INTERNATIONAL JOURNAL OF ELECTRONICS AND COMMUNICATION ENGINEERING & TECHNOLOGY (IJECET)

ISSN 0976 – 6464(Print)
ISSN 0976 – 6472(Online)
Volume 5, Issue 3, March (2014), pp. 94-101
© IAEME: www.iaeme.com/ijecet.asp
Journal Impact Factor (2014): 7.2836 (Calculated by GISI)
www.jifactor.com

IJECET
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PERFORMANCE ANALYSIS OF PILOT-AIDED MIMO-OFDM LTE DOWNLINK SYSTEM USING HYBRID LS-LMMSE TECHNIQUE

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ABSTRACT

This paper focuses on the channel estimation in OFDM system and it implemented by using pilot type channel estimation by hybrid LS-LMMSE. A LTE system is basically MIMO-OFDM system, where a cyclic prefix is inserted at the beginning of each OFDM symbol in order to suppress both inter-carrier interference (ICI) and inter symbol interference (ISI). The inserted CP is usually longer or equal to the channel length but in some cases, the CP can be shorter. In case of LS and LMMSE channel estimation technique, simulation results shows that LMMSE performs better than LS estimator where cyclic prefix is equal to or longer than the channel length. In other case, LMMSE gives better performance than LS only for low SNR values and for high SNR value, LS gives better performance. Therefore, a hybrid LS-LMMSE channel estimation technique is to reduce the effect of the channel length on system. Simulation results for hybrid system shows its true efficiency and specially for the case where the channel length exceeds the cyclic prefix length.

Keywords: MIMO, OFDM, Channel Estimation, Channel Length, Cyclic Prefix, Hybrid LS-LMMSE.

1. 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. Orthogonal Frequency Division Multiplexing (OFDM) is most commonly employed in wireless communication systems because of the high rate of data transmission potential with efficiency for high bandwidth and its ability to combat against multi-path delay. To combat the effect of frequency selective fading, MIMO is associated with orthogonal frequency-division multiplexing.

(OFDM) technique. OFDM is modulation technique which transform frequency selective channel into a set of parallel flat fading channels. A cyclic prefix CP is added at the beginning of each OFDM symbol to eliminate ICI and ISI. [1]

LTE (Long Term Evolution) is the next generation MIMO-OFDM based system. LTE downlink system adopts Orthogonal Frequency Division Multiple Access (OFDMA) as a access technique. LTE Downlink system is MIMO-OFDM based which delivers high data rates of up to 100Mbps for 2x2 MIMO systems.[2]

Channel estimation is an important part for the design of receivers in mobile communication systems. In order to recover the transmitted information correctly, the effect of the channel on the transmitted signal must be correctly estimated. In most of research work, the CP is equal or longer than the channel length but it is also important to study the performance of MIMO-OFDM system where the CP length is shorter than channel length. So that this task becomes more difficult because of ICI and ISI.

There were many articles based on the channel estimation for LTE system. Also the performance of LS and LMMSE technique for LTE Downlink system under the effect of channel length was studies in [2].

In this paper, we propose a hybrid LS-LMMSE channel estimation technique which is robust to the channel length effect.

Organization of paper is like this, an overview of LTE Downlink system is described in section II. A LTE MIMO-OFDM system model is given in section III. The LS and LMMSE channel estimation techniques are discussed and description of the proposed hybrid technique is given in section IV. Section V gives the simulation results of both the systems. The conclusion is given in the last section.

2. LTE DOWNLINK PHYSICAL LAYER

LTE physical layer will provide peak data rate in uplink up to 50 Mb/s and in downlink up to 100 Mb/s with a scalable transmission bandwidth ranging from 1.25 to 20 MHz to accommodate the users with different capacities. In order to improve the spectral efficiency in downlink direction, Orthogonal Frequency Division Multiple Access (OFDMA), together with multiple antenna techniques are exploited. LTE air interface exploit both the time division duplex (TDD) and frequency division duplex (FDD). Figure 1 shows the structure of the LTE radio frame. The duration of one frame in LTE Downlink system is 10 ms. Each LTE radio frame is divided into 10 sub-frames of 1 ms. As described in Figure 1, each sub-frame is divided into two time slots, each with duration of 0.5 ms. 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.

