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EFFECT OF PAPR ON IBO IN OFDM SYSTEMS

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ABSTRACT

The cumulative growth of wireless communication systems strive for Orthogonal Frequency Division Multiplexing as a dominant candidate for the multicarrier transmission scheme. In this paper, we have analyzed PAPR reduction techniques, PTS and proposed a technique which is H-PTS. The impact of the IBO enhancement w.r.t PAPR can reduce the non-linear distortion. These two techniques are simulated and their effect on IBO is studied. Simulation results shows that reducing PAPR will have a direct effect on IBO. The IBO in PTS and Hybrid-PTS changes accordingly to their systems. Thus, eventually non-linear distortion produced by the HPA is also less. Through this study, it is also analyzed that PTS considered to a very good technique for PAPR reduction and also reducing the effect of non-linear distortion.

KEYWORDS: High Power Amplifier (HPA), H-PTS (Hybrid-PTS), Input Back off (IBO), Orthogonal Frequency Division Multiplexing (OFDM), Partial Transmit Sequence (PTS), Peak-To-Average Power Ratio (PAPR)

INTRODUCTION

Each and every part of the business in some or another way is related to mobile activities. The tremendous growth in the smartphones and tablets give rise to the exponential internet users. Due to this advancement, the need for better communication technologies, efficient wireless methods are needed to cope with this present situation. To overcome this challenge, newer wireless mobile communication technologies are evolving from 1G to now 4G. The 4G and beyond technologies would continue to provide the mobile related services for several years from now as 4G and beyond technologies provide high data rates, improvement in spectral efficiency and radio latency, high BTS density and spectrum flexibility [1]. But the limitation for these 4G and beyond systems in which transmission or reception technique used i.e. OFDM signals has large value of Peak to Average Power Ratio (PAPR). This causes large variations in the amplitude of multi-carrier signal which further causes the problems for Digital to Analog Converter (DAC) and High Power Amplifier (HPA) [2]. As the HPA has a linear range for receiving sufficient transmit power and when multi-carrier signal with high values of PAPR passes through it, gets distorted [3]. To overcome from this problem, either the range of HPA is too increased or the PAPR has to be reduced. But this enlargement of HPA's linear range will also cause some inefficiency. So, there is only one condition left to reduce PAPR to an extent so that it can easily pass through the HPA without any kind of degradation. Also, to avoid the non-linear distortion, the Input Back-Off (IBO) of HPA must be larger than PAPR but not much as power consumption of HPA increases with increase in IBO, as 41% of total power is wasted only by HPA [4], [5].

Several methods for reduction of PAPR have been proposed but the Partial Transmit Sequence (PTS) and Selected Mapping (SLM) have always been on some of the best techniques for PAPR reduction as they do not cause amplitude distortion of the user data [2], [6]. The author in [7] suggested the PAPR Reduction using Cyclic Convolution method. Ref. [8] tells about the analysis of PAPR Reduction using Wavelet Packet Modulation. The authors in [9] showed the SLM based PAPR Reduction of OFDM Signal using New Phase Sequence. The Ref. [10] investigates PAPR Reduction for Orthogonal Frequency and Code Division Multiplexing (OFCDM) using Selected-Mapping (SLM) and Partial transmit Sequence (PTS).

In this paper, we have shown that OFDM have a high value of PAPR. We investigate the PAPR reduction techniques by using PTS and another one which is a taking both these techniques into consideration as initially it is segmented partially then phase rotation for different sequences have been completed. We also show that by using these two PAPR reduction techniques, PAPR reduces and their effect is also on the Input Back-Off (IBO) which in turn reduced the probability of occurring of the non-linear degradation of the OFDM signal by HPA. We have suggested the effect of IBO which is dependent on the amount of the PAPR. In general the IBO value if greater than PAPR value causes distortion of the OFDM signal and reduction in the PAPR value will benefit the OFDM transmitter system and also reduces the degradation of the OFDM signal.

The rest of the paper is organized as follows: Section II offers the detailed study of an OFDM system and IBO & PAPR. The PTS and another proposed technique is described in Section III. In Section IV, Simulation results are shown. Finally, the paper is concluded in Section V.

