Zero-Padded Conjugate Transmission to Cancel ICI in OFDM System

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Abstract

In OFDM (Orthogonal Frequency Division Multiplexing) to minimize effect of Inter-carrier interference the proposed technique Conjugate transmission with Zero padding and adaptive receiver is proposed in this research article. To transmit the signal according to proposed scheme, first regular OFDM signal is transmitted as a signal in the first path and conjugate signal of regular OFDM is transmitted using proposed algorithm in second path. Two consecutive symbols of the proposed OFDM signal is transmitter after padding Zeros between them to minimize the effect of inter-carrier interference for better time and frequency synchronization between transmitter and receiver signal. To adaptively update the frequency offset error receiver is designed with block least mean-squared algorithm (BLMS). BPSK, QPSK and 16-QAM modulation techniques are used and simulation results are carried out using MATLab software. Simulation results for proposed scheme are compared with regular OFDM system, Conjugate Cancellation (CC) and Phase Rotation Conjugate technique (PRCC) with reference to BER and simulation graphs shows that proposed scheme shows better BER rate performance as comparison to conventional techniques for AWGN wireless channel.

Keywords: Adaptive Receiver, Block Least Mean-Squared (BLMS) Algorithm, Inter-Carrier Interference (ICI), Orthogonal Frequency Division Multiplexing (OFDM)

1. Introduction

With the recent developments in wireless communication systems in last few years, the need to send data on high rates increases day by day. To provide the high speed services like data, voice and video signals need efficient wireless systems. OFDM is a most efficient multicarrier modulation system used to transmit data on high data rates in mobile environment because OFDM is multicarrier modulation technique and flat fading spectrum can be achieved from frequency selective fading. Also, OFDM is easy to implement using Fast fourier transform (FFT) and Inverse-fast fourier transform across transmitter and receiver respectively. For data transmission at high rates for wireless systems OFDM is very efficient technique due to its several properties like high bandwidth and it becomes very efficient technique for data transmission over multipath fading environment due to its unique properties like high bandwidth efficiency and resistance to multipath fading[1]. Due to this OFDM is used in various wireless applications i.e. DAB (Digital audio broadcasting), DVB (Digital video broadcasting), Wireless local area networks IEEE802.11a, IEEE- 802.11g etc[2-4].

In spite of advantages OFDM system has disadvantages also like PAPR (Peak-average power ratio) and more sensible to frequency or phase offsets that arises due mismatch in oscillator frequencies of transmitter and receiver, that affects orthogonality property in OFDM systems and induces Inter Carrier Interference (ICI) problem.

Authors implement various ICI reduction and minimization techniques to improve the efficiency of OFDM system considering different wireless environment. Authors propose different ICI reduction methods to reduce the effect of ICI like frequency Equalization[5], Correlative-coding methods[6], Time-domain windowing[7], SC (self-cancellation) schemes[8-11], Pulse-shaping[12], estimating frequency offset and using different tracking procedures[13], Carrier Conjugate (CC)[14] and Phase Rotated

Carrier Conjugate (PRCC)[15] etc. These techniques are mainly used with modulation techniques BPSK, QPSK. From proposed methods, self-cancellation technique is commonly used method to suppress ICI due to its simplicity and easy implementation.

In this research paper new technique to reduce effect of ICI is used. Proposed signal is transmitted using concept of Zero-padding at transmitter side in two different paths using concept of Time division multiplexing. At the receiver side concept of Adaptive receiver is used which works on BLMS algorithm to track the frequency offset errors in each iteration and to give the optimum error signal. Proposed method performance is compared with already existing ICI schemes in terms of Bit Error rate (BER) using MATLab software.

The following sections are included in research paper: OFDM and signal representation is described In Section II, In Section III discuss proposed signal model. Section IV shows proposed simulation results and comparison with conventional techniques. Result discussion in Section V of paper.

