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Survey on Intercarrier Interference Self-Cancellation techniques 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 the two ways for ICI self-cancellation data conversion and data conjugate are described and the comparisons are made.

Index Terms: **Additive white Gaussian noise (AWGN), Bit error Rate (BER), carrier frequency offset (CFO), inter carrier interference (ICI), 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]. Themajorcause 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 two ways to perform self-cancellation data conversion and data conjugate method. In this paper ICI self-cancellation is discussed based on data conversion and conjugate method. Furthermore, BER performances of data-conversion method and data-conjugate method the original OFDM with or without convolution coding are compared with each other. 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 introduced: data conversion and data conjugate. Next in IV comparison of the two 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 sub carrier separation is ε and then the received signal on sub carrier *k* can be written as:

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

$where\ k = 0,1 \dots . N-1$

N is the total number of the sub carriers, X(k) denotes the transmitted symbol for the *k*th sub carrier 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 sub carriers, which can be expressed as:

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

Fig. 2 shows the amplitude of the $S(l\text{-}k)$ for frequency offset ε =0.1, 0.15 and 0.30 and for l=0, N=52 It is clear from the figure 2 that as the offset value increases the ICI coefficient also increases. Hence it is necessary to reduce the inter carrier interference.

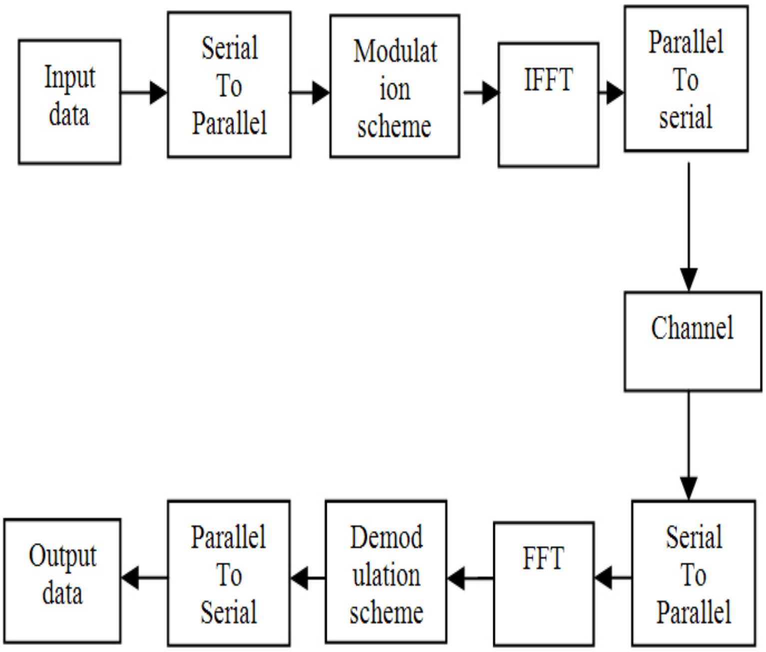

Fig 1: Basic OFDM Model

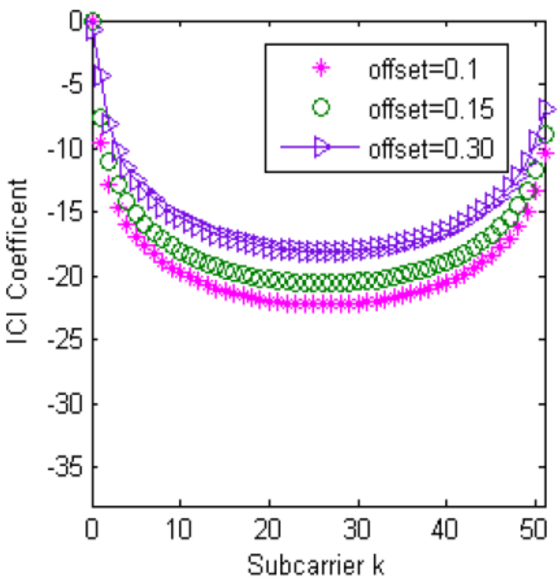

Fig 2 Amplitude of S(l-k)

III. ICI SELF CANCELLATION

It is seen that the difference of ICI coefficient between two consecutive sub carrier 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

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group of sub carriers 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. Two ways of self-cancellation are data conversion and data conjugate.

