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Performance Improvement of OFDM System with CFO using ISP Pulse Shaping Technique

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***Abstract*—Remarkable progress has been established in wireless communication system due to accomplishment of OFDM system. Although it's many advantages, performance of OFDM system is degraded due to the CFO (Carrier frequency offset).Doppler shift and frequency mismatch are responsible for introducing CFO which is demolish the orthogonality between the subcarriers and generate ICI. In this paper performance of OFDM system is evaluated with CFO in terms of BER and after that by using ISP pulse shaping technique performance of OFDM system is improved. Results obtained by simulation shows that introducing CFO degrades the performance and introducing ISP pulse shaping technique improved the performance of OFDM system. Computer simulation has been done by using MATLAB software.**

***Index Terms*— Orthogonal Frequency Division Multiplexing (OFDM), Carrier Frequency Offset (CFO), Improved Sinc Power pulse (ISP), Inter Carrier Interferences (ICI), Signal to Noise Ratio (SNR), Bit Error Rate (BER).**

I. INTRODUCTION

It has been proven that Orthogonal Frequency Division Multiplexing (OFDM) system has reached high data speed transmission in wireless environment due to its ability to decompose a wideband frequency selective fading channel in to several parallel narrow band flat fading channels [1],[2].Multi-path delay spread tolerance, immunity to frequency selective fading channels, high spectral efficiency, efficient modulation and demodulation techniques and robust to impulse noise are the foremost advantages of OFDM system [3],[4]. OFDM technique has potential of increasing the data rate in band limited channel. However, inter-carrier interferences (ICI) and high peak to average power ratio (PAPR) are main downsides of OFDM system [2], [3].

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A lot of research has been carried out for reducing the two major limitations of OFDM system and to boost up the overall Performance of the system.

One of the limitation is sensitivity of OFDM signal against carrier frequency offset which destroys the orthogonality between subcarriers and causes inter-carrier interferences (ICI) [2],[3],[4],[5],[6],[7],[8]. To make reliable data decision the ICI of OFDM system has to be reduced. For that perfect and capable ICI reduction technique is necessary to demodulate the received data .Numerous techniques have been offered to reduce ICI like Frequency domain equalization, windowing at the receiver, ICI self-cancellation and use of pulse shaping [9]. Another one limitation is the large variation in envelope of OFDM signal, which causes high peak-to-average power ratio (PAPR) [2, 3].

Simulation results show that introducing CFO degrades the performance and introducing ISP pulse shaping technique improved the performance. Also it has been observed that ISP pulse shape provides better improvement in comparison of without pulse shaping OFDM system.

In this paper, Section 2 introduces OFDM System model with Effect of CFO and ISP pulse shaping functions is listed in Section 3. Section 4 includes simulation results. Lastly, conclusion of the paper is given in Section 5.

II. SYSTEM MODEL

OFDM communication system with pulse shaping function has been shown in Figure 1. In this system QPSK constellation is used to mapped binary information. The high speed serial data stream is split up in to a set of low speed sub streams and modulated onto the orthogonal carriers through Inverse Fast Fourier transform (IFFT). Signal s (t) which is represented as in (2.1) is transmitted through the channel with ISP pulse shaping functions [2].

OFDM block with pulse-shaping is represented as:

$$s(t) = e^{j2\pi f_c t} \sum_{k=0}^{N-1} D_k \, p(t) e^{j2\pi f_k t} \qquad (2.1)$$

