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An Improved Intercarrier Interference Mitigation Technique in OFDM Systems

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Abstract--Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique which divides the available spectrum into many carriers. Efficient spectrum usage makes it most desirable candidate for high data rate transmission. However the major drawback is its sensitivity to CFO which causes Inter carrier Interference (ICI). This ICI causes severe degradation of the Bit error Rate (BER) performance of the OFDM receiver. There are numerous techniques for reducing ICI including time domain windowing, frequency domain equalization and ICI self-cancellation, but the simplest one is self-cancellation. In this paper an efficient ICI self-cancellation technique is introduced and the comparisons are made with existing techniques.

Index Terms: Additive white Gaussian noise (AWGN), Bit error Rate (BER), carrier frequency offset (CFO), inter carrier interference self-cancellation (ICI SC),orthogonal frequency division multiplexing (OFDM).

I. Introduction

OFDM with the high capacity transmission has been applied into many digital transmission systems, such as digital audio broadcasting (DAB) system, digital video broadcasting terrestrial TV (DVB-T) system, asymmetric digital subscriber line (ADSL), IEEE 802.11a/g Wireless Local Area Network (WLAN), IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMax) systems, and ultra-wideband (UWB) systems [1]. There are two major problems in OFDM named as peak average to power ratio (PAPR) and inter carrier interference (ICI). This paper consider Inter Carrier Interference problem. OFDM communication systems require precise frequency synchronization, since otherwise ICI will occur [2]. The major cause of ICI is due to synchronization error and Doppler Effect. There are numerous methods to reduce the effect of ICI named: time domain windowing, frequency domain equalization, frequency offset estimation and cancellation and ICI self-cancellation method. Among all these the simplest one is ICI self-cancellation. There are numerous ways to perform self-cancellation. In this paper an improved ICI self-cancellation is introduced with improved CIR and reduced BER. Furthermore, BER performances of the proposed scheme are compared with standard OFDM signal and existing schemes. The rest of the paper is described as: in section II basic OFDM model and the ICI problem is described. In section III ICI Self-Cancellation is described and proposed scheme is introduced. Next in IV simulation results are shown and in V conclusions are made.

II. OFDM MODEL

In OFDM communication system, inverse discrete Fourier transform (IDFT) is performed at transmitter and Discrete Fourier transform (DFT) is performed at receiver. Figure 1 shows the basic OFDM model.
At the transmitter side first the high speed data is converted to many low data using serial to parallel conversion, then after modulation the IDFT is performed and finally OFDM symbols are converted to serial. Then the orthogonal symbols are transmitted over wireless channel. Similarly at receiver side the serial data is first converted parallel then FFT is done to get data in frequency domain. Output data is gained after demodulation and serial conversion.

In an OFDM communication system, assuming the channel frequency offset normalized by the subcarrier separation is ε and then the received signal on subcarrier *k* can be written as:

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

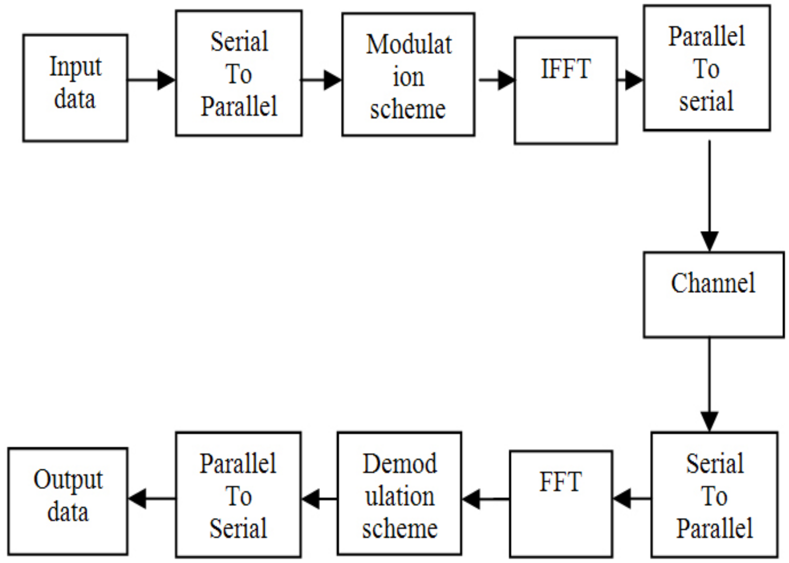

Fig. 1: Basic OFDM Model

N is the total number of the subcarriers, X(k) denotes the transmitted symbol for the k^{th} subcarrier and n_k is an additive noise sample. The first term in the right-hand side of eq. (1) represents the desired signal [3]. The second term is the ICI components. The sequence S(*l*-*k*) is defined as the ICI coefficient between l^{th} and k^{th} subcarriers, which can be expressed as:

$$S(l-k) = \frac{\sin\big(\pi(l+\epsilon-k)\big)}{N\sin\left(\frac{\pi(l+\epsilon-k)}{N}\right)} exp^{\left(j\pi\left(1-\frac{1}{N}\right)(l+\epsilon-k)\right)} \quad (2)$$

Fig. 2 shows the amplitude of the *S*(*l*-*k*) for frequency offset ε =0.1, 0.15 and 0.30 and for l=0, N=52

It is clear from the Fig. 2 that as the offset value increases the ICI coefficient also increases. Hence it is necessary to reduce the inter carrier interference.

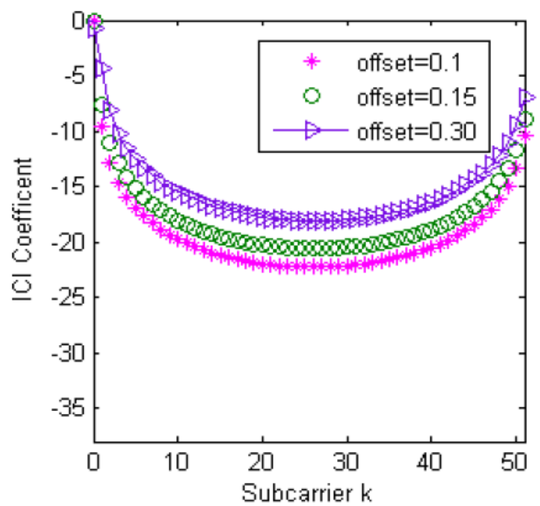

Fig 2 Amplitude of S(l-k)

III. ICI SELF CANCELLATION

It is seen that the difference of ICI coefficient between two consecutive subcarrier S(*l*-*k*) and S(*l*+1-*k*) is very small. Hence the idea of self-cancellation is generated. The main idea is to modulate one data symbol onto a group of subcarriers with predefined weighting coefficients. By doing so, the ICI signals generated within a group can be self-cancelled each other [3]. Thus it is called self-cancellation method.

A. Data conversion

The data-conversion self-cancellation scheme for ICI mitigation based on a data symbol allocation of $X'(k) = X(k)$, $X'(k+1) = -X(k)$ for $k = 0,2,\ldots N-2$ in consecutive subcarriers to deal with the ICI [2]. The received signal on subcarrier k given as :

$$Y'(k) = \sum_{\substack{l=0,\\ l=even}}^{N-2} X(l)[S(l-k) - S(l+l-k)] + n(k) \quad (3)$$

And on the subcarrier k+1 the received signal will be :

$$Y'(k+1) = \sum_{\substack{l=0,\\ l=even}}^{N-2} X(l)[S(l-k-1) - S(1-k)] + n(k+1) \quad (4)$$

To further reduce ICI, demodulation is done. The resultant signal $Y(k)$ is determined by the difference between the adjacent subcarriers.

$$Y''(k) = \frac{1}{2}[Y'(k) - Y'(k+1)] \quad (5)$$

CIR of data conversion method is given as :

$$CIR = \frac{|2S(0) - S(1) - S(-1)|^2}{\sum_{\substack{l=2\\ l=even}}^{N-2} |2S(l) - S(l+1) - S(l-1)|^2} \quad (6)$$

