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Comparative Analysis of Weighted OFDM Technique with Various PAPR Reduction Techniques in OFDM System

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Abstract:

Orthogonal Frequency Division Multiplexing is a technique which is used in next generation mobile radio communication systems. OFDM signals bandwidth efficiency is increased since here serial data is multiplexed in to large number of sub channels which are orthogonal to each other which helps in the reconstruction of the original signal at the receiver. The main disadvantage of OFDM is that it has got high PAPR(Peak To Average Power Ratio) . In this paper we explore comparative analysis between various techniques that can be employed to reduce PAPR resulted from OFDM. The performance is analyzed through simulations. According to numerical results obtained, PAPR and BER of a system is reduced significantly by using Weighted OFDM scheme as compared to Clipping OFDM method and to Partial Transmit Sequence PAPR reduction technique.

Keywords — **OFDM, PAPR, Clipping OFDM, Weighted OFDM, Partial Transmit Scheme, BER, SNR.**

I. INTRODUCTION

Multi-carrier modulation (MCM) is a method of transmitting data by splitting it into several components, and sending each of these components over separate carrier signals. The composite signal can have broad bandwidth and can be split to multiple individual carriers with a narrow bandwidth. This technique is employed in a modern digital wireless communication system with a bounded spectrum and large number of users, making it bandwidth efficient. High data rates at cost efficiency can be achieved by using advance digital multicarrier wireless communication system. In single carrier system an entire communication bandwidth is needed but in multicarrier system the available communication bandwidth is divided in many subcarriers. Each subcarrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These advantages of multicarrier technique encourage us to implement OFDM for real time communication. All 4G wireless communication systems can Utilize OFDM as a platform because of its huge capacity of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility. It has many advantages such as high bit rate, strong immunity to multipath and high spectral efficiency.

In this method of digital signal modulation, a single data stream is split across several narrowband channels at different frequencies. Narrow band channels with different frequencies reduces the interference and cross talk. Numerous closely spaced orthogonal sub-carrier signals with overlapping spectra are emitted to carry data.
Each sub carrier is modulated using a conventional modulation scheme such as QAM (Quadrature Amplitude Modulation) or Phase Shift Keying at low symbol rates to maintain the data rates similar to the conventional single carrier modulation schemes in the same bandwidth. The main advantage of OFDM digital modulation over single-carrier schemes is its ability to cope with severe channel conditions such as attenuation of

high frequencies, narrowband interference and frequency selective fading due to multipath without complex equalization filters

However, one of the most serious problems in OFDM is the high Peak-to-Average Power Ratio (PAPR) of the transmitted OFDM signal, since these large peaks introduce a serious degradation in performance when the signal passes through a nonlinear High-Power Amplifier (HPA). The non linearity of HPA leads to in band distortion which increases Bit Error Rate (BER) and out-of band radiation, which causes which causes adjacent channel interference thus degrading the performance of the OFDM. These high peaks can be alleviated by techniques like clipping, weighted OFDM method, Partial Transmit Scheme and so on, out of which clipping is the simplest method but it leads to signal distortion.

In Section II, the causes for PAPR and criteria to select methods for PAPR reduction is explained. A comparative analysis between various PAPR reduction techniques is described in section III, followed by simulation results and conclusion in section IV and section V respectively

II. PEAK TO AVERAGE POWER RATIO (PAPR)

When the phase of different sub carriers in the OFDM system add up to form large peaks, it gives rise to PAPR . 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 sub-carriers 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 reduction of PAPR is to improve the Bit Error Rate (BER) performance of an OFDM signal. The criteria for selecting a method to reduce PAPR include

- Low Average Power.
- No Need of Bandwidth expansion.
- Less implementation complexity.
- No need of additional power.
- Bit Error Rate (BER) should be negligible/low.

Different techniques for the PAPR reduction can be used based on system requirement and technique choice is dependent on factors namely, data rate loss, computation complexity, spectral efficiency etc. Techniques 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.

Since the overlapping sub carriers are orthogonal to each other, the integral of the product of two signals is zero over a time period. 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.

