International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 4 (April 2014), PP.48-52

Performance of LTE Channel Estimation Algorithms for Different Interpolation Methods and Modulation Schemes

Hala M. Abd Elkader[1], Gamal Mabrouk[2],Adly Tag El-Dien[3] and Reham S. Saad[4]
[1,3,4]*Dep. of Elec. Eng. Shoubra Faculty of Engineering, Benha University, Egypt*
[2]*Department of Communications Engineering, Military Technical College, Cairo, Egypt*

Abstract: - In this paper, we present performance of pilot based channel estimation techniques such as Least Squares (LS) and Linear Minimum Mean Square Error (LMMSE) for different interpolation methods and modulation schemes. The performance is evaluated using the mean squared error (MSE) as the performance metric of interest for downlink LTE system. Simulation results show that for low SNR environment, applying QPSK modulation for any interpolation method produces the best MSE performance, but for high SNR environment, linear interpolation produces the worst MSE performance for QPSK and 16-QAM modulation schemes.

Keywords: -Channel Estimation, LS, LMMSE, Interpolation, LTE.

I. INTRODUCTION

Channel Estimation is the process of characterizing the effect of the physical medium on the input sequence. The channel estimate is essential for removing inter symbol interference, noise rejection techniques etc. In the wireless communication systems, excellent channel estimation technology has a directly impact on the decoding performance of the receiver. Therefore, in order to enhance the quality of communication, a channel estimation algorithm that is easy to implement and with high performance must to be proposed [1], [2].
An important block of the LTE receiver is the channel estimator which plays a crucial role in determining the error performance of the system [3]. LTE uses Orthogonal Frequency Division Multiplexing (OFDM) as its digital multi-carrier modulation scheme. OFDM is preferred not only because it offers high data rate transmission but also because of its flexibility and robustness against multipath fading [4].
The Channel estimation in OFDM based systems is typically done using pilot signals called reference signals placed intermittently along with data in the time frequency grid. These methods give good performance at the cost of reducing the bandwidth efficiency of the system. The loss is severe as the mobility and data rate increases, as the pilot spacing needs to be reduced to track the channel variations both in time and frequency [5].
There are two main problems in designing channel estimators for wireless OFDM systems. The first problem is the arrangement of pilot information. The second problem is the design of an estimator with both low complexity and good channel tracking ability. The two problems are interconnected [6].
Pilot symbols provide an estimate of the channel at given locations within a sub-frame. Through interpolation it is possible to estimate the channel at the data symbols from the known channel estimates at the pilot symbols. Various interpolation techniques can be considered that vary in their computational complexity and accuracy such as: linear interpolation, Spline interpolation and PCHIP interpolation. This paper investigates the performance of the one dimensional (1D) application of linear, spline and PCHIP interpolation methods on LS and LMMSE channel estimation over QPSK and 16QAM modulation schemes.
The remainder of this paper is organized as follows. Section 2 discusses the LTE downlink system model. Section 3 gives detail description of traditionalchannel estimation techniques. In section 4, it presents simulation results .Section 5 is the conclusion of the paper.

II. SYSTEM MODEL

A. *OFDM System Description*

The block diagram of an OFDM system is described in figure 1.