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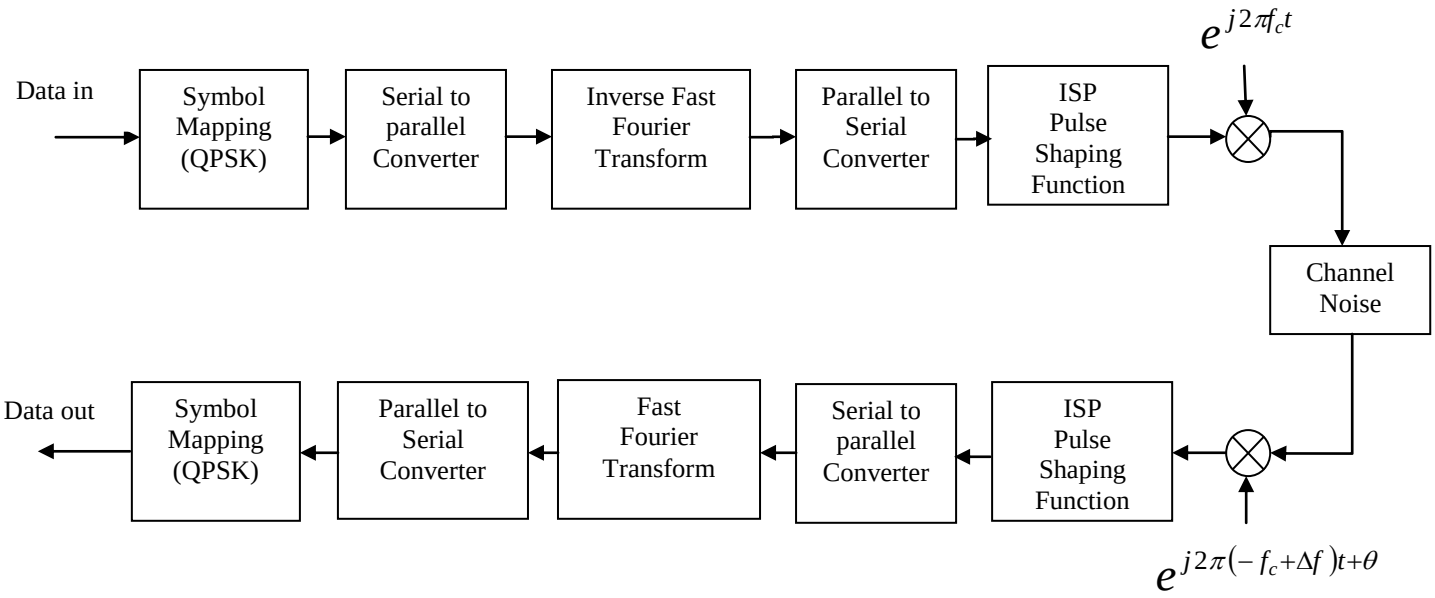

Figure1: Simulation Block diagram of OFDM System

Where j= $\sqrt{-1}$, Number of subcarrier is N, Carrier frequency of OFDM system is f_c, Subcarrier frequency of the K_{th} subcarrier is f_k, Where $k = 0, 1\ldots N-1$, Time limited pulse shaping function is p (t). Transmitted symbol is D_k which is assumed to have zero mean and normalized average symbol energy. Also we consider that all data symbols are uncorrelated [10, 11] i.e.:

$$E\left[D_k D^*_m\right]=\begin{cases}1, & k=m, k, m=0,1,\ldots., N-1\\ 0, & k\neq m, k, m=0,1,\ldots., N-1\end{cases} \quad (2.2)$$

Where D^*_m is the complex conjugate of D_k .To ensure the orthogonality of subcarrier, it is very important to satisfied the below equation for OFDM system [10, 11]. The subcarrier frequency is

$$f_k=\frac{k}{T_s}; \qquad k=0,1,\ldots.N-1$$

$$f_k-f_m=\frac{k-m}{T_s}, \qquad k,m=0,1,\ldots\ldots., N-1 \quad (2.3)$$

For maintaining orthogonality between subcarriers, the minimum required subcarrier frequency spacing is $1/T_s$ .The received signal at the receiver can be represented as:

$$r(t)=s(t)\otimes h(t)+w(t) \quad (2.4)$$

In above equation convolution is denoted by $\otimes$, channel impulse response is h (t) and the additive white Gaussian noise is represented by w (t) which process with zero mean and variance $N_0/2$ per dimension

Ideal channel is assume for this work, i.e., h (t) = $\delta(t)$ in order to investigate the effect of the frequency offset only on the ICI performance. At the receiver, the received signal r' (t) becomes:

$$r'(t)=e^{j2\pi\Delta f_c t+\theta}\sum_{k=0}^{N-1}D_k p(t)e^{j2\pi f_k t}+w(t)e^{j2\pi(-f_c+\Delta f)t+\theta} \quad (2.5)$$

Where the phase error is θ and Δf is the carrier frequency offset between transmitter and receiver oscillators.

