Review on Channel Estimation in MIMO OFDM Wireless System

Monika[1], Mahendra Tyagi[2]
[1]M. Tech. Research Scholar, Dept. of ECE, LRIET, Solan, India
[2]Assistant Professor, Department of ECE, LRIET, Solan, India

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Abstract- *A Modern wireless broadband system of MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing) is more popular because of good data transmission rate and its robustness against multipath fading & good spectral efficiency. This system provides reliable communication & wide coverage. A main challenge to MIMO-OFDM system is retrieval of the channel state information (CSI) accurately and synchronization between the transmitter & receiver. The channel state information is retrieved with the help of various estimation algorithms such as pilot-aided, blind and semi blind channel Estimation. In this paper performance analysis of channel estimation through different algorithms for estimating channel using different modulation scheme are investigated. The estimation of channel is based on Least Square, Minimum mean square channel estimation algorithm. This paper describes the basic introduction of OFDM, MIMO-OFDM system and explains the different channel estimation algorithms.*

Key Words: MIMO (Multiple Input Multiple Output), OFDM (Orthogonal Frequency Division Multiplexing) Channel Estimation, CSI, LS Estimation, MMSE Estimation.

1. INTRODUCTION

MIMO is a system which has multiple inputs and multiple outputs, it is used to send and receive the multiple signals at the same time by using the multiple antennas at the transmitter and receiver side. The use of multiple antennas at the sender and receiver side will abolish the problem caused by multipath fading. The system also need the modulation techniques to send the signal, here the OFDM modulation technique is discussed. The system requires modulation technique because the message signal or voice signal cannot travel long distance because of the low frequency. Modulation technique is a technique where the change in characteristics of the carrier signal occurs with respect to the instantaneous properties like message/voice signal. If we talk about the generation of multiple signals at the same time it drops us towards the signal interference, so whenever MIMO comes in forefront, it is preferred with orthogonal frequency division multiplexing (OFDM) technique. Peculiar techniques like OFDM and MIMO stand as promising choices for prospect high data rates [7]. It shows robustness for multipath fading and interference. The precoding techniques can be used to transmit the signal and to receive the signal with the minimum errors at the receiver side. There are two kinds of precoding techniques one is linear and another is nonlinear. In the author has tried to minimize the imperfection of CSI by proposing a precoder design. The intend design has achieved the improvement in error rate representation when evaluated with other precoding schemes. In [8], Saeed and Witold considered a channel that is multi user Gaussian broadcast. They have applied the block diagonalization zero forcing pre-coding technique to achieve the better optimized channel and proved this scheme is indeed optimal multi-user zero forcing pre-coding under total sum of power constraint.

1.1 Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency division multiplexing (OFDM) communication system has number of advantages over conventional communication techniques namely FDMA, TDMA and CDMA. [10] It is widely used modulation and multiplexing technology, which has become the basis of many telecommunications standards including wireless local area networks (LANs), digital terrestrial television (DTT) and digital radio broadcasting in to a large extent of the earth. In the past, as well as in the present, the OFDM is referred in the literature as Multi-carrier, Multi-tone and Fourier Transform. The OFDM concept is based on spreading the data to be transmitted over a large number of carriers, each being modulated at a low rate. The carriers are made orthogonal to each other by appropriately choosing the frequency spacing between them. A multicarrier system, such as FDM (Frequency Division Multiplexing), divide the total available bandwidth in the spectrum into sub-bands for multiple carriers to transmit in parallel. [11] It combine a large number of low data rate carriers to construct a composite high data rate communication system. Orthogonality gives the carriers a valid reason to be closely spaced with overlapping without ICI.

1.2 Orthogonality

The main aspect in OFDM is maintaining orthogonality of the carriers. If the integral of the product of the two signal is zero over a time period, then these two signals are said to be orthogonal to each other. Two sinusoids with frequencies that are integer multiple of a common frequency can satisfy this criterion. Therefore, orthogonality is defined by:

$$\int_0^T \cos(2\pi n f_o t)\cos(2\pi m f_o t)\,dt = 0 \quad (n \neq m)$$

Where n and m are two unequal integers; f_o is the fundamental frequency; T is the time period over which the integration is taken. For OFDM, T is one symbol period and f_o set to 1/T for optimal effectiveness.