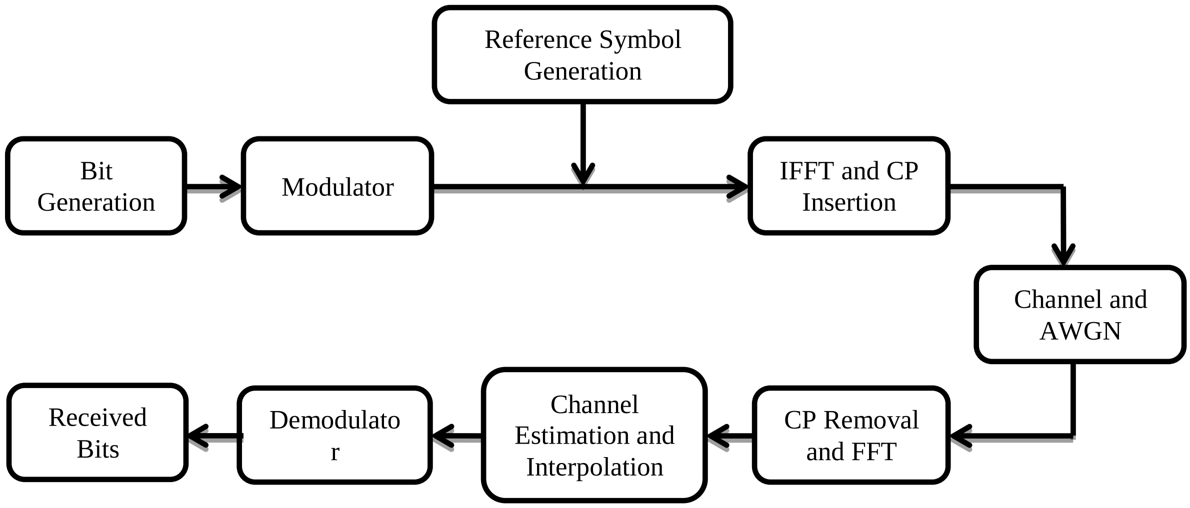

Fig. 1: Block Diagram of OFDM System

At the transmitter side, the data bits are generated then modulated. Each complex data-valued complex symbol is then assigned to a data subcarrier location. Also reference complex symbols (or pilots) are generated and inserted at the reserved pilot subcarrier location. Data and pilot symbols are then transformed into a time-domain sequence using the inverse Fast Fourier Transform (IFFT). Cyclic Prefix (CP) samples are chosen from the last part of the OFDM symbol, where a number of samples are copied and inserted at the beginning of the OFDM symbol to prevent Inter-Symbol-Interference (ISI) between consecutive OFDM signals.

At the receiver side, the OFDM demodulator is implemented using an N-point Fast Fourier Transform (FFT) operation to convert the signal back to the frequency domain after removing the CP. channel estimation is then performed to estimate the channel at the pilot subcarrier locations and is followed by interpolation, to estimate channel at data subcarrier locations. Finally, the signals are demodulated to obtain received bits [4], [7], [8].

B. *LTE Downlink Frame Format*

The frame format of LTE is illustrated in figure 2.

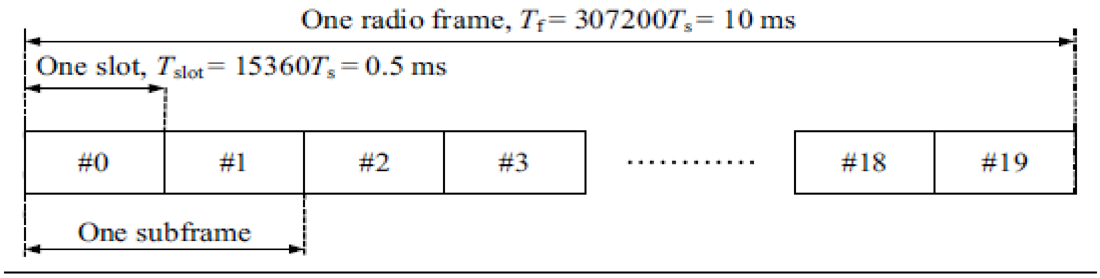

Fig. 2: LTE Frame Format

The LTE signal consists of frames with duration of 10 ms; each consists of ten sub-frames, each one has a period of 1 ms, and each sub-frame consists of two slots of 0.5 ms each. The slot in the time domain consists of seven OFDM symbols for the normal CP or six OFDM symbols for the long CP. Each OFDM symbol in the frequency domain consists of 12 subcarriers. The smallest unit in the LTE transmission frame is one symbol by one subcarrier, which is called a Resource Element (RE). Twelve adjacent subcarriers of one slot are grouped into a so-called resource block (RB) [3], [8].

The pilot subcarriers are equally spaced in frequency domain as pilots symbols are placed on every 6 subcarriers. In the time domain, the pilot symbols are transmitted in first, fourth and fifth OFOM symbol with different pilot subcarrier positions within the slot based on antenna ports configuration [4], [9].

III. CHANNEL ESTIMATION ALGORITHMS

In pilot aided channel estimation, the pilot signals are extracted from the received signals on respective pilot positions from each antenna port. The channel transfer function is estimated from transmitted (known) pilot symbols and received pilot symbols. The channel estimation at data subcarrier position is obtained through interpolation [9]. Assuming the received signal is

$$Y = HX + W \quad (1)$$

Where: *X* is the symbols transmitted by the sender; *Y* is the symbols received by the receiver; *H* is the channel frequency response; *W* is the zero-mean complex data-valued Additive White Gaussian Noise (AWGN) [1], [2], [4].

A. *Least Squares (LS) Algorithm*

The LS channel estimator can be expressed as:

$$\hat{H}_{LS} = X^{-1}Y \quad \textbf{(2)}$$

The LS algorithm ignores the influence of the noise. The performance of LS algorithm is not very good, but the complexity is the lowest [1], [4].

