Volume 2, Issue 5, May 2012 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Reduction of Intercarrier Interference in Orthogonal Frequency Divisions Multiplexing Systems

Harjinder Singh
UCoE, Punjabi University Patiala
harjindr@gmail.com

Sandeep Kaur
UCoE, Punjabi University Patiala
sandeepbhullar647@gmail.com

***Abstract*— Future wireless communication system is expected to have a high data rate transmission. OFDM is a promising candidate for achieving high data rates in mobile environment because of its multicarrier modulation technique. A well-known problem of OFDM is its sensitivity to frequency offset between the transmitted and received carrier frequencies. This carrier frequency offset (FO) causes loss of orthogonality between sub-carriers and the signals transmitted on each carrier are not independent of each other. The orthogonality of the carriers is no longer maintained, which results in inter-carrier interference (ICI).In this paper frequency offset is reduced by using ICI self cancellation method and this scheme is confirmed through simulated results based on theoretical equations.**

***Keywords*— Orthogonal Frequency Division Multiplexing (OFDM), Intercarrier Interference (ICI), Frequency Offset (FO), ICI self cancellation (SC) and Carrier to Interference Power Ratio (CIR).**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is becoming the chosen multi-carrier modulation technique for wireless and multimedia communication systems. Multimedia wireless services require high-bit-rate transmission over mobile radio channels. OFDM can provide large data rates with sufficient robustness to radio channel impairments [1]. Because of high capacity transmission of OFDM, it has been applied to digital transmission system, such as digital audio broadcasting (DAB) system, digital video broadcasting TV (DVB-T) system, asymmetric digital subscriber line (ADSL), ultra-wideband (UWB) system [2], IEEE 802.11a/g Wireless Local Area Network (WLAN), IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMax) systems and HIPERLAN2 (High Performance Local Area Network) [9]. Its application in mobile communication is more complex especially because of the mobility of the mobile user; thus more exact symbol timing and frequency-offset control must be used to ensure that sub-carriers remain orthogonal. However, the difference between the frequency of the oscillator in the transmitter and the receiver causes frequency offset which if not estimated and compensated for could ruin the orthogonality of the subcarriers thereby causing large bit errors in the received signal [3].

In OFDM system two major problems are inter carrier interference and peak to average power ratio (PAPR). In this paper focus is on ICI caused by frequency offset which leads to loss of orthogonality [4]. Some techniques are previously developed for reducing the effect of ICI: Frequency offset estimation and compensation techniques, Doppler diversity [2], ICI self cancellation scheme [2] [6], Frequency domain equalization [2] [5] [6] but it only reduce the ICI caused by fading distortion which is not the major source of ICI. Time Domain Windowing [2] [5] [6] only reduce the ICI caused by band limited channel which is also not the major source of ICI. The major source of ICI in OFDM is its vulnerability to frequency offset errors between the transmitted and received signals, which may be caused by Doppler shift in the channel or by the difference between the transmitter and receiver local oscillator frequencies [5]. The works presented in this paper concentrate on a quantitative ICI power analysis of the ICI self cancellation scheme. The average carrier-to-interference power ratio (CIR) is used as the ICI level indicator, and a theoretical CIR expression is also derived.

The rest the paper is organized as follows: In section II, OFDM system model has been described. In section III, ICI Self Cancellation has been described.

.

II. OFDM SYSTEM MODEL

The basic OFDM system contains input data, serial to parallel transmission, modulation scheme, parallel to serial transmission, channel, demodulation scheme, IFFT and FFT as shown in figure 1. The input data stream is converted into parallel data stream and mapped with modulation scheme. Then the symbols are mapped with Inverse Fast Fourier Transform (IFFT) and converted to serial stream. The complete OFDM symbol is then transmitted through the channel.

On the receiver side this symbols are converted back to parallel stream and mapped with FFT scheme. Then the symbols are mapped with demodulation scheme and converted to serial data as output data.

