Carrier Frequency Offset Estimation For MIMO-OFDM Beamforming Systems

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Abstract: In wireless communications systems, Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) are used to improve spectral efficiency and spatial diversity. Beamforming is used to improve bandwidth utilization. It increases the network range in wireless systems. The main challenge of OFDM system is Carrier frequency offset (CFO). The project focuses on CFO estimation technique to compensate for the effect of CFO on OFDM system. Carrier Frequency Offset estimation are used to improve the efficiency of MIMO-OFDM system.

Keywords— MIMO-OFDM; Beamforming; Carrier frequency offset;

I. INTRODUCTION

Orthogonal frequency division multiplexing is a modulation technique which is used for wireless communication systems[1]. A Beamformer is used for communicating between pairs of terminals. CFO is very sensitive in OFDM systems. So by using CFO estimation process, better performance of MIMO-OFDM can be achieved. CFO is produced in OFDM systems due to Frequency mismatch in the transmitter and receiver side, Doppler Effect (DE), and Inter Carrier Interference (ICI) that destroys the orthogonality between the subcarriers in the OFDM systems[9]. It also attenuates the desired signal, and results in the degradation of the overall system performance. The blind channel estimation method is used to overcome these problems.

II. LITERATURE SURVEY

MIMO is a multiple antenna technology, it consists of multiple inputs and multiple outputs for wireless communications. Antennas at each end of the communications are combined to minimize the errors. Multiple input multiple output techniques are aimed to increase the performance of wireless systems through multiplexing or diversity gain [1]. Orthogonal frequency division multiplexing is a method for encoding the data onto different carrier frequencies. OFDM is used in many of the latest wireless and telecommunications systems [2].

The combination MIMO-OFDM is very effective since OFDM enables support of more antennas and simplifies equalization in MIMO systems and therefore achieves larger bandwidths. Beamforming method is used to create radiation pattern of the antenna array by adding the phases of the signals in the direction of the desired target [4]. Beamforming reduces the error between the desired and actual beamformer patterns. It is done using some algorithms.

CFO is one of the problems of OFDM systems. This leads to the loss of their orthogonality between the different subcarriers and accumulation of phase error over successive symbols [10]. These effects can degrade the system performance. In order to remove these issues, signal processing algorithm is developed. It is to estimate the frequency offset and to correct it. The signal processing algorithms for CFO estimation in OFDM systems are mainly divided into Blind and Non Data aided . There are several techniques used to estimate frequency offset and compensate CFO in time-domain and frequency-domain approaches. Estimation techniques in time domain are based on cyclic prefix or training sequence, in blind estimation algorithms, Cyclic Prefix (CP) is used to estimate CFO.

III. SYSTEM MODEL

A. MIMO-OFDM

In MIMO-OFDM, signal is transmitted through a number of antennas in order to achieve diversity gain and transmission rate. Better performance of MIMO-OFDM system is based on the Fourier Transform algorithm [1]. OFDM is suitable for various transmission systems such as Wireless Fidelity (WIFI), Worldwide Interoperability for Microwave Access (WIMAX), Digital Video Broadcasting (DVB). Combining OFDM with MIMO technique increases spectral efficiency of 1Gbit/sec. The general structure of MIMO-OFDM system model is shown in Fig 1. The system consists of 2 transmitter and 2 receive antenna. OFDM consists of two blocks serial to parallel (S/P) and parallel to serial (P/S) converters. The OFDM signal for each antenna is obtained and detected by using the Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT). Cyclic prefix is inserted in front of the OFDM symbol which is used for channel estimation. The
main function of cyclic prefix is to insert guard to the OFDM symbol against Inter Symbol Interference (ISI), so this cyclic prefix is called as guard interval of the OFDM symbols.

