Comparative Analysis of PAPR Reduction Techniques in OFDM System

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***Abstract*— This presents a unique Weighted Orthogonal Frequency Division Multiplexing (WOFDM) system for high speed wireless communications. OFDM a popular technique and is advantageous over other modulation techniques. OFDM signals bandwidth efficiency is increased since serial data is multiplexed in to large number of orthogonal sub channels. The main drawback in OFDM system is high PAPR. To overcome this problem, WOFDM signal is used without causing any distortion in weight removing at receiver side. The performance is analyzed through simulations. According to numerical results obtained PAPR and BER of proposed scheme is reduced compared to Clipping OFDM method**.

***Keywords---* OFDM, PAPR, Clipping OFDM, Weighted OFDM, BER, SNR.**

I. INTRODUCTION

Recently there is a high demand for multimedia data services which give us a life in the age of 4th generation wireless communication system. By using of multimedia data service, where the users are in large number with bounded spectrum and this modern digital wireless communication system has a requirement to adopt a technology which is bandwidth efficient and which is robust against multipath channel environment and that technology is known as multicarrier communication system [1], [2]. It provides high speed data rate at minimum cost for many users as well as with high reliability by using advance digital multicarrier wireless communication system. If we talk about single carrier system it requires the entire communication bandwidth but in multicarrier system the available communication bandwidth is divided in many subcarriers. In the multicarrier system each subcarrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These positive features of multicarrier technique encourage us to study OFDM. It is a platform for all 4G wireless communication systems due to its huge capacity in terms of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility.

OFDM is used in many high data rate wireless systems. Since the overall channel in OFDM is divided into multiple narrowband signals, it is more resistant to frequency selective fading than single carrier systems. It also makes efficient use of the available spectrum and the channel equalization in OFDM is much simpler. The entire link failure happens due to a single fade or interference in a single carrier system but only a small percent of the subcarriers will be affected in case of a multicarrier system, and one of the main reason to use OFDM is its high robustness against narrowband interference. The first person to suggest OFDM for wireless communications was Climini in 1985. The advancements in the DSP hardware in the early 1990s made OFDM a realistic option for wireless systems. In OFDM, the information is split into N parallel streams and are transmitted by modulating N distinct carriers. The pecularity of OFDM is the orthogonality of sub-carriers.

The main drawback of OFDM is its Peak-to-Average Power Ratio (PAPR) due to a noise like amplitude variation and a high dyanamic range in the OFDM signal. These high peaks can be alleviated by techniques like clipping, weighted OFDM method, Selected Mapping and so on, out of which clipping is the simplest method but it leads to signal distortion.

Seema Kushwah [1] described various properties of an OFDM system and the performance for different methods like normal OFDM, convolution scheme, weighted OFDM and modified weighted OFDM system. Veena Gopinath[2] described various challenges in OFDM system and solutions. The author presented a weighted OFDM system to improve the performance of the system. C.Kayalvizhi & C.Paranitharan[3] addressed the merits and demerits of OFDM system and the advantages of weighted OFDM over conventional OFDM.The authors[4][5][10] described the differences between conventional and weighted OFDM in terms of bit error rate. The authors[6] [7] presented the importance of OFDM and PAPR reduction techniques. Xiaodong Li, J. Armstrong [8][9]discussed the effects of Clipping and Filtering on the Performance of OFDM.

Section II explains the causes and criteria to select methods for PAPR reduction. The proposed method called weighted OFDM, to reduce PAPR, is described in section III, followed by simulation results and conclusion in section IV and section V respectively

II. PEAK TO AVERAGE POWER RATIO

The signal distortion at the nonlinear high power amplifier of the transmitter occurs due to the high PAPR of the transmitted signal. The main idea to reduce PAPR is to improve the Bit Error Rate (BER) performance of an OFDM signal. PAPR arises due to the occurrence of out of phase of the different subcarriers in a multicarrier system. The peak value of the system can be very high as compared to the average of the whole system when there are a huge number of independently modulated subcarriers in an OFDM system. The spiky power spectrum at the IFFT output results in high PAPR[2].

Because of high PAPR, RF amplifiers need to be operated in a very large linear region, leading to complexity of the desired system. Several techniques such as clipping, peak windowing, coding and so on have been developed for PAPR reduction. However, these methods fail to achieve PAPR reduction with low complexity and without performance degradation. The criteria for selecting a method to reduce PAPR include

- Average power should be low.
- Bandwidth expansion is not needed.
- Implementation complexity should be small.
- No need of additional power.
- Bit Error Rate (BER) should be negligible/low.

