ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 10(40), DOI: 10.17485/ijst/2017/v10i40/120272, October 2017*

Comparison of Compressed Sensing MMSE Channel estimation with conventional LS and MMSE

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Abstract

Multiple-input multiple-output (MIMO) Orthogonal frequency division multiplexing (OFDM) technology is becoming mature in wireless communication systems. It has led to the third and fourth generation wireless systems which have been providing good range, reliability and higher data rates. To extract the benefits provided by the MIMO systems, it is necessary to estimate the noisy channel through which the information is transmitted. To acquire the channel parameters, we propose compressed sensing (CS) method based on priority which considers the channel with few dominant taps, i.e., sparse nature of the channel is exploited. In this method, priority is taken into consideration, where all user equipments (UE) are not of equivalent significance and more inclination is given to the user with high need. When the number of UEs is more than the available channels, rating is given to UEs based on some heuristics. With this proposed method, we can obtain better performance in-terms of BER and SNR when compared to the conventional methods such as least square (LS) and minimum mean square error (MMSE) techniques. Simulation results show the comparison between the proposed method and the conventional method which proves that the compressed sensing technique outperforms the LS and MMSE techniques.

Keywords: Channel Estimation, Compressed Sensing, MIMO-OFDM, MMSE, LS, UE

1. Introduction

One major task of Wireless communication system is that the transmitted signal suffers from fading and interference. Multiple -input multiple- output (MIMO) addresses the solution against these problems. MIMO uses multiple antennas at the transmitters and receivers which makes it possible to have multiple paths from the source to the destination. It can be used to improve the overall efficiency in range in Wi-Fi applications such as Hotspots or within the home where we are using wireless technology. Multipath propagation improves the overall efficiency, since it guarantees that at least one path does not suffer from fading. The key modulation technique that enables MIMO is OFDM[1-2].

In order to recover signal that are transmitted more efficiently, information regarding the channel state is required for receiver. This paper mainly concentrates on MIMO frameworks that utilize OFDM which offer capability to estimate the channel. OFDM is a key method in Communication systems, due to its high rate transmission and robustness to inter-symbol-interference. If Channel State Information (CSI) will be accessible to transmitter and increases the performance, resulting in less complexity of recipient algorithm of channel estimation[3]. In OFDM, transmission occurs point to point and it is normally accepted that interval guard bit has extreme spread of delay. Thus approaches for estimation of channel based on time methodologies accomplish preferable execution over conventional approaches by lessening the

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quantity of parameters to be evaluated. Such methods will be powerful for the estimation of channel using compressed sensing[4].

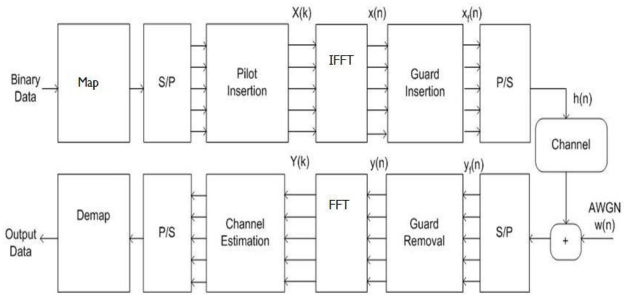

Figure 1. Implementation of OFDM System[5].

2. System Overview

OFDM is one of the methods to enhance capacity of system on various frequencies by parallel transmission of data. Non-overlap sub channels of frequency are obtained by dividing among total available band of frequencies. At the first stage encoder present at the transmitter side maps the data by using any modulation scheme. In this paper Quadrature amplitude modulation (QAM) scheme is considered. This scheme helps us to overcome the possible phase drift that occur at the signal received at receiver side. Then in serial to parallel conversion stage, the input symbol stream of QAM which are serial, changed over to parallel stream with width equivalent to quantity of subcarrier. After that carriers of pilot are inserted to estimate channel followed by inverse Fast Fourier transfer (IFFT) for each subcarrier symbols that are parallel modulated, IFFT size are considered more than the subcarrier number that are used to transmit information[6]. This is done to yield a range with relative out of band radiation subsequent to stage of IFFT, it includes cyclic prefix. To make the framework vigorous to multipath proliferation, after that stage serial signals are obtained which are transferred over wireless channel and gets affected due to interference of noise. The OFDM receiver fundamentally plays out the operation that is reverse to transmitter. To start with, recipient needs to gauge offset frequency and timing symbol, utilizing particular symbol training in preamble. By choosing fast Fourier Transform for each symbol to recuperate the Quadrature amplitude modulation (QAM) estimations of all sub carriers and pilot training symbols are utilized to correct the channel response and rest of phase drift. The values of QAM are then remapped to binary values and then by using decoder, data bits are obtained.

