A PAPR reduction analysis of various techniques in OFDM system

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Abstract— **Communication is one of the important aspects of life. With the increasing demand of transpiring voice, data communication and video over the internet in the developing 4G wireless communication system that experienced a fast growth due to high mobility they allow. The advancement in signal processing and very large scale integrated circuit make it an efficient implementation of FFT operations so that OFDM gives a luring solution for wireless channels. As we all know OFDM is a multicarrier communication technique that is used both in wired and wireless communication. One of the major problem occurred in OFDM is peak to average power ratio (PAPR). In order to minimize the PAPR problem of OFDM signal with distortion and distortion less techniques in communication system. This gives a clear understanding of different techniques to reduce PAPR and BER of the signal. The analysis of the performance of some commonly used techniques and proposed an improved technique from one of those techniques.**

Keywords- ***Orthogonal frequency division multiplexing (OFDM), peak to average power ratio (PAPR), bit error rate (BER), selective mapping (SLM).***

I. INTRODUCTION

With the increasing requirement of high data rate wireless communications, OFDM is one of the good wireless access technologies. Traditionally single carrier modulation techniques can achieve only limited data rates because limitation imposed by the effect of multipath on wireless channel. In wireless multimedia applications high data rate is desired. The main accuse of OFDM on high-speed equalization was not important because information was sent equally on different subcarriers [1]. Orthogonal Frequency Division Multiplexing (OFDM) is important wireless technologies of multiple-carrier modulation as it offers high spectral efficiency, resistant to delay spread and reduced inter symbol interference (ISI) [2]. OFDM has been widely deployed in many wireless communication standards such as mobile World-wide interoperability for Microwave Access (WIMAX), dedicated short range communication (DSRC), 4G cellular systems, Digital Video Broadcasting (DVB), and Long Term Evolution (LTE). Regardless of its advantages, the major drawbacks of OFDM system is the high PAPR value which leads to power inefficiency and signal interference because of power amplifiers used. This problem increases the quantization errors, data rate; also degrade in the system performance [3]. Orthogonality between the sub carriers minimizes interference. OFDM is to crack the high speed wireless communication technologies and combining them can provide wireless evolution from 3G to 4G system. OFDM is a set of frequency division multiplexing in which multiple sub carriers are utilized by single channel on adjacent frequencies. It can be either a multiplexing technique or a modulation technique. In this system, PAPR is an unpredictable outcome. Especially, Complementary Cumulative Distribution Function (CCDF) is a basic parameter to measure PAPR. Several authors have proposed various schemes for reducing the peak magnitude of the transmitted signal, which include selective mapping, clipping and filtering, coding, partial transmit sequence, Turbo Coded technique and companding technique. The average value is less than the peak value of the independently modulated sub-carriers in OFDM system. The ratio of the peak value to the average value is called peak-to-average power ratio (PAPR) [4]. Although the advantage of OFDM is high frequency spectrum efficiency, robust to channel fading, insusceptible to compact interference, strong echoes can be handling and distortion is less nonlinear. It has disadvantage of high PAPR and synchronization. To overcome PAPR, randomizer is used that spreads the energy across wide bandwidth. Multi-carrier modulation (MCM) is a technique to split the data into various elements, and then sending each of these elements over separate carrier signals. Recently, as a means of enhancing the bandwidth of digital communications over media with physical limitations, MCM is used [5]. This technique is used in some audio broadcast services. A large PAPR increases the complexity of the analog to digital converter and digital to analog converter and reduces the spectral efficiency.

II. OFDM BASICS

OFDM is a technique that transmits data by using a large number of narrow-band subcarriers. In this a higher bit rate channel is divided into orthogonal sub channels in the lower bit rate frequency domain. The time synchronization and