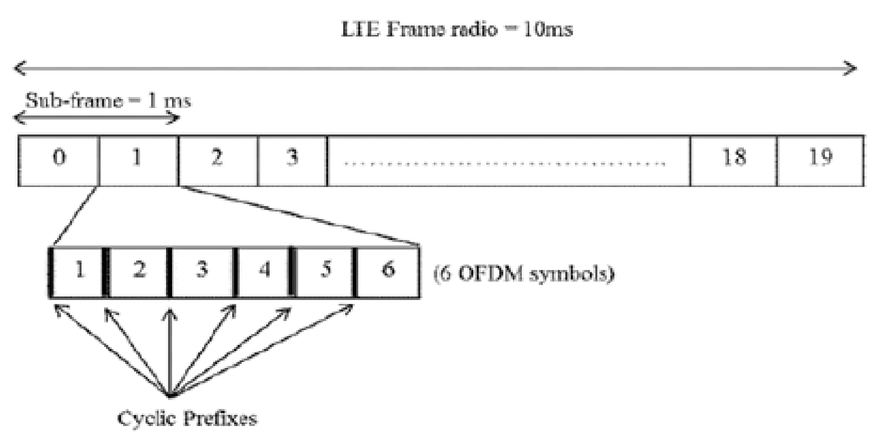

Figure 1: LTE radio frame structure [1]

The subcarrier are spaced by 15 KHz from each other. Therefore, each PRB occupies a bandwidth of 180 KHz (12 x 15 KHz).

The LTE specification define parameters for system bandwidths from 1.25 MHz to 20 MHz as shown in Table 1.

Table 1: LTE Downlink Parameters

Transmission Bandwidth (MHz)	1.25	2.5	5	10	15	20
Sub-frame duration (ms)	0.5					
Sub-carrier spacing (KHz)	15					
Sampling frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT size	128	256	512	1024	1536	2048
Number of occupied sub-carriers	76	151	301	601	901	1201

3. LTE DOWNLINK SYSTEM MODEL

LTE system is basically MIMO-OFDM based system. The system model is given in figure 2.

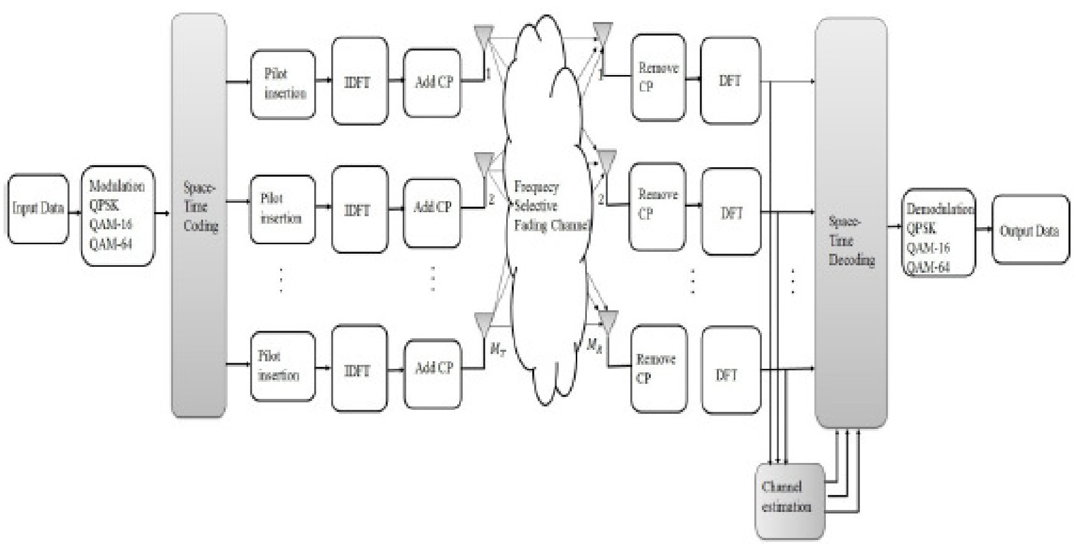

Figure 2: MIMO-OFDM system [1]