![MIMO-OFDM System Model](image)

**Fig 1: MIMO-OFDM System Model** [2]

**B. Principle Of MIMO-OFDM**

In MIMO-OFDM system the modulating signals from multiple antennas are transmitted simultaneously [3]. At the receiver modulated signals are received after demodulation. The MIMO-OFDM system is shown in Fig 2. It consists of multiple parallel transmission paths which are very similar to the single antenna OFDM system. Each and every cyclic prefix is inserted before the final transmission. The channel encoding and modulation of signals can also be done on their respective branches. In MIMO-OFDM system multiple signals are transmitted over the different channels and each received signal is a combination of transmitted signal and noise. Finally the receiver must estimate and correct the errors and frequency offsets. At the receiver Cyclic Prefix (CP) is removed and Fast Fourier Transform is performed per each receiver branch.

**C. MIMO-OFDM Beamforming System**

Beamforming is a technique in which arrays of antennas are exploited to achieve maximum reception in a specified direction [4]. The same frequency signals arriving from different directions are eliminated. This is achieved by varying weights of antennas in the array. This spatial separation is exploited to separate the signal from the interfering signals. Beamforming techniques can be broadly classified as fixed method and adaptive method [5]. In fixed beamformers their parameters are fixed during operation while Adaptive beamformers are continuously updated based on the received signals. Beamforming can transmit data towards directions of given clients instead of radiating data in all directions [6]. Beamforming technology provides wider coverage. Technically beamforming technology is based on digital signal processing (DSP) logic and MIMO technology. Beamforming can provide the right direction to the given client direction. Beamformer in the transmitter side changes the phase and amplitude of the signal. It can create a constructive interference and destructive interference, making the signal in correct direction stronger and others weaker.

Conventional arrays use the beamforming techniques which detect the presence and direction of arrival of each signal. One of the simplest form of DOA estimation is used in conventional beamformer [7]. It is based on scanning the array beam and computing the output power for each beam phase angle. The conventional beamformer is limited in its angular resolution, so it has less implementation complexity. The low resolution property of the conventional beamformer is reduced by estimating the spatial spectrum of multiple sources. The steering direction is the bearing that the array is steered towards to look for a particular incoming signal. A beamformer is a spatial filter that processes the data obtained from an array of sensors in a manner that serves to enhance the amplitude of the desired signal wave front relative to background noise and interference.

**D. Principle Of Beamforming**

In wireless communication system the transmitted signals are propagated through few distinct paths like the line of sight path between transmitter and receiver [8]. By applying beam forming techniques therefore significant SNR gains can be achieved in comparison with Omni directional beam pattern. Beam forming methods can be applied when the directions of the dominant propagation paths are known. Also by knowing the directions of the dominant propagation paths at the transmitter side, the transmitted power can be concentrated within the corresponding angular region and is not wasted for directions that do not contribute to the received signal. In beam forming, the amplitude and phase of each antenna are controlled so that it adjusts the side lobe levels. Main functions of Beamforming are, detection of presence of signal, estimate the direction and arrival of signals and reduce the noise. Direction of arrival is to estimate the direction of arrival of the signal. Directional transmission and reception is the design criteria for beamforming. The transmitter and receiver beamformers nullify the noise and increase the system performance.
Beamforming is done by filtering the signals and combining the output to extract the desired signal and reject the interfering signals. Beamforming is done to the input signal which is applied to the Linear Constellation Precoder (LCP) and then passed to an IFFT block, after beamforming signals passes to the MIMO transmitted side, the signals containing same input are received at the receiver. A MIMO which utilizes the channel information at the transmitter and receiver is known as beamforming [9]. In this paper, the signal processing operations are referring to beamforming as a vector operator. Beamforming is a signal processing technique. Beamforming in OFDM system is presented in time domain (narrow band) and frequency domain (wide band) configuration.

