Parallel ICI Cancellation of MC-CDMA Systems under Typical Urban Channel

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Abstract – Multi carrier systems are robust to channel noise, however due to Doppler shift and carrier frequency offset there arises inter carrier interference which degrades the performance of the system. In this paper a parallel cancellation algorithm in spatial frequency domain is proposed to mitigate the effect of ICI, the performance of the approach is evaluated under typical urban channel environment. A clear analysis is performed to adapt the modulating frequency with a finite set of sub carriers.

Index Terms – ICI cancellation, multi carrier system, parallel cancellation MC-CDMA.

1. INTRODUCTION

Modern electronic gadgets require high data rate wireless transmission which can be attained only when the ICI can be mitigated to mere level. Multi carrier code division multiple access (Mc-CDMA) reaps the benefits of both OFDM and CDMA where the data is spreaded by spreading codes such as gold codes, Pseudo Noise sequences, Walsh Hadamard sequences and mapped into sub carriers which are spread in frequency domain [1]. This approach finds its own trademark for high speed data transmission over different multipath propagation channels. However, due to the miss-match of carrier frequency offset and Doppler shifts the orthogonality between the subcarriers is lost resulting in ICI. This interference degraded the BER performance of the multi carrier system and hence it is to be treated with appropriate equalization methods [2].

ICI is caused due to the difference between the transmitter and receiver local oscillator frequencies which may be due to the presence of Doppler shift occurred in the channel. This undesired ICI deteriorates the performance of the multi carrier system so there is huge demand of ICI mitigation methods. This paper presents parallel cancellation for space frequency coded system which is incorporated for MC-CDMA systems. This approach is robust to the variation in the size of blocks and lowers the error for multi carrier systems.

This paper is organized as, section 1 presents the need and necessity of ICI cancellation algorithms, section 2 presents the related work done by earlier researchers, section 3 presents the proposed approach for MC CDMA system and its mathematical analysis, section 4 presents the experimental results achieved under varying different constraints and the achievements that could be attained with the proposed approach.

2. RELATED WORK

Many ICI cancellation approaches are proposed so far for multi carrier systems, some of them which are related to the work are presented in this section

In [3] seyedi et.al, presented a general ICI self-cancellation scheme that can be implemented through windowing at the transmitter and receiver and this approach requires 2N additional multiplications, where 'N' is the number of sub carriers.

In [4] Yeh et.al, propose a parallel cancellation approach for space time coded system, apart from low complexity it also inherits the backward property of traditional parallel cancellation approach

In [5] Li et.al presented ICI selef cancellation for coded OFDM systems, which integrates the ICI self-cancellation technique into the Index modulation-OFDM framework and able to achieve an attractive tradeoff between the spectral efficiency and ICI cancellation performance of the system.

Parallel cancellation scheme provides a much higher signal-to-ICI ratio (SICIR) than does the regular OFDM system when Doppler shift or residual carrier frequency offset (CFO) exists Hence the PC scheme lowers error floor for OFDM systems in frequency selective fading channels with Doppler frequency. This characteristic is inherently extended to the proposed approach and improves the BER significantly.

3. PROPOSED APPROACH

Below figure depicts the proposed ICI cancellation approach,

In the proposed the input data stream is first spreaded with Pseudo noise sequence / gold codes which are then mapped into orthogonal symbols, these symbols are converted into space frequency coded form Almouti's code format [10]

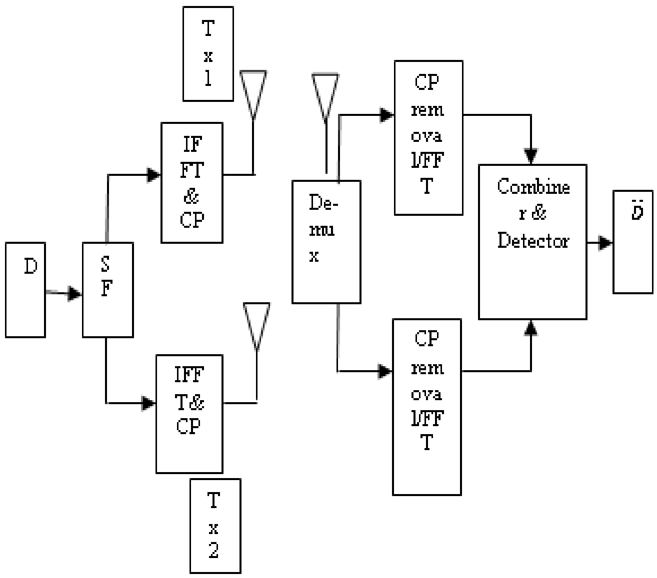

Figure 1: Block diagram of the proposed approach

At the transmitter $d = [d_0\ d_1\ \dots\dots\dots d_{N-1}]^T$ is the input vector. In this system, two length N blocks are formed via SF coding as two parallel input data vectors for upper and lower branches as follows