II. OFDM TRANSMISSION SCHEME

Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. With the application of IFFT, the orthogonal sub-carriers are generated. The OFDM signal is given as:

x (t) =1/(Nc)^1/2 Σ(for k=0 to Nc-1) [Xk e^j*2*pi*fk*t] (o<=t<=T) (A)

where X= [X0, X1,…….XNc-1] is input data block, T is duration of one OFDM symbol, Nc is the no. of sub-carriers, F is the frequency spacing between two sub-carriers f=1/T, e^j*2*pi*fk*t is the value which provides the orthogonal sub-carrier and it is derived from the twidall factor**.** The functional block diagram of OFDM transmitter is shown in figure 1. The source encoder converts the signal coming from information source into binary digits in an efficient manner. The channel encoder incorporates redundancy so that it can be detected at the receiver side. The interleaver is used to reduce burst errors. The purpose of mapping is to super-impose binary digits on to carrier. The serial to parallel is there as IFFT is always N-point. IFFT produces orthogonal sub-carriers. Afterwards, the parallel to serial converter is integrated as we need serials signals for transmission so as to reduce the cost and complexity of the transmitter. The cyclic prefix is used to add guard time-interval in the signal which is used to reduce ISI in OFDM symbols. Then DA converter is used for the conversion of digital signal to an analog one. At the end, the HPA is installed so to increase the power of the transmitted signal [11], [12].

Input Back-Off

The operating point of HPA is set as input Back-Off (IBO) which is defined as-

IBO = 10*log10 (Pmax/Pavg) (B)

Pmax refers to the saturation input power of HPA, and Pavg is the average power of the input signals [3]. The main objective is that the effect of IBO of HPA can be reflected automatically as when the PAPR reduces by using any one of three proposed techniques. Also to avoid the non-linear distortion, the IBO must be larger than the PAPR of the signal. However, the magnification of the IBO can become the cause of the inefficiency in the HPA. So, a appropriate value of IBO is needed.

III. PAPR REDUCTION FOR OFDM

A. Peak-To-Average Power Ratio

The PAPR of OFDM signals is defined as the ratio of maximum instantaneous power and the average power of the multi-carrier signal.

$$\text{PAPR}=\frac{Max|x(n)|^2}{Pavg} \quad \text{(C)}$$

Where Pavg= E [Ix(n)I^2] is expectation or mean value of x(n). As x(n) is random in nature. So, a Complementary Cumulative Distribution function (CCDF) is used to describe the statistical properties of the PAPR in OFDM systems.

CCDFm = Probability [PAPR > m] and m is constant (D)

B. Partial Transmit Sequence

PTS is one of the best techniques for the PAPR reduction of OFDM signals. In this technique, initially the OFDM symbol vector x=[x1,x2………xNc] is divided into U-sub blocks where Xu=[xu,1,xu,2………xu,Nc] and N=Nc/u gives the number of sub-streams in a sub-block such that X= Σ [Xu] (for U=1……Nc). Thereafter, each sub block which contains some number of sub-streams is multiplied with an orthogonal frequency so as to make it as a orthogonal sub-carrier by the help of IFFT i.e. Zu= IFFT[Xu] [14]. At the end, each sub-carrier is multiplied with a phase factors Su=[e^j*ɵ,1,e^j*ɵ,2……….e^j*ɵ,u] and all are combined to have a PTS-OFDM symbol i.e. T=Summation[Zu*Su] (for U=1…..Nc). The block diagram of the PTS is also explained with the help of the diagram in figure 2(a).

C. Hybrid Partial Transmit Sequence

This technique uses the features of both the techniques i.e. SLM & PTS. The OFDM symbol vector X= [x1, x2,……xNc] is divided into U-sub blocks such that Xu= [xu,1, xu,2…….xu,Nc] and each sub-block have some number of sub-streams in it. Now, instead of doing the IFFT of each sub-block, each sub-block is multiplied by phase vectors due to which phase of sub-streams in sub-block gets rotated. Y=Σ[Xu*Su] (for U=1.....Nc) where Su= [e^j*ɵ1,u, e^j*ɵ2,u……..e^j*ɵ,u]. The Y means that all sub-blocks are added. After the IFFT of Y occurs, then this gives the OFDM signal. Although this technique is not efficient as PTS & SLM, but this technique is not that much complex due to fewer computations because of only 1-IFFT block used to produce orthogonal sub-carriers. Its block diagram is represented in figure 2(b).

IV. SIMULATION RESULTS AND DISCUSSIONS

The PTS and a hybrid PTS technique which is a combination of both are studied and their PAPR reduction is done with the help of computer simulation. After PAPR reduction & before it, the IBO characteristics and its comparison with PAPR for different cases have also been shown. The PAPR value at a CCDF of 0.1% is used for comparison of all the techniques. For PTS and Hybrid PTS, the two different configurations i.e. 16-QAM and 32-QAM have been used. The OFDM vector is divided into 8-phase segments. The phase sequence vector which is used to rotate the phase of the sub-streams is a combination of {1,-1} as it produces the walsh-hadamard sequences. The PAPR is plotted for both the original OFDM and for the reduced one to show the comparison that occur due to the reduction of the peak amplitudes values of the OFDM signals.

