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Channel Estimation Techniques for LTE Downlink

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Abstract- *In order to minimize the adverse impact of channel noise one can introduce the equalizers with various optimizing algorithms at the receiver side to achieve the better performance of the wireless communication system. Thus estimation the channel will improve the performance of the receiver. Henceforth our aim is to use the adverse impact of channel noise using LS and MMSE channel estimation in order to reduce the distortion that will help improve performance of the wireless communication system.Computer simulations show that, in the case where the cyclic prefix is equal to or smallerthan the channel length, MMSE performs better than LSE but at the cost of computational complexity. MATLAB simulations are used to evaluate the performance of the studied estimators in terms of Mean Square Error (MSE) for LTE Downlink systems with SISO.*

Index Terms: *OFDM,LS,MMSE*

I. INTRODUCTION

Long Term Evolution (LTE) is defining the next generation radio access network. LTE Downlink systems adopt Orthogonal Frequency Division Multiple (OFDM) and MIMO to provide up to 100 Mbps (assuming a 2x2 MIMO system with 20MHz bandwidth). The performance LTE heavily depends on the accurate estimation of Channel State Information (CSI), which is crucial for every communications.The complexity of MIMO channel estimation is infeasible for most low-complexity receivers in practice. Hence, the pilots (reference signals) introduced in LTE have been chosen orthogonal to allow low-complexity channel estimation for multi-antenna transmissions.

A. Previous works of Channel Estimation

Channel estimation techniques for LTE systems were carried out in many articles e.g. [1][4].However, in most of these research works, the CP length is assumed to be equal or shorter than the maximum propagation delay of the channel. But in some cases and because of some unforeseen channel behavior, the cyclic prefix can be longer than channel length. In this case, both ICI and ISI will be introduced and this makes the task of channel estimation more difficult.
Equalization techniques that could flexibly detect the signals in both cases in LTE systems are discussed in [4-6]. The performance evaluation of the two estimators for LTE systems was discussed in many articles e.g. [1] [3].

B. Proposed Method

In this paper, we will focus on the study of the performance of LSE and MMSE channel estimation techniques for LTE Downlink systems under the effect of the different environment condition and with mobility. The channel estimation based on block type pilot arrangement is studied through different algorithms for both estimating channel at pilot frequencies. Computer simulations show that, in the case where the cyclic prefix is equal to or small than the channel length, MMSE performs better than LSE but at the cost of computational complexity. MATLAB simulations are used to evaluate the performance of the studied estimators in terms of Mean Square Error (MSE) for LTE Downlink systems with SISO.
The rest of this paper is organized as follows: Section II contains a Overview of LTE downlink system. Section III presents the proposed Channel estimation Techniques. Section IV contains the simulation results and finally conclusions are presented in Section V.

II. OVERVIEW OF LTE DOWNLINK SYSTEM

According to [1],[5], the duration of one frame in LTE Downlink system is 10ms. Each LTE radio frame is divided into 10 sub-frames of 1ms. As described in Figure 1, each sub-frame is divided into two time slots, each with duration of 0.5ms. Each time slot consists of either 7 or 6 OFDM symbols depending on the length of the CP (normal or extended).In LTE Downlink physical layer, 12 consecutive subcarriers are grouped into one Physical Resource Block (PRB). A PRB has the duration of 1 time slot. Within one PRB, there are 84resource elements(12 subcarriers x 7 OFDM symbols) for normal CP or 72 resource elements (12 subcarriers x 6 OFDM symbols) for extended CP.

LTE provides scalable bandwidth from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD).Table 1 shows the different transmission parameters for LTE Downlink systems.

A. Reference Signal

In Baseband OFDM systems shows in Fig.1 (e.g. DVB-T), pilot symbol (called reference signals in LTE) are inserted during subcarrier mapping in both time and frequency directions such that the receiver can estimate time-variant radio channels. One major enhancement in LTE is the introduction of multiple antennas. Being different from the typical MIMO-OFDM channel estimation problems [1], [13] in academia, the reference signals transmitted from multiple antennas are orthogonal to each other. As a consequence the channel impulse response between different Tx-Rx antenna pairs can be estimated individually. We therefore consider in our system model only a single transmit and a single receive antenna. The received OFDM symbol y at one receive antenna can be written as [4]