A. Data conversion

The data-conversion self-cancellation scheme for ICImitigation based on a data symbol allocation of$X'(k) = X(k)$, $X'(k+1) = -X(k)$ for $k = 0,2,\ldots.\ N-2$ inconsecutive sub carriers to deal with the ICI [2]. The received signal on sub carrier k will be

$$Y'(k) = \sum_{\substack{l=0,\\ l=even}}^{N-2} X(l)[S(l-k) - S(l+1-k)] + n(k) \qquad (3)$$

and on the sub carrier k+1 the received signal will be

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

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

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

CIR of data conversion method is given as [4]

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

BData conjugate

In the data-conjugate scheme, subcarrier signals areremapped 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]

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

CIR of data conjugate scheme is given by

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

IV. CONCLUSION

Simulation results in review shows that BER performance of the four OFDM systems in the AWGN channel when QPSK modulation is used and phase noise variances are supposed to 0.03 and 0.06, respectively. As seen in the figure 3 the data conjugate method has the best BER performance, compared with data conversion method, original OFDM and OFDM with convolution coding in the AWGN channel specially, the difference becomes higher as the phase noise variance is large. Hence it is concluded that the data conjugate method outperforms data conversion method in the OFDM with phase noise although data conversion method has better CIR in OFDM only with frequency offset as mentioned in [5]. So, data conjugate ICI self-cancellation method may be very useful to the multi carrier system of the high transmission quality.

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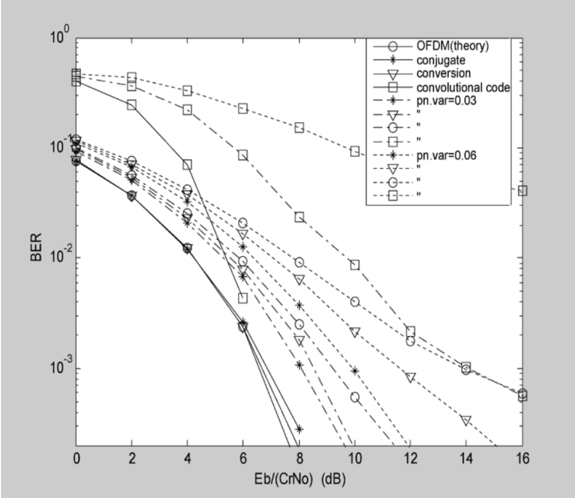

Fig 3 BER comparison in AWGN channel (QPSK, N = 64).

Similarly in figure 4 comparisons is made using QAM modulation technique.

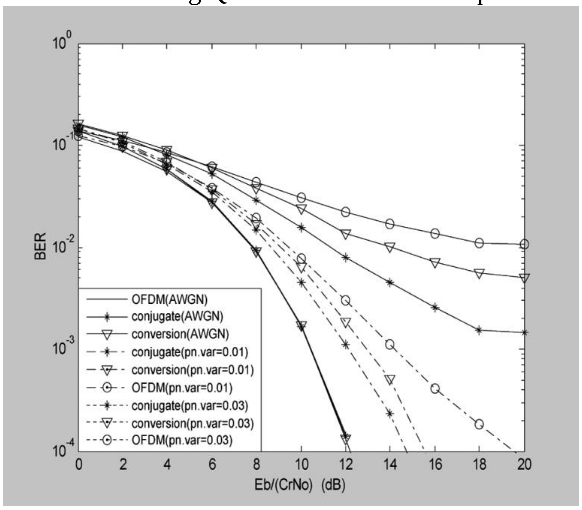

Fig 4 BER comparison in AWGN channel (16-QAM,N = 64).

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