Joint ICI (Inter Carrier Interference) and INQ (In Phase and Quadrature Imbalance) Compensation in MIMO-OFDM System

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Abstract:- **This paper investigates the problem of joint ICI (Inter Carrier Interference) and INQ (Inphase and Quadrature imbalance) mitigation in MIMO-OFDM system. We consider the case where the analog front-end suffers from an IQ imbalance and the local oscillator suffers from carrier frequency-offset (CFO).While fast time variations of wireless channel and the presence of CFO induces intercarrier interference (ICI).CFO in conjunction with IBI(Interblock Interference) results into sever intercarrier interference.We propose a MIMO data detector/decoder with PPIC(Progressive Parallel ICI Canceller) and per-tone equalizer (PTEQ),it eliminate these channel impairments iteratively and progressively.It is very suitable for VLSI implementation and it is a potential candidate for data detection/decoding in future high data rate, high mobility,Finally, our simulation results show how these methods would improve the performance in terms of BER in a highly time-variant environment with high delay.**

Index Terms—MIMO-OFDM, Inphase and Quadrature imbalance, ICI cancellation, Message passing MIMO detector, Carrier frequency offset.

I - INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) combined with multiple-input multiple-output (MIMO) wireless technology is an attractive air-interface solution for wireless systems. MIMO is known to boost capacity. For highdata-rate transmission, the multipath characteristic of the environment causes the MIMO channel to be frequency-selective. OFDM can transform such a frequency-selective MIMO channel into a set of parallel frequency- flat MIMO channels, and therefore decrease receiver complexity. The combination of the two powerful techniques, MIMO and OFDM, is very attractive, and has become a most promising broadband wireless access scheme.

Most promising technique to achieve high spectral efficiency and high mobility is MIMO technique with OFDM. In a MIMO system, as data are transmitted/ received through different antennas, many channel impairments need to be dealt with, such as multipath fading, AWGN noise, inter antenna interferences etc.

In particular ,there are two important issues with implementing working OFDM system, they are Intercarrier Interference(ICI) and Inter block Interference(IBI).In a rapidly fading environment, channel variations within an OFDM symbol duration in the OFDM subcarrier waveforms and result in intercarrier interference (ICI) which, in turn, degrades the bit-error-rate (BER) performance of the system. Many types of MIMO detectors such as MAP detector, sphere decoder, MMSE SIC detector are used to eliminate these channel impairments.

The channel time-variation, the cyclic prefix (CP) length may be shorter than the channel impulse response length, which in turn gives rise to inter-block interference (IBI). To deal with these channel impairments message passing MIMO data detector/decoder (MPD) is proposed in this paper. In recent years, ICI cancellation has received considerable attention. In [1], [2], [3], the performance degradation due to ICI is analyzed. In [2] and [3], authors analyzed the effect of ICI by modeling it as Gaussian noise.

A simplified bound on ICI power has also been derived. To mitigate the introduced ICI, techniques using receiver antenna diversity have been proposed [4], However, sensitivity analysis has shown that as normalized Doppler spread (defined as the maximum Doppler spread divided by the sub-carrier spacing) increases, antenna diversity becomes less effective in mitigating ICI in OFDM mobile systems [5]. Jeon and Chang have proposed another method for ICI mitigation which assumes a linear model for channel variations [6]. However, they assumed that some of the coefficients of the channel matrix are negligible, which is only the case under low Doppler and delay spread conditions.