$$y = Xh + w \qquad (1)$$

Where the vector h contains the channel coefficients in the frequency domain and w is additive zero mean white Gaussian noise with variance at the receive antenna. 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 of every slot. When long CP is used, they are transmitted during the first and the fourth OFDM symbols. From (1), the received pilot signals can be written as[1]:

$$y = X_p H_p + w_{p(2)}$$

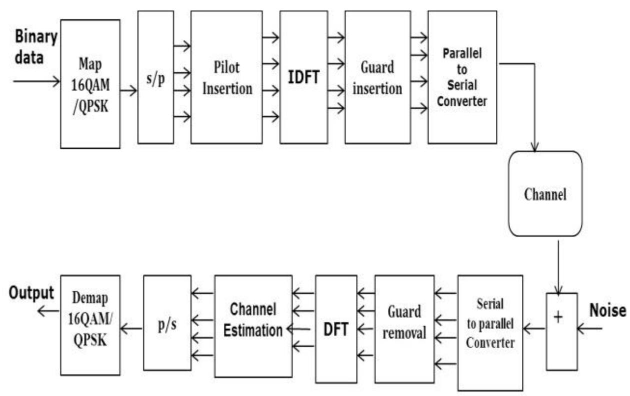


Fig.1: OFDM system block diagram [4]

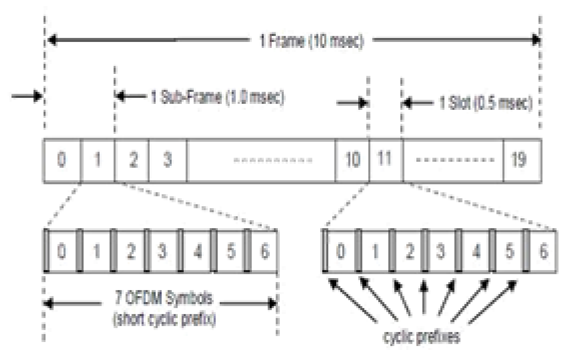


Fig.2: LTE frame structure [1]

III. CHANNEL ESTIMATION IN LTE

A.LS Channel Estimation

The Least-Square Error (LSE) channel estimator for sub-carriers on which pilot symbols are located, is given by [1]:

$$H_p^{LS}=(Xp)^{-1}Y_p \quad (3)$$

H_P^{LS} represents the least-squares error (LSE) estimation obtained over the pilot subcarriers. The remaining channel coefficients have to be obtained by interpolation.

B. Mean Minimum Square Error (MMSE) Channel Estimation

Minimum-Mean-Square-Error (LMMSE) channel estimator requires the knowledge of the second order statistics of the channel and the noise. It performs better than the LS estimator, but it requires higher computational complexity. The LMMSE channel estimate can be obtained by filtering the LS estimate [1].

$$H_P^{LMMSE} = R_{H\,H_p}(R_{H_p\,H_p} + \sigma_\mu^2(\text{XXH})\text{-}1)\hat{H}_p^{LS} \qquad (4)$$

Where the $R_{H_p\,H_p}$ is the autocorrelation matrix of the channel at pilot symbols position and $R_{H\,H_p}$ is the cross correlation matrix between the channel at the data symbol positions and the channel at the pilot symbol position

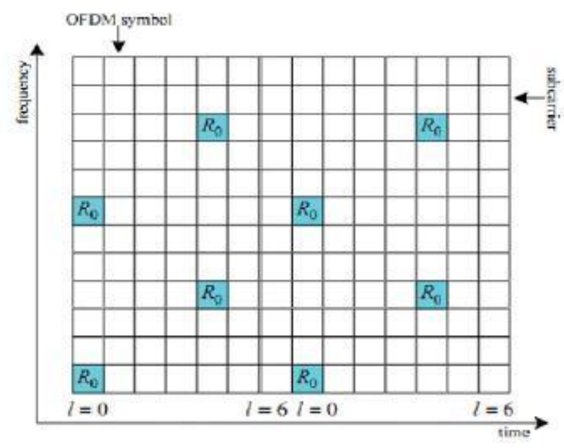


Fig. 3: Downlink reference signal structure on one antenna port [1]

IV. SIMULATION RESULTS:

MATLAB simulations were carried out to evaluate the performance of LTE SISO downlink. The frequency flat fading channel and frequency selective fading channel is used in which we have consider flat fading channel and frequency selective channel with low mobility and frequency selective channel with high mobility. We have considered the extended cyclic prefix used in LTE Downlink system. Remaining parameters are kept same as that being used in LTE downlink system. We have considered SNR=0:20 dB. As the BER for the Multipath fading is simulated for the (no. of taps) L = 8, which is less than the length of the CP, however if we increase the no of taps for the multipath fading then the resultant BER performance is getting worse and more errors would occur.

