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Comparative Study And Survey Between Intercarrier Interference Reduction Techniques

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ABSTRACT-This paper considers an orthogonal frequency division multiplexing (OFDM) system over frequency selective time-varying fading channels. The frequency offset between transmitter and receiver local oscillator is main drawback of OFDM systems, which causes intercarrier interference (ICI) in the subcarriers of the OFDM system. This ICI degrades the bit error rate (BER) performance of the system. In this paper an ICI self cancellation scheme, new or modify self-ICI cancellation scheme and ICI conjugate cancellation method is compared.

Keywords- BER,DAB,DVB-T,ICI,FFT,IFFT,OFDM,PSK,WiMax,UWB,ICI self cancellation,Modified self cancellation,Conjugate self cancellation.

1. INTRODUCTION

OFDM is an emerging modulation scheme in the current broadband wireless mobile communication system due to the high spectral efficiency and robustness to multi-path interference [1]. orthogonal frequency division multiplexing (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 [1-5]. However, one of the well known problems in the OFDM applied systems is its sensitivity to the frequency offset caused by the mismatch of local oscillators, Doppler frequency drift and sampling clock offset. Without the estimation and adjustment for the frequency offset in the received signal, the effect of inter-carrier interference (ICI) will degrade the system performance.

2.OFDM SYSTEM DESCRIPTION AND ICI PROBLEM

An OFDM system at least contains the function of parallel transmission, signal modulation and IFFT/FFT [1-2]. Fig. 1 illustrates the block diagram of the baseband, discrete-time FFT-based OFDM systems. Each parallel data is mapped with M-ary PSK scheme and then, those data are modulated by an IFFT on N-parallel subcarriers. With a cyclic prefix [1-3], the complete OFDM symbol is transmitted over a discrete-time channel. At the receiver, the data are retrieved by a FFT and then, demapped with corresponding scheme to obtain the estimated data.

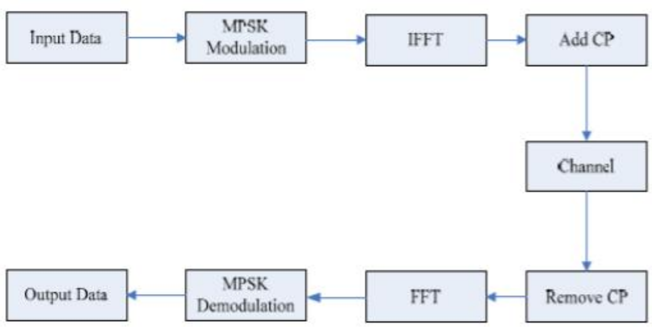

Fig 1: Block diagram of the FFT-based OFDM systems

In OFDM systems, the transmitted signal in time domain could be expressed as

$$x(n) = \frac{1}{N}\sum_{l=0}^{N-1} X(l)e^{j2\pi ln/N} \quad (1)$$

where $x(n)$ denotes the nth sample of the OFDM transmitted signal, $X(l)$ denotes the modulated symbol within the lth subcarrier and N is the number of the subcarriers. Assuming the channel frequency offset normalized by the subcarrier frequency spacing denotes as ε and, then, the received signal in time domain could be written as

$$y(n) = [x(n) + w(n)]e^{j2\pi n\varepsilon/N} \quad (2)$$

where $w(k)$ denotes an additive white Gaussian noise. Therefore, the corresponding frequency domain response can be obtained by FFT, which gives

$$Y(k) = X(k)S(0) + \sum_{\substack{l=0 \\ l\neq k}}^{N-1} X(l)S(l-k) + n(k), \quad k = 0,1,\ldots,N-1 \quad (3)$$

The sequence $S(l\text{-}k)$ is defined as the ICI coefficient between lth and kth subcarriers, which can be expressed as

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$$S(l-k)=\frac{\sin(\pi(l-k+\varepsilon))}{N\sin(\frac{\pi}{N}(l-k+\varepsilon))}\exp(j\pi(1-\frac{1}{N})(l-k+\varepsilon)). \quad (4)$$

To analyze the effect of ICI on the received signal, we consider a system with =16 carriers. The frequency offset values used are 0.2 and 0.4, and is taken as 0, that is, we are analyzing the signal received at the sub-carrier with index 0. The complex ICI coefficients are plotted for all sub-carrier indices in below Figures 2.1, 2.2 and 2.3. Figure 2.1 shows that for a larger, the weight of the desired signal component, decreases, while the weights of the ICI components increases. We can also notice that the adjacent carrier has the maximum contribution to the ICI.

