ICI Cancellation using Zero-Padded Conjugate Transmission with Adaptive Receiver for OFDM Systems

Amandeep Kaur, Garima Saini

Abstract: ***To overcome the effect of Intercarrier Interference (ICI) in OFDM system, the Zero-padded Conjugate scheme with adaptive receiver is proposed. In the conjugate algorithm first path contains the regular OFDM signal and in second path conjugate of first path is transmitted using Time Division multiplexing (TDM) for Time variant channels. Zero padding is done between two consecutive symbols to mitigate the effect of intercarrier interference to provide better time and frequency synchronization. Adaptive receiver uses block least mean-squared algorithm (BLMS) to adaptively update the frequency offset error. The simulation results are carried out using BPSK, QPSK and 16-QAM modulation techniques. The proposed scheme provides better BER rate than regular OFDM system, Conjugate cancellation (CC) and previous work for AWGN channel.***

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I. INTRODUCTION

In wireless communication, concept of parallel transmission of symbols is used to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques used for parallel transmission. It becomes very efficient technique for data transmission over multipath fading environment due to its properties like high bandwidth efficiency and resistance to multipath fading. Also its implementation becomes easier with the help of Fast Fourier Transform and Inverse Fast Fourier Transform for demodulation and modulation respectively [1].

OFDM is considered as special case of Frequency Division Multiplexing (FDM) in which, each of the several low rate user signal is modulated with a separate carrier and transmitted in parallel. These sub-carriers are orthogonal to each others. Due to its orthogonality property it provides the advantages like higher bandwidth efficiency. So, OFDM system is adopted for many wireless transmission standards like DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting), HIPERLAN2 (High Performance Local Area Network) and IEEE 802.11a and IEEE 802.11g [2]–[4] etc.

The main disadvantage of ODFM system is its sensitivity to synchronization error, such as frequency or phase offsets, Frequency offset results from Doppler effects i.e. due to mismatch between the transmitter and receiver local oscillators, due to which the orthogonality of subcarriers is no longer maintained, and results in Intercarrier Interference (ICI). ICI is the major problem in multipath fading environment.

ICI cancellation techniques are essential in improving the performance of OFDM system in an environment which induces frequency offset error. A lot of ICI mitigation methods have been extensively investigated to combat the ICI, including frequency-domain equalization [5], correlative coding [6], time domain windowing [7], and the self-cancellation schemes [8]–[11], pulse shaping [12], frequency offset estimation and tracking techniques [13] and so on. These methods are suitable for lower modulation techniques like BPSK. Among these methods, the ICI self-cancellation method is a simple way to suppress ICI that uses redundant modulation.

In Conjugate cancellation (CC) method [14] of ICI cancellation, the first path represents the standard OFDM signal and the second one is formed by a conjugate of the first paths. CC method is not performing effectively for high offset frequency situations. Another effective method used for ICI cancellation is general phase rotated conjugate cancellation (PRCC) [15]. Simply an artificial phase rotation is introduced which is determined by the frequency offset estimate in the training mode. The optimal phase rotation is derived with the criterion of maximizing the carrier-to-interference ratio (CIR), to achieve better performance.

In this paper to further enhance the performance of OFDM system for time-varying frequency offset situations the concept the Zero-padded Conjugate scheme with adaptive receiver is proposed. As the main problem of ICI occurs due to frequency mismatching between transmitter and receiver oscillator, so Zero padding is done between two consecutive symbols to mitigate the effect of intercarrier interference to provide better time and frequency synchronization. Adaptive receiver uses block least mean-squared algorithm (BLMS) to adaptively update the frequency offset error. The proposed scheme provides better BER rate than regular OFDM system, Conjugate cancellation (CC) and previous work for AWGN channel.

The rest of the paper is organized as follows: In Section II OFDM system and related work is described, In Section III, the improved design methodology is proposed. In Section IV, paper is concluded.

