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Channel Estimation for MIMO OFDM Systems using LS and MMSE Channel Estimation Techniques

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Abstract

Multiple Input Multiple Output, also known as MIMO, is a very useful technology that can be used to meet the increasing demand for wireless communications and to achieve transmission speed and data. Various channel estimation techniques can be used to predict the transmission and reception of data between antennas. In this paper, the LS (least squares) and MMSE (Minimum Mean Square Error) estimation method is used, which yield good results.

Index Terms: *LS, MIMO, MMSE, BER, SNR, OFDM.*

1. Introduction

As the number of users of wireless communication has increased, so have the challenges of meeting the demands. In the future, demand is expected to grow rapidly. The technique of orthogonal frequency division multiplexing is popular for solving such problems. It is used exclusively for broadband services. In this manner, high-speed data can be transmitted over a large number of low-rate careers. Orthogonal Frequency Division Multiplexing (OFDM) is a multi-career wideband digital communication system. It is used in modern communication systems, such as Cellular 4G, wireless networks, Digital TV, etc. In this system, a large number of closely spaced orthogonal careers are used to carry data on parallel streams. Lower symbol rates are obtained while achieving the same data rate for a fixed bandwidth. It is possible to eliminate inter symbol interference (ISI) by inserting a guard interval due to the slow symbol rate. The disadvantages are that there might be some loss in efficiency due to guard bandwidth, and there is high peak to average power ratio (PAPR). In LSE technology, the square distance between the original signal and the received signal is reduced.

This paper is organized as follows: Section II deals with related work in channel estimation, Section III deals with system architecture and Section IV algorithms. Finally the results are given in V and deals with the conclusion in Section VI.

2. Related Work

[1] Compares four channel estimation algorithms for MIMO LTE downlink systems. The simulation results show that for uncontrolled systems, LS estimation in combination with linear approximations works very well and strengthens the channel complexity with moderate complexity. Linear and spline interpolations are less complicated and perform worse than LS. Due to the reference signal grid design, the LTE downlink system is not suitable for LTE downlinks. For coded systems, similar trends are experienced but performance improves.

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[2] Channel estimation for LTE downlink based on interpolation to estimate channel coefficient. The Lagrange polynomial interpolation method is proposed. Here, they evaluate the MIMO transmission for single input single-output (SISO) and downlink LTE systems and then compare the results obtained with the nonlinear and sinus cardinal interpole. The simulation results show that the Lagrange method improves linear interpolation in terms of block error rate (BLER) and throughput versus signal to noise ratio (SNR). Despite the complexity of this algorithm, it provides significant improvements in LTE downlink system performance.

[3] Studied the performance of two linear channel estimators for LTE downlink systems, LPS Square Error (LSE) and Linear Minimum Squares Error (LMMSE), QPSK and 18 QM modulation techniques and channel length. The impact will also be studied. On the performance of channel estimation. Matlab simulations are used to evaluate the proposed work of a 2 x 2 LTE downlink system. The results for the CP length are greater than or equal to the simulation channel length. Matlab simulations are used to evaluate the proposed work of a 2 x 2 LTE downlink system.

Proper pilot model design in [4] improves the spectral efficiency and reliability of the OFDM system. In this paper the problem of pilot model design for the SISO-OFDM system is addressed. In this work, the same average power is maintained in the pilot symbols and data symbols, while the distance between the pilots varies. The new pilot design gives the best performance in terms of the BER established as the correct pilot model. Equi-Powered and Equi-Space Pilot-Symbols give the lowest MSE and maximum channel capacity.

In [7], it has been found that in communication systems, high level differential symbol interference leads to high bit error rates occurs in the restoration of the transmitted order. Along with expansion-induced factors such as, multipath propagation and differential map interference is also caused by limited bandwidth channels. The system filters the infinite impulse response (IIR), resulting in the spread of digital signal. The pulses overlap adjacent pulses and interfere gradually. This type of intervention is a challenge. Developing digital communication channels with high transmission rates. Inter-user interference (IUI) refers to interference in wireless communication systems. Power from one transmitter to another. In the paper, a common inter-user intervention is suppression. Electromagnetic interference (EMI) is a disturbance caused by an external source. Electromagnetic induction affects any electrical circuit through electrostatic coupling or the like. This disturbance or performance reduces circuit performance completely. In the case of the data path, the total loss or transmission error of the transmitted data increases.