The desired received signal power on the sub carrier can be represented as

$$E\left[|C(k)|^2\right] = E\left[|X(k)S(0)|^2\right]=E\left[|X(k)|^2|S(0)|^2\right]=E\left[|X(k)|^2\right]E\left[|S(0)|^2\right] \quad (5)$$

It is assumed that $X(k)$ is zero mean and statistically independent, and the auto correlation function of $X(k)$ can be derived as

$$E\left[X(l)X^*(m)\right] = \begin{cases} E\left[X(l)X^*(l)\right]=E\left[|X(l)|^2\right]=2 & ,m=l. \\ 0 & ,m\neq l. \end{cases} \quad (6)$$

The second term in Eq. 3 is the ICI components and the average power can be represented as

$$\begin{aligned} E\left[|I(k)|^2\right] &= E\left[\left|\sum_{\substack{l=0\\l\neq k}}^{N-1}X(l)S(l-k)\right|^2\right]=E\left[\sum_{\substack{l=0\\l\neq k}}^{N-1}X(l)S(l-k)\sum_{\substack{m=0\\m\neq k}}^{N-1}X^*(m)S^*(m-k)\right] \\ &=\sum_{\substack{l=0\\l\neq k}}^{N-1}\sum_{\substack{m=0\\m\neq k}}^{N-1}S(l-k)S^*(m-k)E\left[X(l)X^*(m)\right] \\ &=\sum_{\substack{l=0\\l\neq k}}^{N-1}S(l-k)S^*(l-k)E\left[|X(l)|^2\right]=E\left[|X(l)|^2\right]\sum_{\substack{l=0\\l\neq k}}^{N-1}|S(l-k)|^2. \end{aligned} \quad (7)$$

According to the definition of CIR, the CIR can be represented as

$$CIR=\frac{E\left[|C(k)|^2\right]}{E\left[|I(k)|^2\right]}=\frac{E\left[|X(k)|^2\right]E\left[|S(0)|^2\right]}{E\left[|X(l)|^2\right]\sum_{\substack{l=0\\l\neq k}}^{N-1}|S(l-k)|^2} \quad (8)$$

The desired signal is transmitted on subcarrier “0” is considered, the CIR expression in Eq. 8 can be derived as

$$CIR=\frac{|S(0)|^2}{\sum_{l=1}^{N-1}|S(l)|^2} \quad (9)$$

Eq. 5 shows that the CIR is a function of N and ε. In fact, the CIR of OFDM systems almost depends on the frequency offset ε when N is large. The theoretical curve calculated by Eq. 9.

3.ICI SELF CANCELLATION SCHEME

In ICI self cancellation scheme its main work is to modulate input data on number of subcarriers with predefined self coefficients such that generated ICI signals cancels each other [6]. In this scheme each data bit is sent through two adjacent subcarriers, one with weight ‘+1’ and another with ‘-1’ [7].Y (K) = Y(K)-Y(K+1) and to cancel the effect of ICI at receiver side, adjacent subcarriers are subtracted, X(K)-(-X(K)) =2X(K).