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frequency spacing and of the subcarriers are chosen in such a way that they are orthogonal to each other, means that they do not cause interference to each other. The name 'OFDM' is derived from the fact that the digital data is transmitted in parallel using many subcarriers, each of a different frequency (Frequency Division Multiplexing), which are orthogonal to each other, hence Orthogonal Frequency Division Multiplexing [6]. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Orthogonal frequency division multiplexing (OFDM) has become a popular modulation technique in high-speed wireless communications system. As data is sent parallel on different subcarriers there is no need of high-speed equalization in OFDM system. In an OFDM system, data is varied in the frequency domain to *N* adjacent subcarriers. These *N* subcarriers span a bandwidth of *B* Hz and are detached by a spacing of $\Delta f = B/N$. The continuous-time baseband representation of this is

$$x(t) = 1/\sqrt{N} \sum_{k=0}^{N-1} X[k]\, e^{j2\Pi\Delta fkt/T} \qquad t \in [0, T] \qquad (1)$$

where $T = 1/\Delta f$ is the symbol period and $\{ X[k] \}$ k=0 to N-1 are the data symbols drawn from a finite constellation. In existing wireless communication systems, a user can choose between either a high data rate or a high mobility. For multimedia applications, high data rate is important. OFDM is also used for dedicated short range communication (DSRC) for road side to vehicle communication and also as a backbone for fourth generation (4G) mobile wireless system. Different FFT sizes have different impact on BER. For OFDM, there are no such non- linear effects as error propagation, coding and lower constellation sizes can be employed to provide fall-back rates that are significantly robust against delay spread [7].

Pros and Cons of OFDM

There are many advantages of OFDM system:
• OFDM is an efficient way to deal with multipath, in a given delay spread.
• OFDM is less sensitive to sample timing offsets than the single carrier systems.
• OFDM provides good protection against narrowband and co- channel interference.
• OFDM makes single frequency networks (transmitter macro diversity) possible, which is especially attractive for broadcasting applications.
On the other hand, it has two main drawbacks:
• OFDM is more sensitive to frequency error and phase noise.
• OFDM has large peak to average power ratio (PAPR), which tends to reduce the efficiency and synchronization problem to sample the incoming signal correctly.
The graphical representation of OFDM problem of High PAPR, sensitive to Doppler shift and frequency synchronization are shown in Fig.1.

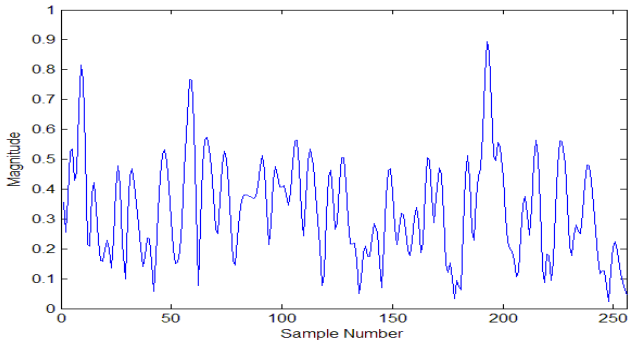

FIG.1 HIGH PAPR

III. PAPR REDUCTION TECHNIQUES

Peak to average power ratio can be defined as the ratio of peak power of the signal to its average power of the system. It is the measure of the amplitude fluctuations of the signal. PAPR is increased because of the occurrence of large amount of sub-carriers that are modulated independently in OFDM system and the signals which undergoes coherent addition resulting in same phase. An OFDM signal consists of 'N' data symbols that are modulated independently on N orthogonal subcarriers, and then with the same phase, these N signals are added, high peak amplitude is estimated [8]. The value of this high peak may be N times of the average amplitude. As a result it leads to the certain disadvantages which show complexity of converters and reduction in efficiency of power amplifiers. The PAPR of the OFDM transmitted signal x (t) is the ratio of the maximum instantaneous power and the average power.

By definition,

$$\text{PAPR} = \max \frac{[x(t)]^2}{E[(t)]^2} \qquad (2)$$

where x (t) is the original signal
$\max[x(t)]^2$ is the peak signal power
$E[x(t)]^2$ is the average signal power
Where E [.] is the expectation operator.

The major impact of a high PAPR are-
1. Increased complexity

2. Reduction in efficiency of radio frequency (RF) amplifiers.

Leman Dewangan et al. [9] discussed various PAPR reduction schemes for OFDM signal along with their benefits and drawbacks. Various methods are promoted to overcome these disadvantages and suggest some new techniques. These PAPR reduction techniques results in PAPR and BER performance degradation when compared with the original OFDM signal. Efficient scheme is proposed to reduce PAPR to minimum without affecting system performance with low implementation cost.