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II. SYSTEM MODEL

A.OFDM Signal model

In an OFDM system, the input bit stream is multiplexed into N symbol streams, each with symbol period T_s, and each symbol stream is used to modulate parallel sub-carriers. These sub-carriers are spaced by $1/NT_s$ in frequency. After applying inverse Fast Fourier transform, baseband discrete-time OFDM signal is given as;

$$x_m = \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{N}mk} \quad 0\leq m\leq N\text{-}1 \qquad (1)$$

where N is the total number of subcarriers, and X_m is the a symbol modulating the m_{th} subcarrier. After passing through an additive white Gaussian noise (AWGN) channel, with the presence of frequency offset a linear phase rotation is produced, which is given as;

$$y_m = x_m e^{j\frac{2\pi}{N}m\varepsilon} + w_n \qquad 0\leq m\leq N\text{-}1 \qquad (2)$$

where ε is the frequency offset by subcarrier frequency spacing, and w_n is the AWGN noise. After performing the Fast Fourier transform (FFT), the frequency domain signal on received signal is as shown;

$$Y_k = \frac{1}{N}\sum_{m=0}^{N-1} y_m e^{-j\frac{2\pi}{N}mk}$$

$$= X_k s(\varepsilon) + \sum_{l=0,l\neq k}^{N-1} X_l s(l-k+\varepsilon) + w_k \qquad (3)$$

where the term $s(l\text{-}k\text{+}\varepsilon)$ referred as the ICI coefficient. The first term in the expression (3) is the desired information signal i.e. X_k , and second term is regarded as sum of interferences from X_k.

$$s(u) = \frac{1}{N}\sum_{m=0}^{N-1} e^{-j\frac{2\pi}{N}nu} = \frac{\sin(\pi u)}{N\sin(\frac{\pi u}{N})} e^{j\pi u(\frac{N-1}{N})} \qquad (4)$$

B. Objective

As the major drawback of ODFM system is its sensitivity to synchronization error, such as frequency or phase offsets, Frequency offset results from Doppler effects i.e. due to mismatch between the transmitter and receiver local oscillators, due to which the orthogonality of subcarriers is not longer maintained, and results in Intercarrier Interference (ICI). So objective of this thesis work is to

- To implement the efficient technique
- Improve the BER (Bit error rate)

For AWGN channel to cancel out the effect of ICI and make OFDM system more efficient

C. CC Scheme [14]

In Conjugate cancellation (CC) method, the first path represents the standard OFDM signal and the second one is formed by a conjugate of the first paths. At the receiver side, the received time-domain signal of first path is same as given in expression (2) and second path signal is given as;

$$y'_{k,CC} = X_k[s(\varepsilon) + s(-\varepsilon)]$$

$$+ \sum_{l=0,l\neq k}^{N-1} X_l[s(l-k+\varepsilon) + s(l-k-\varepsilon)] + W_k^* \qquad (5)$$

At receiver side, combination of first and conjugate of second path achieves the ICI cancellation. The combined output and the CIR are given as below;

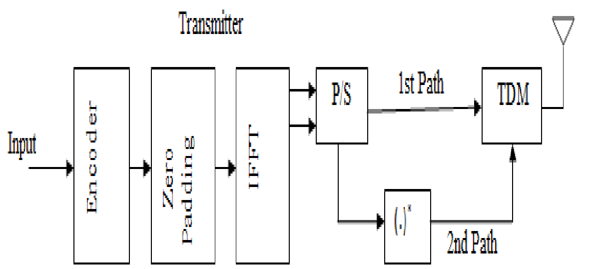
$$CIR_{CC} = \frac{|s(-\varepsilon)+s(\varepsilon)|}{\sum_{k=1}^{N-1}|s(k-\varepsilon)| + s(k+\varepsilon)} \qquad (6)$$