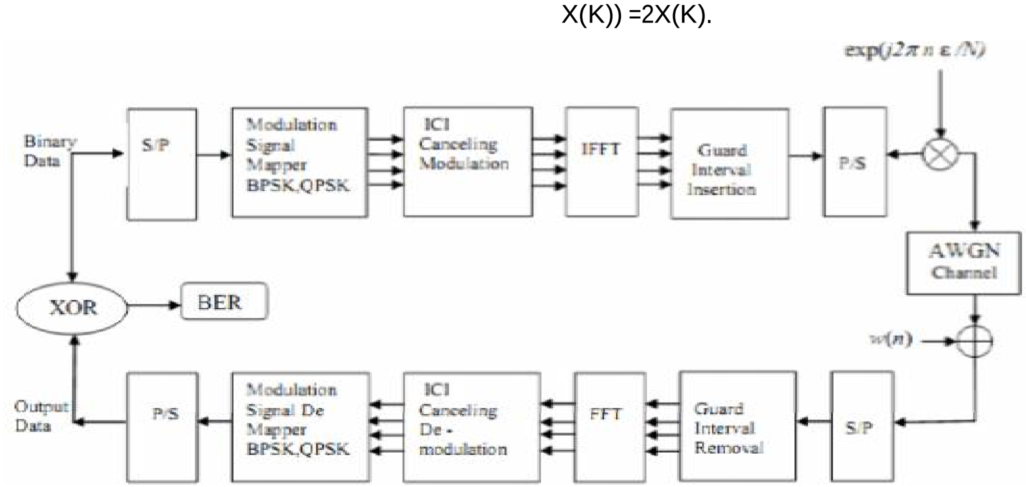

Fig 2: Block diagram of ICI Self Cancellation Scheme

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4. NEW-ICI SELF CANCELLATION SCHEME

In this scheme each data is map with symbol X(k) which is to be transmitted onto a pair of non adjacent subcarriers k and (N-1—k) with weightings '+1' and '-1', rather than to adjacent carriers.In case of ICI self cancellation modulation scheme, each pair of subcarrier transmits only one data symbol and in modified ICI demodulation is suggested to work in such a way that each signal at the (N-1-k)th subcarrier is multiplied by '-1' and then summed with one at kth subcarrier.Y'(k)-Y(k)-Y(N-1-k)

$$= X(k)[2\times S(0)-S(N-1-2k)-S(2k-N+1)]+ \sum_{\substack{l=0\\ l\neq k}}^{\frac{N}{2}-1} X(l)[S(l-k)-S(N-1-l-k) -S(l-N+1+k)+S(-l+k)]+\{w(k)-w(N-1-k)\}$$

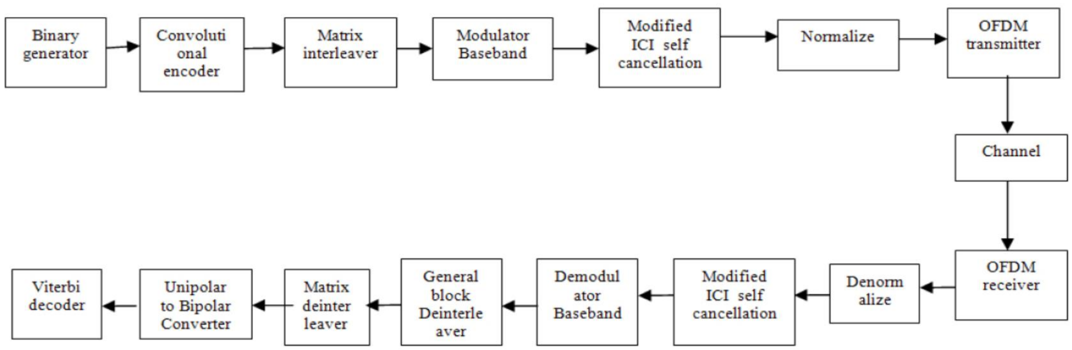

Fig 3: Block diagram of NEW-ICI Self Cancellation Scheme

5. ICI CONJUGATE CANCELLATION METHOD

In this cancellation method, before transmission first part of data is sent as it is and conjugate is taken for second data. In next block digital signal is converted to analog via the digital-to-analog converter (D/A) before being sent down to the channel. At the receiver side, guard interval is removed and the received symbol is converted from analog to digital using the analog-to-digital converter (A/D). In next process first part of data is transferred as it is in serial to parallel converter and conjugate is taken for second part of data before transferring to the serial to parallel converter and then first and second part of data are sent in FFT block. After FFT and IFFT block data is sent for parallel to serial (P/S) conversion and then for demodulation. ICI cancellation is done after demodulation using diversity combiner.

