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# SURVEY ON DIFFERENT CHANNEL ESTIMATION ALGORITHMS IN MIMO OFDM SYSTEMS

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Abstract—MIMO OFDM is a powerful combination technique for current and future broadband wireless communications. MIMO technology transmits signal through multiple antennas there by multiplying capacity and OFDM provides transmission at high speeds. Obtaining channel state information (CSI) is the main challenge of MIMO OFDM systems. Different channel estimation algorithms like Least Square (LS) estimation, minimum mean square estimation (MMSE), EM based estimation, H-inf estimation can be effectively used for the retrieval of CSI. This paper carries out an extensive survey in the area of different channel estimation algorithms.

Index Terms— MIMO OFDM, CSI, LS estimation, MMSE, EM estimation, H-inf estimation.

#### I. INTRODUCTION

Future and current wireless communication requires high speed and high data rate. To support this ever growing demand for high speed data communications MIMO OFDM can be used. Multiple input multiple output systems use multiple antennas at transmitter and receiver section, and data signals over these antennas, there by multiplying capacity. OFDM is a digital multicarrier multiplexing technique which provides high transmission rate, lower delay and small jitter that keep up the demand for more communication capacity. Thus by employing MIMO OFDM, we can achieve data communication with high spectral efficiency. In a MIMO OFDM communication system it is important to retrieve the transmitted signal correctly at the receiver. Therefore channel estimation is a crucial and fundamental factor for MIMO OFDM systems.

Channel estimation depends upon the channel state information (CSI). CSI denotes the propagation of transmitted signal to receiver and it also accounts to the effect of scattering, fading, and power decay with distance of transmission. This method is called Channel estimation. By estimating CSI, we can provide adaptive transmission mechanisms to current channel conditions, which in turn help to achieve reliable communication with high data rates in MIMO systems. . Therefore channel estimation is a crucial and fundamental factor for MIMO OFDM systems. Usually channel state information is estimated at the receiver and is fed back to the transmitter. Therefore channel side information at transmitter (CSIT) and channel side information at receiver (CSIR) may be different. Channel estimation is more difficult in MIMO systems as compared to SISO systems due to the presence of multiple channels and multiple number of antennas. There are many algorithms for channel estimation. Least

Square channel estimation and Minimum Mean square channel estimation are the classical algorithms for channel estimation. There are other methods also. In this paper an extensive survey is carried out on the channel estimation of MIMO OFDM systems. MIMO technology is the most significant method which is employed to improve the signal to noise ratio for wireless technologies. MIMO systems combined with OFDM ensure that the signals are transmitted orthogonally with each other. OFDM necessitates time and frequency synchronization to sustain its orthogonality between subcarriers and also resistive to frequency offset which can be caused either by Doppler shift due to relative motion between the transmitter and receiver or by the difference between the frequencies of the local oscillator at the transmitter and receiver[2].

## **II.SYSTEM MODEL**

Traditional wireless communication systems provided constant bandwidth but there was no possibility of increasing the data rate. The major parameters considered in designing a communication system are bandwidth, data rate and software and hardware complexities. The new wireless communication system consists of integrating the two methods, MIMO and OFDM and for advanced capacity requirement and increased data transmission rates. Block diagram of MIMO OFDM system model is shown in figure 1.

Bit streams to be transmitted are coded using a channel coder and is given to the MIMO encoder. Each signal is fed to a OFDM modulator in which IDFT of the data sequence is taken. Then cyclic prefix is added. The data sequences are transmitted over multiple transmitter antennas. At the receiver section the signal will be a mixture of transmitted signal and noise over the channel.

At OFDM demodulator section, cyclic prefixes are removed and DFT operation is performed. After channel decoding orginal data is recovered. The received signal vector  $V_{j}$  can be expressed as

$$Y_j = XH_j + Z_j \tag{1}$$

Where X represents the transmitted signal and  $H_j$  represents the frequency response of the channel.  $Z_j$  is a

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vector of independently and identically distributed (i.i.d) zero mean complex Gaussian noise variables.



# Fig. 1: Block diagram of MIMO OFDM system model III.CHANNEL ESTIMATION

In a MIMO OFDM system, the transmitter modulates the message bit sequence and performs IFFT on the symbols to convert them into time-domain signals, and sends them out through a channel. The received signal is distorted by the wireless channel characteristics. In order to recover the transmitted bits, the channel effect must be estimated and compensated in the receiver. Thus, the transmitted signal can be recovered by estimating the channel response just at each subcarrier [3]. Different channel estimation algorithms are discussed in this section.

#### A. LEAST SQUARE (LS) ESTIMATION

We consider an OFDM frame structure where each frame consists of  $N_{SYMB}$  consecutive OFDM symbols. The first and the third last bits are reserved for transmitting the pilot sequences. Out of the  $N_C$  available subcarriers, K are used for transmitting data and the pilot sequences are transmitted over all K tones. The pilot symbols are used for obtaining an estimate of the channel impulse response which is then used for the coherent detection of the transmitted symbols [4]. The MSE expression of the LS algorithm for MIMO OFDM systems in the presence of PC is given as follows:

The computation of the LS estimate requires an  $N_{TL} \times N_{TL}$  matrix inversion which is computationally an intensive task. It was shown in that with a proper pilot sequence design, the LS channel estimator for MIMO OFDM can be simplified so that the matrix inversion is not needed while the estimator still achieves the minimum mean square error (MSE).