The frequency-domain equalizer is proposed to compensate for the IQ-imbalance taking into account ICI and IBI. The frequency-domain equalizer is obtained by transferring a time domain equalizer to the frequency-domain resulting in the so-called per-tone equalizer (PTEQ)[7].In recent years, the message passing data detector/decoder Attracts the attention of many researchers. Practical aspect of the message passing data detector/decoder is due to that it consists of many small, independent detection/ decoding functions to deal with channel impairments. The proposed message passing data detection/decoding and ICI cancellation scheme is shown in fig 1

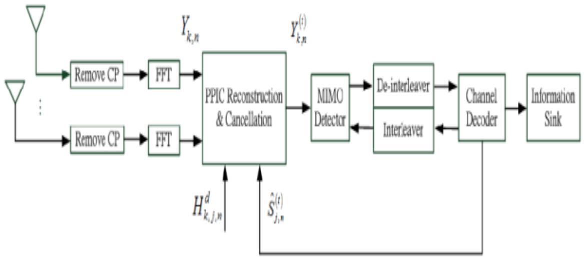


Fig. 1. Block diagram of the proposed message passing data detection/decoding and ICI cancellation scheme.

.In OFDM we suffer from IBI and ICI due to the channels time variation, it leads to loss of orthogonality.CFO arise due to imperfections in the receiver and/or transmitter analog front-end, whereas user mobility and CFO give rise to channel time variation. PPIC Reconstruction and cancellation is used to cancel ICI progressively and iteratively.

MIMO detector retrieves the information without ICI and IBI and achieves high data rate through message passing algorithm. This aspect is particularly important in data transmissions where data rate requirements are high, and processing delay must be low. While the IQ imbalance results into mirroring effect, the CFO induces intercarrier interference (ICI). CFO in conjunction with IBI results into sever intercarrier interference. If we want to cancel ICI efficiently, we should go for compensation of INQ (Inphase and Quadrature imbalance) frequency offset and Carrier frequency offset.

PROGRESSIVE PARALLEL ICI CANCELLER

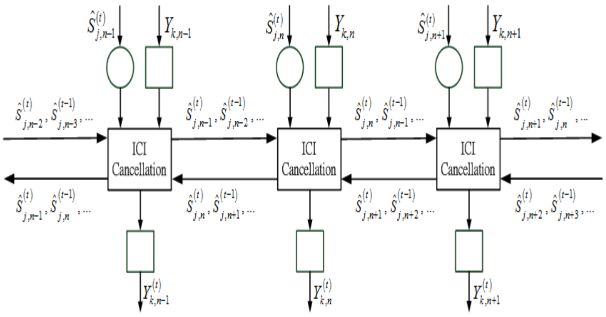


Fig. 2. Factor graph of the proposed PPIC architecture

We propose PPIC for ICI cancellation instead of PIC architecture because the computational complexity is higher and the system architecture is more complex in PIC. The message type is soft data symbol. The estimated soft data symbols are exchanged between adjacent subcarrier nodes and stored. At the $1st$ iteration, the nth subcarrier node receives and stores the soft symbols from the $(n+1)h$ subcarrier node and the $(n-1)th$ subcarrier node. At the $2nd$ iteration, the nth subcarrier node receives and stores the soft symbols, which are estimated at the $2nd$ iteration, from the $(n+1)h$ subcarrier node and the $(n-1)th$ subcarrier node, and the soft symbols, which are stored at the $1st$ iteration, from the $(n+1)th$ subcarrier node and the $(n-1)th$ subcarrier node. These stored data symbols are actually estimated by the $(n+2)h$ subcarrier node and the $(n-2)th$ subcarrier node at the $1st$ iteration. So, the ICI from the $(n+1)h$ subcarrier, $(n+2)th$ subcarrier, $(n-1)th$ subcarrier and $(n-2)th$ subcarrier are reconstructed and cancelled. In this way, the ICI are reconstructed and cancelled iteratively and progressively from the received signal. At the 1st iteration, the two strongest interfering subcarriers are cancelled. At the $2nd$ iteration, the two strongest and the two adjacent less strong interfering subcarriers are cancelled. At the ith iteration, the ICI from $2i$ adjacent subcarriers are cancelled.

