DIFFERENT CHANNEL ESTIMATION TECHNIQUES USED IN MIMO-OFDM COMMUNICATION SYSTEMS-A SURVEY

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Abstract: Modern communication system is more fascinated about wireless communication, in which the data can be delivered wirelessly. Wireless communications, usually works through "Electromagnetic" (EM) waves by which the data is send by air, which acts a medium. But the medium or channel considered in wireless system changes over time i.e., it is time-varying in nature. Even the signals transmitted through wireless systems may get affected by multipath propagations. In realism, the status of channel is unknown. So, the "Channel Estimation" is very essential in wireless communications. Mostly the estimation of channel is carried out at the receiver end. Therefore to precisely estimate the channel various techniques are employed. The techniques like Least Square (LS), Minimum Mean Square Error (MMSE), blind and semi-blind, training based channel estimation methods. As the estimation is carried out at the receiver the pilot sequences are utilized by which the evaluation can be done with ease and accurately estimate the channel. In technologies like, OFDM, MIMO-OFDM this estimation plays a very crucial role as high data rate signals are transmitted through the subcarriers which are modulated and overlapped orthogonally with each other. The paper gives the introduction to OFDM and MIMO-OFDM systems and also briefs about different pilot allocation methods used for estimation and discusses about the channel estimation algorithms deployed in wireless communications.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Multiple Input Multiple Output (MIMO), Least Square (LS), Minimum Mean Square Error (MMSE), Electromagnetic (EM).

I. INTRODUCTION

Wireless communications has evolved as the most capable technology during the past few decades. This technology has been classified according to the generations which specifies about the transfer rate, and service types. The generations like 1G, 2G, 3G, has evolved and the 4G is the present technology that is in usage but under research, 5G technology can be evolved for the future which may have advanced features. The current 4G technology supports the services handled by multimedia like, video and audio files, internet, and high definition images can be transferred with better-quality. This wireless technology is more attracted by the users due its "flexibility" and "portability" and the freedom to use the services with easiness.

In wireless systems the devices can be mobile or fixed. So, when the devices are mobile consider the transmitting device and the receiving device will be in motion and the channel will be changing according to the time therefore the channels can be time varying in nature. If the devices are fixed consider numerous antennas are mounted, while the data is delivered from transmitting antenna to the receiving antenna through the wireless channel the data or the signal may take multiple paths to reach the receiver. This causes degradation of the signal due to multipath propagation in the channel. To regain the faded signal received at the receiver is complicated. Hence, estimation of channel is very important in wireless communication systems. This process is done at the receiver side. The estimation is carried out by knowing the "Channel State Information" (CSI) which helps to know the properties, behavior and link reliability of the channel.

CSI can be known by using different channel estimation algorithms. The estimation is done at the receiver by using a set of known symbols or sequences known as pilot symbols assumed at the transmitter. Thus the channel impulse response is evaluated by channel estimation methods for each known symbol or burst that is transmitted and corresponding received samples. By using technologies like OFDM and MIMO-OFDM these bursts of data or symbols are transmitted at high rates through the channel wirelessly.

This paper is organized as, the brief introduction to wireless communication is given in section-I. Section-II describes about the OFDM and MIMO-OFDM technologies. Section-III talks about various channel estimation methods used in wireless communication system. Section-IV shows the comparison between MMSE and LSE and when the channel estimate is not utilized through simulation results. Section-V gives the conclusion of the paper. Section-VI lists the References.

II. OFDM & MIMO-OFDM SYSTEMS

In the modern technology OFDM and MIMO-OFDM systems are mostly used. These technologies supports high data transfer, enhanced quality, efficient spectral usage. Interference and fading effects can be reduced by using these systems. In this section the brief introduction to OFDM and MIMO-OFDM system and also basic block diagrams of these systems are included for better understanding. [2]

2.1 OVERVIEW OF OFDM SYSTEM

OFDM system is one of the popularly used wireless technology that transmit data symbols on orthogonal subcarriers.The OFDM symbols are allocated with different subcarriers that have different frequencies therefore they are closely packed without interference thereby saving the bandwidth. The important technique in OFDM is Multi-Carrier-Modulation technique. This technique helps to partition the high rate data or bit streams into 'N' parallel bit streams and are modulated by 'N' subcarriers that are orthogonal.

For efficient performance of the system "Inverse Fast Fourier Transform"(IFFT) and " Fast Fourier Transform" (FFT) is applied for modulation and demodulation both at the transmission and recipient side respectively. This IFFT and FFT transforms are used to convert frequency domain signals into time domain and vice versa.

These modulated signals are added with Guard bands and cyclic prefix to eliminate "Inter Symbol Interference" (ISI) and "Inter Channel Interference" (ICI) and to estimate the channel at the receiver the pilot symbols are inserted. These signals or symbols are transmitted by the help of subcarrier through the channel. The signal received may be delayed or added with the noise in the channel. Therefore the estimation of channel is very important to retrieve the original signal at the receiver.

The OFDM system is very robust to ISI and ICI effects and fading. The errors occurred due to the above effects can be reduced by using error detecting mechanisms or by the diversity technique. Therefore the OFDM system coupled with the MIMO system gives better performance.

