Performance Analysis of OFDM System Using ISP Pulse Shaping Technique

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Abstract— Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique, in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers, which are orthogonal to each other. Some of its main advantages are multipath delay spread tolerance, high spectral efficiency, efficient modulation and demodulation procedure using computationally efficient Inverse Fast Fourier Transform and Fast Fourier Transform process correspondingly. OFDM is very sensitive to carrier frequency offset, which affect the orthogonality among the subcarriers and results causes Inter carrier interference (ICI). The BER performance of OFDM system is evaluated for ICI reduction using ISP pulse shaping techniques with the effect of CFO.

Index Terms—Additive White Gaussian Noise (OFDM) Channel, Carrier Frequency Offset (CFO), Inter Carrier Interference (ICI), Orthogonal Frequency Division Multiplexing (OFDM), Cyclic Prefix (CP), Rectangular Pulse (REC), Raised Cosine Pulse (RC), Better than Raised Cosine Pulse (BTRC), Sinc Power Pulse (SP) and Improved Sinc Power Pulse (ISP)

1 INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is broadly known as the efficient communication in the broadband wireless mobile communication system due to the high spectral efficiency and robustness to the multi path interference. Currently, OFDM is adopt in many communication systems, such as Worldwide Interoperability for Microwave Access (WiMAX), digital video broadcasting (DVB) system, HIPERLAN2 (High Performance Local Area Network) and Wireless Local Area Network (WLAN) systems. In OFDM, the entire spectrum is divided into narrow-banded subcarriers that provide resistance against frequency-selectivity of the channel. However, one of the problems in the OFDM systems is its vulnerability to the frequency offset errors caused by frequency mismatch at oscillator or the Doppler frequency shift due to mobility. In such situations, the orthogonality of the subcarriers is no longer maintained that results in inter-carrier interference (ICI), which degrades the system performance.

The undesired ICI degrades the performance of the system. It is not possible to make reliable data decisions unless the ICI power of OFDM systems is minimized. Thus, an accurate and efficient Inter Carrier Interference (ICI) reduction procedure is necessary to demodulate the received data. Some methods have been presented to reduce ICI, including frequency domain equalization, windowing at the receiver, ICI self-cancellation scheme, and the use of pulse shaping. The performance of a pulse shaping function is evaluate and compared with the parameters such as ICI power, BER (Bit Error Rate) [2].

2 OFDM SYSTEM MODEL

Figure 1 shows the block diagram of a typical OFDM transceiver with various pulses shaping function. The transmitter section converts digital data to be transmitted, into a mapping of subcarrier amplitude and phase. It then transforms this spectral representation of the data into the time domain using an Inverse Fast Fourier Transform (IFFT). The In order to transmit the OFDM signal the calculated time domain signal is then mixed up to the required frequency.
The receiver performs the reverse operation of the transmitter, mixing the RF signal to base band for processing, then using a Fast Fourier Transform (FFT) to analyze the signal in the frequency domain. The amplitude and phase of the subcarriers is then picked out and converted back to digital data. The IFFT and the FFT are complementary function and the most appropriate term depends on whether the signal is being received or generated. In cases where the signal is independent of this distinction then the term FFT and IFFT is used interchangeably.

### 3 PULSE SHAPING FUNCTIONS

In the OFDM spectrum, each carrier consist of a main lobe followed by a number of sides lobes with reducing amplitude. As long as Orthogonality is maintained there is no interference among the carriers because at the peak of the every carrier, there exist a spectral null. That is at that point the component of all other carriers is zero. Hence the individual carrier is easily separated. When there is a frequency offset the Orthogonality is lost because now the spectral null does not coincide to the peak of the individual carriers. So some power of the side lobes exists at the centre of the individual carriers which is called ICI power. The ICI power will go on increasing as the frequency offset increases. Now the purpose of pulse shaping is to reduce the side lobes [6]. If the side lobe can reduced significantly then the ICI power will also be reduced significantly. Hence a number of pulse shaping functions are proposed having an aim to reduce the side lobe as much as possible.