INDIVIDUAL TECHNIQUES

Several PAPR reduction techniques have been discussed. These techniques are divided into two groups - signal scrambling techniques and signal distortion techniques which are shown as:

a) Signal Scrambling Techniques

- Block Coding Scheme
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

b) Signal Distortion Techniques

- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier
- Clipping and Filtering

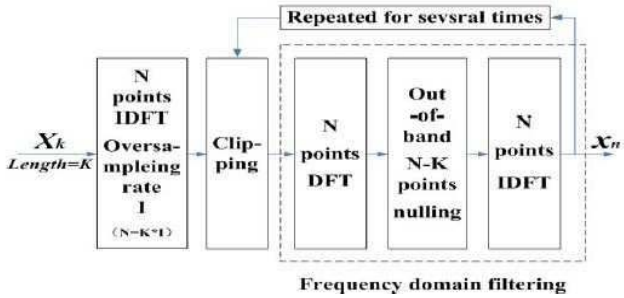

Fig. 2 Clipping and Filtering technique

One of the most pragmatic and easiest approaches is clipping and filtering as shown in Fig.2 in which signal above a predetermined threshold level is clipping which introduces both in-band and out-of-band distortion that can destroy orthogonality of the subcarriers. Clipping also introduces peak regrowth in OFDM signal which can be reduced by Deep Clipping. The filtering processes repeated several times to remove peak re-growth of the signal. Clipping operation is always performed to sample a signal to reduce in-band distortion. Cimini et al. [10] have presented the simplest method for reducing PAPR for multicarrier transmission system which is known as amplitude clipping and filtering method. Here the signals are clipped before amplification which is more efficient technique for PAPR reduction. As clipping of signal is a nonlinear process which caused major in-band distortion that degrades the BER performance and out-of-band radiation, minimize the spectral efficiency. Other PAPR reduction technique is Peak Windowing with improved spectral efficiency but it increase out of band radiation and BER.

Peak Windowing

It is an improved clipping method. The basic aim of peak windowing is to reduce the out-of-band radiation by attenuate the peak signals using narrow band windows such as Gaussian window. .In this scheme a predetermined threshold level is defined and if the peak goes beyond this threshold level, it is multiplied by a window function. The most commonly used window functions are Cosine, Kaiser, Hamming and Gaussian Windows etc. Fig.3 shows the OFDM transmitter with peak windowing technique. Peak windowing scheme does not employ hard clipping and therefore, gives good result as compared to clipping technique but still interference can't be avoided completely. Dongwan Kim et al. [11], discussed various schemes that are peak windowing method, clipping and filtering technique, in order to minimize PAPR in OFDM

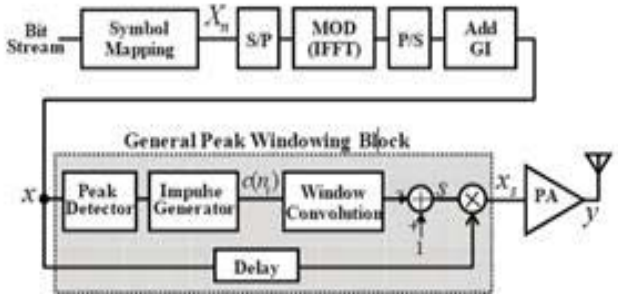

Fig.3 OFDM Transmitter with Peak Windowing

system. In spite of these schemes to reduce the peak values regardless of the pattern, it does not efficiently reduce PAPR by error vector magnitude (EVM) and adjacent channel leakage ratio (ACLR). In this, advanced peak-windowing scheme is used that selects the best PAPR reduction scheme corresponding to PAPR pattern.

Coding methods

The method is proposed to design block codes that not only reduce the PAPR, but also give error correction capability.

Probabilistic (Scrambling) techniques

The probabilistic methods are based on distortion less techniques OFDM system with different scrambling sequences and selecting that sequence which gives smallest PAPR.

Selective Mapping (SLM)

In SLM technique the input data symbols are multiplied by each of the phase sequences and generate alternative new input symbol sequences. Each of these phase multiplied input data sequences is made the IFFT operation as shown in Fig.4 [8]. Computational complexity, PAPR reduction capability and avoiding Side Information are the major issues associated with SLM. Salini I V et al. [12] expressed a hybrid technique of Conventional SLM to reduce PAPR. In this method the iteration of IFFT blocks are reduced

through the partitioning of subcarriers. It also reduced the computational complexity of the system. This method removes the transmission of phase sequence as side information if the phase sequence amplitude is greater than 1. This method gives better reduction in PAPR with good efficiency. Also, Bauml et al. [13], proposed SLM a simple distortion less technique at the transmitter, where phase series are generated randomly from the constellation set {+1, +j}. A favourable signal is selected from a set of various signals where all represents the same information and that sequences which have lowest PAPR are chosen for transmission. Thus, the probability of PAPR exceeding some threshold was made as small as possible at the expense of added complexity.