B. *Linear Minimum Mean Squared Error (LMMSE) Algorithm*

LMMSE algorithm considers the impact of noise. It suffers from a high computational complexity compared to the LS estimator but gives better mean square error performance [8]. The estimated channel response at the reference signal (RS) position can be written as:

$$H_{LMMSE} = R_{HH_P}[R_{H_PH_P} + I\frac{\beta}{SNR})]^{-1}\hat{H}_{LS} \quad \textbf{(3)}$$

Where R_{HH_p} represents the cross correlation matrix between all subcarriers and the subcarriers with reference signals, $R_{H_pH_p}$ represents the autocorrelation matrix of the subcarriers with reference signals, *I*is the identity matrix,*SNR*is the signal to noise ratio and $\hat{H}_{LS}$ is the channel response at the pilot position gained by LS estimation method. When the modulation mode is QPSK, we set β =1; If the modulation method is 16QAM, we **set β = 17 / 9 [1], [7].**

IV. SIMULATION RESULTS

The simulation is based on the LTE downlink channel estimation. The simulation parameters are listed in table 1.

Table I: Simulation Parameters

Simulation Parameter	value
Modulation Scheme	QPSK-16QAM
system Bandwidth	1.4 MHZ
Number of occupied RBs	6
Number of occupied subcarriers	72
FFT/IFFT size	128
Pilot Spacing	6
TX/RX antenna	Single User SISO

The MSE performance of LS and LMMSE channel estimation for linear, spline and pchip interpolation methods and for QPSK and 16QAM modulation schemes is shown in figure 3 and figure 4.

From figure 3, for the same modulation scheme and at low SNR, performance of linear interpolation is the best. But for higher SNR, the performance of linear interpolation is poor compared to other methods. Comparing QPSK and 16-QAM modulation schemes, at low SNR, performance of QPSK modulation with different interpolation methods is better than performance of 16-QAM modulation with different interpolation methods but for higher SNR, the performance of Spline and Pchip QPSK modulation is the best. The performance of Spline and Pchip 16-QAM modulation is better than the performance of linear QPSK modulation.

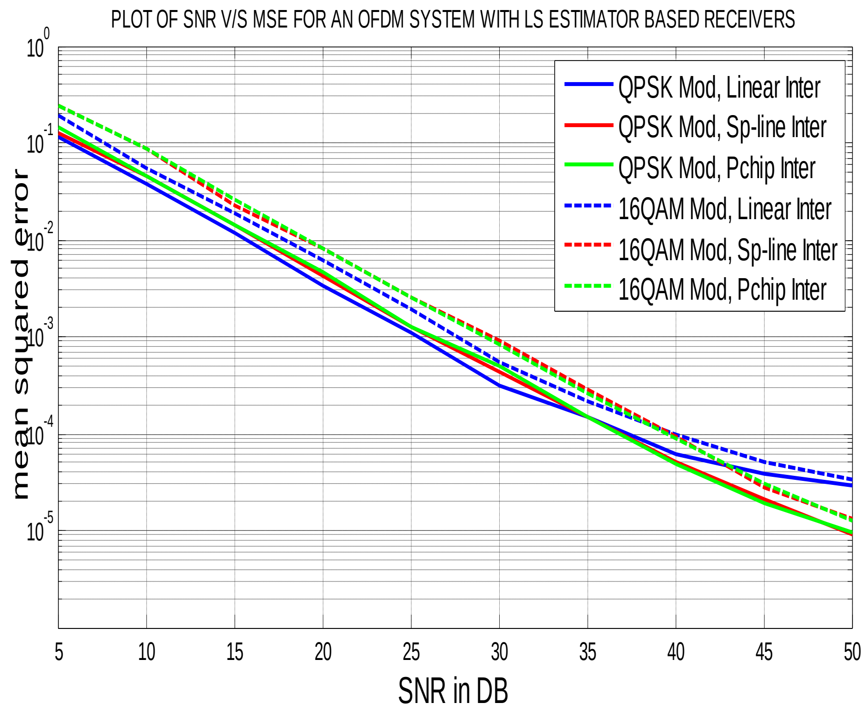

Fig.1: MSE Performance of LS Channel Estimator with different Interpolation methods and modulation Schemes

