Different criterions for PAPR reduction methods in OFDM systems and Performance Measurement for such systems

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Abstract – One of the challenging issues in today's OFDM system which is MCM is to handle high PAPR of the transmitted OFDM signals. The OFDM receiver detection efficiency is very much sensitive to nonlinear devices used in signal processing such as HPA and DAC. The criterion of PAPR reduction is to find methodology which can reduce PAPR drastically and at the same time it can keep reasonably good performance of other factors like BER performance, low implementation complexity ,low average power etc.

Key words– Orthogonal Frequency Division Multiplexing (OFDM), Multi Carrier Modulation (MCM), Peak to Average Power Ration (PAPR), High Power Amplifier (HPA), and Digital to Analog converter (DAC), Bit Error rate (BER).

I. INTRODUCTION

The growth of wireless communication has been producing the demand for high speed, efficient and reliable communication over hostile wireless medium [1]. The basic concept of OFDM is to divide the total bandwidth into many narrowband sub channels which are transmitted in parallel [2].

One of major problem of OFDM is that the peak amplitude of the emitted signal can be considerably higher than the average amplitude. This PAPR issue originates from the fact that an OFDM signal is the superposition of N sinusoidal signals on different subcarriers [3]. Hence OFDM is a kind of multicarrier transmission when N samples of each transmitted symbol are obtained by the application of the inverse discrete Fourier transform to the group of N successive input symbols [4]. In other words OFDM is a multi-carrier modulation technique where data symbols modulate a parallel collection of regularly spaced sub-carriers [5].

OFDM is simple to use on channels that exhibit time delay spread or, equivalently, frequency selectivity. Frequency selective channels are characterized by either their delay spread or their channel coherence bandwidth which measures the channel decorrelation in frequency [5]. In OFDM we send the information on large numbers of carriers instead of sending it on one carrier of larger bandwidth. The large numbers of carrier are orthogonal to each other. The transmitted signal is the combination of a number of sinusoids which can add coherently and result in a high peak magnitude but the average value of the signal might be low due to destructive interference and therefore the PAPR ratio is high.PAPR results in high power consumption and lower efficiency and is hence undesirable [6].

If the modulation scheme is QAM than the spectrum of the signal on the line is identical to that of N separate QAM signals, at N frequencies separated by the signalling rate.

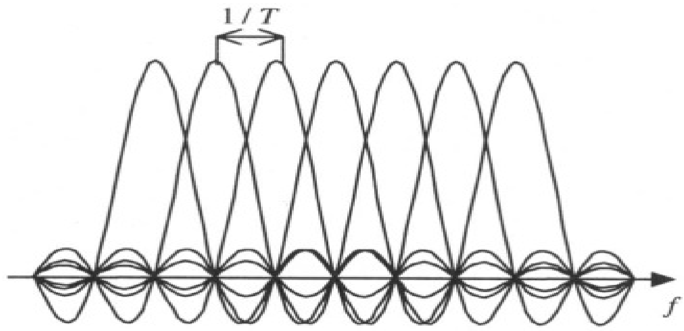

Fig.1 Spectrum overlaps in OFDM.

Each such QAM signal carries one of the original input complex numbers. The spectrum of each QAM signal is of the form sin *(kf) / f,* with nulls at the centre of the other sub-carriers, as in the earlier OFDM systems, and as shown in Figure 1 [7]. Signal peaks causes distortion and saturation in power amplifiers, leading to inter-modulation of subcarriers and out of band radiation. Also, circuit is difficult to implement as designing the ADCs becomes more complex due to this. On the other hand, this gives high cost amplification which leads to inefficient transmission. Thus, it is quite necessary to reduce the PAPR [8].

PAPR is defined as a symbol period of the instantaneous power value and the ratio of the average power value. Use the equation is expressed as: [9]

$$\text{PAPR (dB)} = 10\log_{10}\left(\frac{\max[|x(t)|^2]}{E\{|x(t)|^2\}}\right) \quad (1)$$

X (t) represents the output signal after IFFT operation.

In other words that the high peaks of OFDM signal occurs when the sinusoidal of subcarriers are added constructively. These high peaks necessitate using larger and expensive linear power amplifiers. Since large peaks occurs irregularly and infrequently. This means that the power amplifiers will be operating inefficiently [10].

