A Review Paper on Performance Analysis of Channel Estimation in MIMO-OFDM System

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Abstract— With the advancement in wireless communication, the desire to achieve data transmission at high speed is also increasing. But accomplishing high data rate transmission over broadband wireless channel seems a challenging task. Multiple-input-multiple-output (MIMO) communication when combined with OFDM System allows reliable transmission of data. The pilot based channel estimation is one of the most used technique for the channel estimation. This paper reviews the research that has already been done to propose different techniques for channel estimation. The paper analyses the implementation of Recursive Least Square (RLS) and Least Mean Square (LMS) algorithms for channel estimation in the MIMO-OFDM system. The information gathered through this review paper will help us to explore the work in the same field.

Key words: Multiple-Input-Multiple-Output, Orthogonal Frequency Division Multiplexing, Least Mean Square, Recursive Least Square, Minimum Mean Square

I. Introduction

Orthogonal frequency division multiplexing (OFDM) is a technique to encode digital data on the multiple frequencies. Itis widely used in wireless networking, TV and audio broadcasting, wireless networks and 4G. OFDM plays a major role in both for wireless and wired communications. It started in the 1870s when it was used to carry the information via multiple channels using atelegram. R. Chang proposed the fundamental principle of OFDM [1]. The basic principle of OFDM was using multiple channel spectra under limited bandwidth while making sure no interference. Although the OFDM was studied from past 40 years in RF domain, the research on OFDM in optical communications started in the late 90s. It was investigated in the late 2000s by some groups to do long-haul optical transmission using optical orthogonal frequency database multiplexing. The research came out with its two major parts;DDO-OFDM and CO-OFDM [5].

DDO is direct detection optical OFDM which include low-cost components for easy working while CO-OFDM is Coded-Orthogonal OFDM. It is costly and works better with optical efficiency and high receiver sensitivity [10].

The world’s first CO-OFDM was experimented having line rate of 8 Gb/sec reported in the year 2007, and its transmission efficiency goes on increasing ten times a year from past few years [8]. DDO is much more variant than CO. Also, it has abroader range of applications due to its low cost.

The basic principle of Orthogonal Frequency Division Multiplexing is to split a high-rate data stream into some lower rate streams. Orthogonal Frequency Division Multiplexing (OFDM) data is developed by taking symbols in the spectral space through QAM (Quadrature Amplitude Modulation),etc. and convert the spectra to thetime domain by taking the Inverse Discrete Fourier Transform since Inverse Fast Fourier Transform is more cost effective to implement. The main features of a practical Orthogonal Frequency Division Multiplexing system are as follows:

- The processing is performed on the source data. For example,Quadrature Amplitude Modulation.
- The symbols are modulatedusing IFFT (Inverse Fast Fourier Transform) onto orthogonal sub-carriers.
- By adding a cyclic prefix to the OFDM frame, orthogonality of data is maintained.
- Synchronization cyclic prefix is used to distinguish the start and end of each frame. [15].
- Demodulation of the received signal by using Fast Fourier Transform.
- Channel equalization: the channel can be assessedboth by using sending known so -called pilot symbols or a training sequence at predefined sub-carriers [8].
- Decoding and de-interleaving.

II. OFDM Applications

OFDM has various applications in wireless communication. The use of optical fiber technology has brought a big change in the fields of telecommunications because of its long distance without interference signal or information carrying qualities. Optical frequency database multiplexing is now used worldwide for the transfer of vast information through signal carriers**.** Some of the applications of OFDM are mentioned below;

A. DAB (Digital Audio Broadcasting)

DAB is digital audio broadcasting. It has a number of advantages over FM radio for both listeners and broadcasters. Its use has provided a greater choice of programs which are not available on FM. With the use of DAB, listeners can have multiple mono voice commentaries over the same event atthe same time [6].

B. High Definition TV

With the use of OFDM, a country or server can get same channels but with different regional languages. Like in the United States of America, they have an 8 level VSB modulation scheme where VSB is Vestigial Side Band [11].

C. Wireless LANs

The OFDM can store larger data with less disturbance and interference. The OFDM can provide 58 Mbps of thedata rate.

