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Analysis of Joint Estimation of CFO, I/Q Imbalance& Channel Response for OFDM MIMO Systems

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Abstract: In this project we are going to analyse the joint estimation of inphase and quadrature-phase (I/Q) imbalance and carrier frequency offset (CFO). The channel response for multiple-input multiple output (MIMO) orthogonal frequency division multiplexing (OFDM) systems is done using training sequences. The CFO,I/Q imbalance are caused due to mismatch of carrier frequency at the transmitter and local oscillator frequency at the receiver. This paper presents a novel approach for joint estimation of I/Q imbalance, CFO and channel estimation for Multiple Input Multiple Output (MIMO) OFDM systems. A new energy is introduced called channel residual energy (CRE). The proposed method uses OFDM block for training. In this paper, we show that by minimizing the CRE, we can jointly estimate the I/Q imbalance and CFO without knowing the channel response. The results show that the mean-squared error (MSE) of the proposed method is close to the Cramer-Rao bound (CRB).

Keywords: MIMO, OFDM, Carrier Frequency Offset.

I. INTRODUCTION

In recent years, direct conversion receiver has drawn a lot of attention due to its low power consumption and low implementation cost. However some mismatches in direct conversion receiver can seriously degrade the system performance, such as in-phase and quadrature-phase (I/Q) imbalance and carrier frequency offset (CFO). TheI/Q imbalance is due to the amplitude and phase mismatches between the I and Q-branch of the local oscillator whereas the CFO is due to the mismatch of carrier frequency at the transmitter and receiver. It is known that the I/Q imbalance and CFO can cause a serious inter-carrier interference (ICI) in orthogonal frequency division multiplexing (OFDM) systems. As a result, the bit error rate (BER) has an error-flooring. In assuming that the channel frequency response is smooth, a frequency-domain estimation method has been proposed to jointly estimate the I/Q imbalance and channel frequency response. Recently, exploiting the fact that the size of the DFT matrix is usually larger than the channel length in OFDM systems, a time-domain method was proposed for the joint estimation of I/Q and channel response Recently, exploiting the fact that the size of the DFT matrix is usually larger than the channel length in OFDM systems, a time-domain method was proposed in for the joint estimation of I/Q and channel response. Both the frequency-domain and time-domain methods need only one OFDM block for training and can achieve a good performance. For CFO estimation, a low complexity maximum likelihood (ML) technique was proposed. As a result, the bit error rate (BER) has an error-flooring. There have been many reports in the literature on the compensation of the I/Q imbalance and CFO The joint estimation of CFO and I/Q imbalance was investigated.

II. OFDM

An Orthogonal frequency division multiplexing (OFDM) is one of the most favourable technologies deployed in 4G systems as it essentially transforms the frequency selective fading channel into a flat fading channel. Even though this technology has been discovered for more than forty years, its wide spread success in commercial applications started in 1990's with the introduction of Digital Subscriber Line (DSL), which brought affordable broadband internet access to home users. OFDM was also adopted in the wireless local area network (WLAN) standards, such as IEEE 802.11a, IEEE802.11gand the upcoming IEEE802.11n. OFDM is also a potential candidate for the fourth generation mobile communication systems as it forms its physical layer standard [4].

OFDM has many advantages that satisfy our increasing demand in high bandwidth wireless communications.

- It is highly spectral efficient as it allows overlapping of subcarriers spectrum and as it divides the single frequency selective channel into number of parallel narrowband flat fading sub-channels it is highly immune to fading in wireless environment.
- It also eliminates inter-symbol interference (ISI) through the use of cyclic prefix technique.
- OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation

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functions. Meanwhile, as the cost of digital signal processor is dropping, OFDM systems become more affordable and easier to be implemented. OFDM is also a very flexible technology.

- It is not limited to simple single-input single-output (SISO) systems; it can be extended to multiple-input multiple-output (MIMO) systems for spatial diversity, or it can assign subsets of subcarriers to individual users for multiple access. Orthogonal Frequency Division Multiple Access (OFDMA) is one of the typical multiple access schemes derived from OFDM.

