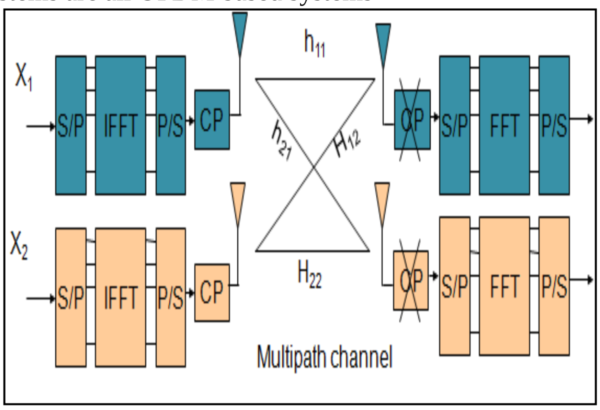

Fig. 1: MIMO-OFDM

As shown in fig 1, MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. The terms input and output refer to the radio channel carrying the signal, along with the devices having antennas. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency or to achieve a diversity gain that improves the link reliability.

Multi-antenna MIMO technology has been developed and implemented in some standards, e.g. IEEE 802.11 products. Some limitations are the physical antenna spacing is selected to be large, multiple wavelength at the base station. The antenna separation at the receiver is heavily space constrained in hand sets, though advanced antenna design.

Multi-user MIMO can have a higher potential, practically, the research on multi-user MIMO technology is more active. Spatial multiplexing techniques make the receivers very complex, and therefore these are typically combined with OFDM or with (OFDMA) modulation, where the problems created by a multi-path channel are handled efficiently. MIMO technology can be used in non wireless communications systems. MIMO system is modeled as

$$Y = Hx + n \quad (1)$$

Where, Y and x is the receiver and transmit vectors, respectively. H and n are the channel matrix and the noise vector, respectively.

III. LTE DOWNLINK MODEL

The standard LTE Downlink system is a MIMO-OFDMA based system. OFDMA is adopted as a technique access allowing multi access at the same channel. Fig.2 gives a description of a baseband OFDM system. A high data rate stream is divided into multiple parallel substreams by the means of the inverse discrete Fourier Transform (IDFT) operation. In order to avoid ISI and ICI, a CP is inserted at the beginning of each OFDM symbol. Usually, the inserted CP with length of LCP is equal to or longer than maximum channel delay.

The multi-path channel is modeled by a Finite Impulse Response (FIR) with L taps for each channel path:
$h(t,\tau) = \sum_{l=0}^{L-1} h_l(t)\delta(t-\tau_l)$

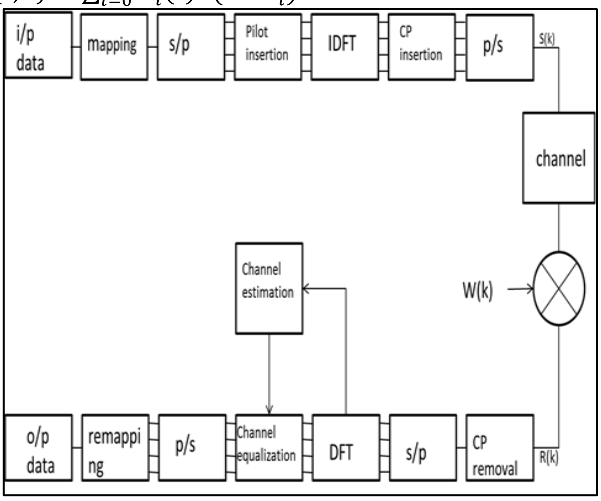

Fig. 2: LTE Downlink Model

Let X=[X_1, X_2 ,…,X_{N-1}]and Y=[Y_1, Y_2 ,…,Y_{N-1}] are respectively the input data block of IDFT and the output data of DFT block at the receiver. h_l and τ_l are respectively the impulse response and the multipath delays of the channel. It is sufficient to consider in our system model only a single transmit and a single receive. The received OFDM symbol at one receive antenna, after removing the CP and performing the DFT, can be written as:

$$Y = HX + W \quad (2)$$

Y is the received OFDM symbol; X is a diagonal matrix and H is a channel frequency response matrix. The complex additive W is the additive complex-valued white Gaussian noise vector with zero mean and variance the transmitted signals and the noise are assumed to be independents of each other.