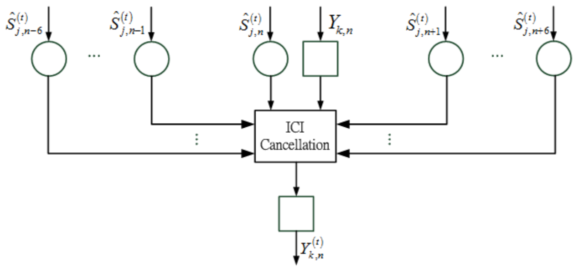


Fig. 3. An architecture of PIC ICI canceller.

Moreover, the system architecture of PPIC is much simpler than PIC. As shown in Fig. 2, the architecture of PPIC is similar to a systolic array. Each subcarrier node is only connected to the adjacent two subcarrier nodes and exchanges messages with them.

Nevertheless, as shown in Fig. 3, if the adjacent twelve interfering subcarriers are intended to be cancelled, each subcarrier node of the PIC architecture is connected to the adjacent twelve subcarrier nodes, and receives messages from them. This complicates the system architecture design of the standard PIC ICI canceller. Compared to PIC we can further reduce BER in PPIC. The parallel structure of the proposed message passing MIMO data detector/decoder with PPIC ICI canceller is very suitable for VLSI implementation.

II- SYSTEM MODEL

We assume perfect timing synchronization and both perfect and imperfect channel estimation in this paper. Consider an OFDM-based wireless MIMO communication system with Nt transmits and receive antennas. The transmitted time domain signal can be represented by the following equation:

swhere $i = 0 \sim Nc-1$, $j = 0 \sim Nt-1$, Nc is the FFT size, Sj,n is the symbol transmitted on the jth antenna and nth subcarrier and belonging to the constellation $\mathcal{S}$ with size $|S| = 2m$, m is the modulation order, sj, i is the ith sample of the time domain signal transmitted on the jth antenna. The cyclic prefix vector can be represented as:

$$\vec{s}_{CP,j}(i) = s_{j,N_c-N_G+i}$$

where $i = 0\sim NG-1$, NG is the length of guard interval. The ith sample of the received time domain signal at the kth antenna can be derived as:

$$y_{k,i} = \sum_{j=0}^{N_t-1} \sum_{l=0}^{N_G} h_{k,j,l}^{(i)} s_{j,\left((i-l)\right)_{N_c}} + z_{k,i}$$

where, $i = 0\sim Nc-1, k = 0\sim Nr-1$, $h_{k,j,l}^{(i)}$ is the lth channel tap gain between the jth transmit antenna and kth receive antenna,$((\cdot))Nc$ denotes a cyclic shift in the base of Nc and zk,i is a sample of AWGN noise with zero mean and variance $\sigma 2\ z$ after removing the cyclic prefix ,FFT operations ,the received frequency domain signal Yk,n can be formulated as:

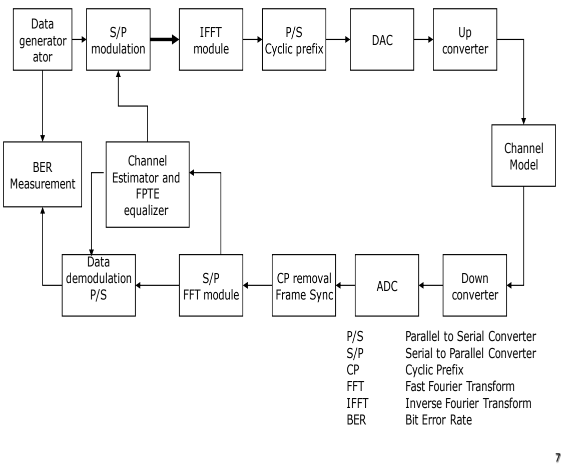
$$H_{k,j,n}^{d} = \frac{1}{N_c} \sum_{l=0}^{N_G} F_l(d) e^{-j\frac{2\pi l(n-d)}{N_c}}$$

$$H_{k,j,n}^{0} = \frac{1}{N_c} \sum_{l=0}^{N_G} \sum_{i=0}^{N_c-1} h_{k,j,l}^{(i)} e^{-j\frac{2\pi nl}{N_c}} = \sum_{l=0}^{N_G} h_{k,j,l}^{\text{ave}} e^{-j\frac{2\pi nl}{N_c}}$$

where n, $d = 0\sim Nc-1$, $h$ave k,j,l is average of the lth channel tap over the useful time duration of an OFDM symbol. where $n = 0\sim Nc-1$, d is the interfering subcarrier index. Define $F_l(n)$ as the FFT of the lth channel tap with time Variations. Without loss of generality, in the following sections, only the nth subcarrier of the MIMO-OFDM receiver is considered.