The paper is organized as follows, after the introduction section the section II describe the motivation of PAPR which is followed by overview of different techniques for PAPR reduction. Section III describes the different criterions of PAPR reduction in OFDM system. Second last section describes performance measure with few results on PAPR reduction techniques. The comparison of PAPR reduction techniques is also described in second last session end in the last section conclusion is being given.

II. Motivation of PAPR Reduction

A. Nonlinear characteristics of HPA and ADC:

Mostly radio stations have HPA in the transmitter to achieve sufficient transmission power at the transmitting end. To achieve maximum output power efficiency, HPA is almost operated at or near the saturation region. Point to be considered here that the nonlinear characteristic of HPA is extremely sensitive to the variations in signal amplitudes.

In general, HPA requires a large back- off from the peak power to reduce the distortion caused by the nonlinearity of HPA and this gives rise to a low power efficiency, which is a significant burden, especially in mobile terminals.

The input-output characteristics of high power amplifier (HPA) in terms of the input power P_{in} and the output power P_{out} in figure 2 [11]. The maximum possible output is limited by P_{in} when the corresponding input power is given by due to the aforementioned saturation characteristic of the amplifier. The input power must be backed off so as to operate in the linear region as illustrated in Figure, describing the nonlinear region by Input Back-Off (IBO) or Output Back-Off (OBO).

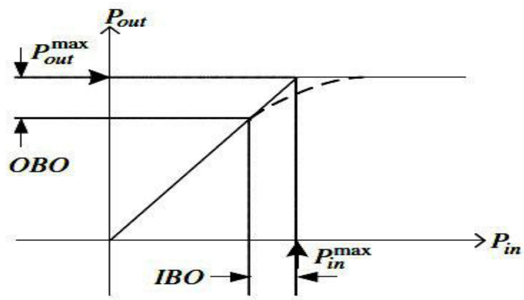

Fig.2 Input- Output characteristic of an HPA

$$IBO = 10\log_{10}\frac{P_{in}^{max}}{P_{in}} \quad (2)$$

$$OBO = 10\log_{10}\frac{P_{out}^{max}}{P_{out}} \quad (3)$$

However, the variation of OFDM signal amplitudes is very wide with high PAPR. Therefore, HPA will introduce intermodulation between the different between different subcarrier and introduce additional interference into system due to high PAPR of OFDM signal. This additional interference leads to the increase in BER. To lessen the signal distortion which means to keep low BER, we require a linear work in linear amplifier region with a large dynamic range. However, this linear amplifier has poor efficiency and will be expensive.

It is therefore important to aim at a power efficient operation of non linear HPA with low back offs values and try to prevent provide possible solution to interference problem brought about[. The real solution is to prevent occurrence of such problem is to reduce PAPR of transmitted signal with doing manipulation of OFDM signal at the transmitting end

A high precision DAC supports high PAPR with reasonable amount of quantization noise, but it might be very expensive for given sampling rate of the system. Where as a low precision DAC would be cheaper but its quantization noise will be significant, resulting in reduction of Signal –to - Noise Ratio (SNR) [1].

B. Distortions:

If the OFDM signal is clipped, it will lead to introduction of in-band distortion and out of band radiation into the wireless communication system. Thus the best solution has been to reduce PAPR before OFDM signals enters the territory of nonlinear HPA and DAC.

C. Power saving**:**

When a HPA have a high dynamic range, it exhibits poor efficiency. It has been shown that PAPR reduction can significantly save the power [12]. Hence the size of handset can be reduced as the battery Ah will be reduced to give the same backup.

D. Increased coverage**:**

Power efficiency is very is necessary in wireless communication as it provides adequate data coverage.

III. Criterions of PAPR Reduction in OFDM System

A. Bandwidth Expansion**:**

Bandwidth is rare resource of any wireless system. It should not be increased because either we have to pay a large amount of money to use it or it is not available. So we must use techniques like channel coding etc. When channel coding is used the loss in data rate is increased due to side information. Therefore the loss in bandwidth due to overhead information should be avoided or it should be kept at minimum.

B. BER Performance Degradation**:**

The PAPR reduction techniques should be made in such a way that the BER performance should not be degraded or least affected.

C. Implementation Complexity**:**

If we are achieving the good PAPR reduction at the cost of high complexity, in such cases the hardware cost will be more and it can have lots of delay consuming a lot of time in processing. FFT techniques to implement the modulation and demodulation functions increase the computational efficiency of OFDM system [13].

D. Low Average Power Concept**:**

It can reduce PAPR but it can require large linear operation in HPA which will increase cost. The low average power can increase the BER in system.