IV. CHANNEL ESTIMATION

In order to estimate the channel, LTE systems use pilot signals called reference signals. When short CP is used, they are being transmitted during the first and fifth OFDM symbols of every slot. When long CP is used, they are transmitted during the first and the fourth OFDM symbols the received pilot signals can be written as:

$$Y_p = X_p H_p + \mu_p \quad (3)$$

(.)p denotes positions where reference signals are transmitted. In this paper, we study the performance of LS and LMMSE channel estimation techniques. beginning of a sentence.

A. *Least Square (LS):*

The goal of the channel least square estimator is to minimize the square distance between the received signal and the original signal. The least square estimates (LS) of the channel at the pilot subcarriers can be obtained by the following equation:-

$$\hat{H}_P^{LS} = (X_P)^{-1} Y_P \quad (4)$$

$\hat{H}_P^{LS}$ represents the least-squares (LS) estimate obtained over the pilot subcarriers.

B. *Linear Mean Minimum Square Error (LMMSE):*

The LMMSE channel estimator is designed to minimize the estimation MSE.The LMMSE estimate of the channel responses given in (2) is

$$H_P^{LMMSE} = R_{HH_P}\left(R_{H_PH_P} + \sigma_\mu^2 (XX^H)^{-1}\right)\hat{H}_P^{LS} \quad (5)$$

H_P^{LMMSE} represents the cross correlation matrix between all subcarriers and the subcarriers with reference signals. R_{HPHP} represents the autocorrelation matrix of the subcarriers with reference signals. The high complexity of LMMSE estimator is due to the inversion matrix lemma. Every time data changes, inversion are needed. The complexity of this estimator can be reduced by averaging the transmitted data. Therefore, we replace the term $(XX^H)^{-1}$ (4) with its expectation $E[(XX^H)^{-1}]$

$$\hat{H}_P^{LMMSE} = R_{HH_P}\left(R_{H_PH_P} + \frac{\beta}{SNR} I_P\right)^{-1} \hat{H}_P^{LS} \quad (6)$$

Where β is scaling factor depending on the signal constellation (i.e. β=1 for QPSK and β=17/9 for 16-QAM). SNR is the average signal-to-noise ratio, and I_P is the identity matrix.

V. SIMULATIONS RESULTS

IN this part we propose the LS –LMMSE estimation techniques for 2*2 MIMO-OFDM LTE downlink system under the effect of the channel length .here QPSK and QAM modulations has been used. Consider, number of subcarrier in each OFDM symbol is N=300, and the length of Lcp=36. Number of LTE radio frames is 100 and it's sent through a frequency selective channel.

A. Simulations Parameter:

LTE bandwidth	5 MHz
No. of used subcarrier	300
Cyclic prefix length	36
No of transmitted frames	100
No of transmitted antenna	2
No of received antenna	2
Modulation scheme	QPSK
Channel model	Rayleigh