In [8], it has been found that using MIMO, you can be a good data rate expert. With the help of various receiving wires and SM (spatial multiplexing) system. It helps in achieving excellence for downlink and uplink throughput. MIMO based architecture limits the ambiguous effects seen with informational effects. Examples include time, repetition and position. Wide inclusion assists in calculating the back held by MIMO endorsers. The impotence of the cutting is reduced, due to various procurement estimates.

In [9], it has been found that existing channel estimation (CE) methodology is critical. To solve such problems, the paper proposes an optimized semi-blind sparse (OSBS) CE algorithm for MU-MIMO OFDM. Transmitter QPSK modulation is applied to block, initially, modulate the input signal. Next, pulse shaping algorithm (PSA) is used to reduce ISI (inter-symbol interference). For symbol mapping, an IFFT the operation is performed on each transmitter (Transverse Fast Fourier Transform). Next, stream the icons multipath channel through transmitter antennas towards the antennas of the receiver by adding AWGN (Additive White Gaussian Noise). Operations in the transmitter are performed in reverse in the receiver block. Then CE is done. Cost performance is reduced by using the OSBS algorithm and using EDE algorithm. Finally, the channel capacity (CC) is called the gauge. The experimental results of the proposed system yields better results when contrasted with bit error rates (BER) and other methods focused on PSNR. symbol error rate (SER), LS and MMSE.

3. System Architecture

The basic OFDM system block diagram is shown in Fig.1.

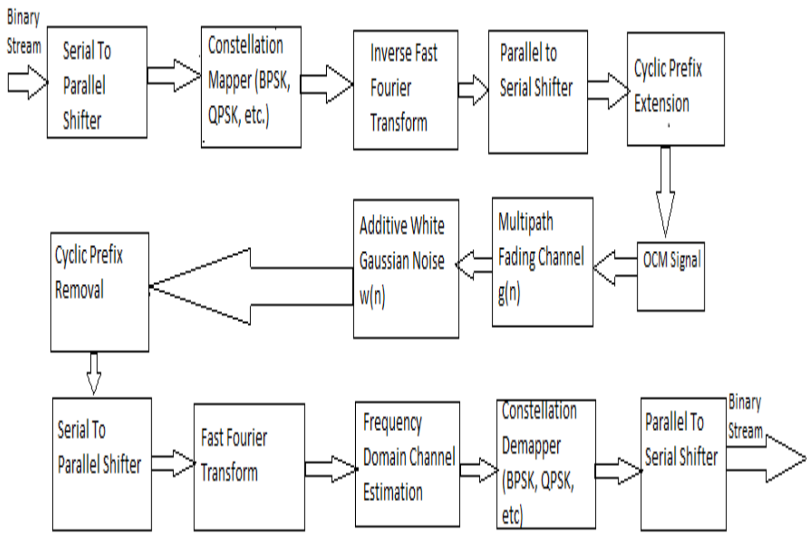

FIGURE 1. OFDM Basic Structure

In this system, a binary stream of data is first shifted into the parallel blocks. These parallel blocks are then mapped to symbols according to the selected modulation scheme, such as, BPSK, QPSK, 16QAM, etc. The Inverse Fast Fourier Transform (IFFT) is used to move the data into the time domain. Once in the time domain, the signal is shifted from parallel blocks to serial data stream. A cyclic prefix extension is added to each frame to combat ISI.

Now, the OFDM signal is subjected to a multipath fading channel in addition to Additive White Gaussian Noise (AWGN). At the receiver end, the cyclic prefix is removed. The data is shifted to parallel blocks for processing.