$$d_1 = [d_0\ \ -d_1^*\ \dots\dots\dots d_{N-2}\ \ -d_{N-1}^*]^T \quad (1)$$

$$d_2 = [d_1\ \ d_0^*\ \dots\dots\dots d_{N-1}\ \ -d_{N-2}^*]^T \quad (2)$$

Furthermore, two length N/2 even and odd poly-phase component vectors of' d' are defined as follows

$$d_e = [d_0\ \ d_2\ \dots\dots\dots d_{N-4}\ \ d_{N-2}^*]^T \quad (3)$$

$$d_o = [d_1\ \ d_3^*\ \dots\dots\dots d_{N-3}\ \ d_{N-1}^*]^T \quad (4)$$

Hence d_1 and d_2 can be expressed as the corresponding even and odd poly-phase component vectors as follows

$$d_{1e} = d_e\,, d_{1o} = -d_o^* \quad (5)$$

$$d_{2e} = o\,, d_{2o} = d_e^* \quad (6)$$

At time 't' , d_1 and d_2 are sent to two parallel IFFT's and transmitted with CP via transmit antennas Tx1 and Tx2 respectively . After Cyclic prefix removal the two received signal vectors y_1 and y_2 at time 't' after FFT are combined as

$$y = y_1 + y_2 = H_1 d_1 + H_2 d_2 \quad (7)$$

Equivalently the even and odd vectors of 'y' are

$$y_e = H_{1e}d_{1e} + H_{2e}d_{2e} = H_{1e}d_e + H_{2e}d_o \quad (8)$$

$$y_o = H_{1o}d_{1o} + H_{2o}d_{2o} = -H_{1o}d_o + H_{2o}d_e \quad (9)$$

Where H_1 and H_2 are two diagonal matrices whose diagonal elements are FFTs of respective channel impulse responses h_1 and h_2 for the transmit antenna Tx_1 and Tx_2 respectively. Similarly H_1 and H_2 can also be expressed as the corresponding even and odd matrices as H_{1e} and H_{1o} and H_{2e} and H_{2o} .

The even and odd vectors of 'y' are

$$y_e = H_{1e}d_{1e} + \overline{H_{2e}}d_{2e} = H_{1e}d_e + \overline{H_{2e}}d_o \quad (10)$$

$$y_o = H_{1o}d_{1o} + \overline{H_{2o}}d_{2o} = -H_{1o}d_o + \overline{H_{2o}}d_e \quad (11)$$

Again, assuming that channel responses are known or can be estimated at the receiver and fading is constant across two adjacent subcarriers or $H_{1e} = H_{1o}$ and $\overline{H_{2e}} = H_{2o}$ the decision variables are obtained as follows

$$\widehat{d_e} = H_{1e}^* y_e + \overline{H_{2o}} y_o = (|H_{1e}|^2 + |\overline{H_{2o}}|^2) d_e \quad (12)$$

$$\widehat{d_o} = H_{2e}^* y_e + \overline{H_{1o}} y_o = (|H_{2e}|^2 + |\overline{H_{1o}}|^2) d_o \quad (13)$$

The estimate vector $\hat{d}$ is obtained by combining $\hat{d}_e$ and $\hat{d}_o$

4. EXPERIMENTAL RESULTS

In this work, to evaluate the performance of the ICI cancellation approach for MC-cdma , 1024 sub carrier with BPSK modulation is adapted. The system is evaluated under typical urban channel where the Doppler shift, modulating frequency, bandwidth were varied and the performance is assessed under different conditions. To implement the space frequency coded format a 2x2 antenna system is considered and the channel to be Rayleigh distribution jakes model. Monte Carlo iteration of 100 were chosen to calculate the BER on average for those iterations.