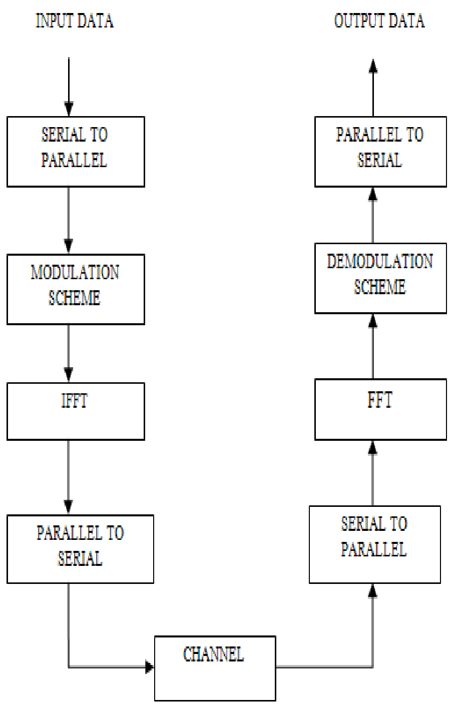

Fig 1: Block Diagram of FFT Based OFDM System

III. ICI SELF CANCELLATION SCHEME

A. Self-Cancellation

ICI self-cancellation is a scheme that was introduced by Zhao and Sven-Gustav Häggman in order to combat and suppress ICI in OFDM [8]. 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 [7]. Thus it is called self-cancellation method. The complex ICI coefficients S (*l*-k) are given by

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

Fig. 2 shows the amplitude of the *S*(*l*-*k*) where $l = 0$ and $N = 52$. The frequency offset values are $\varepsilon = 0.1, \varepsilon = 0.15, \varepsilon = 0.30$. It is evident that the amplitude of *S*(*l*-*k*) increases, when the frequency offset is getting larger and larger.

1. Cancellation Method

The data pair $(X, -X)$ is modulated on to two adjacent subcarriers$(l, l+1)$. The ICI signals generated by the subcarrier l will be cancelled out significantly by the ICI generated by the subcarrier $l+1$. The signal data redundancy

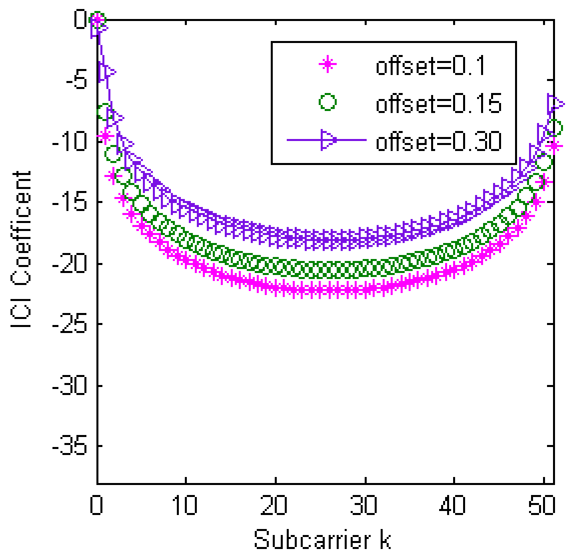

Fig 2: The amplitude of *S*(*l*-*k*)

makes it possible to improve the system performance at the receiver side. In considering a further reduction of ICI, the ICI cancellation demodulation scheme is used. In this scheme, signal at the (k +1) subcarrier is multiplied by"-1" and then added to the one at the k subcarrier. Then, the resulting data sequence is used for making symbol decision.

2. ICI cancelling modulation

In an OFDM communication system, assuming the channel frequency offset normalized by the subcarrier separation is ε and the ICI self-cancellation scheme requires that the transmitted signals be constrained such that X(1) = -X(0), X(3) = -X(2),......., X(N -1) = -X(N -2) using this assignment of transmitted symbols allows the received signal on subcarriers *k* to be written as[10].

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

Similarly the received signal on subcarrier *k*+1 becomes

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

In such a case, the ICI coefficient is denoted as (Zhao and Häggman, 2001),

$$S'(l-k) = S(l-k) - S(l+1-k) \quad (4)$$

Fig. 3 shows a comparison between |S'(l-k)| and |S(l-k)| on a logarithmic scale. It is seen that |S'(l-k)| << |S(l-k)| and

|S``(l-k)| is even smaller than|S(l-k)| for most of the l-k values. Hence, the ICI components are much smaller than they are in |S(l-k)|.