COMPENSATION OF INQ AND CFO

OFDM is sensitive to the analog front-end imperfections; mainly the amplitude and phase imbalance (IQ imbalance) and the carrier frequency-offset (CFO). In OFDM a cyclic prefix that is equal or longer than the channel delay spread is required to maintain orthogonality between subcarriers.



This is pending on the fact that ideal conditions are satisfied such as: no IQ, zero CFO, and the channel is time-invariant over the OFDM block period. In practice, it is very difficult to satisfy all these conditions. This motivates us to search for alternative equalization techniques that are robust against these imperfections mainly the IQ imbalance the CFO.

The presence of IQ imbalance and CFO and the fact that the channel order is larger than the CP cause a severe degradation in performance for OFDM systems. In this paper we consider OFDM transmission over time-invariant channels with a cyclic prefix that is shorter than the channel order and the analog front-end suffers from an IQ imbalance as well as a CFO.

MIMO DETECTOR

Based on factor graph, a joint design of a message passing MIMO data detector/decoder with a progressive parallel intercarrier interference canceller (PPIC) for OFDM-based wireless communication systems is proposed in this paper as shown in fig 4.

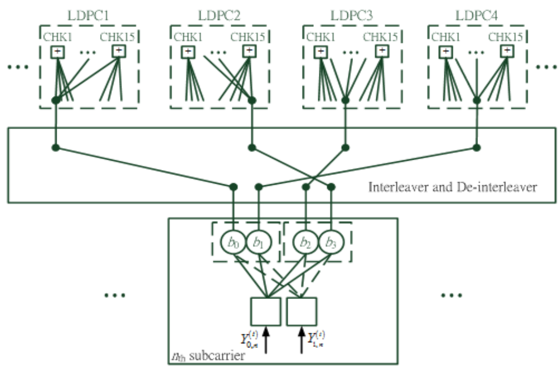


Figure 4 Messages passing on factor graph for a 2×2 MIMO channel

The message type chosen in this work is log-likelihood ratio (LLR) of bit probabilities for the MIMO data detector/decoder and soft data symbols for the PPIC ICI canceller. The proposed algorithm detects the transmitted data iteratively, by jointly dealing with channel fading effects, AWGN noise and interferences in time domain, frequency domain and space domain.

With the insertion of cyclic prefix, the time domain ISI can be avoided. With the message passing MIMO detector (denoted as MPD in the following sections), the space domain interantenna interference can be suppressed and with the aid of PPIC, the frequency domain ICI can be cancelled. Besides, the computational complexity of the proposed PPIC architecture is relatively lower than the standard PIC architecture.

The system architecture is also simpler and more suitable for the VLSI implementation. By iterative detection, decoding and progressive ICI cancellation, the system performance can be jointly optimized.

III- SIMULATION REULTS

CHANNEL ESTIMATION FOR MIMO OFDM

Fig 5 shows output of channel estimation ,to increase the data rate we should maintain high SNR so we go for proper channel estimation.