2.2 OVERVIEW OF MIMO-OFDM SYSTEM

MIMO technology uses multiple transmitting and receiving antennas. It uses "Spatial multiplexing" and "Diversity" technique to know about the antenna configuration and to gain the knowledge about the channel respectively. This system helps to develop the system capacity and coverage area. There are many benefits using OFDM and MIMO systems. So, coupling these two technologies as MIMO-OFDM [2] giver superior results and performance can be improved.

MIMO-OFDM is the mostly used broad band technology in this generation. This system helps to improves the link reliability, spectrum efficiency. The received signal gain can be increased as signals are received from multiple antennas. The multi-path fading effects can be reduced but by knowing the exact channel properties at the transmitter. Channel State Information (CSI) is important to evaluate the channel and know the signal properties.

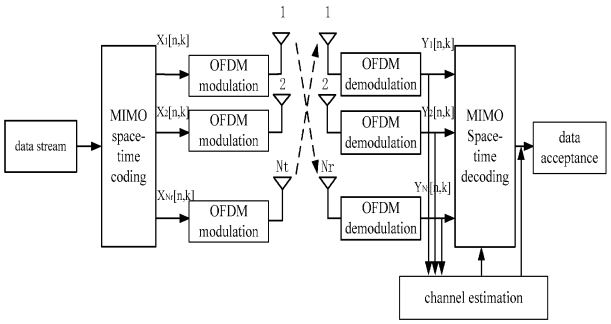

Fig 2.1 : Block diagram of MIMO-OFDM System.

III CHANNEL ESTIMATION

Channels are the very crucial part of wireless communications system to transfer data. In wireless or mobile communications, the transmit and receive devices can be mobile or fixed. Therefore to regain the signal properties at the receiver end when it is affected by time varying channels and Multi-Path Propagations channel estimation [4] is very essential. Awareness of Channel Impulse Response is very crucial in wireless/ mobile channels, by gaining this information the evaluation of the channel is done in this manner by testing and planning the wireless communication system can be designed.

To estimate the channels accurately various channel estimation schemes has been proposed. Mainly used channel estimation techniques are 1) Blind Channel Estimation 2) Semi-Blind Channel Estimation 3) Training symbol based channel estimation schemes. But the estimation of the channel is carried out by using the known sequences or symbols called as pilots. These pilot positions are known both at the transmitter and the receiver such that the receiver can retrieve the original data. All the above mentioned channel estimation schemes uses pilots to estimate the channel. But the position or placement of pilots is also an important factor. The three main types of pilot arrangement is Block type, Comb type, Lattice type.

3.1 PILOT ARRANGEMENT

MIMO-OFDM, OFDM systems mostly uses “Block type” and “Comb type” pilot arrangements. The following section briefs about these two type of pilot arrangements [3],[5]

a)BLOCK TYPE

In this type the fixed pilots are designed for each subcarrier that are placed orthogonally. Transmission of the pilots is done periodically . By using these pilot symbols the channel estimation is evaluated and the original signal transmitted is detected at the recipient. The Block type pilot arrangement is utilized mainly when the channel is time variant over the OFDM symbols that is this type of position allocation is done for slow fading channels

b) COMB TYPE:

In this type of arrangement the pilot symbols considered are inserted into a set of OFDM symbols at fixed positions. The estimation of channel is executed by using these pilot symbols. The other symbols called as data symbols are estimated by using interpolation techniques. This type of fading is considered when the channel is fast fading .

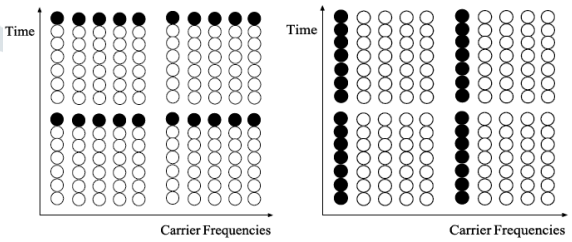

Fig 3.1: Block type and Comb type pilot arrangement.

3.2 CHANNEL ESTIMATION SCHEMES

To accurately estimate the channel when it is time varying or to know the channel behavior, effectual channel estimation methodologies are employed. The three main channel estimation schemes employed are Blind channel estimation, Semi-Blind channel estimation and Training symbol based channel estimation. [5]

a)Blind Channel Estimation:

In this type of channel estimate [7] pilot symbols are not included at the transmitter and the receiver. The receiver estimates the channel without the usage of pilot symbols. To efficiently estimate the channel without pilots the receiver uses a large amount of received data to understand the channel properties and estimates the channel. The benefit of this method is that the overhead due to pilots can be reduced. But the computational complexity increases, as to extract the signal properties large number of received data is considered which increases computational time also. This channel estimation does not give good results when compared to other estimation methods.