Fig.4 demonstrate the simulation result which shows comparison between LSE and MMSE channel estimation using frequency flat fading with low mobility. In this figure, we plot mean square error of LSE and MMSE channel estimation vs SNR.

TABLE 1

A. Simulation parameters:

Bandwidth	20 MHz
FFT size	2048

Pilot ratio	¼
Guard type	Cyclic Extended
Number of active subcarriers	1200
Sampling rate	30.72 MHz
Modulation Technique	QPSK
Channel type	AWGN,Rayleigh

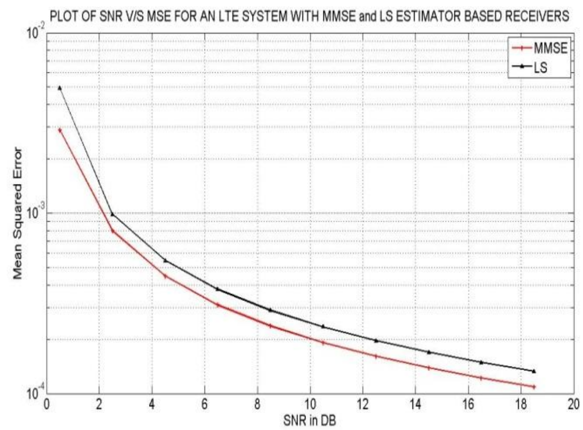


Fig.4: LS and MMSE channel estimation for flat fading channel

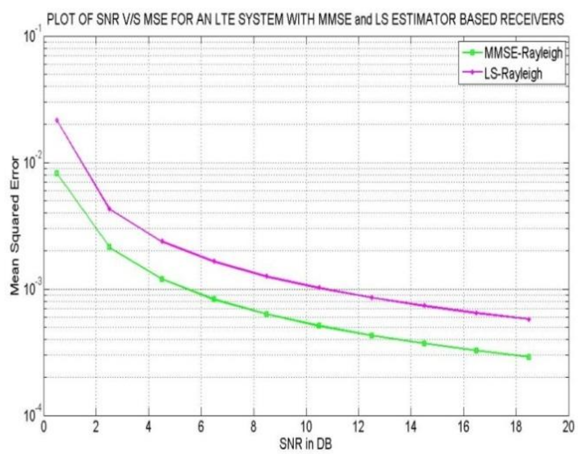


Fig.5: LS and MMSE channel estimation for frequency selective fading channel

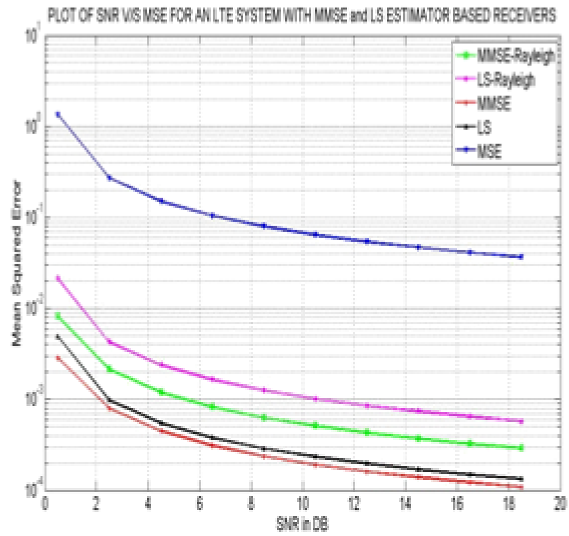


Fig.6 LSE and MMSE channel estimation using frequency selective fading and flat fading channel

Fig.6 demonstrate the simulation result which shows combine comparison between LS and MMSE channel estimation using frequency selective fading and flat fading channel.