2. OFDM System Model

2.1 Signal Model of OFDM

In OFDM system input data bits are divided in sub carrier with different carrier frequencies and then multiplexed in terms of N symbol streams, with each symbol with time period T_s. All the modulated sub-carriers transmitted with carrier spacing of $1/NT_s$ in term of frequency domain. Signal is transmitted after modulation by implementing IFFT (Inverse Fast-Fourier transform), and discrete-time representation of OFDM signal across transmitter is represented below;

$$x(m) = \frac{1}{N} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{N}kn} \qquad \text{here } 0 \le m \le N\text{-}1 \qquad (1)$$

In expression (1) N represents number of total sub-carriers and the m_{th} subcarrier is modulated using X_m. When signal is passed across an additive white Gaussian noise (AWGN) wireless channel, a phase rotation occurs in transmitted signal due to the effect of frequency offset and signal is represented as;

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

Here ε represents frequency offset, and AWGN wireless channel noise is given by w_n. The frequency domain signal received at receiver side after applying FFT is as given below;

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

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

In the received signal the term $s(l\text{-}k+\varepsilon)$ is considered as ICI coefficient. In expression (3), first term provides the actual transmitted signal information i.e. X_k, and second term given the sum of the interferences in received signal after passing through AWGN channel.

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

2.2 ICI signal in OFDM Systems

The biggest drawback of OFDM is frequency offset which occurs due to difference in transmitter and receiver frequency. This frequency offset is experienced in OFDM system due to frequency mismatch between transmitted and received signal. The ICI effect is as shown below:
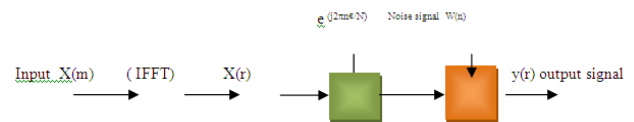

Figure 1. ICI in OFDM.

Signal received is shown as follows,

$$Y(r) = X(r)e^{j2\pi r\varepsilon/N} + w(r) \qquad (5)$$

In given expression (5), 'ε' represents frequency offset, which is represented as $\Delta f N T_S$. Here Δf shows difference in transmitted and received signal carrier frequencies and T_S shows symbol period of the subcarrier. White Gaussian noise in the received signal W(n) due to AWGN wireless channel. Across received signal frequency offset effect is shown by taking Y(k) received symbol from the k_{th} received sub-carrier

$$Y(k) = X(k)S(0) + \sum_{l=0,l\neq k}^{N-1} X(l)S(l-k) + n_k$$

$$K = 0,1,\ldots\ldots N\text{-}1 \qquad (6)$$

In expression (6) the N represents the total number of subcarriers, X(k) represents the transmitted symbol for the k_{th} subcarrier, n_k represents the FFT of w(n) signal, and S(l-k) represents the complex coefficients for the received signal. The ICI complex coefficients in received signal are shown below,

$$S(l\text{-}k) = \frac{\sin(\pi(l + \varepsilon - k))}{N\sin\left(\frac{\pi(l + \varepsilon - k)}{N}\right)} \exp(j\pi(1\text{-}1/N)(l+\varepsilon\text{-}k)) \quad (7)$$

Where normalized frequency offset is represented by ε, that is, $\varepsilon=\Delta f /(1/ NT)$, where Δf is the difference in the frequency for transmitter and the receiver frequencies, and NT represents FFT period interval. The first term in the equation represents desired signal. The second term shows ICI components in received signal.
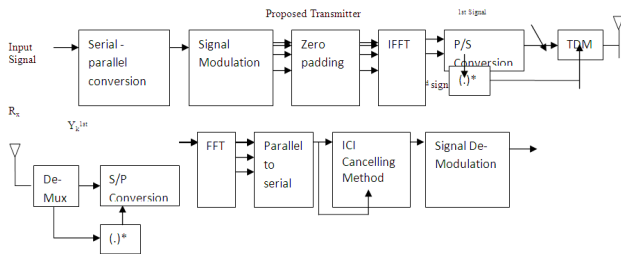

Figure 2. Proposed technique Transmitter and Receiver.