OFDM is a multicarrier transmission technique, which divides the single wideband channel into number of parallel narrowband channels called sub-channels; each subcarrier in each sub-channel is being modulated by a low rate data stream. We know that in frequency division multiplexing (FDM) technique, lot of spectrum is wasted in the form of guard bands between the adjacent channels for channel isolation and filtering purposes. In a typical system, up to 50% of the total spectrum is wasted in this manner. This problem becomes worse as the sub-channel bandwidth becomes narrower and total frequency band increases.

But, as mentioned earlier OFDM technique over comes this problem by splitting the available bandwidth into number of parallel narrowband sub-channels. The subcarriers of each sub-channel are made orthogonal to one another, allowing them to be spaced very close together with no overhead (like guard bands), as in FDM. This basic concept of OFDM saving the spectrum is illustrated in Fig.2.1.

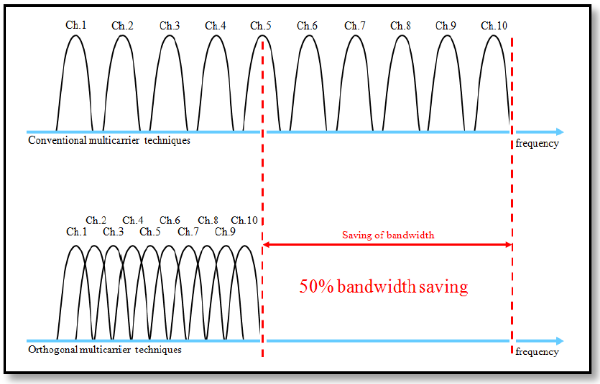

Fig.2.1 Basic concept of OFDM system

The basic steps performed in the OFDM system are shown in Fig.2.2. To generate OFDM signal, the high data rate input stream is converted into number of low data rate stream using serial to parallel converter. Each subcarrier is modulated with one of this low data rate streams in IFFT block and finally this signal is transmitted serially after adding cyclic prefix. At the receiver, exactly opposite steps are carried out as shown in Fig.2.2. Since each parallel sub-channel is essentially low data rate channel and since it is narrowband, it experiences flat fading. This is another advantage of OFDM technique, which will reduce the complexity of equalizer at the receiver end.

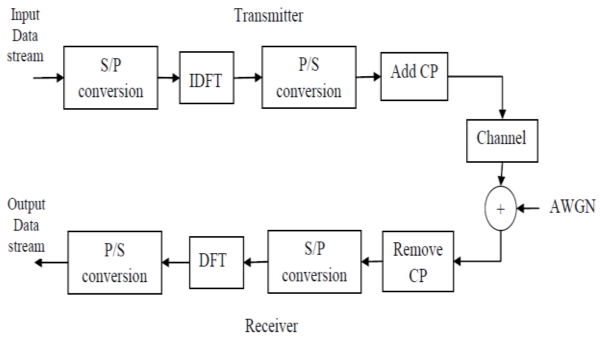

Fig.2.2 Basic steps in OFDM technique

III. MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM

Perhaps another one of the most interesting trends in wireless communication is the proposed use of multiple input multiple output systems. A MIMO system uses multiple transmitter antennas and multiple receiver antennas to break a multipath channel into several individual spatial channels. Now MIMO systems represent a huge change in how wireless communication systems are designed. This change reflects how we view multipath in a wireless system.

The Prospects of MIMO

From an information theoretic perspective, increasing the number of antennas essentially allows to achieve higher spectral efficiency compared to single-input single-output systems. Actual transmission schemes exploit this higher capacity by leveraging three types of partially contradictory gains:

- Array gain refers to picking up a larger share of the transmitted power at the receiver which mainly allows to extend the range of a communication system and to suppress interference.
- Diversity gain counters the effects of variations in the channel, known as fading, which increases link-reliability and QoS.[9]
- Multiplexing gain allows for a linear increase in spectral efficiency and peak data rates by transmitting multiple data streams concurrently in the same frequency band. The number of parallel streams is thereby limited by the number of transmit or receive antennas, whichever is smaller.

