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Research Paper

PERFORMANCE ENHANCEMENT BY LMMSE CHANNEL ESTIMATION TECHNIQUE FOR LTE-ADVANCED DOWNLINK SYSTEM

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Long Term Evolution-Advanced (LTE-A) system is based on Multiple-Input; Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) technology has become the mainstream technology for next-generation wireless communications. To increases data rate in LTE-A systems by reducing the error rate, the major challenge is Channel Estimation (CE). CE is an important part of OFDM receiver, which is the important basis for obtaining channel information, achieving channel equalization and choosing transmission method. The main purpose of this paper is to improve the performance using channel estimator Linear Minimum mean square error (LMMSE) Physical Downlink Shared Channel (PDSCH) of LTE-A systems. In order to perform CE the transmitter and receiver architecture of PDSCH is also designed based on 3GPP release 10 using MATLAB. The simulations shows LMMSE channel estimator outperforms well than the other channel estimators like least square (LS) and Minimum Mean Square Error (MMSE) in terms of Mean Square Error (MSE) for 2×2 LTE-A downlink systems.

Keywords: LTE-A,OFDM, Channel estimation, LS, MMSE, LMMSE

INTRODUCTION

In today's scenario rapid evolution in wireless and cellular communications usage, and the resulting huge demand, new communications technologies are needed to support the growth of mobile telephony and in turn tremendous increase in Internet data traffic are need. Therefore various techniques have been proposed in recent years to meet the requirements of 4G. LTE-A is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard. LTE-A also introduces multicarrier to be able to use ultra wide bandwidth, up to 100 MHz of spectrum supporting very high data rates. In radio communications, multipath propagation can cause errors and affect the quality of communications. These errors are due to Inter Symbol Interference (ISI). As a result of multipath propagation several replicas of the transmitted signal arrive at the receiver at different delays. So channel estimation is a vital part in the receiver designs of LTE-A downlink systems. Channel estimation is implemented to obtain the transfer function of the real channel, which is necessary

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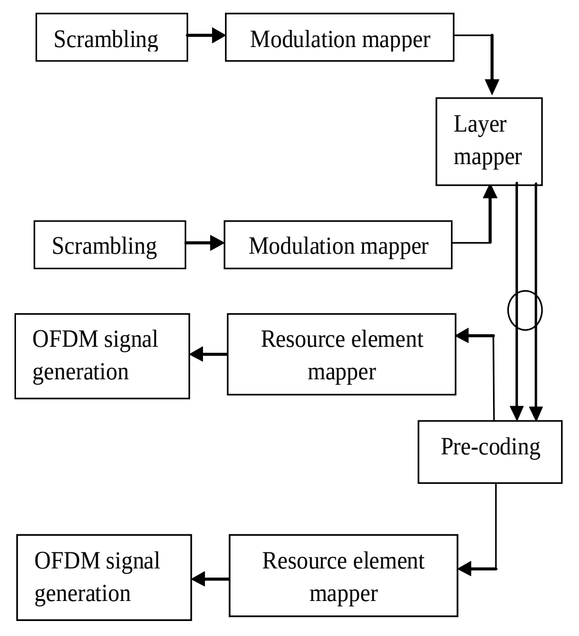
for modulated OFDM systems. The main purpose of the channel estimation is to minimize mean square error between transmitted and received signals. In this paper the performance of the PDSCH channel for LTE-A system is increased by using LMMSE channel estimator under Rayleigh channel environment. The incoming signals are modulated using QPSK, 16-QAM, 64-QAM modulation scheme. The modulated signals are sent through the channel. The corrupted signal from the channel has been undergone the different channel estimators such as LS, MMSE, LMMSE algorithms before the demodulation takes place at the receiver side and hence the increase the data rate by reducing the error rate. In wireless communication, the channel is usually unknown a priori to the receiver .Therefore to do the channel estimation; a pilot symbol aided modulation is used, where known pilot signals are periodically sent during the transmission. In general, the performance of channel estimation depends on the number, the location and the power of pilots symbols inserted into OFDM blocks.

OFDM is a special case of multicarrier transmission which is highly attractive techniques,offers a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency .In OFDM ,non-frequency selective narrowband sub channels into which the frequency wide band channel is divided are overlapping but orthogonal. In frequency-selective fading, the coherence bandwidth of the channel is smaller than the bandwidth of the signal. Different frequency components of the signal therefore experience fading. OFDM is used to overcome frequency selective fading.

OVERVIEW OF LTE-A DOWNLINK SYSTEM

The role of the physical layer is primarily to translate data into reliable signal for transmission across the radio interface between the eNodeB and user equipment. Each block of data is first protected against transmission errors, usually first with a Cyclic Redundancy Check (CRC), and then with channel coding.