III. PULSE SHAPING FUNCTION

In the OFDM spectrum each carrier is represented by main lobe with a number of side lobes having lower amplitudes. Since peak power is associated with main lobe and ICI power is associated with side lobes, so the intention of pulse shaping function is to increase the width of main lobe and/or reduce the amplitude of side lobes [10]. Proper pulse shaping techniques makes a digital communication system possible to transmit data within a limited BW with minimum ISI [12, 13].

Simple implementation, independent of number of carriers, no affect in coding rate, and large reduction in PAPR are some good properties of pulse shaping filter. Also BER performance can be enhance and achieve spectral occupancy by it. In RF communication it is necessary to make signal fit in its frequency band which is accomplished by pulse shaping filter.

In this section ISP pulse shaping functions have been introduced and its Fourier transforms are given as [2, 3, 4, 7, 10, 13].

The pulse shaping functions is

$$P_{ISP}(f) = \exp(-a(fT)^2)\sin c^n(fT) \qquad (3.1)$$

To adjust the amplitude of improved sinc power pulse design parameter 'a' is used in equation (3.1), the degree of sinc power pulse is 'n'. [2, 3, 6, 7, 10].

IV. SIMULATION RESULTS

To demonstrate the performance enhancement of shaping the OFDM system, the simulation results have been done by using the ISP time-limited pulse shaping function which have been mentioned in section 3.

4.1 *Impulse response of ISP pulse with values of a (0.5, 1).*

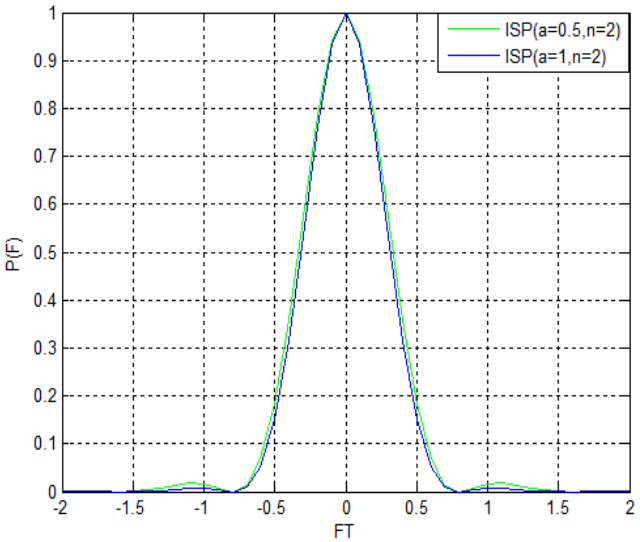

Figure 2: Impulse response of ISP pulse shape.

ISP pulse is depicted in Figure 2 with values of 'a' (0.5, 1) where the amplitude of ISP pulse is adjusted by varying a design parameter 'a' and the degree of the Sinc function is *n*. As the value of design parameter 'a' increases from 0.5 to 1, the width of the main lobe is further reducing up to some extent. But after that for very large values of a, ISP pulse shape become to a very narrow pulse shape which is not preferred for the system having frequency offset.

4.2 *Frequency Spectrum of ISP pulse*

Frequency Spectrum of ISP pulse has been shown in figure 3.From the simulation result it can be observed that ISP pulse is showing better spectrum because width of the main lobe is increases and the amplitude of side lobes is reduces.