3. Channel Estimation

Channel estimation is a vital part in wireless communication. In real scenario, the channel changes over time, usually when the transmitter or the receiver is moving at a vehicular speed which is the case in mobile communication[7]. So it is essential to acquire the channel state information (CSI) in a timely manner. In this paper, estimation of the channel is done by the sequence of training which are well known mutually to transmitter as well as receiver. Recognized bits of training together with their corresponding samples received are utilized by receiver, for the purpose of assessing the channel.

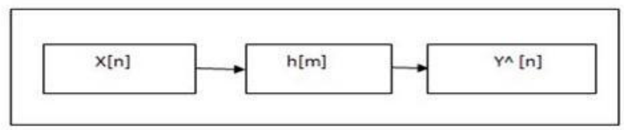

Figure 2. Least square system.

3.1 Least Square Method

In this method of Least Square estimation, it assesses the h[m] system by limiting the error of square among detected signal and estimated signal. LSE mainly minimizes the square distance between the received signal and original signal. This method is known by its low complexity, because they do not need the statistic information of channel.

System is modeled in matrix form as

$$y = Xh \tag{1}$$

In equation (1), error (e) is as follows

$$e = y^* - y \tag{2}$$

In equation (2), expected output is represented by y*

$$s = (y^* - Xh) * (y^* - Xh)^t \tag{3}$$

Equation (3) is simplified by equating for zero, and then finally equation (4) is obtained,

$$h^* = (x^t x)^{-1} x^t y \tag{4}$$

Above equation (4) written as below, by considering x to be invertible matrix

$$H_{LS} = X^{-1} * y \tag{5}$$

3.2 Minimum Mean Square Error

The main Purpose of MMSE estimator is to reduce the mean square error (MSE). It requires prior knowledge of channel statistics, noise variance and high complexity[8]. If X is considered for transmitting in channel h, then MSE (Z) is given as

$$Z = mean\{(Y^* - Y)^\wedge 2\} = E\{(Y^* - Y)^\wedge 2\} \quad (6)$$

Z indicates mean square error

E represents value expected

To get the equations in order to find the channel response, theory of correlation as well as expected value has been utilized. Estimated channel h_{mmse} is obtained by the below formula

$$h_{mmse} = f^*(r_{gy}^* \quad r_{yy}^{-1} * y) \quad (7)$$

f -noise matrix, r_{yy} – y Auto covariance matrix, r_{gy} –g,y Cross covariance matrix.

3.3 Compressed Sensing based MMSE

Compressed sensing (CS) is a new technique that has been developed recently. It has seen as a beneficial signal acquiring framework for signals portrayed as insufficient or compressible in time or frequency. One way of utilization of the CS technique is in channel estimation. If the channel drives response takes after sparse spreading, by applying the CS strategy along these lines, the training sequence length can be abridged compared with earlier estimation systems. Recent measurements show that the deficient or sparse lacking assumption is sensible with packed channels[9]. In recent times the survey on compacted identifying based systems has drawn a lot of contemplation and concerning results can be found by simulations.

When the transmitter sends the signal, and if the number of transmitters is more than the existing channels, pilot symbols corresponding to a particular transmitter will be considered based on weight factors and they will be compressed using Fast Fourier transform to get the coefficients. After insertion of coefficients, they will be transmitted to the receiver, where it is reconstructed using Inverse Fast Fourier transform and later the channel will be estimated using MMSE.

Considering N subcarriers, frequency response of impulse response is given by,

$$H_{i,j} = [H_{i,j}(0), H_{i,j}(1) \dots H_{i,j}\ (N-1)]^T \quad (8)$$

By considering frequency response that has been estimated, where demodulation reference signal are inserted, composite channel frequency response is given by,

$$G_{n,m}^{MMSE} = \frac{R_{est} \quad E_{DMRS}^T}{N} * \left(\frac{R_{est} \quad E_{DMRS}^T E_{DMRS}}{N} + \sigma^2 I\right)^{-1} G_{n,m}^{\wedge} \quad (9)$$

This method is considered as MMSE based compressed sensing (CS MMSE). MMSE is used even though it is complex, because of noise and intercarrier interference of LS method. But matrix inversion at each iteration is required in MMSE, so the CS MMSE is used where the inverse is calculated only once.