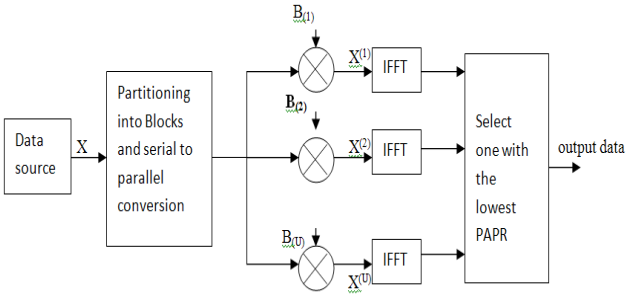

Fig.4 Selective mapping technique

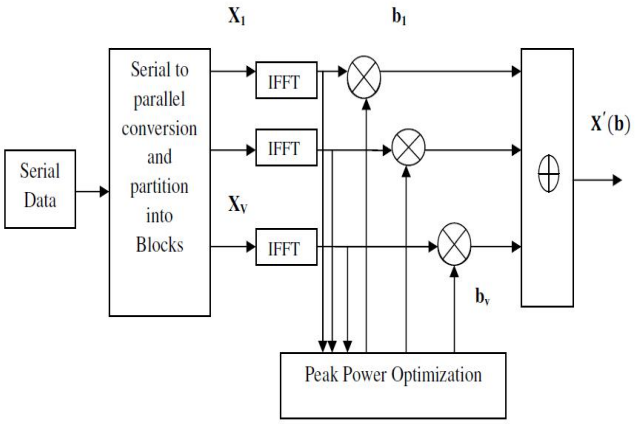

Fig.5 *PAPR reduction using PTS technique*

Partial Transmit Sequence (PTS)

In PTS, the original data block is divided into multiple non-overlapping sub-blocks into several sub sequences and for each sequence multiply by different weights until an optimum value is obtained. After that, the signal with the lowest PAPR is chosen for transmission. A block diagram of PTS technique is shown in Fig. 5. Various techniques are suggested in literature to reduce computational complexity of the PTS scheme.

Prof S.G. Hate et al. [14] defines the significance of multicarrier transmission in wireless communication system. It preside high data rate with the drawback of high PAPR in OFDM system. The high PAPR causes interference. The analysis of PAPR reduction technique such as Partial Time Sequence (PTS) with diverse sub sequences is done in this paper and concludes that PTS technique is the most appropriate technique for PAPR reduction.

Tone Reservation (TR)

The main idea of this method is to keep a small set of tones for PAPR reduction. In this the objective is to find the time domain signal to be added with data block to the original time domain signal so that PAPR is reduced. The amount of PAPR reduction depends on some factors such as the data rate loss occurs with increase in power and complexity [15].

Active Constellation Extension (ACE)

This technique acquire extend of outer constellation points to decrease PAPR in OFDM system. It simultaneously decreases the BER with reduction of peak amplitude of the data symbol. Active constellation extension is a PAPR reduction technique similar to tone injection scheme [16]. Also the block size and constellation size are most importantly considered. Further, there is no requirement of side information without any loss in data rate in OFDM system. An active channel extension with QPSK modulation encoding scheme is shown in Fig.6.