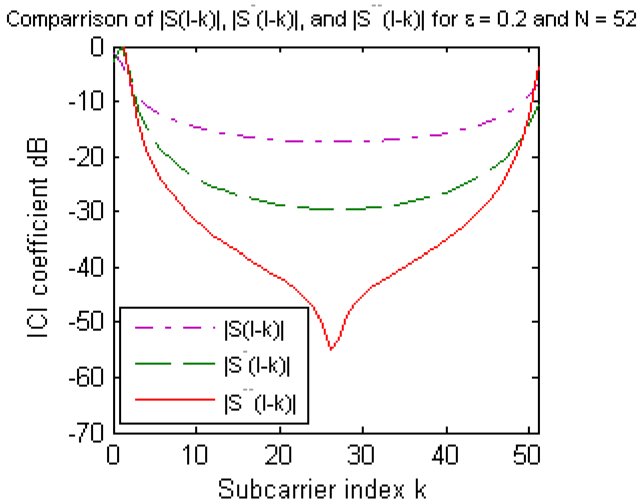

Fig 3: Comparison of |S(l-k)|, |S`(l-k)|, and |S``(l-k)| for N = 52 and ε = 0.2

3. ICI cancelling demodulation

To further reduce ICI, ICI cancelling demodulation is done. The demodulation is designed to work in such a way that each signal at the *k*+1th subcarrier (where *k* denotes even number) is multiplied by "-1" and then summed with the one at the *k*th subcarrier. Then the resultant data sequence is used for making symbol decision. It can be represented as

$$Y''(k) = Y'(k) - Y'(k+1) \quad (5)$$

$$Y''(k) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)[-S(l-k-1) + 2S(l-k) - S(l-k+1)] + n(k) - n(k+1) \quad (6)$$

The ICI coefficients for this received signal becomes (Yi-Hao Peng, 2007)

$$S''(l-k) = -S(l-k-1) + 2S(l-k) - S(l-k+1) \quad (7)$$

When compared to the two previous ICI coefficients |S (*l*-k)| for the standard OFDM system and |S'(*l*-k)| for the ICI canceling modulation, |S''(*l*-k)| has the smallest ICI coefficients, for the majority of l-k values, followed by |S' (*l*-k)| and |S (*l*-k)| [10]. This is shown in Figure 6 for N = 52 and ε = 0.4. The combined modulation and demodulation method is called the ICI self-cancellation scheme. The reduction of the ICI signal levels in the ICI self-cancellation scheme leads to a higher CIR.

The theoretical CIR is given by [2].

$$\text{CIR} = \frac{|-S(-1)+2S(0)-S(1)|^2}{\sum_{l=2,4,6}^{N-1} \left| -S(l-1)+2S(l)-S(l+1) \right|^2} \quad (8)$$

The theoretical curve calculated by Eq. 8 is shown in Figure 4. In this figure, the CIR with the ICI-self-cancellation scheme has a better performance than that without the scheme in OFDM systems.