A number of pulse shaping functions such as Rectangular pulse (REC), raised cosine pulse (RC), Better then raised cosine pulse (BTRC), Sinc power pulse (SP) and Improved Sinc power pulse (ISP) have been considered for ICI power reduction. The functions are defined as below:

#### Rectangular pulse,

\[
P_{RECT}(f) = \sin(fT)
\]  

(1)

#### Raised cosine pulse,

\[
P_{RC}(f) = \sin(fT) \frac{\cos(\pi \alpha fT)}{1 - (2\alpha fT)^2}
\]  

(2)

#### Better than raised cosine pulse,

\[
P_{BRC}(f) = \sin(fT) \frac{2\beta T \sin(\pi \alpha fT) + 2\cos(\pi \alpha fT) - 1}{1 - (\beta fT)^2}
\]  

(3)

#### Sinc power pulse,

\[
P_{SP}(f) = \sin c^K(fT)
\]  

(4)

#### Improved Sinc power pulse,

\[
P_{ISP}(f) = \exp(-a(fT)^2) \sin c^K(fT)
\]  

(5)

Where \(0 \leq \alpha \leq 1\) is the roll of factor, \(a\) is a design parameter to adjust the amplitude and \(K\) is the degree of the Sinc function.

### 4 SIMULATION PARAMETER

An OFDM system has been modeled using MATLAB to allow various parameters of the system to be varied and simulated. The aim of doing the simulations is to measure the performance enhancement of shaping the OFDM system using the various time-limited pulse shaping functions under different mapping schemes and channel conditions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFFT size</td>
<td>64</td>
</tr>
</tbody>
</table>

Table I Simulation Parameter
Number of Carriers in One OFDM signal: 52
Channel: AWGN
Frequency offset: 0, 0.30, 0.45
Modulation: BPSK
OFDM symbol for one loop: 100000

5 SIMULATION RESULT

5.1 Comparison of All Pulses

From figure 2, it is observed that width of ISP main lobe is narrower in time domain as compared to other existing pulses which leads less ISI. It can also be observed that rectangular pulse shape has maximum and ISP pulse shape has minimum side lobes amplitude. So ISP pulse shape is less affected by ICI power than those of other pulse shapes because lesser the side lobes lesser the ICI power.

5.2 ICI Power Analysis

The average ICI power across different sequences can be calculated as

\[ \bar{\Delta^2}_{\text{ICI}} = E[\Delta^2_{\text{ICI}_m}] = \sum_{k=0}^{N-1} \left| \frac{k-m}{T} + \Delta f \right|^2 \]

5.2.1 ICI power performance for different power pulses

Figure 3 shows the average ICI power of a 52 subcarrier OFDM system with respect to the normalized frequency offset. In this figure the pulse shape parameters are selected as, \( \alpha = 1 \), \( n = 2 \), and \( a = 1 \). It is illustrated that the average ICI power is minimum for ISP pulse shape compared to all other pulse shapes. Thus ISP pulse shape outperforms all other pulse shapes in terms of ICI power reduction.

To evaluate the BER performance of pulse shaping technique first the effect of frequency offset on BER performance is investigated using the OFDM model given in figure 1. The different simulation parameters considered are as follows.

5.3 BER Comparison for Various Pulses

In this simulation part various pulse shaping techniques along with different mapping schemes have been considered.

To evaluate the BER performance of pulse shaping technique first the effect of frequency offset on BER performance is investigated using the OFDM model given in figure 1

5.3.1 BER Performance of OFDM Signal
Fig. 4 BER performance of OFDM signal

Performance of BER is shown in figure 3. It is observe that by increasing the value of SNR performance of BER is degraded. From the figure it is observe that BER achieves $8 \times 10^{-1}$ at 15 dB of SNR where at 20 dB of SNR, BER achieves $5 \times 10^{-2}$.

5.3.2 BER performance of OFDM system with ISP and without ISP

![Fig. 5 BER Performance of OFDM System with ISP and without ISP](image)

From figure 5 it is observe that OFDM system with ISP gives better performance in terms of Bit Error Rate (BER) compare to OFDM without ISP as error is reduced in the case of OFDM with ISP.

5.3.3 BER performance with different value of offset

![Fig. 6 BER Performance with Different Value of Offset](image)

From figure 6 it is observe that, in OFDM system with ISP if we increase the value of SNR Bit Error Rate (BER) also increase and performance of OFDM system degrade compare to without CFO.

5.4.4 BER comparison with ISP without ISP and with offset

![Fig. 7 BER Comparisons with ISP without ISP and with Offset](image)

Figure 7 shows the BER comparision of OFDM sytem with ISP , Without ISP and effect of CFO without ISP . and it is observed that ISP performs better as compared to without ISP OFDM system and in presence of CFO also it gives better performance in terms of BER.

VII. CONCLUSION

A number of pulse shaping functions like REC,RECT,RC,BTRC,SP,ISP are considered for ICI power reduction. Due to the carrier frequency offset undesired offset is occur in OFDM system which leads to ICI and it is estimated by pulse shaping. Simulation results shows that ISP pulse shapes provides better performance compare to other pulse shaping function.

REFERENCES