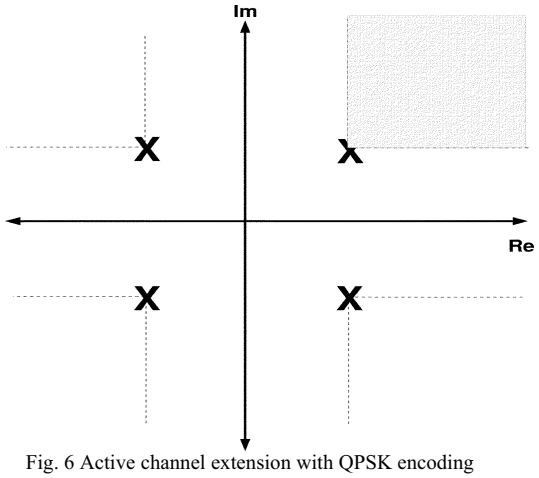

Fig. 6 Active channel extension with QPSK encoding

COMBINED TECHNIQUES

A combined technique describe better performance than individual techniques. Dr. D. Sriram Kumar et al. [17] defines Distortion and Distortion less Methods to analyse and determine PAPR reduction in OFDM system to reduce the effect of inter symbol interference. In this paper the analysis of PAPR reduction performance of OFDM system are Clipping, Clipping and Filtering technique and PTS method with different number of sub sequences. From the results, clipping method demonstrate good PAPR reduction

with large amount of BER degradation. PTS has better PAPR reduction capability but with high complexity. Combined techniques are as follows:

1. JOINT PEAK WINDOWING AND CLIPPING SCHEME

Considering some drawbacks of individual techniques such as out- of- band radiation, spectral efficiency etc. a new distortion scheme is introduced for PAPR reduction that used IDFT interpolation method in order to improve interpolation precision. Also the bit error rate is also improved.

2. ACTIVE CONSTELLATION METHOD WITH TONE RESERVATION

A new PAPR reduction technique based on combination of ACE method with tone reservation method is proposed. In the hybrid technique the ACE method may be implemented using different constellation restrictions, obtaining different PAPR reduction levels and BER performances. Tone reservation use different set of values for no data subcarriers. Depending on this it reduces complexity and PAPR reduction strength may also vary [18].

3. JOINT COMPANDING TRANSFORM WITH HADAMARD TRANSFORM

In this method Joint companding transform and Hadamard Transform both are used to reduce PAPR of OFDM signal. In this Hadamard Transform is applied before the IFFT function and companding transform is applied after the IFFT function at the transmitting end while Inverse Companding Transform is applied before FFT and Inverse Hadamard Transform is applied after FFT at the receiver end. This method gives good performance in BER, also PAPR reduction performance is also get improved [19].

4. DCT COMBINED WITH SLM

In this method, DCT is combined with SLM using Riemann Sequence which is more effective than both individual and combined PAPR reduction methods. If DCT is carried out before SLM then 1.8db PAPR reduction is achieved while if SLM is carried out before DCT then 1.2 dB PAPR is occurred [19].

The survey of literature review includes different methods of PAPR reduction done by various researchers. All the reports showed that Peak to Average Power Ratio reduction is must in data transmission through multicarrier communication (MCM). The major difficulty of multicarrier system is that they display the big response to nonlinear distortion as it degrade BER performance of the system and increase in interference, data missing, respectively. A research is never ending process. Following are the works that is considered in OFDM system as future scope is selective mapping technique can also be substantiate in OFDMA system. The proposed timing offset and frequency offset estimator can be utilized for MIMO OFDM system. From the literature review PAPR is a relevant factor in determining the OFDM system performance. QPSK modulation technique used in simulation can also be replaced by other modulation techniques such as QAM or BPSK and further effects can be examined. Various PAPR reduction schemes have been discussed; some have many merits along with some draw backs. Firstly, PAPR reduction can be obtained with the help of redundant bits, Secondly by correcting the function to eliminate the high amplitude peaks. By adding redundancy it doesn't cause distortion but it increases computational complexity at the transmitter end and lower down the transmission data rate. Various modified form of interleaving, selective mapping, partial transmits sequences; tone insertion and tone reservation PAPR reduction techniques are also proposed. These proposed techniques for PAPR reduction grant an improvement over the existing technique which provides good results with high throughput OFDM signals.

IV. CONCLUSION

OFDM has newly found wide assumption in a wide variety of high data communication system. There are many problems in OFDM one of them is PAPR i.e. Peak to average power ratio. As per discussed about all above techniques to reduce PAPR, BER in OFDM system. Each method proposed in the literature has a drawback and these effects need to be considered for real performance measurement. For PAPR reduction in OFDM different individual and combined techniques are used. Depending upon the applications or depending upon performance of the system we can use appropriate method. A parallel combinational scheme or other hybrid scheme is also available to reduce PAPR and BER in OFDM system under additive white Gaussian noise (AWGN) environment. The new method incorporates both active constellation extension and selective mapping scheme that reduces PAPR and improved BER in OFDM system.

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