3. Proposed Signal Model

Zero padding is done at transmitter side after modulation i.e. modulated symbol X_l (l=0….N-1) is padded with Zero's. The signal is transmitted in frequency domain and the signal on l^{th} transmitted subcarrier is represented by D = $(X_0, 0, X_1, 0,….0, X_{N-1})$. Assuming that both outputs of simple OFDM system and the conjugate of simple OFDM system are combined on the receiver side by using TDM (Time division multiplexing technique) concept as shown in the proposed architecture in Fig.1.2. The domain received signal after passing through the AWGN fading channel, signal across first path is shown as follows;

$$y_m = de^{j\frac{2\pi}{N}m\varepsilon} + w_m \quad (8)$$

Similarly signal on second path is denoted as;

$$y_m^{'} = d^* e^{j\frac{2\pi}{N}me} + w_m^{'} \quad (9)$$

Alternatively, the received two-path data is grouped together and form a 2N-element vector. By implement-

ing FFT on to the signal i.e. received at receiver following signal is obtained;

$$Y_k^{1st} = \sum_{m=0}^{N-1} DS(k-l-\varepsilon) + W_k \quad (10)$$

Signal on second received path is shown as;

$$Y_k^{2nd} = \sum_{m=0}^{N-1} DS(k-l+\varepsilon) + W_k^{'} \quad (11)$$

Where W_k and $W_k^{'}$ are the Fourier transform of w_m and $w_m^{'}$ respectively. Frequency offset of two different paths are represented by by 'ε' and '$\Delta\varepsilon$' respectively and, the final signal output obtained after applying the different phase rotations or shifts on both paths;

$$Z_{k,new} = \left[e^{j\varphi}S(e) + e^{-j(\varphi+\Delta\varphi)}S(-(\varepsilon + \Delta\varepsilon))\right]D$$
$$+ \sum_{l=0,l\neq k}^{N-1} \left[e^{j\varphi}S(k-l+\varepsilon) + e^{-j(\varphi+\Delta\varphi)}S(k-l-(\varepsilon+\Delta\varepsilon))\right]D \quad (12)$$
$$+ \left[W_k + W_k^{'}\right]$$

BLMS algorithm is used to update Frequency offset errors in received signal. By using expression (12), the CIR(carrier to interference ratio) for proposed scheme is caluclated as below;

$$CIR_{proposed}(\varepsilon,\Delta\varepsilon,\phi,\Delta\phi) = \frac{\left|e^{j\phi}S(\varepsilon) + e^{-j(\phi+\Delta\phi)}S(-(\varepsilon + \Delta\varepsilon)\right|^2}{\sum_{l=1}^{N-1}\left|e^{j\phi}S(l+\varepsilon) + e^{-j(\phi+\Delta\phi)}S(l-(\varepsilon+\Delta\varepsilon))\right|^2} \quad (13)$$

4. Result and Discussion

Main aim of proposed technique is to overcome ICI effect from OFDM based system for Time variant and Time invariant wireless channels due to frequency and Doppler shift. Previous techniques not work effectively for higher frequency offsets for time variant channels. Proposed scheme shows effective results for time variant environment also. Results and comparisons are done in terms of BER for proposed with previous techniques using different modulations like BPSK, QPSK and 16-QAM for different frequency offsets values ϵ= 0.05, 0.3 for both time variant and Invariant channels. For simulation following parameters are considered:

Table 1. Parameters Considered For Simulation

Parameters	Value
Number of subcarriers	512
FFT Size	1024

Modulation techniques	BPSK, QPSK, 16-QAM
Frequency offset (ϵ)	0.05, 0.3
Wireless channel used	AWGN Channel

