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A Comprehensive Review on Channel Estimation Techniques in MIMO-OFDM

Ritu Babulkar
M.Tech Scholar
Department of Electronics and Communication Engineering
NITTTR
Bhopal, M.P, India
ritubabulkar2994@gmail.com

***Abstract*— In wireless communication, more than one signals are transmitted in the channel by using the concept of Orthogonal frequency division multiplexing (OFDM) which efficiently handles the inter symbol interference and utilizes the frequency and available bandwidth efficiently. Whereas for OFDM transmission technique is integrated with MIMO channel which contains multiple transmitter and receiver antenna at both ends. By using MIMO-OFDM system, different signals can be transmitted at the same time by utilizing same frequency and get separated in the space. As the transmitting antenna transmit signal in the noisy channel so, it is required to estimate the noise in the channel. The channel estimation technique in noisy channel helps in analyzing the effect of noise on the transmitted data. In this paper, a brief review is presented for channel estimation techniques for MIMO-OFDM.**

***Keywords*— OFDM, MIMO, Channel Estimation, MSE.**

I. INTRODUCTION

Now-a-days, OFDM is of great interest to researchers all over the world [1]. In OFDM, the entire channel is splitted into many narrow parallel sub channels, so the duration of symbol is increased and the inter symbol interference (ISI) produced by the multi-path environments is reduced or eliminated [2,3]. OFDM supports high data rate traffic because the incoming serial data stream is divided into parallel low-rate streams that are transmitted on orthogonal sub-carriers simultaneously [4]. OFDM system has the ability of extenuating a frequency-selective fading channel to a set of parallel flat fading channels, which require simple processes for channel equalization [5]. The available spectrum in an OFDM system is divided into manifold sub-carriers and all these subcarriers are orthogonal to each other [6]. OFDM has been standardized for several applications, such as digital audio broadcasting (DAB), digital television broadcasting, wireless local area networks (WLANs), and asymmetric digital subscriber lines (ADSLs) [7,8].

The capability of OFDM system is improved using MIMO technique, which spatially multiplexes data streams via multiple antennas [9]. MIMO–OFDM, the combination of both OFDM and MIMO technologies, is currently under study and is one of the most propitious candidates for future communication systems, ranging from wireless LAN to broadband access [10]. The MIMO communication systems use multiple transmit and receive antennas, increase the data rate without increasing the bandwidth, increase the diversity, and improve the performance against fading channels using space–time codes [11]. It has been found that the capability of MIMO– OFDM systems grow linearly with the number of antennas, when optimal knowledge of the wireless channel is available at the receiver.

The channel condition is not known in practical application. Thus, the channel estimation, i.e., channel identification plays a major role in MIMO–OFDM system. Channel estimation is one of the most salient processes in communication system. A perfect channel estimation algorithm should comprise both the time and frequency domain characteristics of the OFDM systems.

The channel estimation in MIMO-OFDM is very applicable because at the receiver side there is a multiple users interference can be occurred so in order to eliminate these interferences channel estimation is required. The channel estimation can be done by the proper knowledge of channel at the receiver side [10]. Mostly the channel can be estimated by providing the pilot symbols along with the transmitting signal which is known by the receiver. There is various methods to transmit the pilot symbols along the transmitting data. The pilot symbols are of two types; block type pilot symbols and comb type pilot symbols [12]. In block type pilot the symbols are send periodically along each OFDM symbol and it can be used for slow fading. The pilots are inserted into all of the subcarriers of one OFDM symbol with a certain period of time. In comb type pilot the symbols are inserted over all sub channels in each OFDM symbols. In this method channel estimation can be based on least square and minimum mean square error.

II. MIMO OFDM

MIMO-OFDM system plays an important role in the fourth generation of communication system so that it can increase the data rate and the system capacity and removing the multiple paths fading. The block diagram of MIMO-OFDM consist of Tx transmit antenna, Rx received antenna and N is the number of subcarriers.