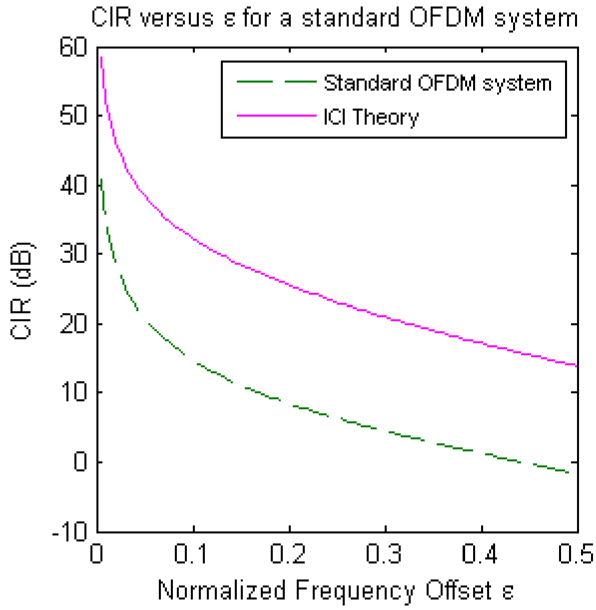

Fig 4: CIR versus ε for a standard OFDM system

V. CONCLUSION

The performance of OFDM systems in the presence of frequency offset between the transmitter and the receiver has been studied in terms of the Carrier-to-Interference ratio (CIR) and the bit error rate (BER) performance. Inter-carrier interference (ICI) which results from the frequency offset degrades the performance of the OFDM system. ICI self-cancellation (SC) method was explored in this paper. The self cancellation scheme reduces carrier frequency offsets existent between two adjacent subcarriers by cancelling out each other. The major advantage of this method is that it does not require very complex hardware or software for implementation. But there are two main drawbacks in this self-cancellation scheme. First, this scheme inherently reduces throughput and bandwidth efficiency by a factor of half due to the repetition symbols. Second, the cancellation capability is somewhat limited when large normalized frequency offset is present.

REFERENCES

[1] Arvind Kumar, Rajoo Pandey,"A bandwidth-efficient method for cancellation of ICI in OFDM systems," Int. J. Electron. Comm, vol. 63. pp. 569-575, 2009.

[2]Yi-Hao Peng, Ying-Chih Kuo, Gwo-Ruey Lee, Jyh-Horng Wen, Nat. Chung Cheng Univ., Chia-Yi, "Performance Analysis of a New ICI-Self-Cancellation-Scheme in OFDM Systems," IEEE Trans. vol. 53, pp. 1333 – 1338 2007.

[3] Shivangi Singh, Santosh Kumar Gupta, Dr. B.S.Rai, "Performance Evalutions to Remove CFO for Multicarrier Modulatin System ," IJECT Vol. 2, Issue 3, Sept. 2011.

[4] Alka Kalra, Dr. Rajesh Khanna, Tanvi Chawla,"BER Improvement Using Bandwidth Efficient ICI Self Cancellation Scheme in OFDM System," vol 2. JUNE 2011.

[5] Shruti M. Kallurwar, Rahila Patel, "An Experimental Study to Reduce the Effect of ICI in OFDM Based WLAN System," IJCST, vol. 3, Issue 1, MARCH 2012.
[6] Ze Zhu, Xiang Tang, JiZhang Zuo,"Self-Cancellation Method of OFDM ICI," IEEE Trans. pp. 1-5, 2008.
[7] Yuping Zhao and Sven-Gustav Häggman, "Intercarrier Interference Self-Cancellation Scheme," IEEE Trans. vol.49, JULY 2001.
[8] Dr. R.L.Yadav, Mrs.Dipti Sharma, "Comparasion of EKF and SC for OFDM ICI reduction," IJSTM, vol. 2, APRIL 2011.
[9] Haitham J. Taha, M.F.M. Salleh, "ICI Self - Cancellation for FFT-OFDM System," IEEE Trans. pp. 5621-5629, 2010.
[10] B.Sathish Kumar, K.R.Shankar Kumar, R.Radhakrishnan, "An Efficient Inter Carrier Interference Cancellation Schemes for OFDM Systems,"IJCSIS, vol.6, 2009.
[11] Ramjee Prasad, "OFDM for wireless communication system",Artech House, 2004.
[12] Theodore S. Rappaport, Wireless Communications Principles and Practice, 2nd ed. Dec 31, 2001.
[13] Adarsh B.Narasimhamurthy, Mahesh K.Banavar and Cihan Tepedelenliogu,"OFDM system for wireless communications.

Authors:

Harjinder Singh: Harjinder Singh is currently Assistant Professor at University College of Engineering, Punjabi University, Patiala, India. He has completed his B.Tech & M.Tech. from Guru Nanak Dev Engineering college Ludhiana , Punjab, India. Mr. Harjinder has 14 years of academic experience. His areas of interest are Wireless communication, Signal processing, Optical communication. He has to his credit many papers in international journals and national and international conferences.

Sandeep Kaur: Miss**.** Sandeep Kaur is currently pursuing M.TECH (final year) in department of Electronics and Communication Engineering at University College of Engineering, Punjabi University, Patiala. She has done her B.TECH. in trade electronics and communication engineering from Yadavindra College of Engineering, Punjabi University, Patiala. She has presented many papers in national and international conferences. Her topic of research is intercarrier interference in orthogonal frequency division multiplexing systems.