OFDM is employed as multiplexing technique in the LTE system. OFDM consists in dividing the transmission bandwidth into several orthogonal sub-carriers. The entire set of subcarrier is shared between different users. The N subcarriers are spaced by 15 KHz. To combat the effect of frequency selective fading, a cyclic prefix (CP) with the length of L_{CP} is inserted at the beginning of each OFDM symbol.

Each OFDM symbol is transmitted over frequency selective fading MIMO channels assumed independents of each other. Each channel is modeled as a Finite Impulse Response (FIR) filter with

L taps. After moving the CP and performing the DFT, the received OFDM symbol at one receive antenna can be written as:

$$Y = XH + \mu \quad (1)$$

Y represents the received signal vector, X is a matrix which contains the transmitted elements on its diagonal. H is a channel frequency response, and μ is the noise vector whose entries have the i.i.d. complex Guassian distribution with zero mean and variance σ^2.

4. CHANNEL ESTIMATION

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.

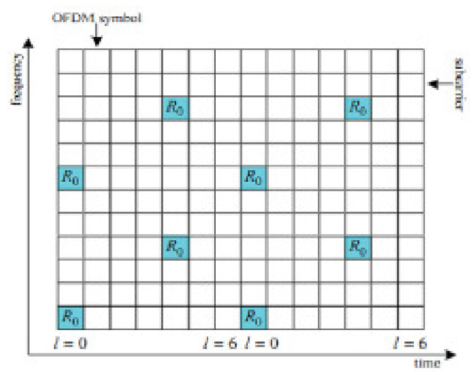

Figure 3: Downlink reference signal structure on one antenna [2]

From (1), the received pilot signals can be written as:

$$Y_P = X_P H_P + \mu_P \quad (2)$$

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

4.1 Least Square LS

The main purpose of the channel least square estimator is to minimize the square distance between the received signals and the original signal.

The least square estimate (LS) of the channel at the pilot subcarrier given in (2) can be obtained by the following equation [3].

$$H_p^{LS} = (X_P)^{-1} Y_P \quad (3)$$

4.2 Linear Minimum Mean 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:

$$H_p^{LMMSE} = R_{HHP} (R_{HPHP} + \sigma^2 (XX^H)^{-1}) Hp^{LS} \quad (4)$$

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

The simplified LMMSE estimator becomes:[3]

$$H_p^{LMMSE} = R_{HHP}\,[R_{HPHP} + (\beta/SNR)I_P]^{-1}\,H_p^{LS} \quad (5)$$

Where β is scaling factor which depend on the signal constellation. SNR is the average signal to noise ratio, and I_P is identity matrix.[3]

4.3 Hybrid LS-LMMSE Channel estimation technique

For LTE Downlink systems, the performance of LS and LMMSE channel estimation techniques under the channel length effect was studied in [2][3]. In that paper, the simulation results shows that, in the case where CP is longer than the channel length, the LMMSE gives better performance than LS but at cost of complexity. In the other case, where CP is shorter than the channel length, LMMSE shows also better performance but only at low SNR value. For higher SNR values, LS gives better performance than LMMSE.

So that we propose hybrid LS-LMMSE channel estimation technique which is robust to the channel length effect. In this hybrid system, when CP is equal to or longer than the channel length, the hybrid LS-LMMSE algorithm will apply directly the LMMSE channel estimation technique. In other hand, when CP is shorter than channel length, the hybrid algorithm will act depending on received SNR value. When received SNR value is low, this algorithm will apply LMMSE channel estimation technique and when SNR value is high, hybrid algorithm will switch to LS estimation.