E. In Band Distortion**:**

In-band distortions that result in rotation, attenuation, and offset on the received signal [14]. The reduction in PAPR should be made in such fashion that in band radiation can be kept at the minimum.

F. Out of Band Radiation

The nonlinear characteristic of HPA, excited by a large input, causes the out-of-band radiation that affects signals in adjacent bands [14]. Out of band radiation should be avoided while reducing PAPR as it will effect nearby system.

G**.** Cost Factor

The cost of the system to reduce PAPR should not be too expensive as it can lead to high cost handset or wireless system.

IV. Performance Measures

With the help of MATLAB® software, we can concentrate on the following performance measures: Power spectral density (PSD), Cumulative distribution function (CDF) Bit error rate (BER) and Crest factor (CF).

PSD**:** The actual power spectral density of the OFDM signal is quite complicated because of guard interval and any spectral shaping. The focus should be on spectral splatter caused by any method like clipping and the effect of filtering [2]

CDF**:** when the number of sub channels is large the baseband OFDM signal can be closely approximated by a complex Gaussian distribution. Since we can take the real and imaginary parts of base band signal alternately to form the real band pass band pass signal, the amplitude of the band pass signal is well approximated by a one sided Gaussian distribution.
*BER***:** Bit error rate for different values of SNR should be considered.

CF**:** Crest factor of OFDM signal should be reduced. As an example CF verses clipping ratio should be considered for OFDM system.
Basically peak-to-average power ratio (PAPR) is the most popular parameter used to evaluate the dynamic range of the time-domain OFDM signal or signal envelop variation or the crest factor (CF) where $PAPR=CF^2$ [15]. Commonly used parameter is the Crest Factor (CF), which is defined as the ratio between maximum amplitude of OFDM signal x (t) and root-mean-square (RMS) of the waveform. The CF is defined as; [16]

$$CF\left(x(t)\right)=\sqrt{PAPR}$$

(4)

A**.** Few PAPR reduction Techniques

The simplest method for PAPR reduction is amplitude clipping. Amplitude clipping limits the peak envelope of the input signal to a predetermine value or otherwise passes the input signal through unperturbed. Coding can also be used to reduce PAPR.A simple idea introduced in is to select those code words that minimizes or reduce the PAPR for transmission.
In the Partial Transmit Sequence the input data block of N symbols is partitioned into disjoint sub blocks. The subcarrier in each block is weighted by a phase factor of that sub block. The phase factors are so selected so that PAPR of combined signal is minimized as shown in the figure of next page. In Selected mapping Technique, the

transmitter generates a set of sufficiently different candidate data blocks all representing same information as original data blocks. As shown in the figure of next page line with the minimum PAPR is selected.

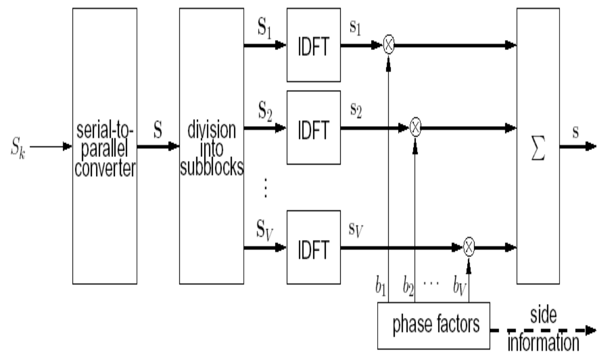

Fig.3 Partial Transmit Sequence

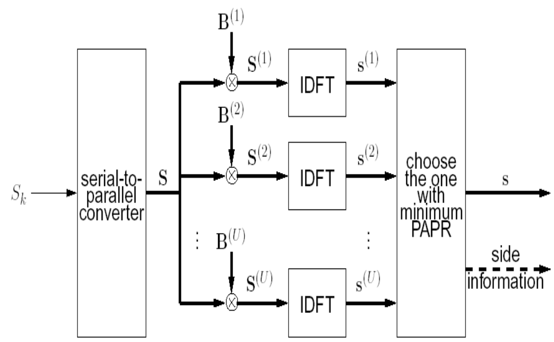

Fig.4 Selected mapping Technique

In a SLM-OFDM system with limited size of side information, the number of selected phase rotation factors is also limited. For example, besides the original symbol group not rotated, 1 -bit side information means one additional phase rotation factor, while 2-bit side information means three additional phase rotation factors are used, etc. The PAPR performance improves with more rotated groups in SLM, but more bits of side information are required and the data rate is lower [17].