D. Mobile broadband

- IEEE 802.16: It operates in licensed spectrum of2 to11 GH
- 75 to 93 miles/h speed
- IEEE 802.20: It operates below 3.5 GHzin the licensed band.
- Up to 155 miles/ h speed [4].

E. LTE

LTE stands for Long Term Evolution. LTE also was known as 4G uses OFDM that lead to increased data rate and improved quality of service at lower cost.

F. MIMO-OFDM

Multiple inputs multiple outputs in combination with orthogonal frequency division multiplexing is a collaborative tool for next generation wireless systems and cellular telecommunications. The key challenges that transmission satellites are facing today include the necessity for high data rate as well as the quality of service. Multiple-input multiple-output (MIMO) wireless technology emerged to meet these demands by offering increased transmitting efficiency through spatial multiplexing gain and improved link reliability through antenna diversity gain [4]. The ongoing fourth-generation mobile cellular technology works on the principle of MIMO-OFDM. The basic block diagram of Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing is shown in fig. 1. [6]

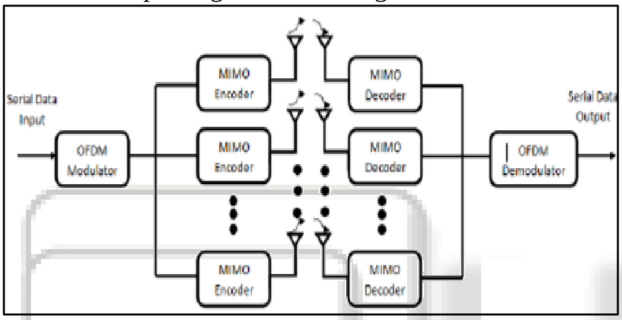

Fig. 1: MIMO-OFDM Block Diagram

To achieve high transmission rate and high spectral efficiency, Multiple Input Multiple Output systems with a combination of orthogonal frequency division multiplexing is under high consideration. Multiple Input Multiple Output offers spatial diversity and therefore increase the capacity while Orthogonal Frequency Division Multiplexing allows systems to work in atime varying or frequency selective environment [9].

III. CHANNEL ESTIMATION

When a signal containing audio or video is transmitted through the air to the receiver, some of its characteristics are changed due to noise and interference in the atmosphere. This distorted signal is unable to provide useful information. Some of these characteristics are frequency, amplitude, and Phase. A wideband radio channel is normally time variant and Frequency selective. For an OFDM communication system, the channel transferred at different subcarriers appears in the receiver with unequal frequency and time domains. Therefore, dynamic estimation of the signal is necessary [7].

Pilot-based channel estimation techniques are widely used to estimate the channel characteristics and filter the received signal. Channel estimation is used for noise detection and decoding of the wireless signal to reduce added noise and interference at the receiving end. The integration of low bit error rates and high data rates in OFDM systems makes the use of estimators that have high accuracy and low complexity. The single dimensional channel estimation is usually employed in OFDM systems to accomplish the differences between complexion and accuracy. The two basic types of single dimension channel estimation include the block type pilot estimation and comb type pilot estimation.

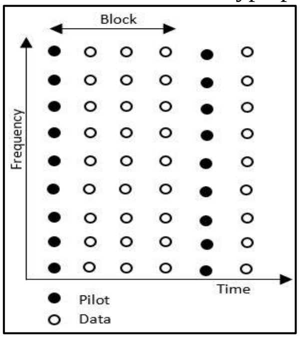

Fig. 2: Block type pilot estimation.

In block type pilot estimation, pilots are inserted in the frequency dimension and in Comb type, the pilotis inserted in the time directions. The pilot signal inserted into a particular OFDM block, which is sent particularly in the time-domain analysis. This type of pilot insertion technique is especially suitable for slow fading radio channels. The block type pilot arrangement is insensitive to frequency selectivity [13].