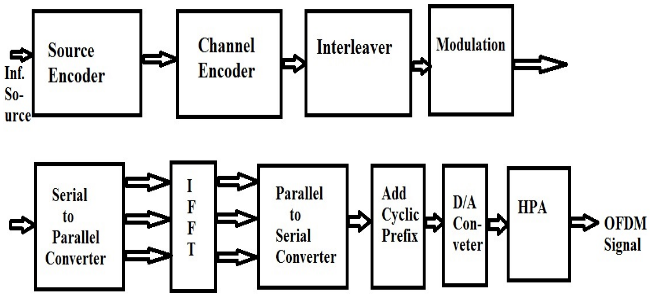

Figure 1: Representation of OFDM Transmitter

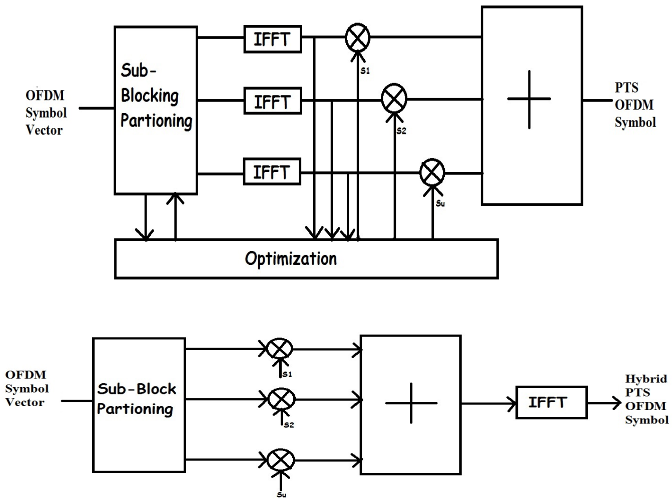

Figure 2: Representing Block Diagram for (a) PTS-Technique (b) Hybrid-PTS Technique

Simulation Graphs

Comparison b/w OFDM PAPR, PTS and H-PTS-OFDM*:* The PAPR reduction through PTS technique and Hybrid-PTS technique is employed in which 8-segments have been used. The phase vector is taken as the Walsh-Hadamard sequence in which the values remain between {1,-1}. The PAPR and CCDF is compared in the following simulations.

Table 1: Summary of PTS Technique

	16-QAM	32-QAM
PAPR Original	12.57db	11.74db
Mean Power	1.195	2.41
PAPR After H-PTS	12.42db	11.59db
Mean Power	2.0738	3.01