Techniques for PAPR reduction may vary according to system requirement and is dependent on factors namely, data rate loss, computation complexity, spectral efficiency etc. Many techniques have been suggested to reduce PAPR with different levels of complexity and are categorized into two groups called signal scrambling and signal distortion techniques. Selected mapping, partial transmit sequence and tone injection/rejection comes under signal scrambling technique whereas clipping & filtering, peak windowing and envelope scaling comes under signal distortion technique[6][7].

In an OFDM system Orthogonality plays an important role in OFDM system and is defined as the integral of the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. The orthogonality condition for continuous time signal can be written as

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)\,dt = 0$$

For discrete time signal condition is

$$\sum_{k=0}^{N-1} \cos(2\pi kn/N)\cos(2\pi kn/N) = 0$$

Where n and m are two different integers of the different signals, f_0 is the fundamental frequency of the subcarriers and T is the time period over which we have taken integration. The block diagram of an OFDM system is shown in Figure 1.

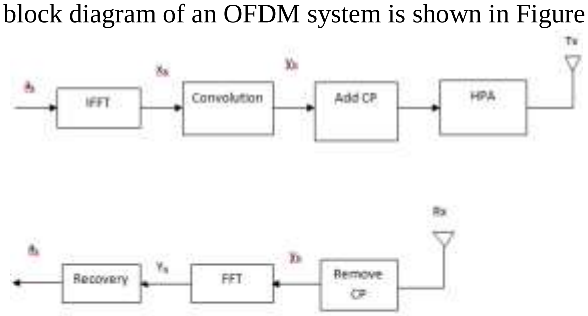

Fig.1. Block diagram of an OFDM system with convolution scheme

Figure.1shows the block diagram of convolutional OFDM system. Iterative clipping and filtering (ICF) is a widely used technique to reduce the peak-to-average power ratio (PAPR) of OFDM signals. In frequency domain with rectangular window, it requires more number of iterations to approach specified PAPR threshold in the Complementary Cumulative Distribution Function (CCDF). Simulation results show that our proposed method can give better SNR and reduced PAPR than ICF method.

III. WEIGHTED OFDM METHODOLOGY

A weighted OFDM signal is provided and the method is motivated by circular convolution so that PAPR of the convoluted signal can be reduced. Later, the simulation results tell us that weighted OFDM signal can provide much SER performance than that of clipping method. In clipping method, whenever the OFDM signal exceeds the predefined threshold level, that portion of the signal level will be clipped. The clipping method is not generally used since it causes signal distortion, low bit rate, high bit error and performance degradation of the system.

To overcome the drawbacks in previous method a W OFDM signal is provided and it is motivated by circular convolution method so that PAPR of the convoluted signal can be reduced [10]. Later, the simulation results tell us that WOFDM signal can provide much BER performance than that of normal clipping method.

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TABLE I
Simulation Parameters

Parameters	Values of parameters
Size of OFDM Symbol N	64
Number of OFDM symbols to be simulated m	32
Size of Alphabet M	16
Up-sampling factor L	1.5
Type of Mapping	QAM
Constellation Phase Offset	Zero
Constellation Symbol Order	Gray

Size of cyclic prefix samples Ncp	<N
Channel	Additive White GaussianNoise(AWGN)

The input parameters for the proposed work are shown in Table I.

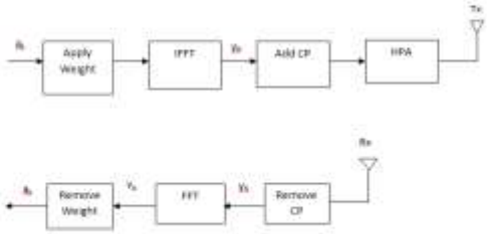

Fig.2. Block diagram of an OFDM system with weighting scheme

The block diagram of proposed work is shown in Fig. 2. It clearly describes step by step procedure and the functional blocks of proposed system.

I. IMPLEMENTATION RESULTS AND DISCUSSION

The input signal used in simulation is 16QAM signal with size 64.

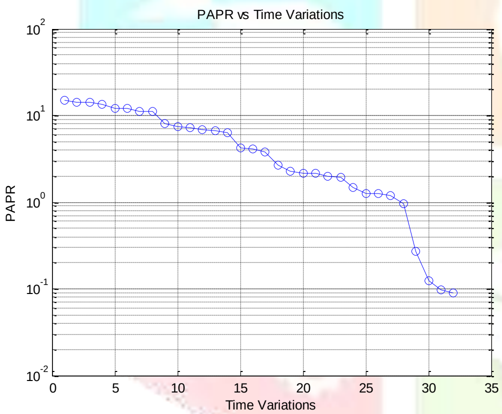

Fig.3.PAPR vs Time Variations

Figure.3 shows the plot between PAPR verses time variations in seconds for Weighted OFDM system. PAPR is reduced due to the increase of time variations.