Figure 1: General signal structure for LTE-Advanced downlink

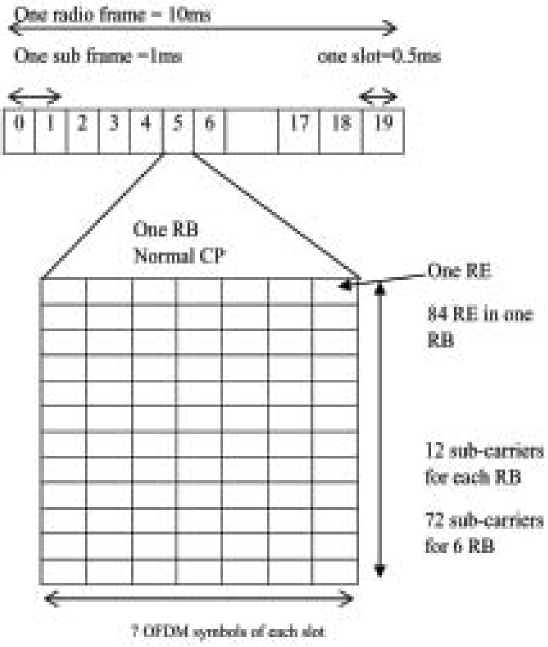


In the Transmitter side the initial scrambling stage is applied to all downlink physical channels, and serves the purpose of interference rejection. The scrambling sequence in all cases uses an order-31 Gold code which can provide 2^{31} sequences which are not cyclic shifts of each other. The scrambling sequence generator is the same as for the pseudo-random sequence used for the reference signals. Following the scrambling stage, the data bits from each channel are mapped to complex valued modulation symbols depending on the relevant modulation scheme, then mapped to layers, mapped to REs, and finally translated into a complex-valued OFDM signal by means of an IFFT. The transmitter and receiver architecture are considered as the same which is given in the release 10 of LTE-A downlink system.

PDSCH FRAME FORMAT

7 OFDM symbols of each slot.

Figure 2: PDSCH Frame Format



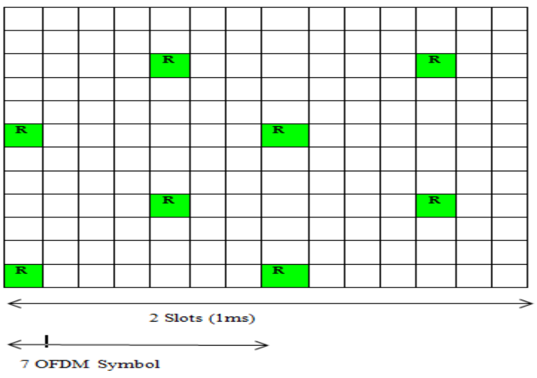
REFERENCE SIGNAL FORMAT

The reference signals can be multiplexed with data symbols in either the frequency, time or code domains. Multiplexing- based techniques have the advantage of low receiver complexity, as the symbol detection is decoupled from the channel estimation problem. The multiplexing reference signals in the code domain is a particular type of superposition with a constraint on orthogonality between known reference signals and the unknown data.

OFDM-based system an equidistant arrangement of reference symbols in the lattice structure achieves the minimum mean squared error estimate of the channel. The required spacing in time between the reference symbols can be obtained by considering the maximum Doppler spread to be supported. In the frequency direction there is one reference symbol every six subcarriers on each OFDM symbols which includes reference symbol, but these are staggered so that within each RB there is one reference symbol every 3 subcarriers based on the Coherence Time and Bandwidth of the channel.

The LTE-A downlink has been specifically designed to work with multiple transmit antennas, RS patterns are therefore defined for multiple 'antenna ports' at the eNodeB. For each antenna port, a different RS pattern is designed. In particular when a RE is used to transmit an RS on one antenna port, the corresponding RE on the other antenna ports is set to zero to limit the interference. The density of RS for the third and fourth antenna ports is half that of the first two; this is to reduce the overhead in the system. For

Figure 3: Reference signal

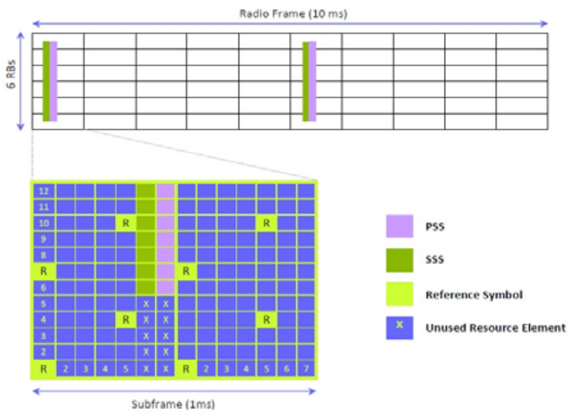


the cell specific RS, a cell-specific frequency shift is also applied. The shift can avoid time-frequency collisions between common RS from up to six adjacent cells.