A. OFDM

OFDM is a wideband wireless digital communication technique that is based on block modulation. With the wireless multimedia applications becoming more and more popular, the required bit rates are achieved due to OFDM multicarrier transmissions. Multicarrier modulation is commonly employed to combat channel distortion and improve the spectral efficiency. Multicarrier Modulation schemes divide the input data into bands upon which modulation is performed and multiplexed into the channel at different carrier frequencies so that information is transmitted on each of the sub carriers, such that the sub channels are nearly distortion less [4].

At the OFDM transmitter end, the N-point IFFT is taken for transmitted symbols. Taking the N-point FFT of the received samples, the noisy version of the transmitted symbols can be obtained in the receiver. N point FFT is used to convert the signal from time to frequency domain [5]. The input data is first mapped into a modulation scheme. The complex plane data is transformed to parallel format and IFFT transform is obtained to produce OFDM signal. The output data is converted to serial format and cyclic prefix is added. Reverse operations are carried out at the receiver end. Cyclic prefix is removed and N-point FFT is taken to retrieve the transmitted data. Following equation can be used for computing FFT and IFFT:

FFT

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi nk/N} \quad \text{(i)}$$

Where (k=0,1,……,N-1)

IFFT

$$X(n) = 1/N \sum_{n=0}^{N-1} X(k) e^{j2\pi nk/N} \quad \text{(ii)}$$

Where (n = 0,1,……,N-1)

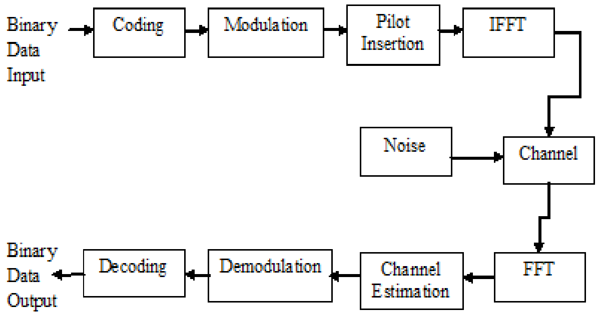

Figure 1: OFDM System

B. MIMO

Wireless channel that is selective fading caused Multipath Fading channels will cause a decrease in the performance of the communication system, to resolve the issue of diversity techniques used. MIMO diversity is one technique that uses multiple antennas at the transmitter and receiver [6].

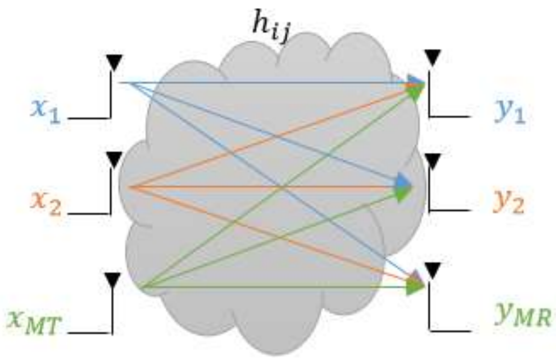

Figure 2: Illustration of MIMO Antennas

III. CHANNEL ESTIMATION TECHNIQUES FOR MIMO-OFDM

In an MIMO-OFDM system, the transmitter modulates the message bit sequence into QAM symbols, performs IFFT on the symbols to convert them into time-domain signals, and sends them out through a (wireless) channel. The received signal is usually distorted by the channel characteristics. In order to recover the transmitted bits, the channel effect must be estimated and compensated in the receiver. The orthogonality allows each subcarrier component of the received signal to be expressed as the product of the transmitted signal and channel frequency response at the subcarrier. Thus, the transmitted signal can be recovered by estimating the channel response just at each subcarrier. In general, the channel can be estimated by using a preamble or pilot symbols known to both transmitter and receiver, which employ various interpolation techniques to estimate the channel response of the subcarriers between pilot tones. Ingeneral, data signal as well as training signal, or both, can be used for channel estimation.

Training and estimation-based channel estimation: Training symbols can be used for channel estimation, usually providing a good performance. However, their transmission efficiencies are reduced due to the required overhead of training symbols such as preamble or pilot tones that are transmitted in addition to data symbols. The least-square (LS) and minimum-mean-square-error (MMSE) techniques are widely used for channel estimation when training symbols are available.