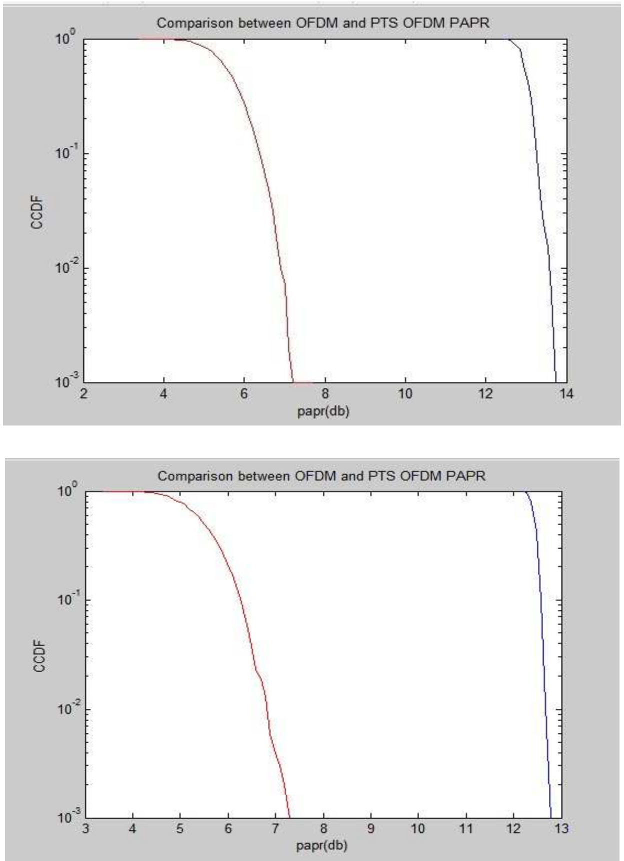

Figure 3: CCDF of PAPR for OFDM Using PTS for (A) 16-QAM (B) 32-QAM

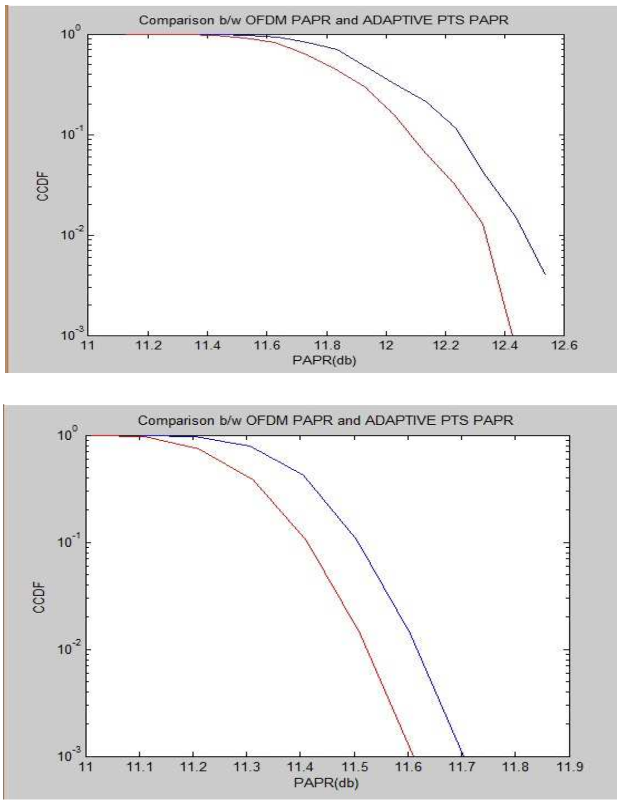

Figure4: CCDF of PAPR for OFDM Using Hybrid- PTS for (A) 16-QAM (B) 32-QAM

Table 2: Summary of Hybrid-PTS

	16-QAM	32-QAM
PAPR Original	13.74db	12.77db
Mean Power	0.8237	1.9688
PAPR After PTS	7.70db	7.33db
Mean Power	0.00013	0.000075

IBO is defined as the operating point of the High-power amplifier and it is defined as below:

$$IBO = 10 * log10 \frac{Pmax}{Pavg} \quad (X)$$

Where Pmax denotes the saturation input power of the HPA, and Pavg is the average power of the input signals. Gh is denoted as the amplifier gain.

$$Pomax = Gh*Pmax \quad (Y)$$

To make an efficient amplifier the amplifier gain is to be 1. From the AM/AM characteristics given in the ref [3], the Pomax is 1. So, also the Pmax is taken as 1. By using these values of Pmax (saturation input power of the HPA), the IBO for both the PTS and Hybrid-PTS have been calculated.

Table 3: Representing Mean Power, PAPR and IBO Results

	Mean Power	PAPR Reduced	Input Back off
PTS (16-QAM)	0.00013	12.77db	38.8db
PTS (32-QAM)	0.000075	7.33db	41.2db
Hybrid PTS(16-QAM)	2.0738	12.42db	-4.31db
Hybrid PTS (32-QAM	3.01	11.59db	-4.7db

For PTS, aimed at 16-QAM the IBO is very small compared to both the PAPR before the reduction process but after the reduction process the IBO comes very large than the PAPR value for both the original PAPR and reduced PAPR. Similarly, 32-QAM is also have high IBO due to reduction but not before reduction w.r.t to the both PAPR. The examination of the Hybrid-PTS for 16-QAM and 32-QAM both produces the negative values of the IBO before the reduction of the PAPR and after it. It also increases the mean and peak power values of the OFDM signal.

V. CONCLUSIONS

We have investigated the PAPR performance of OFDM transmission scheme in which various PAPR reduction techniques which encompasses PTS and Hybrid-PTS. One problem regarding the non-linear distortion caused by the HPA is studied.

The significance of selecting appropriate value of IBO could reduce non-linear distortion. Through simulations, we have concluded that proposed technique that is the PTS & Hybrid-PTS can lead to particular rise the value of the IBO which in turn very helpful in the transmission of the OFDM signals. The optimum value of the IBO is also important since if the IBO is lesser than the PAPR value, so it will lead to distortion in the OFDM signal and if the IBO is very much larger than the PAPR, therefore it will cause inefficiency in the HPA. So, an optimum value of the IBO is appreciated.

The PTS technique introduces the boost in the IBO but it becomes v high than the PAPR. The proposed Hybrid-PTS have value of IBO in negative terms. The relation of PAPR reduction and IBO increment is studied and it is found that on performing the PAPR reduction the average power of the OFDM signals also decreases which proliferate the

IBO value. Through this study it is concluded that the PTS lead to IBO growth so as to compensate the distortion loss because of the limited range of the HPA.

VI. REFERENCES

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