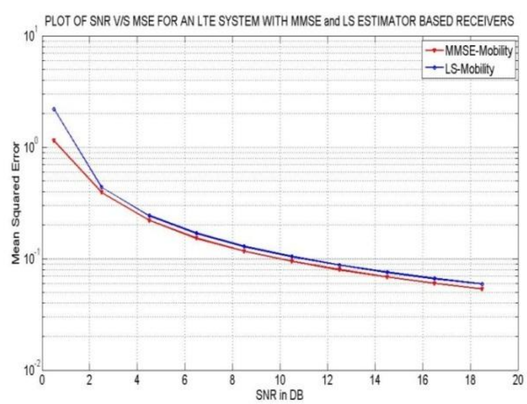


Fig.7: LS and MMSE channel estimation for frequency selective fading using high mobility fd =100

Fig.7 demonstrate the simulation result which LS and MMSE channel estimation using frequency selective fading channel with high mobility. In this Doppler frequency is taken as 100 Hz. Given the Doppler frequency we can calculate the velocity of mobile receiver.

Fig.8 demonstrate the simulation result which shows combine comparison between LS and MMSE channel estimation using frequency selective fading and flat fading channel with and without mobility.

In figure 9 we used 50Hz, 100Hz and 150 Hz Doppler frequency and compare results in terms of MSE

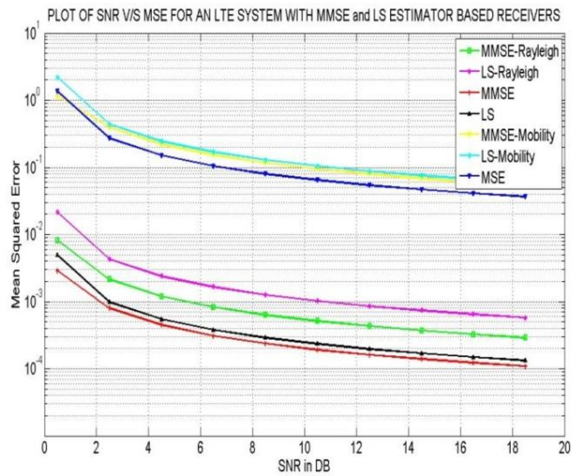
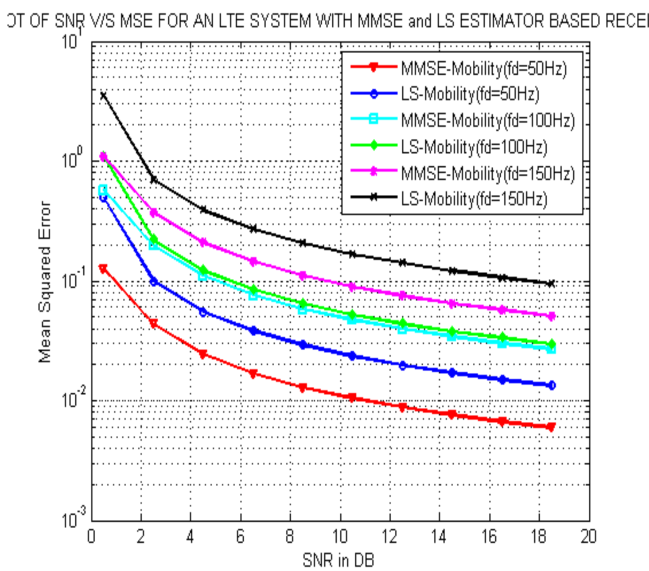


Fig.8: LS and MMSE channel estimation comparing all fading channel with mobility and without mobility.



Fig, 9 LS and MMSE channel estimation for different Dopplerfrequency

V. CONCLUSION

The channel estimation technique use pilot based block type arrangement. We used LS and MMSE algorithm. From the simulation result we can observe that performance of AWGN is better than Rayleigh fading channel in terms of mean square error (MSE). Range of SNR is from 0 to 20dB.The performance at higher Doppler frequency like f_d=100 for Rayleigh frequency selective fading channel also shown. MSE is more in high Doppler shift compare to lower Doppler shift.
Simulation results shows that MMSE perform better than LS.MMSE estimator require a prioriknowledge of noise variance and channel covariance and its complexity is more than the LS estimator but performance of MMSE is better than the LS estimator.

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