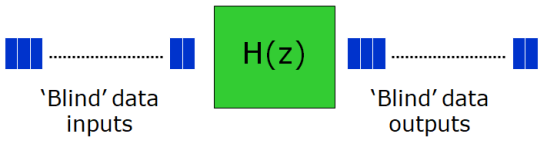

Fig 3.2 : Model for Blind Channel Estimation

b) Semi-Blind Channel Estimation

"Semi Blind Channel estimation"[6] method is the combination of Blind and Training symbols based channel estimation. In this scheme the pilots that are considered at the transmitter are used to estimate the channel at the receiver. The channel in this method can be evaluated by pilots symbols or by the combination of data and pilot symbols. After the channel is estimated the channel co-efficients evaluated are fed back to the transmitter and compared with the original data symbols. If the fed- back symbols matches with the original symbols then the signal at the receiver can be detected properly. If the channel coefficients are in symmetry with the pilot symbols then the predicted symbols at the receiver are updated further without the utilization of pilot symbols. If the signal is approximated properly that signal is used as the reference signal for further prediction of the signals at the receiver. The main advantage of this scheme is that the channel behavior can be tracked efficiently.

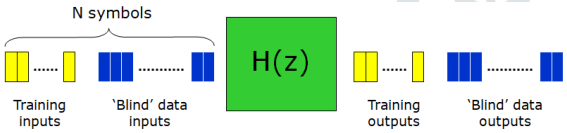

Fig 3.3 : Model for Semi-Blind Channel Estimation

c) Training symbol based channel estimation

In this method the training symbols or the pilots are used to estimate the channel. But the overhead is more in this method due to usage of pilot symbols. But to overcome this drawback the methodologies like "Least Square"(LS) estimate , " Minimum Mean Square Error" (MMSE) algorithms are used. Comparing all the mentioned three channel estimate this "Training symbol based channel estimate " outperforms all the other methods.

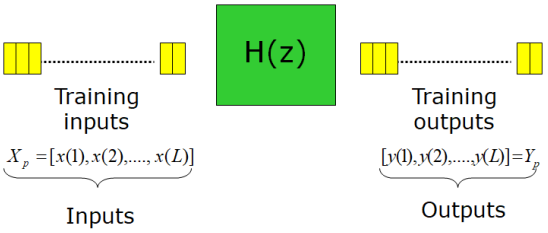

Fig 3.4 : Model for Training symbol based channel estimation

LEAST SQUARE ESTIMATE (LSE):

To minimize the squared distance between the original data and the received data this LS method[2] is used. The errors like MSE and BER can be minimized . The LS estimate of the channel when the pilot subcarriers are considered is given by

$$H_P^{LS} = (X_P)^{-1} Y_P$$

Where H_P^{LS} is the LS estimate of the channel ie., channel matrix

X_P is the input data matrix

Y_P is the output or received data matrix

MINIMUM MEAN SQUARE ERROR (MMSE):

To minimize the "Mean Square Error" (MSE) this MMSE[2] channel estimation scheme is designed. But the evaluation of MMSE is complicated compared to LS estimate but the performance of the system can be enhanced proficiently by this MMSE method. The channel estimate of MMSE is given by H_P^{MMSE}

$$H_P^{LMMSE} = R_{HH_P} \left(R_{H_P H_P} + \frac{\beta}{SNR} I_P \right)^{-1} H_P^{LS}$$

Where H_P^{MMSE} is the channel matrix

R_{HH_p} is the cross correlation matrix

$R_{H_P H_p}$ is the auto correlation matrix

SNR is Signal to Noise Ratio

H_P^{LS} indicates the channel matrix of LS estimate

β is Scaling Factor

Ip is Identity Matrix

The simulations for these algorithms can be executed by using the MATLAB software.

IV SIMULATION RESULTS

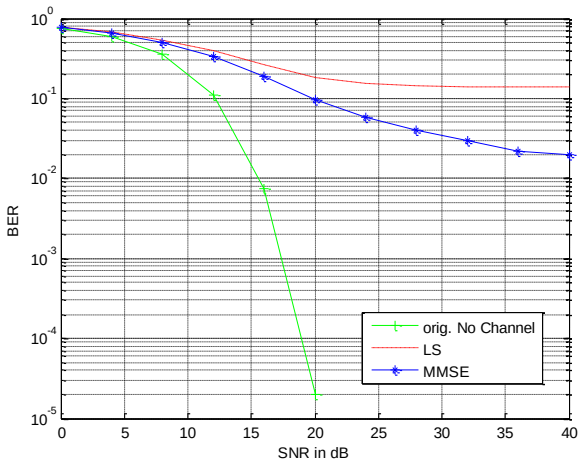

Fig 4.1 : BER vs SNR for LS, MMSE and when no channel estimation is used.

When Simulated the results show that the MMSE show better results compared to the LS estimate, but the complexity is more for MMSE channel Estimation Algorithm.

V CONCLUSION

The paper gives the introduction to MIMO-OFDM and OFDM system. The importance of channel estimation in wireless communication is explained. Different channel estimation methodologies and their models have been briefed and depicted respectively. The pilot allocation methods which is necessary for estimating the channel is also explained and various pilot arrangement types are also included in the paper. The simulation results showing the BER versus SNR is shown for MMSE, LS channel estimation and when channel estimation method is not used.

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