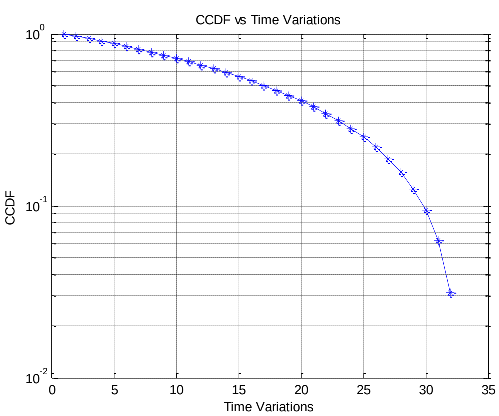

Fig.4.Complementary CDF vs Time Variations

Figure.4 gives plot between CCDF and PAPR with FFT-64 for weighted OFDM.

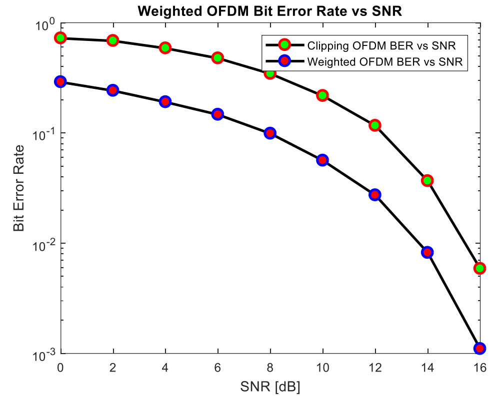

Fig.5 Bit Error Rate vs SNR

The simulation results in figure.5 show that the relation between Bit Error Rate verses Signal to Noise Ratio in terms of decibels. In this paper BER is decreased due to the increase of SNR. Weighted OFDM gives better results than Clipping OFDM.

TABLE III

BER Comparisons between Clipping and WOFDM techniques

SNR in dB	**BER**	
	Clipping OFDM	**Weighted OFDM**
0	0.722	0.289
2	0.684	0.241
4	0.586	0.190
6	0.475	0.146
8	0.344	0.098
10	0.216	0.056
12	0.116	0.027
14	0.037	0.008
16	0.005	0.001

Bit Error Rate comparisons for both Clippling and Weighted OFDM(WOFDM) techniques are shown in Table II. In both methods BER is reduced due to the increase of SNR. Compare to first method proposed method BER is better. For example at 0dB BER for clipping method is 0.722 and for weighted OFDM is 0.289.For 10dB SNR first method gives 0.216 and proposed one gives 0.056.

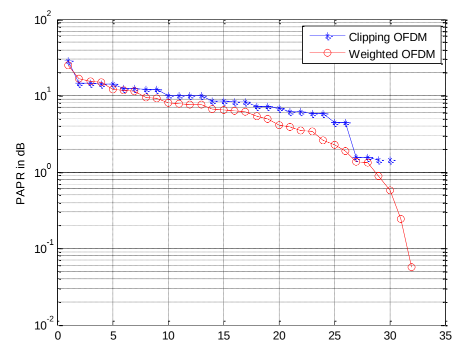

Fig.6.PAPR Comparisons between Clipping and WOFDM

In figure.6 we can see that the PAPR reduction for Weighted OFDM is better than Clipping OFDM for various values of SNR in dB.

TABLE IIIII
PAPR Reduction Comparisons between Clipping and Weighted OFDM techniques

Time Variations	PAPR	
	Clipping OFDM	Weighted OFDM
5	14.23	12.02
10	10.11	8.05
15	8.44	6.44
20	6.86	4.09
25	4.47	2.26
30	1.44	0.57

PAPR for the different time variations are shown in Table III. In both methods PAPR is reduced due to the increase of time variations. Compare to first method proposed method PAPR reduction is better. For example at 5 iterations PAPR for clipping method is 14.23 and for weighted OFDM is 12.02. For 30 iterations first method gives 1.44 and proposed one gives 0.57.Hence, we can clearly observed that the WOFDM outperforms Clipping OFDM.

Conclusion

In this paper, the advantages and disadvantages of an OFDM system are analyzed. The symbol-error rate is also plotted against the signal–to–noise ratio to understand the performance for clipping and weighted OFDM system. The simulation results show that, application of the algorithm results in significant reduction in the PAPR values. It was clearly observed that the PAPR reduction in proposed approach better than that of clipping OFDM, and the BER performance is improved and all simulations are carried out using MATLAB

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