III. PROPOSED SCHEME

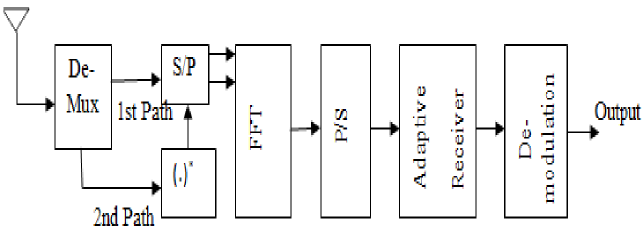
The proposed scheme works with the Conjugate Cancellation scheme. Zeroes are padded before IFFT between two consecutive symbols to mitigate the effect of intercarrier interference. At the transmitter side the original OFDM signal and its Conjugate is transmitted using Time division multiplexing (TDM) through the AWGN channel. At the receiver side the offset seen in two paths by ε and ε +Δε respectively and combined after applying two different phase rotations. The diagram of proposed scheme is as shown in Fig.1.1. The proposed algorithm works in the following steps:

(a) Modulated signal is zero padded
(b) IFFT is performed of zero padded signal
(c) The regular ZP-OFDM and its conjugate replica is combined in one signal and transmitted using Time division multiplexing (TDM) through AWGN channel
(d) Two different phase rotations are applied to both the paths having frequency offset of ε and ε +Δε respectively
(e) FFT is performed on the combined signal
(f) The signal is divided into blocks by taking block size equal to FFT size i.e. L=N and BLMS is used to update the frequency offset error, by taking step size of 0.08.
(g) Compare the desired and estimated signal to calculate the error and update error using BLMS.

Error = (desired signal) - (received signal)



(a)Transmitter



(b) Receiver

Fig.1.1 Block diagram of proposed (a) Transmitter (b) Receiver

IV. SIMULATION RESULTS

The results are carried out using MATLAB simulation to verify the effectiveness of proposed scheme for different modulation techniques like BPSK, QPSK and 16-QAM. The BER is calculated for AWGN channel for time variant environments. Each OFDM symbol is composed of 1024 subcarriers in frequency domain i.e. N=1024. The parameters are shown in the Table: 1.

Table: 1 Parameters

Parameter	Specification
FFT size	1024
No of carriers in one OFDM symbol	512
Modulation techniques	BPSK, QPAK, 16-QAM
Channel used	AWGN

The main key of the proposed scheme is to reduce the ICI effect due to loss of orthogonality. The ICI occurs due to frequency offset (time invariant channels) and due to Doppler shift (time-varying channels). The proposed scheme works for both the time -invariant and the time-variant channels.

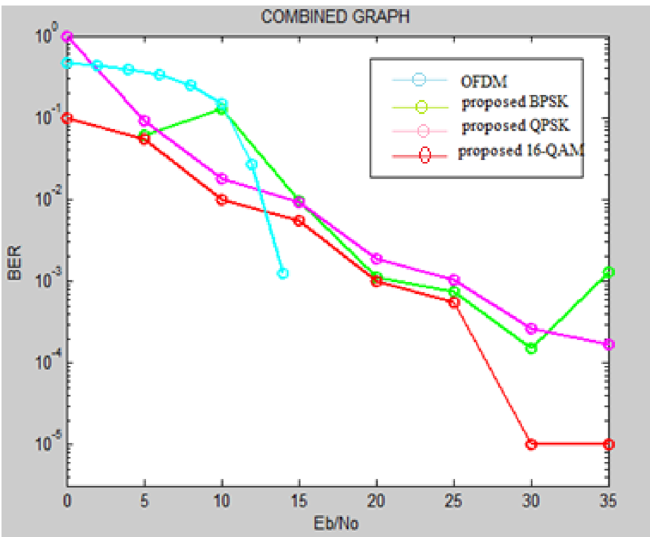


Fig. 1.2 BER comparison of proposed scheme using different modulation schemes with OFDM

Fig.1.2 shows the comparison of BER of proposed scheme with standard OFDM for AWGN channel for fixed frequency offset. We can see that the BER of proposed scheme is better than standard OFDM. Also proposed scheme has better BER for higher modulation like 16-QAM, if we take comparison of BPSK, QPSK and 16-QAM. The bandwidth efficiency of proposed scheme is lower than standard OFDM because it transmits data twice but compensated using larger modulation size.