As seen from the Figure. 3. at signal to noise ratio Eb/No of 10db BER for proposed scheme is 0.01 (BER=0.01) but for conventional techniques CC and PRCC BER=0.055 approximately. Also at Eb/No=20db, BER is equal to 0.001 for proposed scheme that good in comparison to CC and PRCC. This is also analyzed from Fig. At higher signal to noise ratio i.e. more than 25db Bit error rate of given technique is better than the existing methods for 16-QAM modulation but BER performance of conventional techniques is almost same for higher as well as lower SNR.
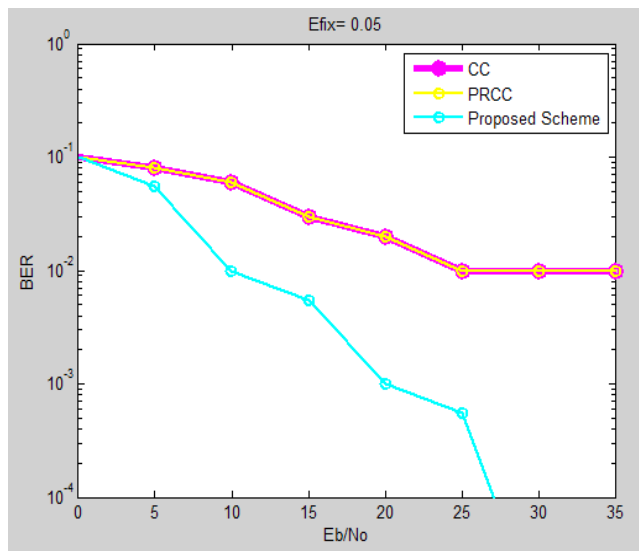
So for different value of Eb/No proposed scheme is performing better than conventional scheme as seen from the given table below:

In Figure 4. BER performance of composed scheme is compared with CC and PRCC for frequency offset ϵ= 0.3 with QPSK modulation. As it is analyzed from the graph that proposed technique shows better performance over conventional schemes for large frequency offset. BER of proposed scheme is 0.01, for CC bit error rate value is 0.19 and for PRCC is 0.02 at Eb/No = 6dB. For Eb/No =20dB PRCC and proposed scheme BER performance is better than CC scheme and there is large difference in BER performance of CC and proposed scheme and less difference between PRCC and proposed scheme. For low BER the performance of all techniques are almost similar but as signal to noise ratio Eb/No increases, BER performance of proposed techniques is superior to existing schemes.
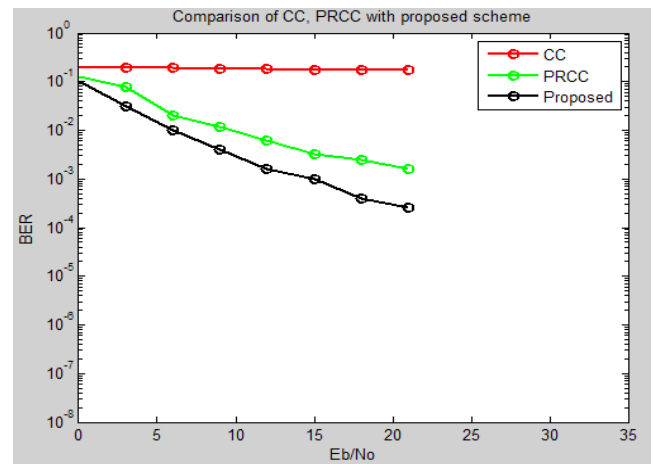

Figure 3. Comparison in terms of BER for proposed method, CC and PRCC schemes for ε_{fix}=0.05 using 16-QAM modulation.

Figure 4. BER comparison of Proposed scheme with CC, PRCC for ε_{fix}=0.3 using QPSK modulation.