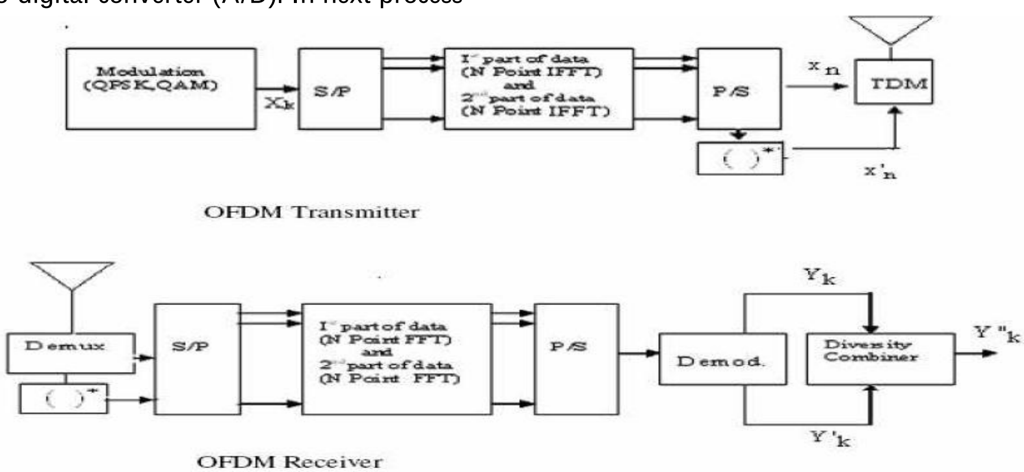

Fig 3: Block diagram of ICI Conjugate Self Cancellation Scheme

Input data bits are encoded by using suitable modulation technique and output of his block is *Xk*. IFFT output at the transmitter is:

$$x_n = \frac{1}{N}\sum_{k=-K}^{K} X_k e^{2\pi jnk/N}$$

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where n = 0,1,2.,.,.,N -1, and N >=2K + 1 where K is number of sub carries N is the period of IFFT. At received sequence after passing through the channel can be expressed as:

$$y_n = \frac{1}{N}\left[\sum_{k=-K}^{K} X_k H_k e^{2\pi jn(k+\varepsilon)/N}\right] + w_n$$

where n = 0,1,2.,.,.,N -1, where Hk is channel transfer function at the frequency of kth subcarrier, ε is relative frequency offset of channel, wn is Additive White Gaussian Noise (AWGN). Output of DFT demodulator can be expressed as:

$$Y_k = \sum_{n=0}^{N-1}\left\{\frac{1}{N}\left[\sum_{n=-K}^{K} H_k X_k e^{2\pi jn(k+\varepsilon)/N}\right] + w_n\right\} e^{-2\pi jkn/N}$$

$$Y_k = (X_k H_k)\left\{(\sin\pi\varepsilon)/N\sin(\pi\varepsilon/N)\right\} e^{j\pi\varepsilon(N-1)}/N + \underbrace{I_k}_{II} + \underbrace{W_k}_{III}$$

The first component is the modulation value Xk is modified by channel transfer function. This component experiences an amplitude reduction and phase shift due to the frequency offset. Second term is ICI term, which arises due to frequency mismatch of oscillator transmitter and receiver. After some manipulation second term ICI can be expressed as:

$$I_k = \sum_{\substack{l=0 \\ l\neq k}}^{N-1} \frac{1}{N} X_l H_l \left(\sin\pi(l+\varepsilon-k)/\sin\pi\left((l+\varepsilon-k)/N\right)\right) \times e^{j\pi(N-1)\left(\frac{l+\varepsilon-k}{N}\right)}$$