Table 1: Simulations Parameter

B. Case 1: L<Lcp for QPSK:

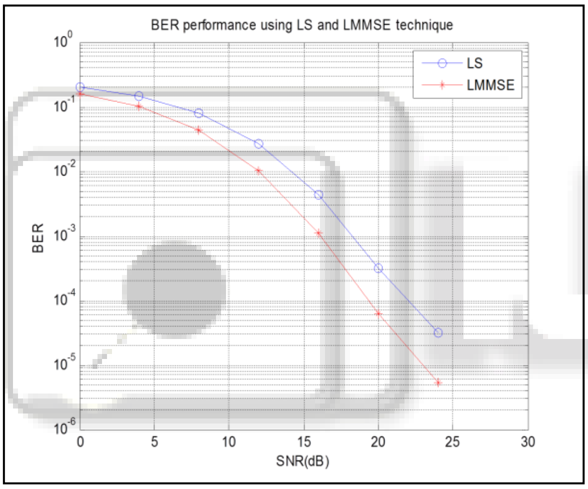

Fig. 3: BER vs. SNR for L=6 and Lcp=36 for QPSK

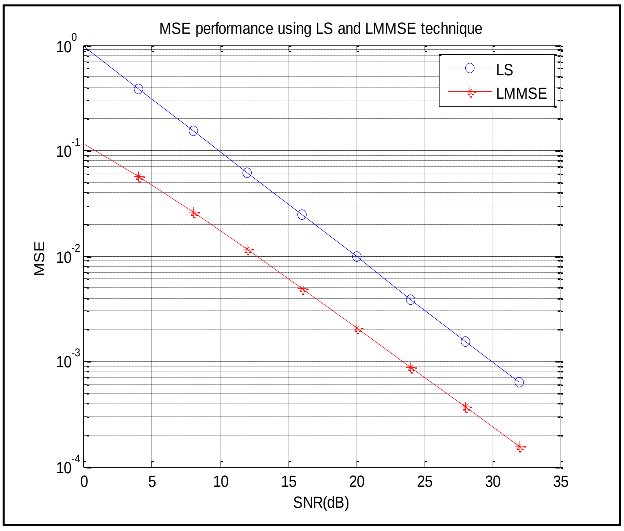

Fig. 4: MSE vs. SNR for L=6 and Lcp=36 for QPSK

C. L<Lcp for QAM

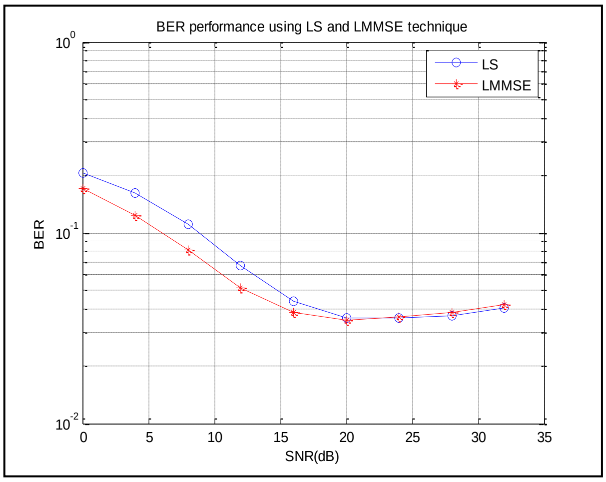

Fig. 5: BER vs. SNR for L=6 and Lcp=36 for QAM

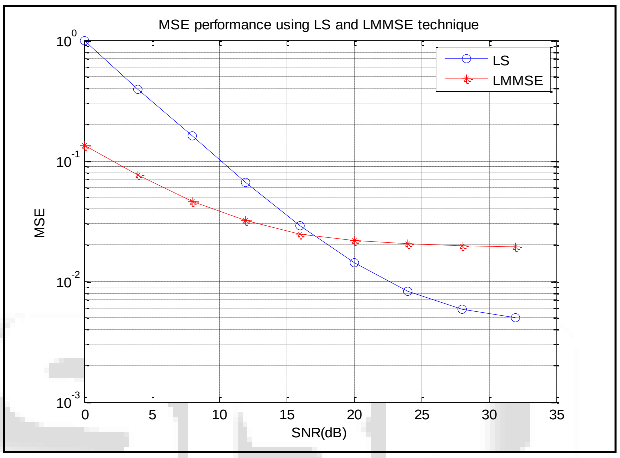

Fig. 6: MSE vs. SNR for L=6 and Lcp=36 for QAM

In this case, the cyclic prefix length is longer than the channel length which means that ISI and ICI are completely suppressed. Figures 3, 4, 5 and 6 shows that LMMSE estimation technique is better than the LS estimator. LMMSE gives the better performance but its complexity is higher due to the channel correlation and the matrix inversion.

