Comparative Study between ICI Self Cancellation and Symmetric Symbol Repetition

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Abstract. The frequency shifts created by the imperfections of local oscillators and the Doppler-effect generating inter-carrier interference responsible for the degradation of system performance. Several studies have been developed to reduce this interference. A comparative study of different methods facilitates the choice of the most appropriate algorithm. Our study investigates and compares two algorithms, the ICI Self Cancellation and Symmetric Symbol Repetition. In terms of CIR, it appears that the method of Symmetric Symbol Repetition offers better performance; however, these same performances degrade rapidly when the carrier offset frequency increases. In terms of performance stability, the ICI Self Cancellation is most appropriate.

Keywords: Orthogonal frequency division multiplexing (OFDM), Inter-carriers Interferences (ICI), Carrier to Interferences Ratio (CIR), Carrier Frequency Offset (CFO), ICI Self Cancellation, Symmetric Symbol Repetition (SSR).

1 Introduction

OFDM has been discovered in the sixties by chang (1966) [1], however, is through new technologies that the OFDM has emerged [2]. The OFDM has invaded the world of wireless communications such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB), and recently the OFDM has found several applications in the optical domain [3] - [4]. It is well known that OFDM is sensitive to carrier frequency offset. The frequency shift caused by the local oscillators and the Doppler-effect causes a loss of orthogonality and results in the appearance of inter-carrier interference (ICI). To overcome this problem, a number of algorithms have been developed. The first was the algorithm of ICI Self Cancellation [5], then the algorithm called Symmetric Symbol Repetition (SSR) [6] and lastly the method of conjugate transmission [7]. Our work is to make a comparative study between the algorithms mentioned. The outcome of the study leads us to say that the method of ICI Self Cancellation is more appropriate in a radio mobile channel, while the algorithm of SSR gives better performances in fixed links. This document is structured as follows; section 2 examines the OFDM characterized by CFO. Section 3 make a comparative study between two existing algorithms, the ICI Self Cancellation and the Symmetric Symbol Repetition. Section 4 concludes the work.

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2 OFDM Characterized by CFO

In digital communication, the transmitter and receiver can be either fixed or mobile. In a fixed link, the imperfections of the local oscillators of the transmitter and receiver are constant and therefore the carrier frequency offset is constant, whereas if the transmitter or the receiver moves, the carrier frequency offset is variable .

Due to the frequency difference between transmitter and receiver, the received signal after the bloc of Fast Fourier Transform (FFT) is equal to [5]:

$$Y(k) = X(k)S(0) + \sum_{\substack{m=0 \\ m\neq k}}^{N-1} X(m)\ S(m-k) \tag{1}$$

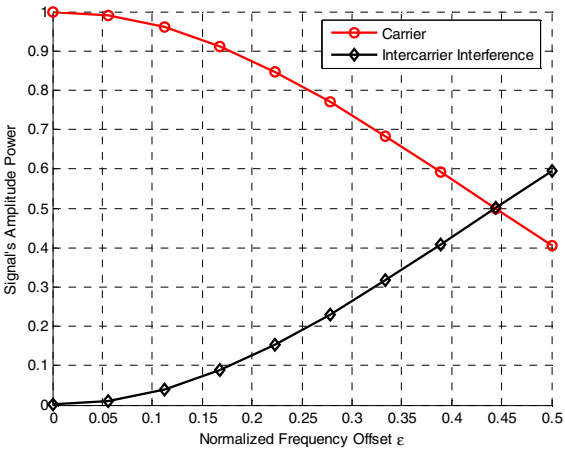

Fig. 1. Signal power and interference power

The complex coefficients are given by the relation [5]:

$$S(m-k) = \frac{sin\pi(m-k+\varepsilon)}{Nsin\frac{\pi}{N}(m-k+\varepsilon)} e^{j\pi(1-\frac{1}{N})(m-k+\varepsilon)} \tag{2}$$

Where ε represents the normalized carrier frequency offset. The carrier power is proportional to [8]:

$$|S(0)|^2 = \left|\frac{sin\pi\varepsilon}{Nsin\frac{\pi}{N}\varepsilon}\right|^2 \tag{3}$$

While the interferences power is proportional to [8]:

$$\sum_{\substack{m=0 \\ m\neq k}}^{N-1} |S(m-k)|^2 = \sum_{\substack{m=0 \\ m\neq k}}^{N-1} \left|\frac{sin\pi(m-k+\varepsilon)}{Nsin\frac{\pi}{N}(m-k+\varepsilon)}\right|^2 \tag{4}$$

Figure 1 describes the variation of useful signal power and interference power. We notice easily that when the normalized carrier frequency offset ε increases, the useful signal power deteriorates while the interference power increases.