#### B. MINIMUM MEAN SQUARE(MMSE) ESTIMATION

By employing the channel characteristics, MMSE usually obtains optimal estimation performance. Here the mean square error is minimized. Consider the LS

estimation given in equation (2). Using a weight vector matrix W, we can minimize MSE. But the matrix inversion procedure is complex. Due to the high computational complexity in MMSE for MIMO systems, we just consider a simplified version by using an expectation–maximization iterative process[4]. The channel frequency vector between the *j*th BS and the *k*th user in the *j*th cell is given as follows:

$$\widehat{H}_{jjk}^{MMSE} = R_{HH} (R_{HH} + \sigma^2 (X_{jjk}^{H} X_{jjk})^{-1})^{-1} H_{jjk}^{LS}$$
(3)
  
C. EM BASED CHANNEL ESTIMATION

The Expectation-Maximization (EM) algorithm is a technique for finding maximum likelihood estimates of system parameters in a broad range of problems where observed data are incomplete.an EM-based iterative algorithm can be efficiently used to estimate the OFDM channel impulse response (CIR) for multipath fading channels with additive white Gaussian noise (AWGN). By making use of pilot tones to obtain the initial estimate, the algorithm can achieve a near-optimal estimate after a few iterations [5].

#### D. H-inf CHANNEL ESTIMATION

H-inf estimation method provides mean square error which is comparable to the optimal MMSE but with a less complexity. H-inf estimation algorithm provides a method in which the ratio between whole channel estimation error and the input interference is less than a predefined threshold [4]. For a given positive scalar vector s, the h-inf estimator needs to satisfy the objective function given as

$$sup_{Z_{j}} = \frac{||\hat{c}_{j} - c_{j}||_{W}^{2}}{||z_{j}||^{2}} < s$$
(4)

#### IV. SURVEY OF CHANNEL ESTIMATION

An improved space-time coding for multiple input and multiple output orthogonal frequency division multiplexing using QPSK modulation for four transmit and four receive antennas was proposed by Rick S. Blum in [6]. The paper also showed a 4-antenna, 16 state codes that achieve an additional 2-dB improvement with lower complexity and a 256 state code that achieves an additional 2-dB gain. The 256-state code performed within 3db of outage capacity.

A number of physical layer issues relevant for the implementation of broadband MIMO-OFDM systems were discussed in [7]. They discussed space-time coding strategies for closed loop MIMO-OFDM systems where knowledge of the channel is available at the transmitter. Error-correction coding was also formulated with an emphasis on high rate LDPC codes. Adaptive analog beam forming techniques were discussed that can provide the best possible MIMO channel environment

Multiuser channel estimation technique for space time block coded orthogonal frequency division

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multiplexing (STBC-OFDM) systems basedon simple blocked pilot grid was presented on [8]. The estimation of multiuser channels is based on least square (LS) and Minimum mean square estimation (MMSE) schemes. Different Doppler fading effects on MMSE performance are also presented in the work.

An extra processing added to conventional LS estimation to improve its performance in MIMO-OFDM systems was investigated in [9]. The new technique is based on knowledge of the power delay profile. The application of the improved estimator is useful when employing advanced MIMO adaptation techniques. Simulation results showed performance of MIMO techniques closed to that offered by perfect channel.

Adaptive filters are used as a method for channel estimation in MIMO-OFDM systems[10]. The method exploits pilots and adaptive filters to estimate channel. The simulation results show that this method has moderate computational complexity than the LS one.

Pilot aided LS channel estimation in MIMO-OFDM system [11] presents theoretical and simulation results of LS channel estimation in MIMO-OFDM system. These results are estimated on block type pilot and comb type pilot structures. The simulation results verify that the theoretical analysis and suggest that the comb type pilot structure is more suitable for time variant channel.

Channel estimation analysis in MIMO-OFDM wireless systems analyzed channel estimation on MIMO-OFDM system for Rayleigh fading channel [12]. The two different algorithms such as LS and MMSE channel estimation algorithms are applied and simulation is performed in this work. Simulation results show that MMSE has less MSE and less BER than LS and also channel estimation using comb type carrier has lower BER than block type pilot carrier.

Enhanced Adaptive channel estimation technique for MIMO-OFDM wireless systems [14] presented an enhanced technique for channel state information estimation in MIMO-OFDM system. It is concluded that RLMS algorithm outperforms LLMS but RLMS has a disadvantage that it is more complex than LLMS. The results show that BER performance is better of proposed algorithm. BPSK outperforms than QPSK modulation but at the same time it is a fact that the capacity of QPSK is higher than BPSK. With the increase in SNR value, BER performance becomes better in both cases. Do RLMS algorithm is better than LLMS algorithm.

### VI. CONCLUSION

An extensive survey in the area of different channel estimation algorithm is carried out in this paper. Least square and minimum mean square estimation algorithms are the classical algorithms. Study reveals that MMSE channel estimation is the one which provides optimal Mean Square Error but with high complexity. Optimal MSE can be achieved using H-inf method but with a low complexity. Pilot based estimation methods are also suited for MIMO OFDM systems.

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