B. Data conjugate

In the data-conjugate scheme, subcarrier signals are remapped in the form of $X'(k) = X(k)$, $X'(k+1) = -X^*(k)$ for k= 0,2 ….. N-2

The final recovered signal is as follows [4]

$$Y''(k) = \frac{1}{2}[Y'(k) - Y'^*(k+1)] \quad (7)$$

CIR of data conjugate scheme is given by :

$$CIR = \frac{|S(0) + S^*(0)|^2 + |S(1) + S^*(-1)|^2}{\sum_{\substack{l=2\\ l=even}}^{N-2} [|S(l) + S^*(l)|^2 + |S(l+1) + S^*(l-1)|^2]} \quad (8)$$

C. Symmetric data conversion

In the symmetric data-conversion scheme [5], subcarrier signals are remapped in the form of $X'(k) = X(k)$, $X'(N-k-1) = -X(k)$ for k= 0,2 ….. N-2

The final recovered signal is as follows

$$Y''(k) = \frac{1}{2}[Y'(k) - Y'(N-k-1)] \quad (9)$$

CIR of data conjugate scheme is given by

$$CIR = \frac{|2S(0) - S(N-1) - S(1-N)|^2}{\sum_{\substack{l=2\\ l=even}}^{N-2} [|S(l) + S(-l) - S(N-l-1) - S(l-N+1)|^2]} \quad (10)$$

D. Real constant weighted conversion

In the constant weighted data-conversion scheme, subcarrier signals are remapped in the form of $X'(k) = X(k)$, $X'(k+1) = -\mu X(k)$ for k= 0,2 ….. N-2, where μ is a real constant.

The final recovered signal is as follows [6]

$$Y''(k) = \frac{1}{1+\mu}[Y'(k) - Y'(k+1)] \qquad (11)$$

CIR of data conjugate scheme is given by

$$CIR = \frac{|(1+\mu)S(0) - \mu S(1) - S(-1)|^2}{\sum_{\substack{l=2 \\ l=even}}^{N-2} |(1+\mu)S(l) - \mu S(l+1) - S(l-1)|^2} \qquad (12)$$

E. plural weighted data conversion

In the plural weighted data-conversion scheme, subcarrier signals are remapped in the form of $X'(k) = X(k)$, $X'(k+1) = e^{-j\pi/2} X(k)$ for k= 0,2 ….. N-2

The final recovered signal is as follows :

$$Y''(k) = \frac{1}{2}\left[Y'(k) - Y'(k+1)e^{-j\pi/2}\right] \qquad (13)$$

CIR of data conjugate scheme is given by [7]

$$CIR = \frac{|2S(0) + e^{-\frac{j\pi}{2}}[S(1) - S(-1)]|^2}{\sum_{\substack{l=2 \\ l=even}}^{N-2} |2S(l) + e^{-\frac{j\pi}{2}}[S(l+1) - S(l-1)]|^2} \qquad (14)$$

F . Conjugate plural weighted

In this scheme [8], subcarrier signals are remapped in the form of $X'(k) = X(k)$, $X'(k+1) = e^{j\pi/2} X^*(k)$ for k= 0,2 ….. N-2
The final recovered signal is as follow s:

$$Y''(k) = \frac{1}{2}\left[Y'(k) - Y'^*(k+1)e^{-j\pi/2}\right] \qquad (15)$$

CIR of data conjugate scheme is given by

$$CIR = \frac{|S(0) + S^*(0)|^2 + |e^{j\pi/2}S(1) + e^{-j\pi/2}S^*(-1)|^2}{\sum_{\substack{l=2 \\ l=even}}^{N-2} [|S(l) + S^*(l)|^2 + |e^{j\pi/2}S(l+1) + e^{-j\pi/2}S^*(l-1)|^2]} \qquad (16)$$