3 Existing Algorithm

To minimize inter-carrier interference, different algorithms have been developed. Our choice was focused on the ICI self-cancellation and Symmetric Symbol repetition (SSR). The ICI Self Cancellation was proposed by Haggman and Zhao in 1996, and again in 2001[5]. The CIR of OFDM is given by the following equation [5]:

$$CIR_1 = \frac{|S(0)|^2}{\sum_{l=1}^{N-1}|S(l)|^2} \tag{5}$$

The CIR of ICI Cancellation is given by [5]:

$$CIR_2 = \frac{|2S(0) - S(1) - S(-1)|^2}{\sum_{\substack{l=2 \\ l\ even}}^{N-1} |2S(l) - S(l+1) - S(l-1)|^2} \tag{6}$$

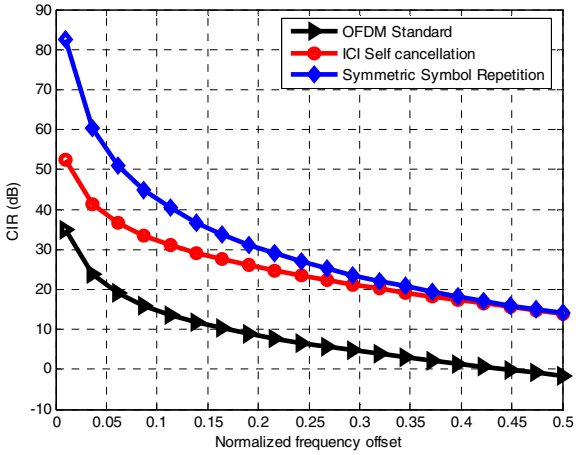

Fig. 2. Comparison between two algorithms

The Symmetric Symbol repetition (SSR) was proposed by Sathanathan [6], in 2000; the obtained CIR is written:

$$CIR_3 = \frac{|2S(0) - S(-1) - S(1)|^2}{\sum_{\substack{l=2 \\ l\ even}}^{N-1} |S(l) + S(N-l) - S(N-l-1) - S(l+1)|^2} \tag{7}$$

Figure 2 plots the different CIR. It clearly shows that both methods improve system performance, but that of symmetric Symbol Repetition is more efficient for small values of normalized carrier frequency offset ε.

To compare the two algorithms, we proposed two criteria for performance comparison; the gain and the stability of the CIR. We will calculate the CIR gain of the ICI Self Cancellation compared to OFDM, it is written as follows:

$$G = 10 * \log_{10}(CIR_2) - 10 * log_{10}(CIR_1) \quad (8)$$

Similarly, we calculate the gain of CIR of Symmetric Symbol Repetition compared to OFDM:

$$G = 10 * \log_{10}(CIR_3) - 10 * log_{10}(CIR_1) \quad (9)$$

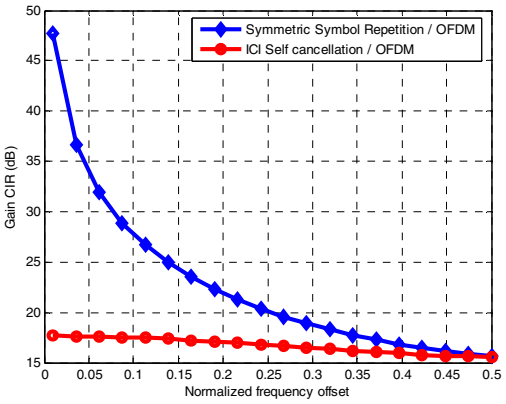

Fig. 3. Gain of the CIR ICI Cancellation and Symmetric Symbol Repetition compared to OFDM

Figure 3 plots the CIR gain of different algorithms studied. For a normalized carrier frequency offset ε which varies from 0 to 0.5, the ICI Self Cancellation gain compared to the OFDM varies from17.65 to 15.65dB. For the same normalized carrier frequency offset ε, the symmetric Symbol Repetition gain compared to the OFDM varies from 47.65 to 15.65dB. The algorithm of symmetric Symbol Repetition is therefore more efficient.

Two situations exist in a digital communication. The transmitter and receiver can be fixed or they can be moving. In the case of a fixed link, the CFO is constant and therefore the objective is to increase performance. The algorithm of SSR is most appropriate because he gives the best performance regardless of the value of CFO. In the case of a mobile link, the CFO is variable, we obtain stable performance. The ICI Self Cancellation algorithm is most appropriate because it gives more stable performance, because it is less sensitive to large variations of the CFO.

4 Conclusion

In this paper, we have studied the OFDM in a channel characterized by the carrier frequency offset. To reduce inter-carrier interference, we studied two different algorithms. If the objective is increased performance, then the algorithm of symmetric Symbol Repetition is required. If instead, the channelis variable, the algorithm of ICI Self Cancellation is required due to its stability.

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