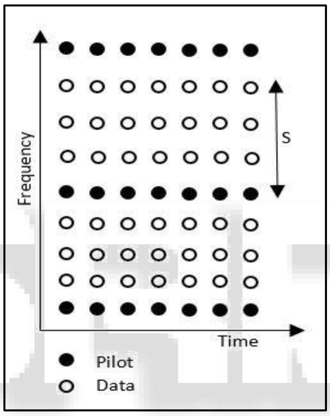

Fig. 3: Comb type pilot estimation

The second kind of pilot arrangement is denoted as a comb-type pilot arrangement. Such type of pilot arrangements is inserted uniformly within each OFDM block. Assuming the payloads of pilot arrangements same, the comb-type pilot arrangement has a higher degree of transmission rate as compared to previous one. Thus the comb-type pilot arrangement system provides much opposition to fast fading channels. Hence, the comb-type pilot arrangement is sensitive to frequency selectivity and insensitive to time variations when comparing to the block-type pilot arrangement system.

Adaptive Channel Estimation is the improved form of Channel estimation process. Here also, Channel estimation is performed using pilot insertion technique but the new terms introduced include Least square estimation and Recursive least square. The technique uses adaptive estimators which update the parameters of estimator continuously. An adaptive filter may be considered as a self-dependent digital filter that adjusts its coefficients to minimize an error function. The relationship between the input-output of the adaptive filter depends on its transfer function executions. Its application area contains channel equalization, noise cancellation, asignal prediction as well as many other characteristics. It avoids the need of knowledge of channel and noise statistics [8].

A. Least Mean Square Algorithm (LMS)

It is the most commonly used channel estimation technique used in multiple-input-multiple-output OFDM systems. It is less complex as compared to MSME and gives better results under some conditions. The only thing in which LMS algorithm lacks is convergence speed. The least mean squares (LMS) algorithm alter the filter coefficients to its appropriate places to minimize the cost function. As compared RLS, the LMS does not comprise any matrix operations. Therefore, the LMS algorithms requireless memory and computational resources than RLS algorithms [14].

B. Recursive Least Square Algorithm (RLS)

RLS algorithm is also the most common type of channel estimation method. It attracts less attention as compared to least mean squares (LMS) algorithms due to its complex and long computations. Recursive least squares (RLS) algorithms have a fast convergence speed and do not have the eigenvalue spread problem. However, RLS algorithms require more computations resources and exhibit more mathematical operations than LMS algorithms [12].

C. Minimum Mean Square Error Algorithm (MMSE)

Minimum mean square error (MMSE) estimator is an estimation method which minimizes the mean square error (MSE), which is a common measure of estimator quality, of the fitted values of a dependent variable. [2]

1) Zero Forcing

Zero forcing equalizer is a linear equalizer algorithm used in multiple inputs multiple output system which tends to inverse the frequency response of a channel. The zero forcing equalizer applies the inverse of the channel frequency response to the received signal which restores the signal after receiving from the channel. The zero forcing equalizer is very useful at the receiver as it brings down the inter-symbolic interference to zero. But, zero forcing equalization has some limitations. The Even impulse response of a channel has finite length, the impulse response of this equalizer needs to be infinite [9].

IV. A REVIEW OF LITERATURE

High data rate over wireless transmission system can be achieved through multiple-input-multiple-output system combined with orthogonal frequency division multiplexing. The study suggested that Pilot arrangement technique to error elimination is the most convenient method for both multiple-input-multiple-output and single-input-single-output. The research utilized the convention Least Square (LS) and Minimum Mean Square (MMSE) estimation algorithms through Matlab simulations. In this research, these methods were evaluated by Bit Error Rate and Mean Square Error level. It was observed that further detection performance couldbe improved through Space Time Blocking Code(STBC) and maximum results can be achieved at both sending end and receiving end. The author observed that MMSE gives better results than LS, but also proved to more complex than LS for the MIMO system using pilot carriers [1].

The best channel estimation technique is very important to get acorrect signal in a wireless transmission system. The research analyzed the results of Least Mean Square (LMS) and Recursive Least Square (RLS) algorithms. Then these results were applied to multiple-input-multiple-output OFDM system based on Space Time Blocking Code (STBC). The simulation results show that convergence speed of Recursive Least Square algorithms is more than least mean square algorithm [2].