CIR ratio for proposed scheme with frequency offset, ϵ = 0- 0.5 is shown in the Figure. 5. CIR is the proportion of received carrier power signal strength to the noise

Table 2. Comparison of Proposed Scheme, CC and PRCC AT E_{FIX}=0.05 with 16-QAM modulation

Eb/No (dB)	5(db)	10(db)	15(db)	20(db)
BER (Proposed Technique)	0.055	0.01	0.005	0.001
BER (CC Technique)	0.08	0.06	0.03	0.02
BER (PRCC Technique)	0.08	0.06	0.03	0.02

signal received at receiver. CIR is represented in decibels (dB). As analyzed from the Fig. 5. Carrier to interference (CIR) ratio is high for low frequency offset values, as frequency offset ϵ increases carrier to interference ratio also increases. Quality of received signal will be better if CIR ratio is high.
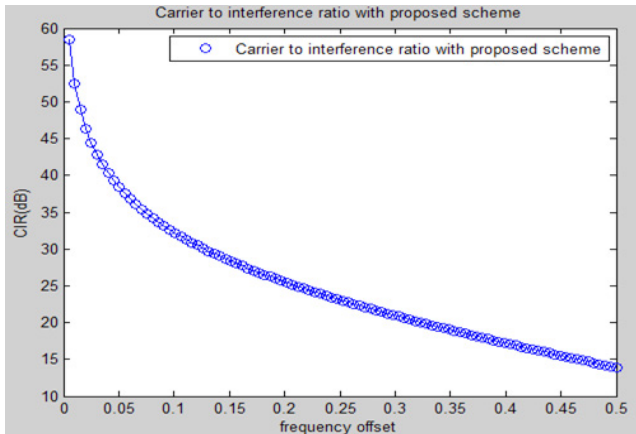

Figure 5. Carrier to interference ratio for proposed scheme with different offset.
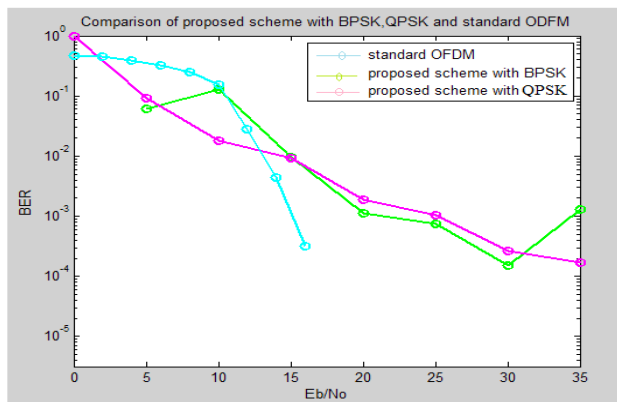

Figure 6. BER performance of proposed schemes for BPSK, QPSK and regular OFDM.

Figure 6. represents the Bit Error Rate (BER) and EB/No analysis of the given scheme using modulation schemes as BPSK, QPSK and regular OFDM system. As its analyzed from graph proposed scheme with BPSK and QPSK modulation performs better for lower values of signal to noise ratio upto 15dB. For higher values of Eb/No performance of proposed scheme for BPSK and QPSK is similar but for more than 30db proposed scheme with QPSK not performs better than BPSK. Also analyzed from the Fig. proposed scheme performs better than standard OFDM for higher as well as lower Eb/No ratio.

5. Conclusion

A technique to minimize the ICI effect from OFDM wireless system is analyzed in terms of BER performance. Concept of Zero padding is used with Conjugate cancellation method for Time varying and invariant wireless channels using various modulation techniques i.e. BPSK as low modulation and QPSK and 16-QAM high data modulation techniques. Simulation results are carried out using MATLab software and performance of proposed technique is analyzed and also comparison is done with conventional methods to reduce effect of ICI. As analyzed from simulation results the proposed solution outperforms than conventional CC and PRCC techniques in terms of BER performance with different frequency offset values.

6. References

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