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RESEARCH ARTICLE

A STUDY ON PAPR REDUCTION ON SPECTRUM AND ENERGY EFFICIENCIES IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING WITH PTS TECHNIQUE

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) faces the Peak-to-Average Power Ratio (PAPR) problem that is a main disadvantage in multicarrier transmission system. Here in this paper an attempt is made to improve the spectrum efficiency (SE), and energy efficiency (EE) in orthogonal frequency division multiplexing (OFDM) systems, Simulation results show that the OFDM system with PAPR reduction could achieve higher SE and EE than that of the system without PAPR reduction with CCDF.

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INTRODUCTION

The Orthogonal Frequency Division Multiplexing (OFDM) possesses several desirable attributes, such as immunity to the inter-symbol interference, robustness with respect to multi-path fading, and ability for high data rates. Thus OFDM has been proposed in various wireless communication standards such as IEEE802.11a standard for wireless Local Area Networks (WLAN), IEEE802.16a standard for Wireless Metropolitan Area Networks (WMAN), (Chuang and Sollenberger, 2000). However, one of the major drawbacks of OFDM system has been its high Peak-to-Average Power Ratio (PAPR). PAPR reduction techniques can be employed such that the linear range of HPA can be reduced. The SE performance of OFDM systems has been well investigated by various researches (Jiang and Wu, 2008; Li *et al.,* 2011; Jiang *et al.,* 2008), and the EE performance has also been studied (Jiang et al., 2007; Bougard, 2006). However, investigations on the SE and EE performances are not available, which have been studied in this paper. The partial transmit sequence (PTS) scheme is used as an example for the analysis, because it can significantly reduce the PAPR of OFDM signals without any signal distortion (Chakravarthy *et al.,* 2009; Yang *et al.,* 2011).

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Besides, the PTS scheme does not waste the spectrum since the side information can be eliminated by the methods proposed in (Lacatus *et al.,* 2009; Koutitas, 2010; Li *et al.,* 2012). Therefore, the data rate is improved and the power consumption is reduced when the PTS scheme is employed in OFDM systems as compared with other PAPR reduction schemes. Therefore, reduction in the PAPR can improve the SE and EE performances for OFDM systems and the quantitative relations between PAPR reduction, SE and EE have also been derived in this paper.

PAPR in OFDM

OFDM is a multicarrier modulation technique, in which the bit stream is divided over several orthogonal subcarriers, each modulated at a low rate. The block diagram of OFDM system is described in Figure1. Orthogonalty is assured by choosing appropriate frequency spacing between them. The number of sub-carrier is chosen to insure that each sub-channel has a bandwidth less than the channel coherence bandwidth thereby experiencing flat fading (Tao Jiang, 2013). In an OFDM-based system, the signal samples are grouped in blocks of N symbols, {Xn, n=0, 1,…,N-1}, which are modulating a set of N subcarriers, with frequencies {fn, n=0,1,…,N-1}.

These subcarriers are chosen to be orthogonal, that is fn=n-f, where _f=1/T, and T is the OFDM symbol period. An OFDM signal consists of a number of independently modulated sub-carriers which can give a large PAPR when added up coherently. When N signals are added with the same phase they produce a peak power that is N times the average power of the signal. So OFDM signal has a very large PAPR, which is very sensitive to nonlinearity of the high power amplifier. In OFDM, a block of N symbols{X , k = 0,1,....,N -1} k , is formed with each symbol modulating one of a set of subcarriers, {f , k = 0,1,.....,N -1} k . The N subcarriers are chosen to be orthogonal, that is, f k f k = D, where Df =1 NT and T is the original time period. The resulting signal is given as:

$$X(t) = 1/\sqrt{N} \sum_{0}^{N-1} X_n e^{j2\Pi ft} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Peak to Average power Ratio is defined by Muller and Huber in 1997.

$$PAPR = \max_{0<t<T}\{ |x(t)|^2\} / E\{ |x(t)|^2\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: $\max[x(t)]^2$ is the peak signal power $E\{[x(t)]^2\}$ is the average signal power Peak value of the signal $\max\{ ([x(t)]^2) \} = \max[x(t).x(t)^*] = N^2$ Similarly the mean square value (average signal power) is $E\{[x(t)]^2\} = E[(x(t).x(t)^*] = N$. So when all the subcarriers are equally modulated, and all the subcarriers align in phase and the peak value hits the maximum, the PAPR will be PAPR = N. (Jiang and Wu, 2008)

The definition of the SE and EE in an OFDM system can be written as:

$$\eta SE = R/B, \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\eta EE = R/Phpa + Pc, \quad \ldots\ldots\ldots\ldots\ldots (4)$$

where R is the achievable data rate and B = NΔf denotes the channel bandwidth. According to the Shannon's formula, the achievable data rate over an additive white Gaussian noise (AWGN) channel could be expressed as:

$$R = B\log(1 + SNR) = B\log_2(1 + P_t/P_w) \quad \ldots\ldots\ldots\ldots\ldots (5)$$

where Pt is the average transmit power, and Pw is the average power of the additive white Gaussian noise.