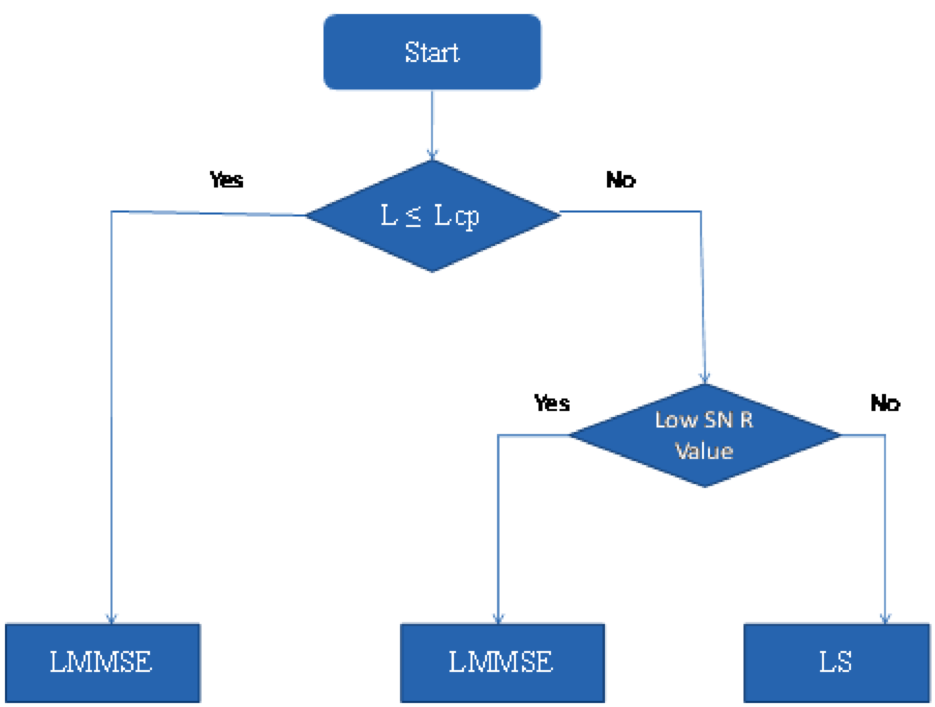

Figure 4: Hybrid LS-LMMSE channel estimation algorithm [3]

5. SIMULATION RESULTS

In this section, we investigates the performance of hybrid LS -LMMSE estimation techniques for 2x2 LTE Downlink system under the effect of the channel length. The transmitted signals are quadrature phase-shift keying (QPSK) modulated. The number of subcarrier in each OFDM symbol is N = 300, and the length of CP is $L_{CP} = 36$. 100 LTE radio frames are sent through a frequency-selective channel. The frequency selective fading channel responses are randomly generated with a Rayleigh probability distribution. Table 2 gives a summary of simulation parameters.

Table 2: Simulation 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

5.1 Case with $L \leq L_{CP}$

In this case, the cyclic prefix is longer than the channel length. So that, ISI and ICI are completely suppressed. The hybrid LS-LMMSE estimation will apply directly the LMMSE estimation technique. Simulation results shows that the LMMSE estimator gives better result than LS but at cost of complexity. Figure 5 and Figure 6 show respectively the performance of LS, LMMSE and hybrid estimator in terms of BER and MSE for L = 10.