SYNCHRONIZATION SIGNALS

Synchronization requirements can be identified in the LTE-A system are the symbol timing acquisition, carrier frequency synchronization which is required to reduce or eliminate the effect of frequency errors and sampling clock synchronization. Two relevant cell search procedures exist in LTE-A are initial synchronization and new cell identification. The synchronization procedures make use of two specially designed physical signals which are in each cell: the Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS). The synchronization signals are transmitted periodically, twice per 10ms radio frame. In an FDD cell, the PSS is always located in the last OFDM symbol of the first and eleventh slots of each radio frame. The SSS is located in the symbol immediately preceding the PSS, a design choice enabling coherent duration is significantly longer than one OFDM symbol.

Figure 4: Synchronization Signals

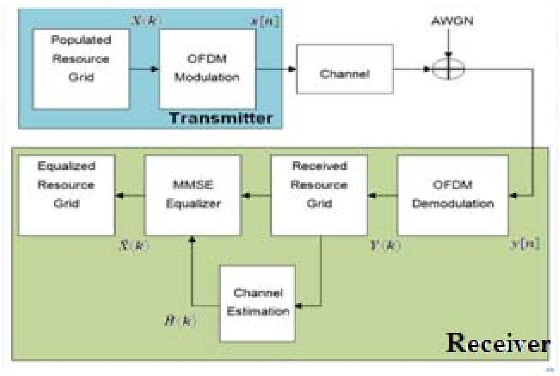


While the PSS in a given is the same in every sub frame in which it is transmitted, the two SSS transmission in each radio frame change in a specific manner. The PSS and SSS are transmitted in the central six RB enabling the frequency mapping of the synchronization signals to be invariant with respect to the system bandwidth; this allows the UE to synchronize to the network without any a priori knowledge of the allocated bandwidth. The PSS and SSS are each comprised of a sequence of length 62 symbols, mapped to the central 62 subcarriers around the D.C subcarrier which is left unused. This means that five REs at each extremity of each synchronization sequence are not used. In the case of multiple transmit antennas being used at the eNodeB ,the PSS and SSS are always transmitted from the same antenna port in any given sub frame, while between different sub frames they may be transmitted from different antenna ports in order to benefit from time-switched antenna diversity. The particular sequences which are transmitted for the PSS and SSS in a given cell are used to indicate the physical layer cell identity to the UE.

CHANNEL ESTIMATION

Pilot –assisted channel estimation is a method in which known signals, called pilots, are transmitted along with data to obtain channel knowledge for proper decoding of received signals. Channel estimation algorithms such as Least Squares (LS), Minimum Mean Square Error (MMSE) and Linear Minimum Mean Square Error (LMMSE) have been evaluated for different channel models in LTE-Advanced downlink. Figure 5 shows the receiver block diagram for the MMSE channel estimation.

Figure 5: MMSE channel estimation in PDSCH LTE-A Receiver



Performance of these algorithms has been measured in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR). The estimation of channel effects is often based on an approximate underlying model of the radio propagation channel. The receiver can precisely recover the transmitted information as long as it can keep track of the varying radio propagation channels.

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 first step in determining the least squares estimate is to extract the pilot symbols from their known location within the received sub frames. The value of these pilot symbols is known and therefore the channel response at these locations can be determined by using the least squares estimate which is obtained by dividing the received pilot symbols by their expected value.

If inter symbol interference is eliminated by the cyclic prefix, then the frequency domain estimation of LS becomes,

$$\hat{H}_{P,LS}(K) = \frac{Y_P(K)}{X_P(K)} + noise \qquad ...(1)$$

In equation (1) $\hat{H}_{P,LS}(K)$ is the least square estimate of the channel at pilot symbol location and $Y_P(K)$ represents received pilot symbol values,$X_P(K)$ represents known transmitted pilot symbol values.