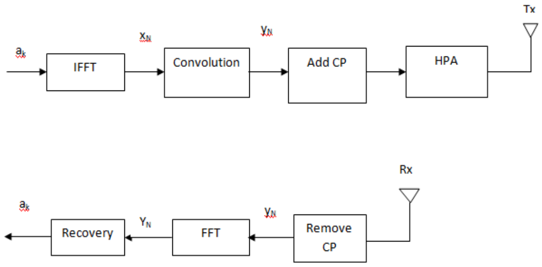

Fig.1. Block diagram of an OFDM system with convolution scheme

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. . COMPARISON BETWEEN VARIOUS PAPR REDUCTION TECHNIQUES

CLIPPING:

Clipping and Filtering reduces PAPR when compared to conventional OFDM systems. Here the signal is clipped at transmitter and filtered at the receiver. In band distortion and out of band distortion occurring at HPA. The advantage is out of band distortion is avoided but disadvantage is that it has got in band distortion un avoided.

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. Where as in PTS technique the performance degradation is less but it requires high number of computations increasing the complexity of the system.

The drawbacks in the clipping and PTS methods can be overcome by using Weighted OFDM technique which can provide much BER performance than that of normal clipping method.

WEIGHTED OFDM :

A weighted OFDM signal is provided and the method is motivated by circular convolution so that PAPR of the convoluted signal can be reduced.

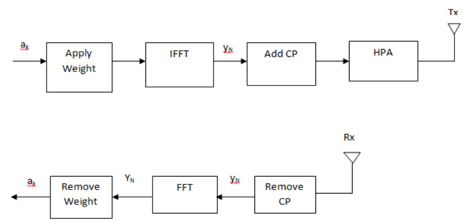

Fig.2. Block diagram of an OFDM system with weighting scheme

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.

In weighted OFDM the modulated signal is convoluted with a special kind of signal. The special signal is chosen in such a way that its fourier transform has no zero on the real line. The weighted OFDM signal is the given convoluted signal. The idea here used is a convolution process. Here the modulated signal is convoluted with a special kind of signal Φ. The signal is chosen in such a way that its Fourier transform has no zero on the real line. The weighted OFDM signal is the given convoluted signal. In this proposed scheme the weighted modulated signal is given to the IFFT block where signal is converted from frequency domain to time domain. Then cyclic prefix is added to reduce ISI. Then
it is given to HPA and is finally transmitted. In the receiver the reverse of transmitter side takes place

When adding, the weight it is non uniform , it cause degradation to bit error performance. So to avoid that in this scheme a positive constant is added to the original weight. This constant is taken randomly. Convoluted signal can be written as a weighted OFDM signal.

Partial Transit Scheme:

In the PTS approach, the input data block is partitioned into disjoint sub blocks or clusters which are combined to minimize the PAPR [5]. Define the data block,[Xn,n=0,1……N-1],as a vector ,X=[X0,X1……XN-1]T. Then, partition X into M disjoint sets, represented by the vectors [Xm,m=1,2……M]. The objective of the PTS approach is to form a weighted combination of the M clusters,

$$\mathbf{X}' = \sum_{m=1}^{M} b_m \mathbf{X}_m$$

Where [bm , m=1,2……..M] are weighting factors and are assumed to be pure rotations[6]. After transforming to the time domain, the above equation becomes

$$\mathbf{x}' = \sum_{m=1}^{M} b_m \mathbf{x}_m$$

The vector $\mathbf{x}_m$, called the partial transmit sequence, is the IFFT of $\mathbf{X}_m$**[7].** The phase factors are then chosen to minimize the PAPR of $\mathbf{x}'$. A PTS transmitter is shown in Fig 3.

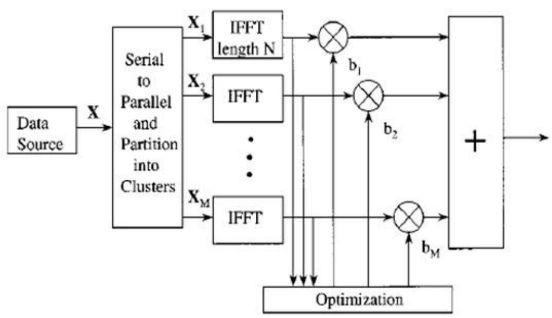

Fig-3

In this technique IFFT is used which is divided into two parts. An intermediate sequence is formed by the partial transformation of the input symbol sequence using the first L stages of the IFFT. This intermediate sequence is partitioned into intermediate subsequence. In this intermediate sub signal sequence remaining (N-L) stages are applied thus formed subsequences are summed to OFDM symbols. This method has a disadvantage of high computational complexity since each iteration is partitioned and also provides less PAPR as when compared to the clipping and the weighted OFDM PAPR reduction techniques.