DFT-based channel estimation

The DFT-based channel estimation technique has been derived to improve the performance of LS or MMSE channel estimation by eliminating the effect of noise outside the maximum channel delay. Note that the maximum channel delay L must be known in advance. This technique is used for noise reduction.

Semi-blind channel estimator

Semi-blind channel estimators are another class of channel estimators that utilize not only that part of signal corresponding to the training symbols but also the part corresponding to data symbols. In particular, a semi-blind channel estimator takes {sp1, sp2, b} to generate a channel estimate.

Blind channel estimation

Using the statistical properties of received signals, the channel can be estimated without resorting to the preamble or pilot signals. Obviously, such a blind channel estimation technique has an advantage of not incurring an overhead with training signals. However, it often needs a large number of received symbols to extract statistical properties. Furthermore, their performance is usually worse than that of other conventional channel estimation techniques that employ the training signal. It consists of a filter, zero-memory nonlinear estimator, and adaptive algorithm.

Pilot based channel estimation

In the pilot mode, only few subcarriers are used for the initial estimation process. Depending on the stage where the estimation is performed, estimation techniques will be considered under time and frequency domains techniques.

IV. RELATED WORK

As OFDM is used in wireless communication for high quality data transmission and enhancing the spectral efficiency. The combination of MIMO system with OFDM system increases the complexity of the system. As a consequence, the wireless channel have an issue of inter symbol interference (ISI) which degrades performance of the entire system. With increased number of users in limited bandwidth there is requirement of channel estimation technique[1].

In the whole scenario there arise a question that why there is need of channel estimation technique? The answer to this question is that the channel estimation is important because if the estimation is not performed, the receiver will not be aware about the level of interference caused in the channel. As a consequence of whole, wrong data stream will be received, error correcting code will not perform well, antenna selection will go wrong, modulation goes wrong, etc. In this literature review several non-blind channel estimation techniques, which needs a large number of received symbols to extract statistical properties, are discussed [6]. The review gives the result analysis of several work and finally comparative analysis is also performed which leads in the direction of finding the problem statement for development of proposed work

Hao Wu, Member, Yuan Liu, and Kai Wang, [1], (2018), showed the impact of extended Kalman filter channel estimation technique over massive-MIMO system. It has been observed that in low SNR scenario, the non-allocating sub carriers with Zero padding gives optimal results. The work is based on fast Fourier transform/inverse fast Fourier transform for reducing the transmission complexity.

In this research work, DFT based channel estimation is also discussed for uplink massive MIMO system. The simulation result shows the limitation of the proposed methodology in low SNR AWGN channel. The optimal result is shown with extended Kalman filter with FFT system that reduces the computational complexity of the system significantly.

From this research work it is concluded that mismatch in carrier frequency can result in inter-carrier interference (ICI).

Aqiel Almamori, Seshadri Mohan [2], (2018), proposed the Channel state information (CSI) estimation for detection of input signal data with Kalman Filter and prior knowledge of the channel or known pilot bits. The researcher designed the system with QPSK modulation based OFDM. The received signal is processed by modified Kalman filter to produce channel state information (CSI) and to estimate the channel noise. The result analysis of modified Kalman filter is less dependent on the statistics of the channel and gives minimum MSE.

The result shows that the proposed algorithm can estimate the CSI with low MSE and comparable sum rate to a MMSE method which needs perfect prior channel statistics. From this research, researcher got the idea of channel estimation for OFDM system from the transmission of known pilot symbols.

Pham Hong Lien, Nguyen Due Quang and Luu Thanh Tra [3], (2017) proposed an modified algorithm for channel estimation by combining CFO technique with mobile OFDM system. Some of the existing channel estimation techniques are such as LS (Least Square), Minimum Mean Square Error (MMSE), Kalman Filter and Extended Kalman Filter based channel estimation. The result analysis is performed with modified algorithm and compared with other existing algorithms. For research performance enhancement, the extended Kalman filter algorithm is modified with CFO which jointly estimates the channel frequency from the transmission of known pilot symbols. The proposed algorithm gives best result in fading environments for high speed vehicular mobile network with OFDM system. From this research, researcher got the idea of channel estimation for OFDM system from the transmission of known pilot symbols.