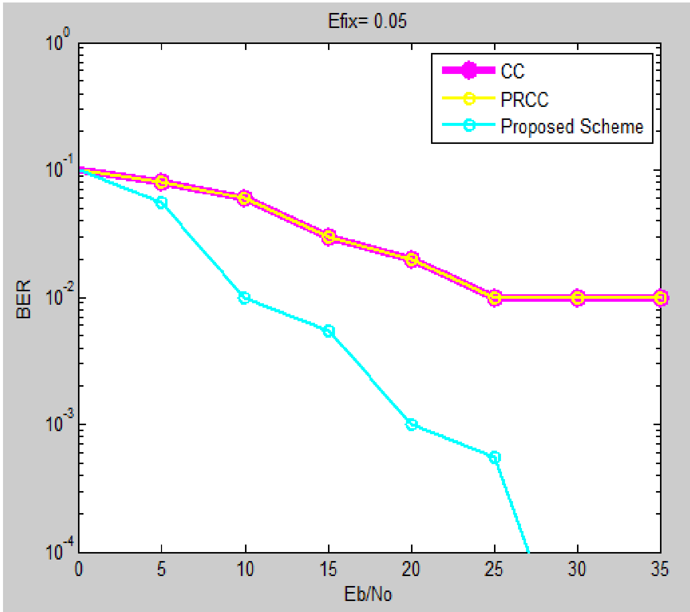


Fig. 1.3 BER comparison of proposed scheme with CC, PRCC using 16-QAM modulation for ε_{fix}=0.05

Fig.1.3 shows the bit error rate comparison of proposed scheme using 16-QAM modulation for fixed frequency offset ε_{fix}=0.05. The proposed scheme provides lower bit error rate than CC and PRCC scheme as BER of these schemes degrades for high frequency offset variations but BER of proposed scheme is better. Also the performance of proposed scheme is analyzed under different frequency offset variations as shown in Fig.1.4.

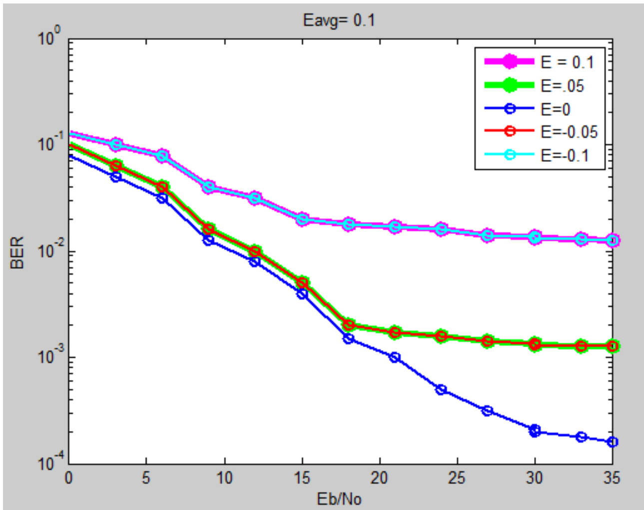


Fig.1.4 Proposed scheme BER with 16-QAM for different frequency offset variations

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed zero-padded conjugate transmission with adaptive receiver to cancel out the effect of ICI. The performance of proposed scheme is analyzed in terms of BER for BPSK, QPSK and 16-QAM modulation schemes. BER performance of proposed scheme is better than CC, PRCC and standard OFDM. The future work is done to improve the performance using different coding schemes.

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