A new blind channel estimation method was designed for multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM). Blind channel estimations have achieved special attention due to its improved spectral efficiency. The proposed blind channel estimation still require a number of blocks to build reliable covariance matrix. The channel can identify the information from a few received blocks by building covariance matrices from a group of selected subcarriers. The proposed method gives better results in terms of both computation efficiency and error approximation. Numerical results to collaborate with future studies [3].

The research focused on the design of an effective and less complex channel estimation technique through OFDM eliminate inter-symbol interference in the frequency selective wireless transmission system. The techniques of eliminating intersymbol interference are attracting mobile research communication as radio channel contains time variant and frequency selective characteristics. It has been stated in the paper that channel estimation with pilot arrangement gives best results when combined with data symbols. The paper explains various efficient pilot based estimation techniques for multiple-input-multiple-output OFDM systems. The technique approaches the use of adaptive estimators which updates the parameters of estimator continuously. An adaptive filter may be considered as a self-dependent digital filter that adjusts its coefficients to minimize an error function [4].

A new decision-directed channel estimation technique was introduced that deals with the process of a pilot shortage in the MIMO-OFDM systems. When the number of transmitting antennas is large, pilot signals suppress significant portion of downlink resources. The proposed channel estimation uses soft symbolic decisions obtained by iterative detection and decoding (IDD) scheme to enhance the efficiency of the channel estimator. Through the soft information from the decoders, the proposed channel estimator selects reliable data sets, subtracts inter-symbol interferences and performs repeated estimation of the channels. With the help of numerical simulations, the proposed channel estimator account to considerable improvement in system performance as compared to other conventional channel estimators in MIMO-OFDM systems. The paper deliberates the importance of channel estimation in MIMO-OFDM systems to achieve the same sort of signal at both transmitter and receiver side. The number of transmitter and receiver networks are increasing rapidly to enhance the quality of next generation wireless systems [5].

The research depicted more interest in the least Square Method (LSM) of channel estimation rather than Minimum Mean Square Error (MMSE). A novel method for channel estimation based on adaptive pilot pacing with Least Square Method is proposed in the paper. Whereas MSME channel estimation technique includes a lot of complex computation and requires a number of pilots.MMSE have good results in low Signal to Noise Ratio (SNR), while with high SNR, LS estimator is more efficient. The researchersuse

MATLAB Monte-Carlo simulations to evaluate the performance of proposed estimator. So, the author prefers the use of channel estimation technique which is less complex meanwhile compromising a little on results. Its application area contains channel equalization, noise cancellation and signal prediction [6].

There are several issues which occur in the carrier frequency offset and channel estimation in MIMO frequency division of wireless communication system. The study focused on the problems of CFO in channel estimation and proposed the adaptive estimation algorithm to resolve the problem. The study estimates the parameters in channel estimation in their same time of the procedure. The results showed that used method is workable in the real-time procedures and time- variable environment [7].

Research focuses on the massive MIMO communication system. The research used the information with a large number of antennas that absorb the higher spectral energy efficiency in comparison to MIMO systems. The uplink channel distribution in MIMO- OFDM systems is considered. As a result, increased number of antennas in the systems create challenges in the channel parameters. So, the study proposed a square algorithm which helps to achieve the estimation of optical channels with low complexity. The result of the study shows that the proposed method helps to solve the reduced dimensional problem in antennas [8].

V. SIMULATIONS AND RESULTS

In this work, first step is the random input data generation. After that, modulation of input data id done, and then PILOT sequence CAZAC sequences are generated. The main part is after the IFFT (Inverse Fast Fourier Transformation) of the incoming signal (Data). IFFT is basically used to convert the signal from frequency domain to time domain. In the existing approach, IDFT is used. In current work, IFFT is used, as it involves the fast implementation and the fast computation of the DFT and provides higher quality results. After the signal got converted to the time domain, then the Cyclic Prefix also added to that. CP (Cyclic Prefix) is used here because it acts as a buffer in which the delayed information from the previous symbols got stored. It also helps in eliminating the inter symbol interfacing from the previous symbols. This is all about the Transmitter part. After adding CP, some AWGN (Additive White Gaussian Noise) Noise was also added. Now come to the Receiver part, in the receiver part, the Cyclic Prefix was removed which was taken earlier. Now, again FFT (Fast Fourier Transform) was used to convert the signal back to Frequency domain from the time domain. After this the demodulation of the signal takes place. This is the final step at the receiver end. At the end, the Mean Square Value (MSE) with respect to SNR (Signal to Noise Ratio) Value is calculated.