Now the Fast Fourier Transform (FFT) is used to shift the data into the frequency domain for further processing, and now once in the frequency domain, channel estimation technique (LS) is applied in this case. The data is then demodulated using the same modulation scheme and in the receiver this is used to shift the symbols to bits, and finally, these bits are shifted from parallel blocks to a serial binary stream.

The OFDM transmission propagates through a noisy channel with multipath fading. The time domain for OFDM signal is represented as $x(n)$. The channel impulse response (CIR) is represented as $g(n)$, and the Additive White Gaussian Noise (AWGN) is represented as $w(n)$. The corrupted OFDM signal is represented as $y(n)$.

The equation is as follows:

$$y(n) = x(n) * g(n) + w(n) \quad (1)$$

In order to simulate more realistic conditions, we use the given channel model which includes Additive White Gaussian Noise (AWGN).

4. Algorithm

To combat the effects of multipath fading, we estimate the channel in the following manner:

We drop the noise term. Since $w(n)$ is AWGN, it has zero mean and so for estimation purposes it is dropped from the expression.

$$y(n) = g(n) * x(n) \quad (2)$$

$$Y(\omega) = X(\omega)G(\omega) \quad (3)$$

By measuring the response Y(ω) to a known input signal X(ω), the channel frequency response G(ω) is estimated:

$$\hat{G}(\omega) = \frac{Y(\omega)}{X(\omega)} \quad (4)$$

Channel equalization in the OFDM system is carried out in the frequency domain as:

$$\hat{X}(\omega) = \hat{G}(\omega)^{-1}Y(\omega) \quad (5)$$

This process is referred to as Least Squares Channel Estimation technique.

We know that X(ω) is referred to as the pilot signal. There are two types of pilot signal:

- Block Type Pilot: In this case, X(ω) spans through the entire frequency range and is transmitted periodically.
- Comb Type Pilot: In this case, X(ω) spans through selected frequencies and is transmitted constantly.

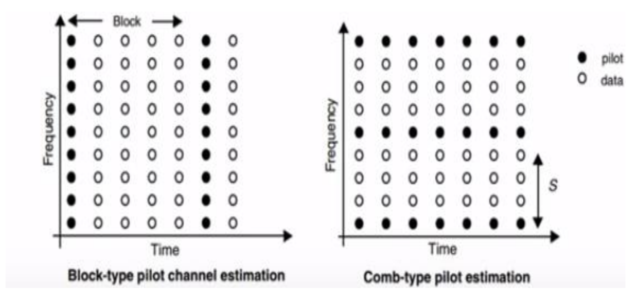

FIGURE 2. Block Type vs. Comb Type Pilot Signal

The LS estimator suffers from the mean square error. Apart from that, it is a very efficient channel estimation technique.

In case of MMSE technique, we proceed as follows:

We assume that ***x*** is a random vector variable of the order ***nX1*** and ***y*** is a known random vector variable of the order ***mX1***. Both of them may or may not have same dimensions. The estimation error vector is given as:

$$e = \hat{x} - x \quad (5)$$

From the trace of the error covariance matrix, the mean square error is given as:

$$\mathrm{MSE} = \mathrm{tr}\left\{\mathrm{E}\left\{(\hat{x}-x)(\hat{x}-x)^T\right\}\right\} = \mathrm{E}\left\{(\hat{x}-x)^T(\hat{x}-x)\right\} \quad (6)$$

Here the expectation ***E*** is taken over by both ***x*** and ***y***. If ***x*** is scalar, then the expression is reduced as follows:

$$\mathrm{E}\left\{(\hat{x}-x)^2\right\} \quad (7)$$

The MSE can also be defined as:

$$\mathrm{tr}\left\{\mathrm{E}\{ee^T\}\right\} = \mathrm{E}\left\{\mathrm{tr}\{ee^T\}\right\} = \mathrm{E}\{e^T e\} = \sum_{i=1}^{n} \mathrm{E}\{e_i^2\} \quad (8)$$

The MMSE estimator can be finally evaluated as:

$$\hat{x}_{\mathrm{MMSE}}(y) = \mathrm{argmin}_{\hat{x}}\ \mathrm{MSE}. \quad (9)$$

5. Result

The OFDM system is first evaluated in the presence of AWGN ignoring multipath fading effects. We are taking input type as image in this case. The FFT/IFFT size is kept 64 and the cyclic prefix extension length is kept 16 for all the simulations. The constellation mapping shows all the possible symbols that can be transmitted by the system, as a collection of points. The bit error rate (BER) of various digital modulation schemes in an OFDM system are examined at different Signal to noise (SNR) values.