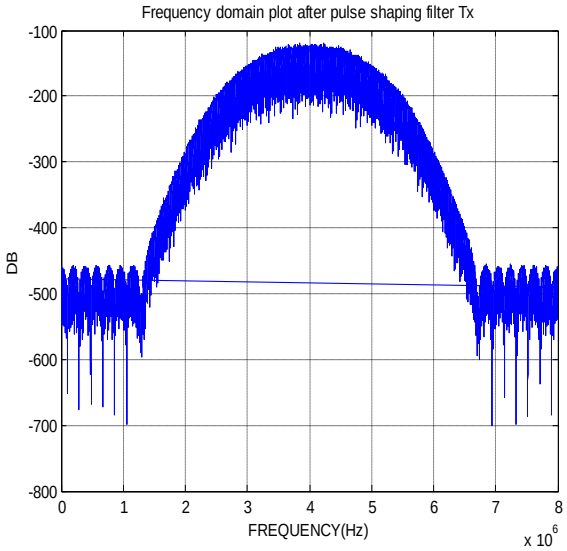

Figure 3: Spectrum performance using ISP pulse

So ultimately it reduces the ICI and also observed that ISP is more spectrum efficient in comparison of without pulse shaping technique.

4.3 *BER comparison of OFDM system with offset and pulse shaping function.*

Simulation parameters which have been used are as follows:

FFT size: 64; No. of subcarriers: 52; No. of Symbols: 10000 and 2 bits per symbol. Channel: AWGN. Cyclic prefix duration: 0.8µs. SNR: 1 to 25.

4.3.1 *BER comparison of OFDM system with different values of CFO*

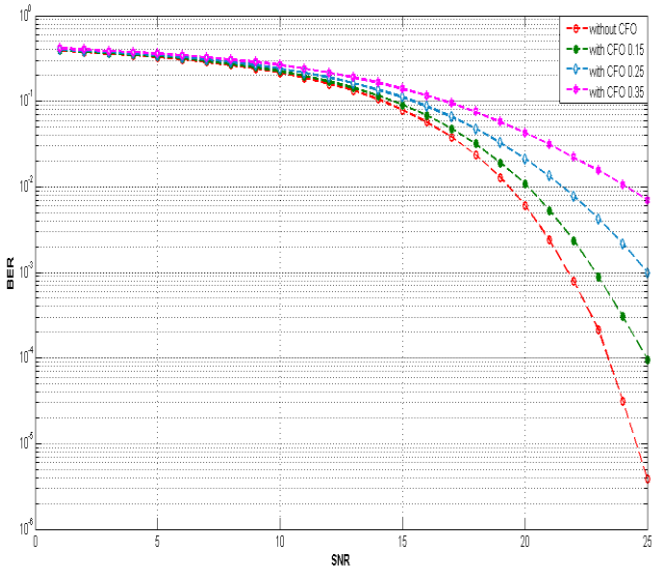

Figure 4: BER Comparison of OFDM system with and Without CFO

The impact of CFO on the accuracy of OFDM system is investigated in Figure 4, where the BER is shown as a function of SNR assuming that all values of CFO have the same average power. The performance of BER degrades as the values of CFO increases. It is observed that BER is higher when the value of frequency offset is more because of the Doppler shift or frequency mismatch.