M.Raju and K.Ashoka Reddy [4], (2016), analyzed the impact of Least Squares (LS), Minimum Mean Square Error (MMSE) channel estimation techniques for MIMO-OFDM System. For result analysis MSE (Mean Square Error) is considered as a performance parameter for channel noise estimation for BPSK, M-ary QAM modulation schemes over the AWGN and Rayleigh fading channel. As a result, the transmitting signal with pilot symbols is constructed. From result it is observed that LS channel estimation technique gives higher MSE as compared with MMSE channel estimation technique for low SNR value for conventional OFDM systems with single transmit/receive antenna. The use of multiple transmitter and receiver antennas delivers more enhanced performance. From this research, researcher got the idea of channel estimation for OFDM system from the transmission of known pilot symbols.

Kalpesh Hiray, K. Vinoth Babu [5], (2016) designed a multi layered perceptron (MLP) neural network based channel estimation technique for estimating the channel efficiently. For result analysis, Monte –Carlo simulations are performed and compared with LS channel estimation technique. The performance parameter used is SER and simulation is performed for low SNR values. The channel is considered as noisy with AWGN. For the SNR value of 6db, SER evaluated is 10^{-2} for LS channel estimation technique whereas for MLPNN channel estimation technique the SER value is achieved at 5 dB, thereby a 1 dB of overall gain is achieved. From this research, researcher got the idea of neural network channel estimation for MIMO-OFDM system from the transmission of known pilot symbols and the work may be extended towards MIMO system.

Yihua Yu and Yuan Liang [6], (2012), discussed about the limitations of the joint carrier frequency offset (CFO) and channel estimation for MIMO-OFDM systems under time-varying channels. Different CFO values are considered for different pairs of transmitting and receiving antenna. The channel estimation is performed by extended H∞ filter (EHF). The result analysis compares the performance of the conventional extended Kalman filter (EKF) and EHF. The technique does not require the information about the noise in the channel and shows that the system is robust under different conditions. The performance parameter taken for the proposed system is RMSE and it is observed that the value of EHF method is near about EKF method, even though the EHF does not have any prior information about noise in the channel whereas the EKF have the prior knowledge of the noise in the channel. From this research work it is concluded that mismatch in carrier frequency can result in inter-carrier interference (ICI). So, from this paper, researcher got the idea of channel estimation for MIMO-OFDM system without knowledge of noise distributions.

Jun-Han Oh and Jong-Tae Lim [7], (2010), proposed a channel estimation technique that work in two steps. The proposed model consists of equalization technique based on threshold value and time varying LS channel estimation techniques. For error reduction of the proposed technique, researcher gives the concept of adaptable threshold values by using noise variance values for different sub-carriers. Further the detected symbols are propagated and determined by the threshold values. As result comparison with pilot based channel estimation technique, the proposed channel estimation technique is better and generates low BER. From this research, researcher got the idea of channel estimation for OFDM system from the transmission of known pilot symbols.

V. CONCLUSION

In order to fulfill the high data speed demand in current increasing multimedia scenario, there is required to research more in this field. Many researchers focused their work in enhancing the performance rate. In this research work, literature focuses on the work performed in the field of noise estimation in wireless channel. It is done because as the noise level in channel will be estimated, there would be convenient for transceivers for successfully receive data bits correctly. Good channel estimation technique will make the system more robust and consequently performance will be enhanced. For implementing the channel estimation technique, researchers are mainly focusing on MIMO-OFDM communicating system as its ability is to enhance the channel capacity or the more and more users can send their data bits in limited bandwidth and it also increases the diversity gain with multiple transmitter and receiver.

As from literature review it is studied and concluded that LS channel estimation technique is less complex in implementation as compared to other techniques but does not estimate noise efficiently. As it estimates noise with more error rate. This shows the limitation of LS technique which was reduced in MMSE channel estimation technique but the design of the MMSE is more complex due to the need for matrix inversion. Also it doesn't reduced the error much to that level and also require known pilot symbol bits. So, these issues was focused while designing the neuro-estimator in future work.

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