In case of Binary Phase Shift Keying (BPSK), 1 bit corresponds to 1 symbol and the SNR is given as 10dB, using Least Squares Channel Estimation. The Bit Error Rate (BER) is approximately 0.013.

In case of Quadrature Phase Shift Keying (QPSK), 2 bits correspond to 1 symbol and the SNR is given as 0dB. The Bit Error Rate (BER) is approximately 0.11.

In case of 8-Phase Shift Keying, 3 bits correspond to 1 symbol and the SNR is given as 5dB. The Bit Error Rate (BER) is approximately 0.19.

In case of 16 Quadrature Amplitude Modulation (16 QAM), 4 bits correspond to 1 symbol and the SNR is given as 5dB. The Bit Error Rate (BER) is approximately 0.2.

In case of 32 Quadrature Amplitude Modulation (32 QAM), 5 bits correspond to 1 symbol and the SNR is given as 20dB. The Bit Error Rate (BER) is approximately 0.0011.

An example of image transmission using QPSK scheme is shown below:

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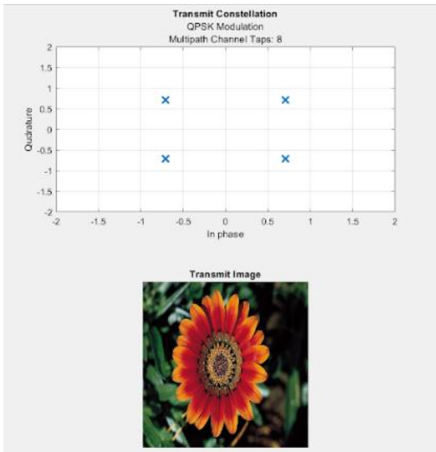

FIGURE 3. Transmitted image for QPSK

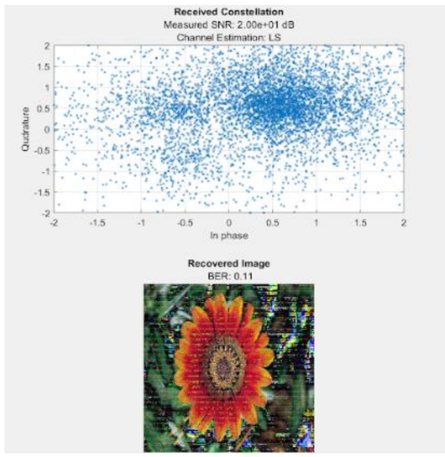

FIGURE 4. Received Image for QPSK

However, when we do not use Channel estimation, the result obtained is as follows:

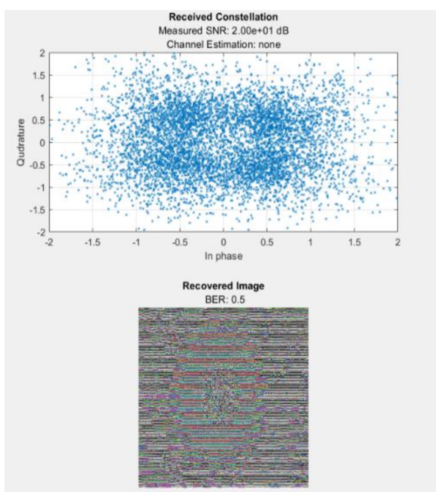

FIGURE 5. Received Image without Channel Estimation

Some more results for different modulations are given as follows:

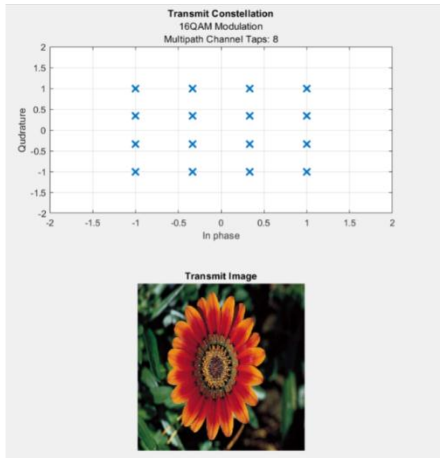

FIGURE 6. Transmit Image for 16 QAM

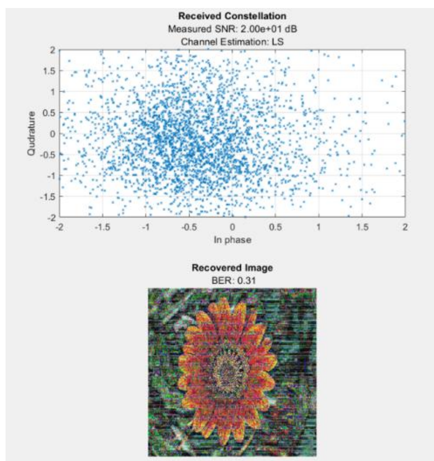

FIGURE 7. Received Image for 16 QAM

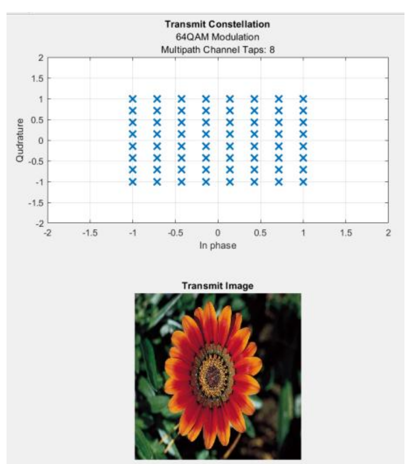

FIGURE 8. Transmit Image for 64 QAM

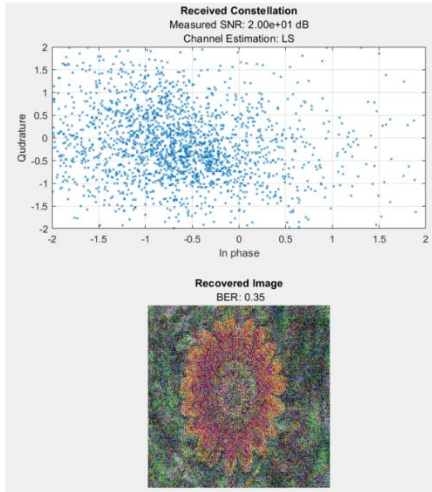

FIGURE 9. Received Image for 64 QAM

When we accept integer type data, we are applying both LS and MMSE estimation techniques. The graph obtained is as follows:

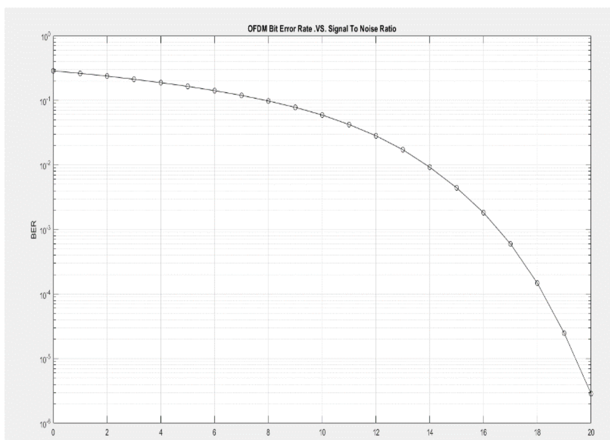

FIGURE 10. Comparison of BER and SNR for Integer values

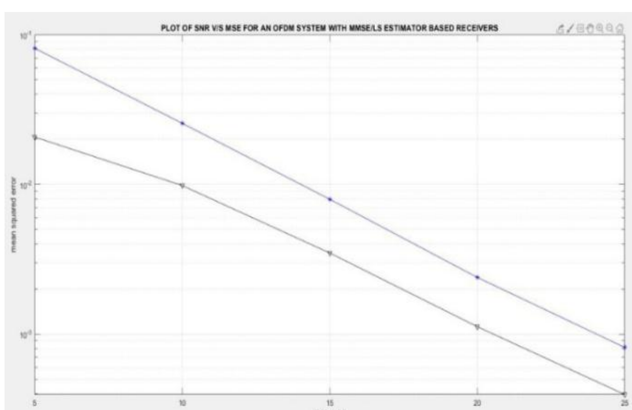

FIGURE 11. Plot of SNR vs. MSE for an OFDM System with MMSE/LS Estimator Based Receivers

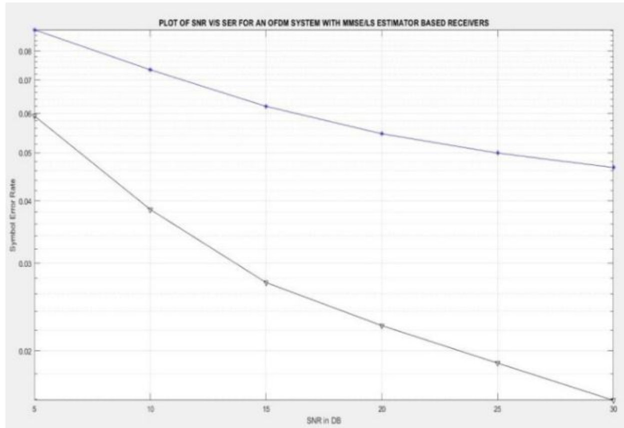

FIGURE 12. Plot of SNR vs. SER for an OFDM System with MMSE/LS Estimator Based Receivers

We can see that as SNR increases, BER decreases.

The results obtained can be explained precisely by the following tabular structure:

Sl. No.	Input Type	Input format	Input Size	Modulation Technique	Estimation Technique	SNR (in dB)	BER
1	Integer	Integer	2B	BPSK	LS	10	0.08
2	Integer	Integer	2B	BPSK	MMSE	10	0.05
3	Image	jpg	600kB	QPSK	LS	10	0.19
4	Image	jpg	600kB	QPSK	LS	20	0.15
5	Image	jpg	600kB	QPSK	LS	30	0.11
6	Image	jpg	600kB	QPSK	LS	40	0.10
7	Image	jpg	600kB	QPSK	None	20	0.50
8	Image	jpg	600kB	8PSK	None	30	0.49
9	Image	jpg	600kB	16 QAM	LS	20	0.31
10	Image	jpg	600kB	32 QAM	LS	20	0.41
11	Image	jpg	600kB	64 QAM	LS	20	0.35
12	Image	png	500kB	QPSK	LS	30	0.16
13	Image	png	500kB	16 QAM	LS	30	0.28
14	Image	png	500kB	32 QAM	LS	30	0.32
15	Image	png	500kB	64 QAM	LS	30	0.39

TABLE 1. Comparative Analysis for BER and SNR of different data types

6. Conclusion

Thus, it can be concluded that Least Squares Estimation Technique is an efficient method for channel estimation. For block and comb type pilot symbols, the least squares is often extended to take advantage of second order signals to statistics. This leads to Minimum Mean Squared Error (MMSE) estimation, which while being more accurate, requires much more computational effort. We have observed various digital modulation schemes, which when paired with OFDM, are more accurate. We have tried different schemes such as BPSK, QPSK, 16-QAM, etc. The input type we have used is integer as well as image input, and instead of experimenting with only integer type data, we have incorporated image input to improve the data acceptance ability of the simulation. Further improvements can be made in this system if more complex data types such as audio/video are incorporated in future.

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