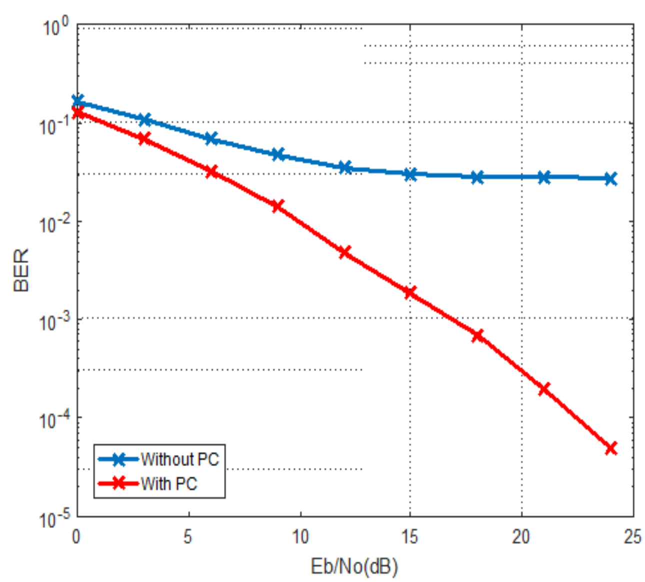

Figure 2: BER analysis with and without ICI cancellation for N=1024, fd=100Hz, d=0.044

The above figure shows BER analysis of the MC CDMA system for 2x2 systems with 1024 sub carriers under cancellation and without cancellation criteria. It is observed that when the ICI is mitigated BER of 0.15 is attained early at 5dB which remained constant in without cancellation criteria.

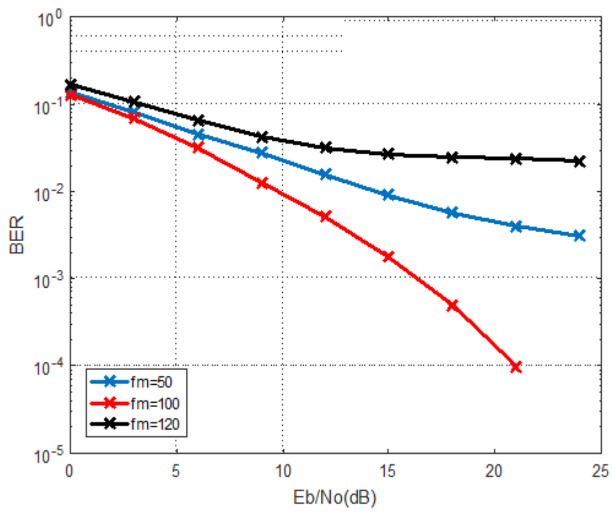

Figure 3: Performance analysis of the proposed approach for f_d=50,100,120 Hz

The above figure depicts the performance of the proposed cancellation approach under different Doppler frequencies, it can be observed that at fd=100 it achieves better BER , hence for further analysis the same will be taken as reference.

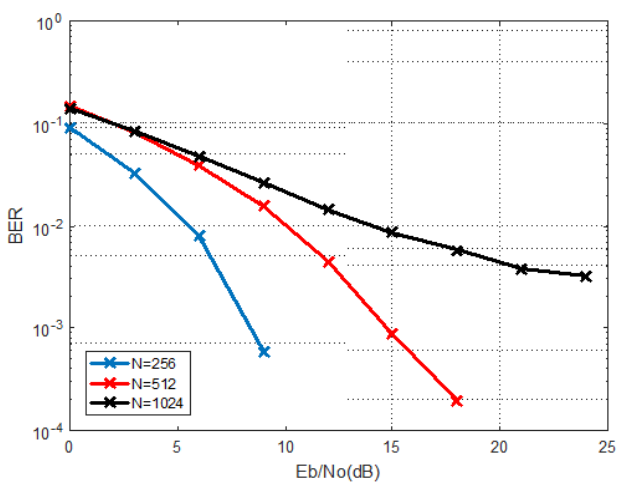

Figure 4: Performance analysis of the proposed approach for N=256,512,1024 sub carriers

It is observed from above figure 4 that the proposed approach leads better performance achievement for when the number of carriers are low however it can also observed that even at 1024 sub carriers it achieves a better BER of 0.015 at 21dB .

5. CONCLUSION

A space frequency coded parallel ICI cancellation approach is presented in the paper for MC CDMA systems under BPSK modulation with different sub carrier and varying Doppler shift, it is observed from the experimental results that this approach yields better results even at high number of sub carriers. This approach could attain a BER of 0.001 at very low Eb/No makes it suitable for high multi carrier modulation schemes. This work can be further extended with complex channel environments like SUI and extended typical channel environments where the vehicular velocity is also considered for the analysis.

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