IV. PROPOSED SYSTEM

It has been shown that the RS-based CFO maximum likelihood (ML) estimator is identical to the null-subcarrier (NSC-)-based ML estimator in the absence of virtual subcarriers, which are the subcarriers at the edges of the allocated frequency band that are deactivated in order to avoid interference with adjacent systems Here, we address the issue of optimal preamble design using the Cramer-Rao bound (CRB) as a metric. This involves optimizing J and the power loading. We show that the

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optimal value of J is a trade-off between the multipath diversity gain (in a sense to be defined later in the paper) and the number of unknowns to be estimated. In the case of uncorrelated channel taps, uniform power loading is optimal. In the case of correlated channel taps, we show that uniform power loading of the active subcarriers is no longer optimal and better power loading schemes are proposed.

Advantages:

- More power loading to activated sub carriers
- High signal to noise ratio.
- Provides trade-off between multipath diversity gain and number of unknowns estimated.

Fading Channel Estimation

As derived in, the fading channel equalizers of that maximize the output SNR of the composite channel, and the recursive equalizer of that minimizes the output mean-square error both require exact knowledge of the fading impulse response a[k, n], as well as the additive noise intensity N0.

However, in practice, only estimates of these quantities may be available at the receiver. For spread-response pre-coding systems over the frequency non selective channel, Wittneben demonstrated SNR loss due to noisy channel estimates and only moderate sensitivity of the output SNR to estimates of N0. These preliminary results motivate us to look at the effects of channel estimation in more detail. Our approach is to formulate a channel estimator independently, and later examine how estimation errors impact the performance of spread-response pre-coding systems.

In this chapter we develop a fading channel estimator based on the Kalman filter, while we analyze the performance of spread-response pre-coding systems when these estimates are used in the equalizer. First, we develop a state-space model for the channel by augmenting the evolution model of with a channel observation model in the form of a pilot tone. We then determine the Kalman filtering equations in order to estimate the channel, and compute the mean-square estimation error as a function of the known channel parameters.

Next, we discuss an approach for obtaining estimates of the fading process when the model parameters are unknown. This approach includes a sequential parameter estimator similar in principle to the Expectation-Maximization (EM) algorithm. Finally, we comment on how these ideas might be extended in order to estimate the frequency selective channel.

V. SIMULATION & RESULTS

Results of this paper is shown in bellow Figs.5.1 to 5.5.