G. Proposed Scheme

In this proposed technique combination of symmetric data conversion and plural weighted conjugate scheme is done. It is noticed that conjugate decreases BER and symmetric conversion increases CIR. Hence by combining these two factors, a new technique has been proposed which provides better ICI reduction. In the proposed scheme, data of subcarrier signals are in the form of $X'(k) = X(k)$, $X'(N-k-1) = e^{j\pi/2} X^*(k)$ for k= 0,2 ….. N-2

The final recovered signal is as follows

$$Y''(k) = \frac{1}{2}\left[Y'(k) - Y'^*(N-k-1)e^{-j\pi/2}\right] \qquad (17)$$

CIR of data conjugate scheme is given by

$$CIR = \frac{|S(0) + S^*(0)|^2 + |e^{j\pi/2}(N-1-l-k) - e^{-j\pi/2}S^*(-N+1+l+k)|^2}{\sum_{\substack{l=2 \\ l=even}}^{N-2} [|S(l) + S^*(l)|^2 + |e^{j\pi/2}S(N-l-1) + e^{-j\pi/2}S^*(l-N+1)|^2]} \qquad (18)$$

IV. SIMULATION RESULTS

A simulation is done to evaluate the performance of proposed scheme. The parameters for the simulations are the total number of subcarriers N □256, QPSK modulation, the normalized frequency offset ε=0.05, AWGN fading channel are considered. The typical results for BER versus signal-to-noise ratio (E_b/N_0) are shown in Fig. 3. Simulation results show that BER performance of OFDM systems and the previous ICI Self-cancellation schemes along with proposed scheme in the AWGN channel. As seen in the figure 3 the proposed scheme has improved BER performance, compared with all the previous schemes described earlier.

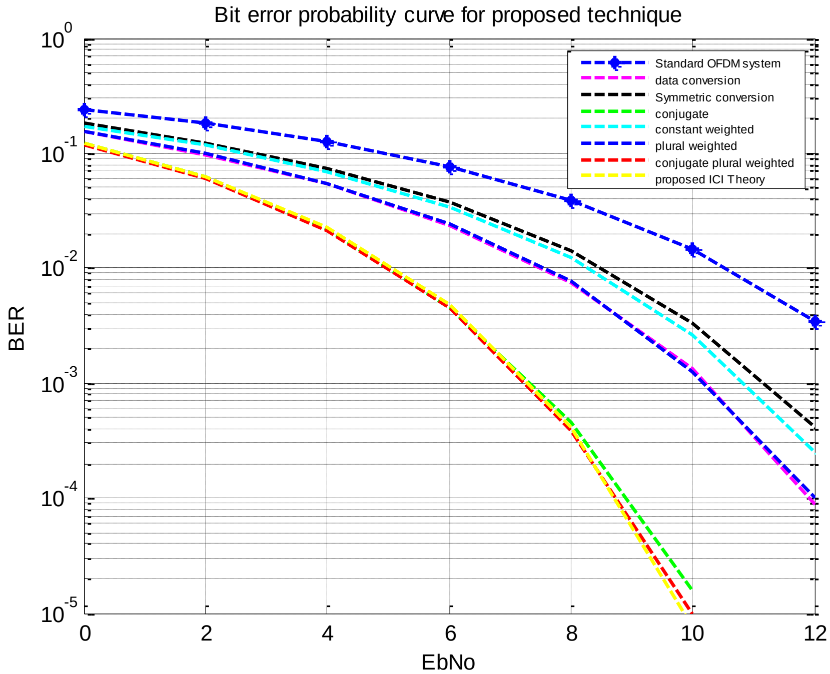

Fig. 3 BER versus SNR for QPSK, N=256, ε=0.05

Also Fig. 4 shows the CIR of proposed scheme is better than conjugate plural weighted but inferior than symmetric data conversion.