2. RELATED WORK

K.-G. Wu et al. [1]: This study proposed a recursive LS estimator to improve the DDCE performance in transmit-diversity OFDM systems. Wu and Chang proposed a regularized LS estimator to improve the DDCE performance in transmit-diversity OFDM systems. The proposed method incorporates the latest channel estimate as a priori information to alleviate the error propagation problem of the standard LS method. The regularization parameter is derived to be adapted with the MSE of the latest estimate and that of the current standard LS estimate. At lower SNR values when the standard LS method suffers more severely from the error propagation problem, the proposed method improves the channel estimation performance considerably.

M. N. Seyman et al. [2]: Seyman proposed that to optimize both placement and power of the comb-type pilot tones, which are employed in LS channel estimation algorithm in MIMO-OFDM systems, a particle swarm optimization (PSO) has been utilized by experimental results have confirmed that the optimized pilot tones derived by PSO in terms of MSE and BER have performed better than the orthogonal and random pilot tones. Also, the simulations have been done over the channels with diverse Doppler shifts values in order to reveal the effect of Doppler shifts on several pilot tones performance.

Y. (G.) Li et al. [3]: Li proposed that Channel parameter estimation is an important task in OFDM systems. They presented criteria for optimum training-sequence design for OFDM systems with multiple transmit antennas and have also simplified the channel parameter estimators developed previously. Using the design criteria, we can construct training sequences that not only optimize, but also simplify the channel estimation during the training period. The simplified estimator has similar performance to that in, but with much lower complexity.

J. Ran et al. [4]: Ran proposed that the system concept and results of a Decision-Directed Channel Estimation technique. The performance enhancement of the Decision-Directed Channel Estimation (DDCE) compared with the purely preamble-based method is analysed. On the one hand, the DDCE method uses the decisions at the output of the demodulator, which leads to a rather low complexity and a delay of only a single OFDM symbol. As a whole, the DDCE method shows a good performance increase with only low computation complexity.

R. J. Lyman et al. [5]: Lyman proposed that how close the predicted value must be to the true value when the receiver emerges from the fade in order to recover correct tracking. Also, we wish to know how to approximate adaptively. The flat spectral shape was chosen as a simple special case. It is hoped that the method we used to solve this prediction problem can be extended to band limited processes of arbitrary spectral shapes. We also hope to extend our approach to more complex carrier tracking and adaptive equalization problems.

S. Kalyani et al. [6]: Identified that the DDCT problem as an outlier contaminated estimation problem and proposed GM and M estimators, which are effective in mitigating error propagation. DDCT of modest computational complexity is possible over large frame lengths even at high fade rates, provided one uses the mathematical theory appropriate for tackling the problem.

3. MIMO-OFDM SYSTEM

In distinction to conservative FDM, the spectral overlapping among sub-carriers are allowed in OFDM since orthogonality will ensure the subcarrier separation at the receiver, providing better spectral efficiency and the use of steep band pass filter was eliminated. Serial transmitted data is send to QAM modulator used to convert parallel signal and IFFT is used to mix frequency of different values and guard interval are inserted in order to avoid ISI. DAC are used to convert digital to analog conversion for time division transformation of signal. On receiver side analog to digital converter is used and guard retrieval for removal of guard bands. Demapping and parallel to serial conversion processed using QAM decoder and FET.

With the help of several narrowband channels, the signal is splitted and distributed into these channels at different frequencies. This technique helps to reduce the effect of interference that is caused among channels which is close to each other in the form of frequency. It transmits the signal into same time period but at different frequencies. Orthogonal frequency division multiplexing (OFDM) with the multiple-transmitting antennas can give improved quality and capacity for broadband.

MIMO-OFDM is easy and efficient in dealing with multipath. OFDM is a modulation technique which has multiple carrier, it retains various carriers, within the allotted bandwidth, to convey the data from source to destination. It uses a multiple parallel narrow band sub carriers rather than single wide band carrier to transit information. In [11] MIMO system has been proposed which incorporates less ISI when used with OFDM and also results in less fading and increased data rates. But as a result of noisy channel estimation done with frequency selective fast-varying channels, it results to the degradation of performance of MIMO system.In [12] studied space–time coding delay, permutation and transmitter multiplicity combined with two branch receiver multiplicity for OFDM used in high information rate wireless networks. Space–time coding transmitter multiplicity is the prime approach to contribute high peak data rates. The delay transmitter multiplicity system using QPSK modulation along interference suppression is the robustious and provides QoS with a minimal retransmission feasibility. Downlink beam forming is further more demonstrated to be an effective approach for increasing both QoS and throughput once the environment sanctions this technique. Wireless network system using downlink beam forming composed with adaptive antenna arrays can bring higher capacity than those retaining delay or space–time coding transmitter multiplicity systems with two sender and two receiver antennas.