4.3.2 *BER comparison of OFDM system with and without CFO using ISP*

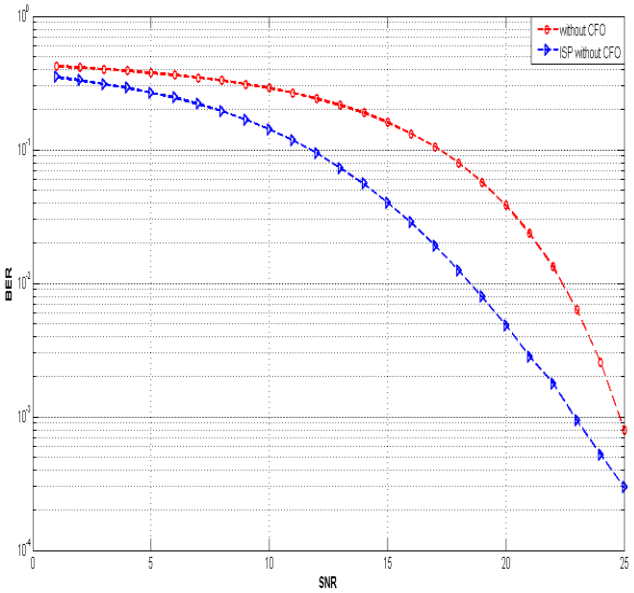

Figure 5: BER improvement of OFDM system without CFO using ISP technique

By using ISP pulse shaping technique the BER performance can be improved for Without CFO - OFDM system as shown in figure 5.

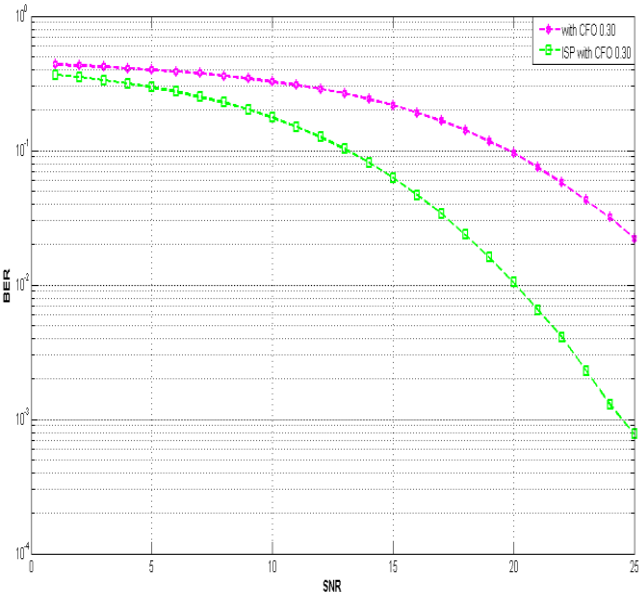

Figure 6: BER improvement of OFDM system with CFO using ISP technique

By using ISP pulse shaping technique the BER performance can be improved for With CFO-OFDM system as shown in figure 6.

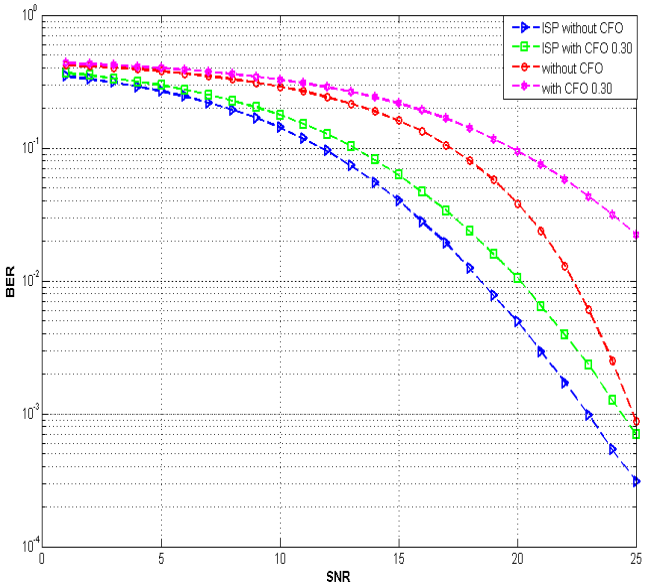

Figure 7: Comparison of OFDM system with & without using ISP technique

OFDM system with and without CFO and ISP pulse shaping function as depicted in figure 7.It has been observed that the BER performance improved by approximately 5 dB in without CFO OFDM system and 7dB in with CFO OFDM system by using ISP pulse shaping.

V. CONCLUSION

In this paper, the performance of OFDM system with and without CFO using ISP pulse shaping technique has been evaluated in terms of SNR and BER. From the simulation results it has been observed that Introducing CFO degrades the performance and shaping the OFDM system by ISP pulse significantly enhances the performance.

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