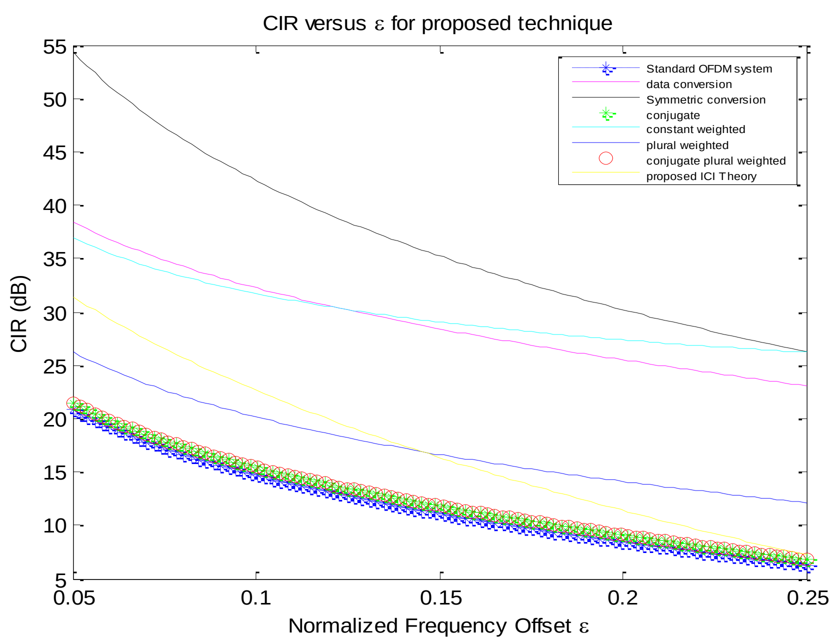

Fig. 4 CIR versus frequency offset

V. Conclusion

This paper studies the ICI self-cancellation schemes to cancel the effect of ICI caused by frequency offset in OFDM systems. A new ICI self-cancellation scheme is presented. Although the bandwidth efficiency of the scheme is reduced by half due to the redundant symbols, it can be solved by increasing the number of subcarriers or using larger signal alphabet size and it is less complex as compared to the other frequency offset estimation and correction schemes. Simulation results show that the proposed scheme can outperform other ICI SC schemes on the basis of CIR and BER.

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References

[1] Yi-Hao Peng, *etal,* "Performance Analysis of a New ICI-Self- Cancellation-Scheme in OFDM Systems," *IEEE Transactions on Consumer Electronics,* vol.53, no. 4, pp.1333-1338, 2007

[2] Qiang Shi "A Novel ICI Self-Cancellation Scheme for OFDM Systems," *IEEE conference on WiCom,* pp 1-4, sept. 2009

[3] Y. Zhao and S. Häggman, "Intercarrier interference self-cancellation scheme for OFDM mobile communication systems," *IEEE Transactions on Communications,* vol.49, no. 7, pp. 1185-1191, 2001

[4] Heung-Gyoon Ryu, Yingshan Li, and Jin-Soo Park, "An Improved ICI Reduction Method in OFDM Communication System," *IEEE Transactions on Broadcasting,* vol.51, no.3, pp.395-400, 2005

[5] LI Ying-shan, *etal,* "ICI Compensation in MISO-OFDM System Affected by Frequency Offset and Phase Noise," *Journal of Communication and Computer,* vol.5, no.12, pp.32-38, 2008.

[6] Yu Fu, Chi Chung Ko, "A new ICI self-cancellation scheme for OFDM systems based on a generalized signal mapper," *in Proc. 5th Wireless Personal Multimedia Communications,* pp.995-999, Oct.2002.

[7] Yi-Hao Peng, *etal,* "Performance Analysis of a New ICI-Self-Cancellation-Scheme in OFDM Systems," *IEEE Transactions on Consumer Electronics,* vol.53, no. 4, pp.1333-1338, 2007.

[8] Qiang Shi , "A Novel ICI Self-Cancellation Scheme for OFDM Systems," *IEEE International Conference on Wireless Communications, Networking and Mobile Computing,* pp 1-4, Sept 2009.

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