I. IMPLEMENTATION RESULTS AND DISCUSSION

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

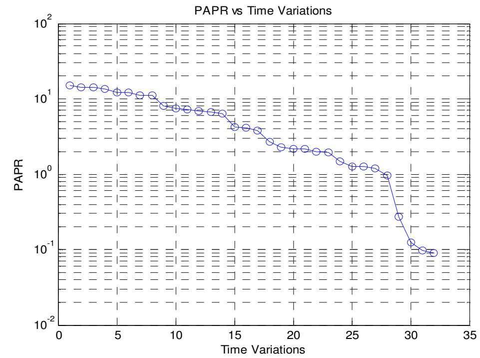

Fig.4.PAPR vs Time Variations

Figure.4 shows the plot between PAPR verses time variations in seconds for Weighted OFDM system. PAPR is reduced due to the increase of time variations.

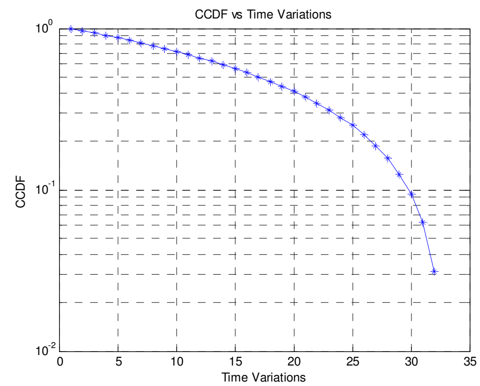

Fig.5.Complementary CDF vs Time Variations

Figure.5 gives plot between CCDF and PAPR with FFT-64 for weighted OFDM.

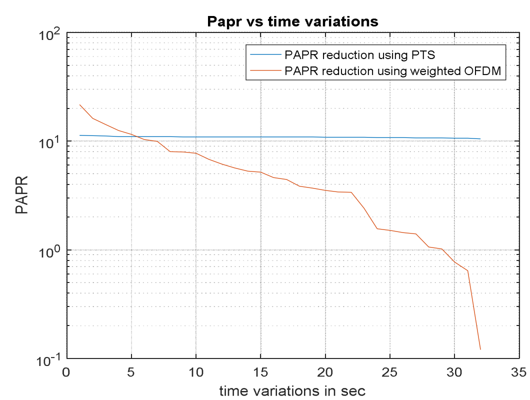

Fig.6.PAPR Comparisons between PTS and WOFDM

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

TABLE 1
PAPR Reduction Comparisons between PTS and Weighted OFDM techniques

Time Variations	PAPR	
	PTS	Weighted OFDM
5	11.09	12.02
10	11.28	8.05
15	10.93	6.44
20	10.86	4.09
25	10.81	2.26
30	10.66	0.57

PAPR for the different time variations are shown in Table 1.

In both methods PAPR is reduced due to the increase
of time variations. Upon comparison, the reduction of the PAPR in PTS technique is less as when compared to the weighted OFDM technique over a period of time variations.

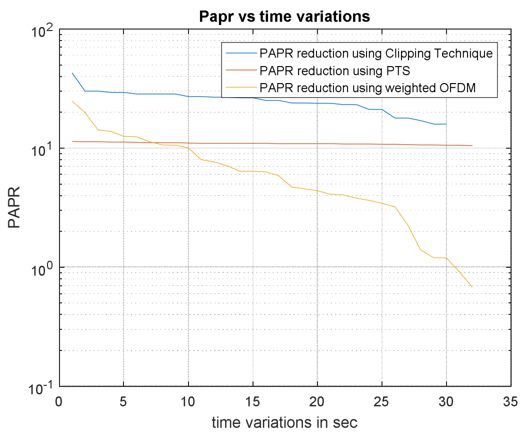

Fig.7.PAPR Comparisons between clipping, PTS and WOFDM

Simulation in the Fig.7. gives a comparison between the PAPR reduction vs Time Variations for Clipping ,PTS and Weighted OFDM PAPR reduction techniques.

TABLE 2
PAPR Reduction Comparisons between Clipping, PTS and Weighted OFDM techniques

Time Variations	PAPR		
	Clipping OFDM	PTS	Weighted OFDM
5	29.30	11.19	12.53
10	26.98	10.06	10.06
15	26.39	10.95	6.388
20	23.71	10.88	4.382
25	21.15	10.76	3.442
30	15.92	10.56	1.191

PAPR for the different time variations are shown in Table 2.

The PAPR is reduced along with the time variations in the following PAPR reduction techniques. Upon comparison Weighted OFDM outperforms both Clipping and PTS in terms of PAPR reduction. The PTS provides better PAPR reduction than that of Clipping Technique. The PAPR in clipping technique can be increased by reducing the threshold signal value which can cause signal distortions.

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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