4. CHANNEL ESTIMATION

Channel estimation is a decisive approach used in wireless mobile network systems where the switching of wireless channel is along with particular time instant, prevalently produced by mobile transmitter or receiver at a particular speed of automobile. Wireless mobile communication is reluctantly influenced by the multi-path obstructions as a result of reflections and surrounding elements such as mountains, infrastructures and another obstruction. An explicit evaluation of the channel varying according to time is required by the system to procure reliable and enhanced data rates at the receiving end. The basic LS method and ALS method can be applied to attain the new channel estimates. Data is transmitted from transmitter to the receiver through channel but sometimes there is interference due to addition of noise. In order to reduce the noise, we need estimated channel, utilized the correlation of channel parameters at adjoining subcarriers to eradicate interference among antennas. In [13], the definitive LS is assigned to accomplish the distinct channel estimates from IAI eliminated data. In conducive to investigate a less complexity channel estimation for a system that is OFDM with space–time coding in time-varying along multipath fading channels. In particular, the author's incentive was to scale down the problem in the desired matrix-inversion for every OFDM data symbols. The approach is developed based on a channel with relatively inadequate delay spread. By decoupling the channel responds from different transmit antennas proceeds to the reduction of complexity. This transformed method brings about a substantial amendment without any added complexity.

Least Square (LS) algorithm, proposed by Widrow and Hoff, it is used for system identification. On the other hand, there are algorithms with faster rates of convergence like, least mean square (LMS) methods are prominent because of its low computational costs, robustness and ease of implementation. The author has used a recursive least square estimator (LSE) to improve the (DDCE) performance in transmit-diversity OFDM systems. The authors Chang and Wu used a regularized least square (LS) estimator to get the better DDCE depiction in transmit-diversity OFDM systems. The intended usage amalgamates the current channel estimate as a priori information to alleviate the complexity of the basic LS method. The regularization criterion derivative is to be altered with the MSE of last and current standard LS estimate. On other hand where the standard LS method at degraded SNR values tends to suffer severely due to error propagation problem. The work done in [1] upgraded the channel estimation problem considerably. The author has discussed least squares estimation in recursive case, the exponential weighted least squares, recursive-in-time solution, recursion for MSE paradigm for instance such as Noise omiter, channel equalization, and reverberation abandonment.

Adaptive Least Square (ALS) algorithm, The Recursive least squares (RLS) is a robust filter which finds the coefficients recursively and thus helps to scale down a weighted through linear least squares cost function consolidating to the input signals. The ALS is repository fast convergence, and is set across maximum of its competitors. None the less, this for betterment at the cost of immense computational intricacy. The author has intended that how near the predicted value ought to be to the true value when the receiver emanates from the fade in order to reclaim correct tracking. Likewise, it is desirable to know how to approximate adaptively. The flat spectral shape was opted as a simple case. It is ascertained that the method used to solve this prediction complexity can be drawn-out to band limited processes of random spectral shapes. It is expected to extend the approach to more complex carrier tracking and adaptive equalization problems [13].

MMSE algorithm is used to minimize the average mean square error. This estimator is more complex than LS estimator but gives the better results. MMSE includes many multiplications and matrices inversions. MMSE faster than the LS estimator.

Various Methods of Channel Estimation

1. Pilot-Aided Channel Estimation: The pilot aided method develops a known pilot symbol or training sequence. This known symbol utilizes to get the parameter for channel estimation. These known symbols interleaved between transmitted signal frame and sent through channel. And at the receiver end, estimation of channel is done using received signal and the known pilot sequence. These pilot aided algorithms are used in communication systems because this system shows high precision and low computational complexity. These algorithms minimize the spectrum efficiency as pilot aided system introduces overheads to the wireless communication system by transmitting known pilot symbols. This pilot aided scheme can be sub classified in to conventional pilot symbol aided, superimposed training.