D. Case 2: L>Lcp for QPSK:

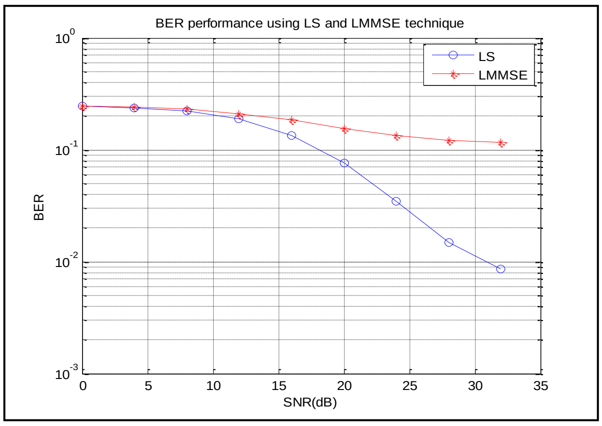

Fig. 7: BER vs. SNR for L=50 and Lcp=36 of QPSK

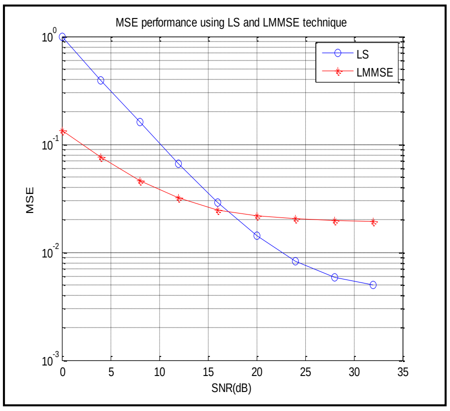

Fig. 8: MSR vs. SNR for L=50 and Lcp=36 of QPSK

E. L>Lcp for QAM:

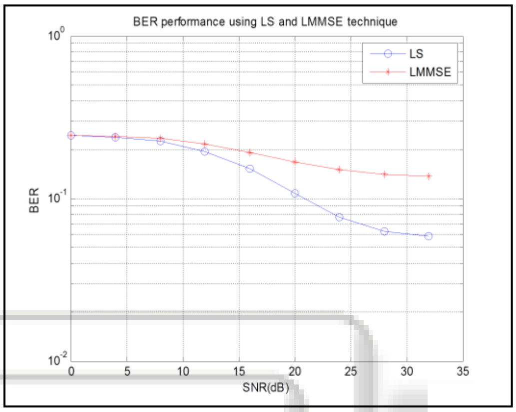

Fig. 9: BER vs. SNR for L=50 and Lcp=36 of QAM

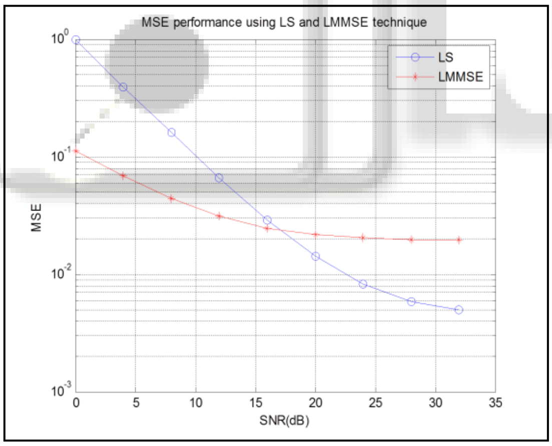

Fig. 10: MSR vs. SNR for L=50 and Lcp=36 of QAM

In this case cyclic prefix length is shorter than the channel length; Figures 7, 8, 9 and 10 shows that LMMSE shows better performance than LS for only low SNR values. For high SNR values, LMMSE loses its performance in terms of BER and MSE, LS estimator seems to better than LMMSE for this range of SNR values.

VI. CONCLUSION

In this paper, we propose to enhancement the performance of LS and LMMSE estimation techniques for LTE downlink system under the effect of channel length. The cyclic prefix inserted at the beginning of each OFDM symbol is usually equal to or longer than the channel length, Simulation results show that in the case if CP length is equal to or longer than the channel length, the LMMSE performs better than LS estimator but at the cost of the complexity because it depends on the channel and noise statistics. In the other case, LMMSE provides better performance only for low SNR values and begins to lose its performance for higher SNR values. In other hand, LS shows better performance than LMMSE in this range of SNR values.

REFERENCES

[1] http://mimoofdm16.weebly.com/index.html
[2] http://www.rfwireless-world.com/ofdm-matlab.html
[3] multiuser mimo-ofdm for next generation wireless systems
[4] http://www.slideshare.net/ntnam113/mimo-ofdm-wireless- communications-with-matlab
[5] http://www.teletopix.org/4g-lte/lte-frame-structure-and-resource-block architecture
[6] helmut bölcskei, eth zurich "MIMO-OFDM WIRELESS SYSTEMS: BASICS, PERSPECTIVES AND CHALLENGES" IEEE august 2006
[7] Bing deng & wenbo wang ‘’ Low complexity channel estimation method of MIMO-OFDM for LTE downlink ’’ IEEE 2011
[8] Abdelhakim khlifi & Ridha bouallegue ‘’An enhanced channel estimation techniques with acpl for LTE downlink systems ‘’ IEEE march 2013
[9] Abdelhakim khlifi & Ridha bouallegue "Performance analysis of LS and LMMSE channel estimation techniques for LTE downlink systems ‘’ Sciencedirect (ELSEVIER)2011
[10] Akhila I.P, R.s.ganesh & Dr. j.jayakumari’ ‘’Channel estimation analysis in MIMO-OFDM wireless system" IEEE 2011
[11] Md.Jobayer alam & Shaha mohammed goni abed sujan "Low complexity channel estimation for OFDM systems based on LS and MMSE estimators" IEEE 2013
[12] Amitava Ghosh and Tim Thomas, "LTE-Advanced: Next generation wireless broadband technology," IEEE Trans. commun., pp. 10-22, June 2010
[13] Yong Soo Cho Chung-Ang, Jaekwon Kim Yonsei , Won Young Yang Chung-Ang ‘’MIMO-OFDM WIRELESS COMMUNICATIONS WITH MATLAB’’2010