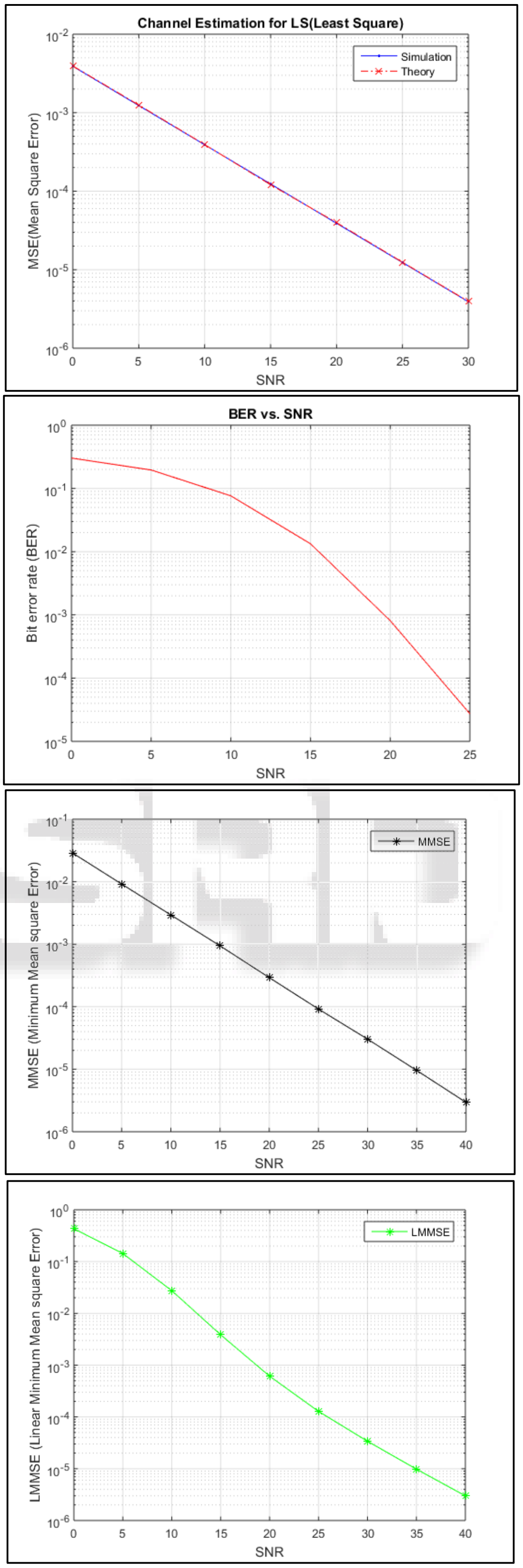

Fig. 4: Graphs

VI. CONCLUSION

In this paper channel estimation based on both comb-type and block-type pilot arrangements in MIMO-OFDM based systems are reviewed. This paper discusses various channel estimation techniques for the multiple-input-multiple-output (MIMO)-Orthogonal Frequency division multiplexing (OFDM) system. The performance of various algorithms such as, LMS,MMSE and LMMSE has been reviewed and compared. For comparison, we have taken MMSE (Minimum Mean Square Error) and LMMSE (Linear Minimum Mean Square Error) Channel estimation algorithms. In LS (Least Square) our main goal is to minimize the square of thedistance between the received signal and the original signal whereas in the LMMSE our main goal is to minimize the estimation. The main difference between the LS and MMSE method is that MMSE Channel Estimation method is more complex than the LS Channel Estimation method. The MMSE method generally shows better result at low SNR whereas the LS method shows the best results at higher SNR values. The major drawback of the MMSE estimate is its high complexity due to this reason; it is not showing the better results when compared to the LS channel Estimation technique.

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