In the **super imposed gaining method**, pilot signal is superimposed on the information signal. In order to transmit the information symbols, the complete transmitted frame can be used. This superimposed method is more bandwidth efficient in comparison with conventional method. Superimposed training method is widely used by research in many research activities. But this superimposed method is more complex in decoupling the information/training signal at the receiver and orthogonal vulnerability of precoding and training matrices occurs.

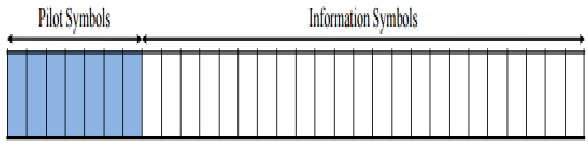

Fig-1: Conventional Pilot Symbol Aided Approach

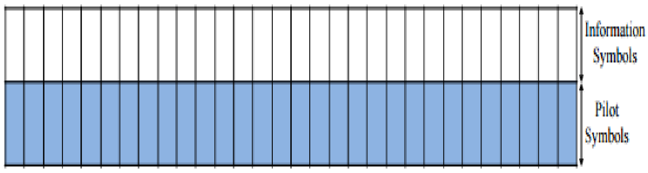

Fig-2: Superimposed Scheme

2. Blind Channel Estimation Method: In Blind channel estimation, training data is not necessary and receiver does not have any knowledge of transmitted sequence. In this method, higher data rates are required. In order to perform channel estimation in this method, statistical properties of communication signals are essential but generally, training sequences are used for channel estimation in static or slowly varying propagation environments. The disadvantage of blind channel estimation is that these methods require the accumulation of a large amount of received data.

3. Semi Blind Channel Estimation Method: The semi-blind scheme is a hybrid method that combines the blind estimation phenomenon with a limited amount of pilot data. These methods are depending on limited amount of pilot data. The semi blind method increases the convergence speed and robust tracking of time-varying channels is accomplished.

4. Decision Directed Channel Estimation Method: The use of former channel estimation is to find the data and apply it to estimate the channel in the last snapshot is called decision directing. In this method, complete transmission session may be used to transfer data symbols. The statistical properties of the communications channel and the received information symbols are used to estimate the CSI in the decision-directed channel estimation method. [1] This decision directed is bandwidth efficient technique. The major demerit of this method is that It is impractical to implement the DDCE in real-time communications systems and the received signal is highly complicated.

5. APPLICATION OF OFDM

- **WLAN (Wireless Local Area Network) IEEE802.11a/g/n:** is a wireless computer network that links two or more devices using wireless method (OFDM) within a limited area like home, school, office building. This makes the user mobile but still be connected to network. Most modern WLAN are based on IEEE 802.11 standard and marketed under Wi-Fi brand name.
- **DAB (Digital Audio Broadcasting):** is a digital radio technology for broadcasting radio stations, used in several countries. It can transmit text, image and audio over 1.5MHz system bandwidth.
- **DVB (Digital Video Broadcasting):** is a set of internationally accepted standard for digital television. It is used in DVB-T for terrestrial TV system, DVB-H for handheld devices. Supports HDTV (High Definition Tele Vision).
- **3PPG LTE (Third Generation Partnership Project Long Term Evolution):** OFDM is applied in 3GPP UMTS (Universal Mobile Telecommunication System) and in LTE 4G in downlink communication. LTE is a 3GPP standard that provide for an uplink speed of up to 50Mbps and downlink speed of up to 100Mbps. LTE will bring technical benefits to cellular network.

6. CONCLUSION

In this paper, it is concluded that MIMO-OFDM systems have the inherent to fulfill the demands of the future wireless communication systems by using the channel estimation techniques. The various channel estimation techniques such as training based, blind channel, semi blind channel based algorithms and their performance are also discussed. The MMSE channel estimator is complex yet faster as compare to the LS and ALS estimator.

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AUTHOR(S) PROFILE

Monika received B. Tech. in Electronics & Communication Engineering from Himachal Pradesh University, Shimla in 2013. She is currently an M. Tech Candidate in the department of Electronics & Communication Engineering at the Himachal Pradesh Technical University, Hamirpur. Her current research interest includes a Review on Channel Estimation in MIMO-OFDM Wireless System.

Mr. Mahendra Tyagi obtained his B.Tech. (2012) from Madhav Institute of Technology & Science Gwalior (MP) and M.Tech.(2014) NIT Raipur, India. At present, he is working as a Assistant Professor in department of Electronics and Communication at LRIET, Solan, Himachal Pradesh, India.