B. Minimum Mean Square Error (MMSE)

Frequency domain MMSE estimates of h becomes,

$$\hat{H}_{MMSE} = F R_{hy} R_{yy}^{-1} y \qquad ...(2)$$

where

$$R_{hy} = E\{hy^H\} = R_{hy} F^H X^H \qquad ...(3)$$

$$R_{yy} = E\{yy^H\} = XF R_{hh} F^H X^H + \sigma_n^2 I_N \qquad ...(4)$$

In equation (3) R_{hy} represents cross covariance matrix between h and y, in equation (4) R_{hh}, R_{yy} represents the auto covariance matrix and σ_n^2 is the noise covariance matrix. The MMSE estimator belongs to the class of statistical estimators. Unlike deterministic LS and its derivations; statistical estimators need knowledge of the second-order statistics of the channel in order to perform the estimation process, normally with much better performance compared to deterministic estimators.

C. Linear Minimum Mean Square Error (LMMSE)

The LMMSE channel estimator is designed to minimize the estimation MSE. The LMMSE estimate of the channel response is given by

$$R_P^{LMMSE} = R_{HH_P} (R_{H_P H_P} + \sigma_\mu^2((XX^H)^{-1}) H^\wedge{}_P^{LS} \qquad ...(5)$$

In equation (5) R_{hh} represents the cross correlation matrix between all subcarriers and subcarrier with reference signals and R_{hh} represents auto correlation matrix of all subcarrier and subcarrier with reference signals. The complexity of this estimator can be reduced by averaging the transmitted data.

The simplified LMMSE estimator becomes

$$\hat{H}_P^{LMMSE} = R_{HH_P}(R_{H_P H_P} + \frac{\beta}{SNR} I_P)^{-1} H_P^{LS} \qquad ...(6)$$

where β in equation (6) is scaling factor depending on the signal constellation ($\beta = 1$ for QPSK and $\beta = 17/9$ for 16-QAM). SNR is the average signal to noise ratio, I_p is the identity matrix.

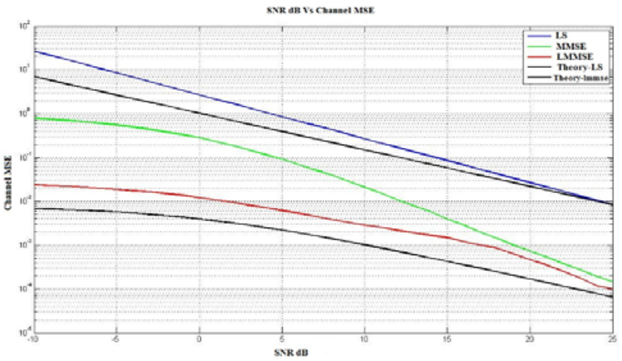
SIMULATION RESULTS

For the simulation in MATLAB using LTE tool box, the FDD Frame structure of PDSCH is taken under Normal CP having six RB. The simulation is carried for all the three channel estimation algorithms. The different parameters of PDSCH in LTE-A downlink system are given in the Table 1. The numerical results are obtained for Signal to Noise Ratio (SNR) range from -10 dB to 25 dB and the Monte-Carlo runs of 1000 under Rayleigh fading channel environment having the tab length of L=5. The number of transmitter and receiver are two i.e 2x2 scenario is taken for the simulation. The Figure 6 shows the SNR (dB) versus Channel MSE for the three channel estimators LS, MMSE and LMMSE and these results are compared with the theoretical bound of channel estimators LS and LMMSE. Simulation results show that channel MSE rate for LMMSE estimator is least when compared to other two estimators LS and MMSE.

Table 1: LTE-A Parameters

Transmission Bandwidth MHz	**1.4**	**3**	**5**	**10**	**15**	**20**
Subcarrier			15KHz			
Subcarrier duration	0.5ms					
Sampling Frequency MHz	1.92	3.84	7.68	15.36	23.04	30.72
FFT N value	128	256	512	1024	1536	2048
Number of Resource Blocks	6	15	25	50	75	110
Modulation Schemes	Downlink – QPSK, 16-QAM, 64-QAM					
Multiple access	OFDMA					
MIMO technology	Transmit diversity, Spatial Multiplexing and Cyclic Delay Diversity					
Peak data rate	150 Mbps (2x2 MIMO)300 Mbps (4x4 MIMO)					

Figure 6: SNR (dB) vs Channel MSE (LS, MMSE, LMMSE)



CONCLUSION

The performance of PDSCH channel of LTE-A downlink systems is enhanced by using LMMSE channel estimation technique. LMMSE channel estimator outperforms well when compared to other channel estimators like LS and MMSE under the Rayleigh channel environment. The channel MSE rate is reduced in the PDSCH using LMMSE channel estimation technique that intern leads to the reduction of bit error rate and hence increase in the overall data rate of the 2x2 LTE-A downlink system. In future same channel estimation technique can be extended other remaining channel types in the LTE-A downlink system and also for different channel environment are to be considered.

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