$N-1$

Third is Additive White Gaussian Noise in frequency domain which can be expressed as

$$W_k = \sum_{n=0}^{N-1} w_n e^{-2\pi kn/N}$$

Now we will analyze the second part of data before transmission we will take conjugate of the original signal:

$$x'_n = \left(\frac{1}{N}\sum_{k=-K}^{K} X_k e^{2\pi jnk/N}\right)^* = \frac{1}{N}\sum_{k=-K}^{K} X_k^* e^{-2\pi jnk/N}$$

n = 0,1,2,3,.,.,.,N-1. At the receiver a conjugate algorithm is requires a conjugate operation on received signal first and FFT is performed:

$$y'_n = \frac{1}{N}\left[\sum_{k=-K}^{K} X *_k H_k e^{2\pi jn(-k+\varepsilon)/N}\right] + w_n$$

Where n = 0,1,2.,.,.,N-1.Out put of DFT demodulator can be expressed as:

$$Y'_k = \sum_{n=0}^{N-1}\left\{\frac{1}{N}\left[\sum_{k=-K}^{K} H_k X *_k e^{2\pi jn(-k+\varepsilon)/N}\right] + W_n\right\}^* e^{-2\pi jkn/N}$$

$$Y'_k = (X_k H_k)\left\{\frac{(\sin\pi\varepsilon)}{N\sin\left(\frac{\pi\varepsilon}{N}\right)}\right\} e^{-j\pi\varepsilon(N-1)}/N + \underbrace{I'_k}_{II} + \underbrace{W'_k}_{III}$$

ICI term can be expressed as:

$$I'_k = \sum_{l=0,\, l\neq k}^{N-1} \frac{1}{N} X_l H_l \left(\frac{\sin\pi(l-\varepsilon-k)}{\sin\pi\left(\frac{l-\varepsilon-k}{N}\right)}\right) e^{j\pi(N-1)\left(\frac{l-\varepsilon-k}{N}\right)}$$

$$W'_k = \sum_{n=0}^{N-1} w_n^* e^{-2\pi kn/N}$$

ISSN 2229-5518

Output of receiver after using conjugate cancellation scheme is:

$$Y_k'' = (Y_k + Y_k')/2$$

Second term is ICI component at output of the receiver after conjugate cancellation scheme will be:

$$I_k'' = (I_k + I_k')/2$$

Third term is Additive White Gaussian Noise at the OFDM receiver output is:

$$W_k'' = (W_k + W_k')/2$$

6. COMPARISION:

Orthogonal Frequency Division Multiplexing (OFDM) is a very important modulation technique in wideband wireless communication and multimedia communication systems. The paper concentrates on reducing the effect of ICI using ICI self cancellation scheme and modified self cancellation scheme and conjugate cancellation comparing their result. This paper shows that Modified ICI self cancellation scheme has much reduced effect of ICI than that showed by ICI self cancellation scheme. Such a technique will improve the performance of the existing OFDM systems. The conjugate cancellation scheme is mucssh better the others it gives the better BER performance and it is less complex the new-ici cancellation. Under the condition of the same bandwidth efficiency and larger frequency offsets, the proposed OFDM system using the ICI self-cancellation scheme performs much better than standard OFDM systems. In addition, since no channel equalization is needed for reducing ICI, the conjugate cancellation scheme is therefore easy to implement without increasing system complexity.

7.CONCLUSION:

In this paper, we proposed a novel technique for OFDM systems which has double bandwidth efficiency than other two schemes. The BER of conjugate scheme when comparable to other cancellation scheme for frequency offsets performs better. Different modulation techniques are considered for ICI reduction and it is also suitable for multipath fading channels. It is less complex and effective. The new or modified self cancellation scheme is much better then ICI self cancellation and the conjugate cancellation scheme is much better then other two schemes. The conjugate scheme provides significant CIR improvement, which has been studied theoretically the proposed scheme is therefore easy to implement without increasing system complexity.

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