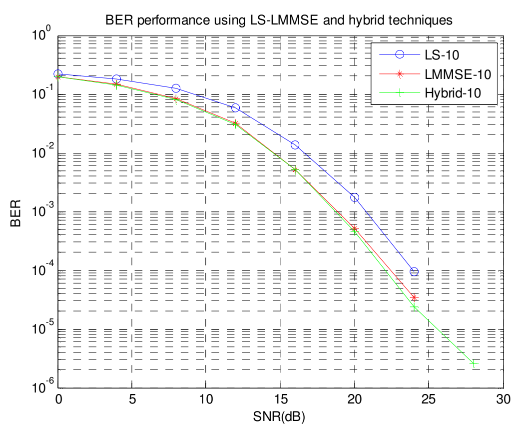

Figure 5: BER versus SNR for L=10

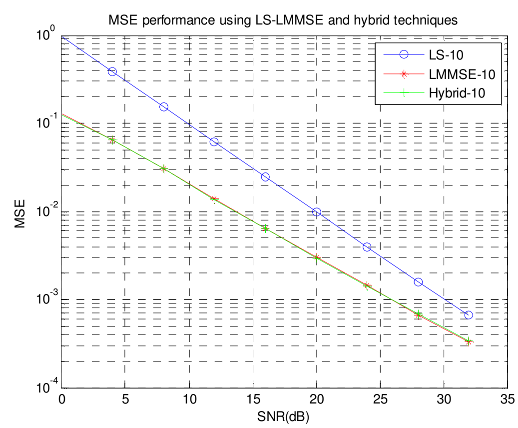

Figure 6: MSE versus SNR for L=10

5.2 Case with $L > L_{CP}$

In this case, the cyclic prefix is shorter than the channel length which shows the true efficiency for the performance of LTE Downlink system. In this case, some unforeseen behavior of the channel can occur. That will cause the introduction of ISI and ICI. Figure 7 and Figure 8 show the performance of LMMSE and Hybrid estimator in terms of BER and MSE respectively for L=46.

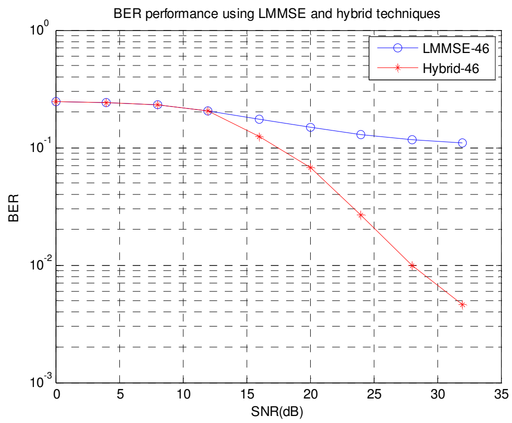

Figure 7: BER versus SNR for L=46

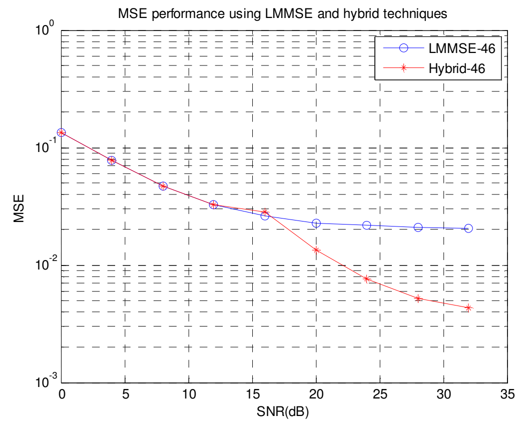

Figure 8: BER versus SNR for L=46

Simulation results show that the Hybrid LS-LMMSE estimator performs better than LMMSE estimator specially for high SNR range. For this range of SNR values, simulation results show large difference between two estimators and this proves well the efficiency of the proposed technique.

6. CONCLUSION

Channel estimation is a challenging problem in wireless system. In this paper, we evaluate the performance of Hybrid LS-LMMSE estimation techniques for LTE Downlink systems under the effect of the channel length. The cyclic prefix inserted at the beginning of each OFDM symbol is usually equal to or longer than the channel length in order to suppress ISI and ICI. Simulation results for LS and LMMSE techniques show that the LMMSE gives better performance than LS in case where CP is longer or equal to the channel length at cost of complexity. In the other case, where CP is shorter than the channel length, LMMSE gives better result only for low SNR value. For high SNR value, LS performs better than LMMSE estimator. In this paper, we compare the simulation results for both the hybrid and Non-hybrid system. Simulation results for the proposed hybrid system have shown the efficiency of hybrid technique and specially for the case where the channel length exceed the cyclic prefix length. In this paper, the hybrid technique applies LMMSE estimator for low SNR value. For high SNR value, the proposed technique applies LS estimator.

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