4. Results

MATLAB is used as a simulation tool and number of error bits is calculated by considering the bits that has been distorted due to noise over channel. Number of error bits over total bits that has been transmitted gives the measure of bit error rate. Figure 3 shows the comparison of bit error rate graph. From the graph it is inferred that compressed sensing based MMSE provides better result compared to conventional LS. Figure 4 shows same scenario, from analyzing the curve it infers that compressed sensing based MMSE provides better result compared to conventional MMSE, Figure 5 shows the same scenario but it includes Comparison of all the three methods such as conventional least square method, compressed sensing MMSE and conventional MMSE. Table 1 shows comparison of bit error rate for all the algorithms.

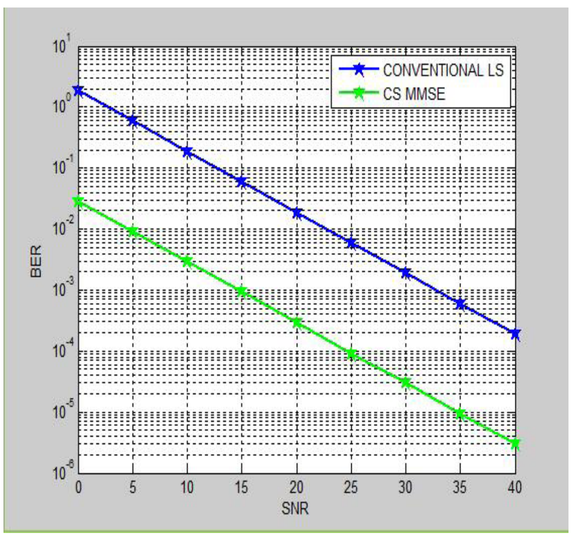

Figure 3. BER Comparison graph (LS and CS MMSE).

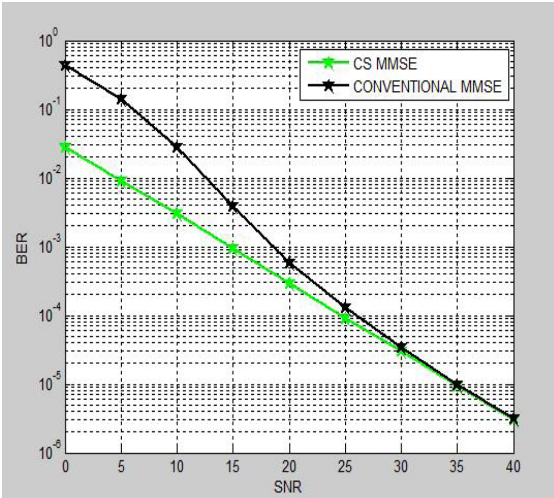

Figure 4. BER Comparison graph (Conventional MMSE and CS MMSE).

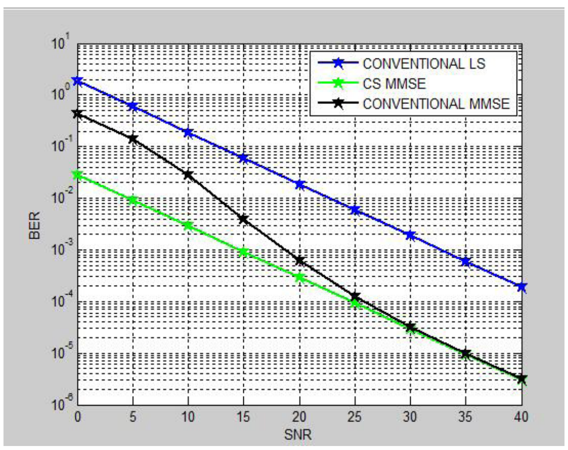

Figure 5. BER Comparison graph (Conventional LS, MMSE and CS MMSE).

Table 1. Comparison Table

SNR(db)	BER (CONVENTIONAL LS)	BER (CONVENTIONAL MMSE)	BER (CS MMSE)
0	1.5848	0.3162	0.0251
5	0.3981	0.1	0.01
10	0.1584	0.0251	0.0025
15	0.0398	0.0031	0.001

5. Conclusion and Future Scope

In this paper Compressed sensing based channel estimation is designed and compared with the conventional methods such as least square and minimum mean square error performance of OFDM based system. From the performance curve, it has been observed that the BER curve obtained from compressed sensing MMSE shows significant reduction in BER than LS and MMSE.

In this work, compression of demodulation reference signal is done by using least square method and minimum mean square method. Enhancement can be done by using matching pursuit algorithm of compression[10], which will increase the level of compression.

6. Acknowledgement

We would like to thank CMR Institute of technology for lending their support throughout the work.

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