B. Results of PAPR reduction Techniques

Few PAPR reduction techniques are simulated in MATLAB software using coding with the following parameters value as shown below in the table 1

TABLE I

Different parameters considered for PAPR reduction

S.N.	PARAMETER	VALUE OF PARAMETER
1	Number of subcarriers	128
2	Oversampling factor	8
3	modulation	QPSK
4	Total input bits	1024000
5	Clipping is done at the value	6.0 e-04

The first technique considers is the most basic method known as clipping. The clipping is done at amplitude level of 6.0 e-04.The graph shows for CCDF of 1/1000 the PAPR in dB reduces from 11 dB to 7.1 dB as shown in figure 5.

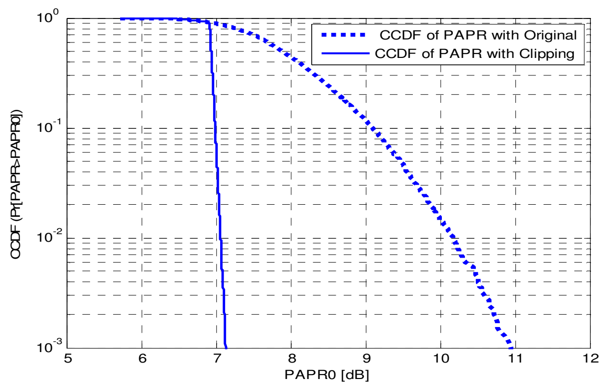

Fig. 5 Effect of Clipping on PAPR

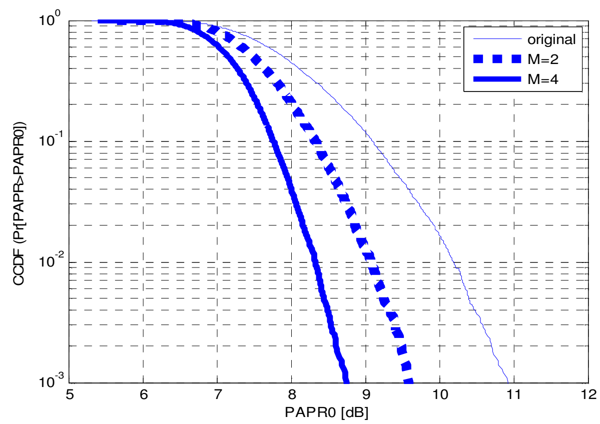

Fig. 6 Effect of Selected mapping on PAPR

The effect of going for Selected mapping technique to reduce PAPR is shown in figure 4. Three cases are taken first one is basic link in second case two path are taken while in last case four path are taken. The graph shows for CCDF of 1/1000 the PAPR in dB reduces from 11.1 dB to 9.5 dB for second case while PAPR in dB reduces from 11.1 dB to 8.5 dB for third case as shown in figure 6.

C. Comparison of PAPR reduction Techniques

Comparison of some PAPR reduction techniques are given in below tables which are self-explanatory

TABLE II
Different parameters considered for PAPR reduction

S.N	method	Distortion less	Power increase	Data rate loss
1	Clipping	No	No	No
	coding	Yes	No	Yes
3	PTS	Yes	No	Yes
4	SLM	Yes	No	Yes
5	Interleaving	Yes	No	Yes

6	TR	Yes	Yes	Yes

TABLE III
Different parameters considered for PAPR reduction

S.N .	Method	Bandwidth expansion	BER degradation	Implementation complexity
1	Clipping	No	yes	Low
2	coding	Yes	No	Low
3	PTS	Yes	No	High
4	SLM	Yes	No	High
5	Interleaving	Yes	No	low
6	TR	Yes	No	High

V. CONCLUSION

Many techniques are there to reduce PAPR. All of them have potential to provide substantial reduction in PAPR at the cost of BER increase, transmit signal power change, increase of computational complexity, loss in data rates etc. Although numerous schemes have been proposed to solve the PAPR problem, no specific PAPR reduction scheme can be consider as the best solution. Since criterion involve trade- offs, it is needed to compromise the criterion to meet the system requirement [18].PAPR reduction techniques should be carefully chosen according to requirement of various systems. Practically the effect of transmit filter, transmit power amplifier and D/A converter must be taken into consideration to choose an appropriate PAPR reduction.

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