E. CFO Estimation

Channel estimation is used in wireless network systems. Data is transmitted from transmitter to receiver through channel but sometimes there is some interference due to addition of noise [10]. By reducing the noise estimated channel can utilize the correlation of channel parameters at adjoining subcarriers to indicate interference among antennas. In channel Estimation Techniques for MIMO-OFDM, the transmitter modulates the message bit sequence into symbols and performs IFFT on the symbols to convert them into time-domain signals, and sends them out through a wireless channel [11]. The received signal is usually distorted due to the channel characteristics. While recovering the transmitted bits, the channel must be estimated and compensated in the receiver [13]. The orthogonality allows for each subcarrier component of the received signal to be expressed as the product of the transmitted signal and channel frequency response at each subcarrier. The transmitted signal can be recovered by estimating the channel at each subcarrier. The channel can be estimated by using a preamble or pilot symbols that are known to both transmitter and receiver.

The disadvantage of OFDM is highly affected to carrier frequency offset (CFO). Carrier frequency offset occurs due to frequency mismatches between transmitter and receiver and also Doppler shift of the mobile channel. By estimating the CFO at the receiver, the performance loss will be significantly reduced; many methods are used to compensate for the CFO. CFO estimation techniques [14] can be classified into Pilot-aided schemes and non-pilot aided, it is also called as blind estimation schemes. Pilot assisted methods use pilot symbols to aid in the estimation of CFO. This method is popular and gives easy and reliable estimates, though there is a loss in data rate and spectrum efficiency of the system. Blind methods exploit better properties of the transmitted signals. Though these techniques preserve the data rate, they lead to processing of the received data to multiple times, which causes delay in decoding. The overall block diagram of proposed system is shown in Fig 3 & Fig 4.
Blind channel estimation

CFO can produce Inter Carrier Interference (ICI) which can be much less than the effect of noise on OFDM systems. Various CFO estimation and compensation algorithms have been proposed [15]. CFO estimation methods can be categorized into two major groups:

1. Training based algorithm
   The training sequence produced in this algorithm is in such way that it can limit the number of computation complexity at the receiver. This algorithm can reduce the effectiveness of the data throughput.

2. Blind Algorithm
   Another algorithm used for CFO estimation is called Blind CFO estimation algorithm. This algorithm uses statistical properties of the received signal, and then CFO will be estimate.

Fig 3: Transmitter of MIMO-OFDM Beamforming with CFO estimation

Fig 4: Receiver of MIMO-OFDM beamforming with CFO estimation
Since the receiver doesn’t have any knowledge about the transmitter sending signals, therefore the blind algorithms are considered to have a high computational complexity. The high computational complexity is the disadvantage of these algorithms. In compared with training based algorithm, blind algorithms have no need of the training sequences; therefore there is no training overhead for these algorithms that is one of the advantages of this algorithm.

IV. RESULT AND DISCUSSION

In this section the simulation result of beamforming in MIMO-OFDM system with carrier frequency offset estimation methods are discussed. The Bit Error Rate (BER) Performance is obtained after Beam forming of the MIMO-OFDM Signals. Normal channel of MIMO-OFDM Beamforming signals is obtained through CFO estimation, and the timing offset and frequency offset performance for the particular channel is also obtained.

Fig. 6 shows the BER performance of MIMO-OFDM beamforming signals. The bit error performance of MIMO-OFDM beamforming system in theoretical values and constellated values is plotted in the graph. Graph plotted b/w SNR and BER, these are inversely proportional.

Fig. 7 shows the normal channel estimation of OFDM signals. Perfect signals are estimated in each time period. All noise interference and other constructive interference are eliminated.

Fig. 8: Estimation of timing offset

Fig. 9: Estimation of frequency offset

By CFO estimation, the frequency offset and timing offset of the channel can be estimated. For the channel, the timing offset estimation is done based on amplitude. And frequency offset estimation is done based on phase angle. To find the performance of channel estimation, the frequency offset of normal channel estimation and maximum likely hood decoding channel estimation are considered.

V. CONCLUSION

The BER Performance is obtained after Beamforming of the MIMO-OFDM Signals. Normal channel of MIMO-OFDM Beamforming signals are obtained. Also the timing offset and frequency offset performance for the particular channel can be found through CFO estimation.
References