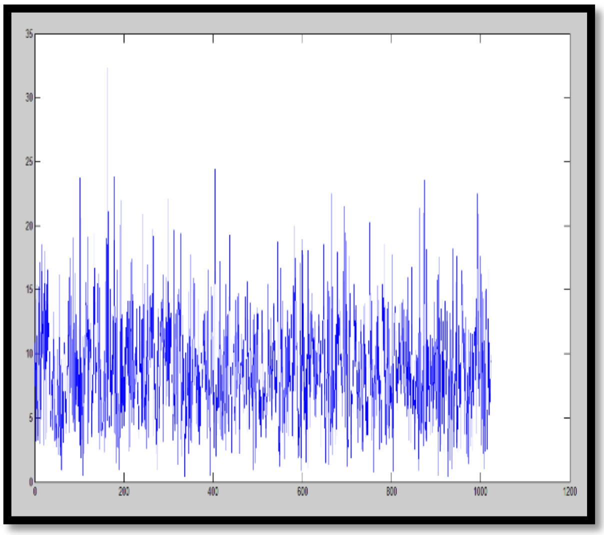

Figure 5.1: Generated AWGN in Frequency Domain

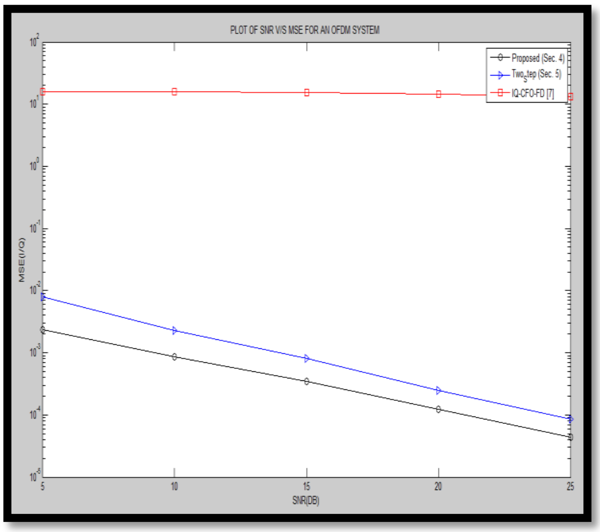

Figure 5.2: Plot of Mean Square Error in a normal OFDM System

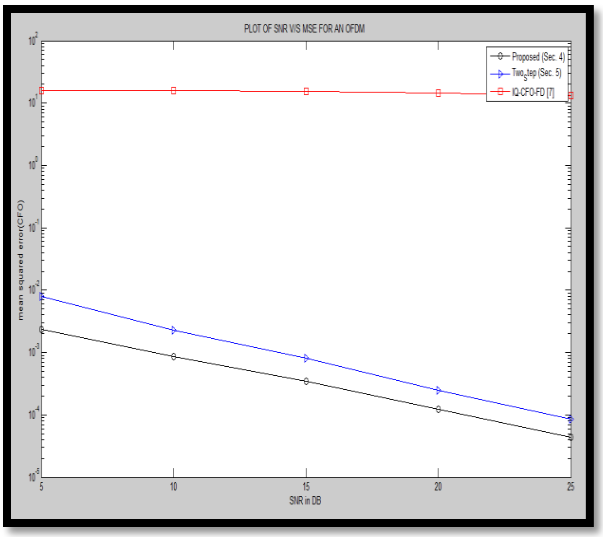

Figure 5.3: Plot of Mean Square Error for I/Q

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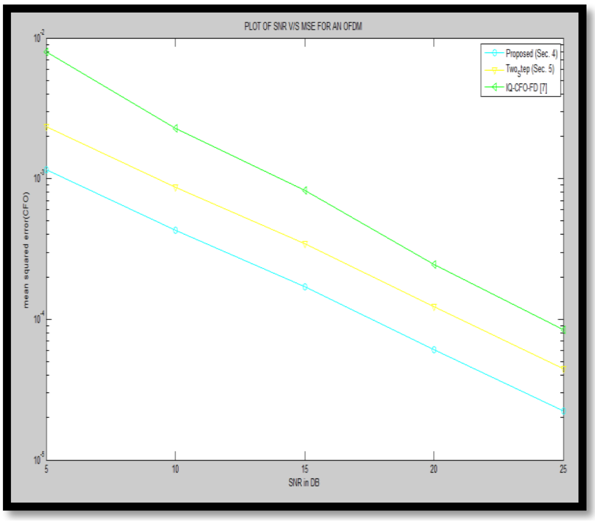

Figure 5.4: Plot of Mean Square Error of CFO

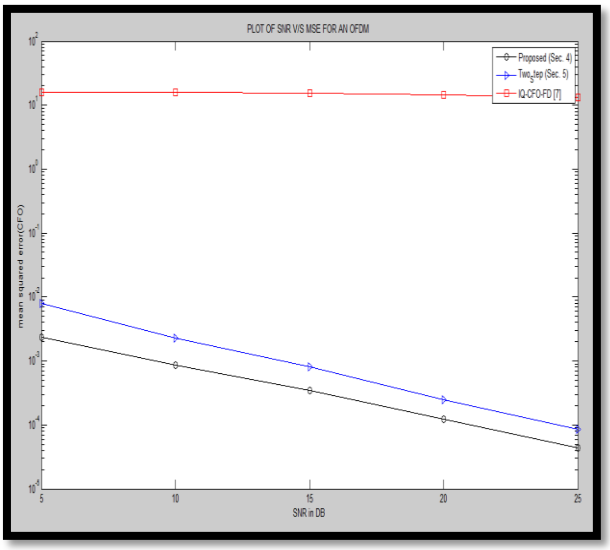

Figure 5.5: Plot of MSE for Channel Estimation

VI. CONCLUSION

TheI/Q imbalance is due to the amplitude and phase mismatches between the I and Q-branch of the local oscillator whereas the CFO is due to the mismatch of carrier frequency at the transmitter and receiver. It is known that the I/Q imbalance and CFO can cause a serious inter-carrier interference (ICI) in orthogonal frequency division multiplexing (OFDM) systems. Inter carrier interference is minimized, only two training blocks required for estimation of CFO and I/Q.

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BIOGRAPHY

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