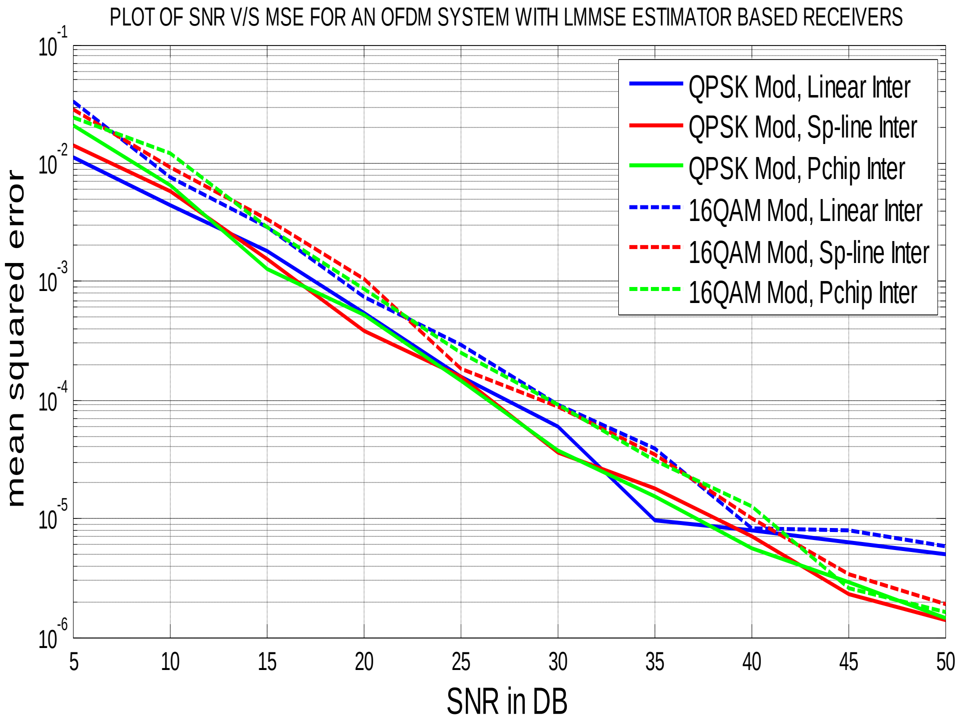

Fig. 2: MSE Performance of LMMSE Channel Estimator with different Interpolation methods and modulation Schemes

From figure 4, for the same modulation scheme and at high SNR, the performance of linear interpolation method is the worst. Comparing QPSK and 16-QAM modulation schemes, at high SNR, Performance of Spline and Pchip QPSK modulation is the best and the performance of Spline and Pchip 16-QAM modulation is better than the performance of linear QPSK modulation.

V. CONCLUSION

This paper demonstrates performance of LS and LMMSE LTE channel estimators for different interpolation methods and modulation schemes. Simulation results show that, MSE performance for the same channel depends on interpolation method and modulation scheme.

ACKNOWLEDGEMENTS

I wish to thank everyone who helped me complete this dissertation. Without their continued efforts and support, I would have not been able to bring my work to a successful completion.

REFERENCES

[1] Wenwen Liu &Xiaolin Li "An Improved LMMSE Channel Estimation Algorithm of LTE System,"Fourth International Conference on Computational and Information Sciences,2012,PP. 231-234.

[2] Wang Hong-jin& Liu Li-fa"A Modified Channel Estimation Based on SVD in LTE-Advanced Systems, " 7th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM),2011. PP. 1-5.

[3] Ahmed M. AL-Samman, TharekAbdRahman, Uche AK Chude-Okonkwo&RazaliNgah, "Hybrid Channel Estimation for LTE Downlink," IEEE 9th International Colloquium on Signal Processing and its Applications,2013, PP. 44-48.

[4] S. Adegbite, B. G. Stewart & S. G. McMeekin, "Least Squares Interpolation Methods for LTE System Channel Estimation over Extended ITU Channels," International Journal of Information and Electronics Engineering, Vol. 3,No. 4, PP. 414-418,2013.

[5] MandaRajarao, R V Raja Kumar, DivyaMadhuri&MadhaviLatha, "Efficient Channel Estimation Technique for LTE Air Interface," Asia Pacific Conference on Postgraduate Research in Microelectronics & Electronics (PRIMEASIA), 2012, PP. 214-219.

[6] Gurpreet Singh Saini&Harnek Singh, "Improving Channel Estimation Accuracy in OFDM System Using MATLAB Simulation," An International Journal of Engineering Science and Technology, Vol. 2,No.2, PP. 285-287, 2012.

[7] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, MIMO-OFDM Wireless Communications with MATLAB, John Wiley & Sons (Asia) Pte Ltd,2010.

[8] Ahmad El-Qurneh, "Low-complexity channel estimation for LTE-based systems in time-varying channels," Master Thesis, University of New Brunswick, 2013.

[9] Thiruvengadathan R, Srikanth S, "Performance of MIMO Channel Estimation in LTE Downlink," Third International Conference on Computing Communication & Networking Technologies (ICCCNT),2012, PP. 1-7.