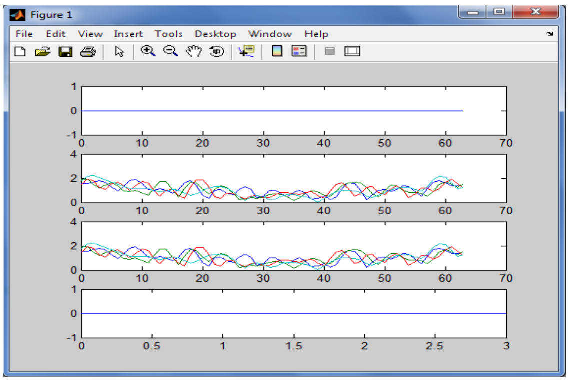


Figure 5 channel estimation

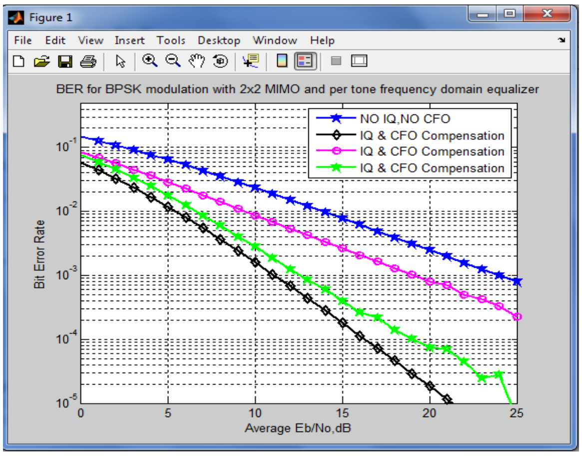


Figure 6 IQ and CFO compensation

REDUCED BER

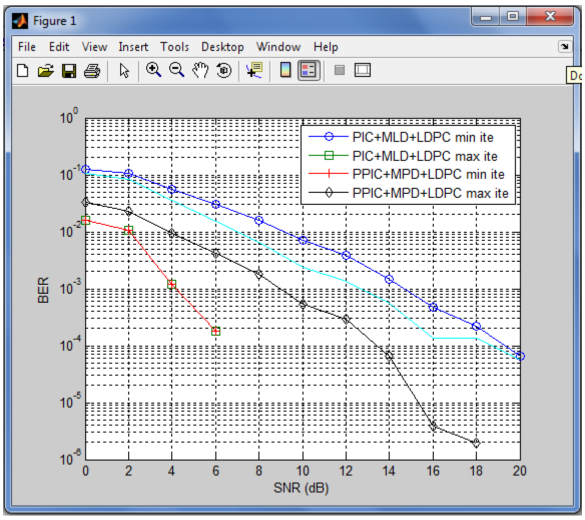


Figure 7 Performance comparison of PPIC ICI canceller, PIC ICI canceller

We have consider AWGN channel.From the channel estimation we analyse ICI and IBI from each channel. In this case we have consider two channels, it generates OFDM signals with overlap for efficient channel utilization. We use inter leaver to differentiate these signals. After channel estimation we have to compensate INQ imbalance and CFO by means per tone frequency domain equalizer._Due to this perfect ICI cancellation has done. Simulated BER performance using ICI cancellation by PPIC is plotted in_Fig 7.It shows comparison of reduced BER with respect to PPIC (Progressive Parallel ICI canceller) and PIC (Peripheral Interface controller).

At minimum iteration of PIC we reduce bit error rate of $10^{-1}$and at maximum iteration we can further reduce the bit error rate. Compared to PIC, ICI cancellation using PPIC can further reduce BER of 10^{-2},at maximum iterations it significantly improves the BER performance.

IV - CONCLUSION

In this paper we propose a PPIC and frequency-domain PTEQ for OFDM transmission over TI channels with imperfect analog front-end receivers. The CP is assumed to be less than the channel order, which means that IBI is present. We show that analog front-end imperfections degrade the performance significantly, and therefore equalization/compensation is crucial. Due to the compensation of INQ and CFO, the proposed PPIC can efficiently cancel ICI progressively and iteratively. However, the computational complexity of PPIC is relatively lower. The parallel structure of the proposed message passing MIMO data detector/decoder with PPIC ICI canceller is very suitable for VLSI implementation. Computer simulations show that the performance of BER can be further reduced in PPIC and improves the performance efficiency.

VII - REFERENCES

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