Effect of PAPR Reduction on SE

The spectrum efficiency definition in mathematical form is that:

$$\eta_{SE} = R/B \quad \ldots\ldots\ldots\ldots (6)$$

$$\text{where } R = B\log_2(1+P_t/P_{nc}+P_s-P_t) \quad \ldots\ldots\ldots\ldots (7)$$

Put the eq no . (8) in the eq (7) then

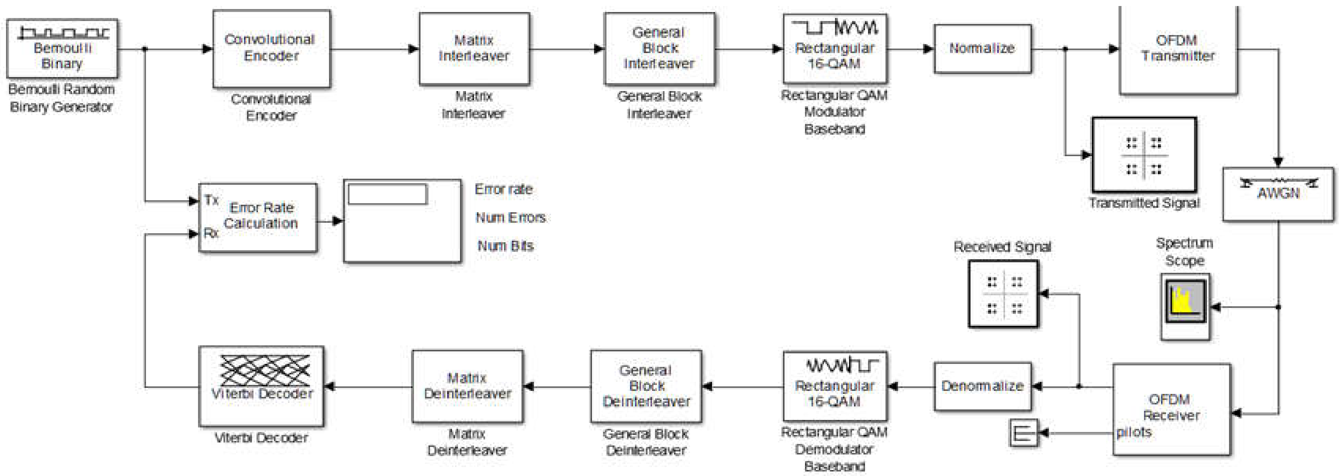

Figure 1. Block diagram of OFDM system with proposed model

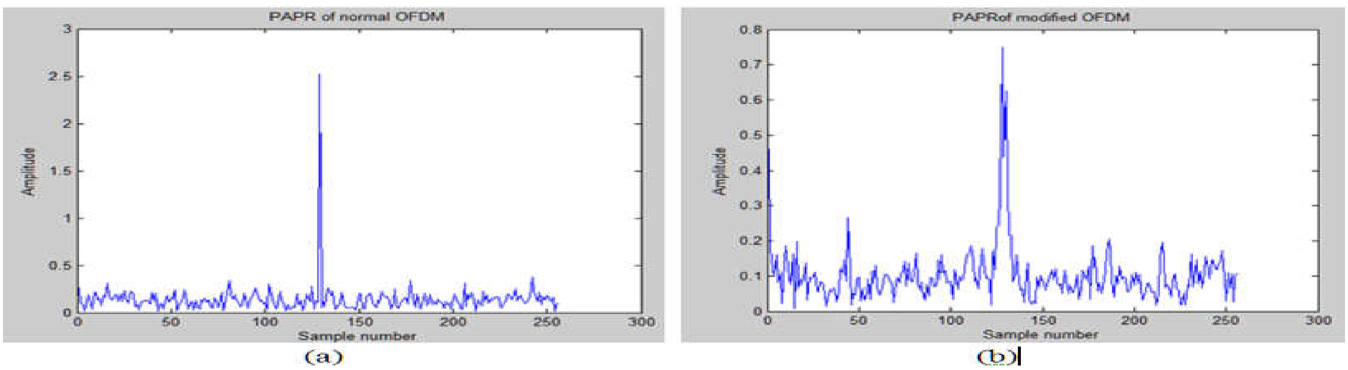

Figure 2. (a) PAPR of normal OFDM (b) PAPR of modify OFDM

$$\eta_{SE} = \frac{B}{B}\log_2\left(1 + \frac{P_t}{P_{nc}+P_{sav}+P_t}\right) \quad \ldots\ldots\ldots\ldots\ldots(8)$$

$$\eta_{SE} = \log_2\left(1 + \frac{P_t}{P_{nc}+P_{sav}+P_t}\right) \quad \ldots\ldots\ldots\ldots\ldots\ (9)$$

This equation show that the combination of the increment of $F_{xi}\sqrt{IBO.P_{oav}}$ and the decrement of the (PAPR>IBO). If the IBO is little then the SE is obtained better than the previous result while the PTS (v=8) method is applied for the PAPR reduction.

Effect on the PAPR reduction on EE

EE performance of OFDM system is able to be improving by decreasing the IBO and reducing the PAPR. The energy efficiency can be written as in mathematical form is that:

$$\eta_{EE} = R/P_{hpa} + P_c, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (10)$$

$$R = B\log_2(1+P_t/P_{nc}+P_s-P_t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (11)$$

Put the equation no. (12) into equation no.(11)

$$\eta_{EE} = \frac{B}{P_{hpa}+P_c}\log_2\left(1 + \frac{P_t}{P_{nc}+P_{sav}+P_t}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

We have already told relating to the effect of PAPR reduction on $\frac{P_t}{P_{nc}+P_{sav}+P_t}$ in the part of effect of the SE. The data rate R can be improved by reducing the PAPR at this time the spectrum bandwidth is constant (Tao Jiang, 2013).

RESULT AND SIMULATION

The research paper shows the BER and energy efficiency and spectrum efficiency. BER is inversely proportional to SNR. When the BER is increased then the SNR is decreased shown in the figure; with the no. of subcarrier is 64, convolution type coding is used, 96 bits frame is used, and taking 25% cyclic Extension. Figure 2(a) & (b) and table:1 represented the result of normal OFDM and modify OFDM. Main motivation of this thesis to developed and catches the better result of the energy efficiency and spectrum efficiency that show in the Figure 3(a),(b) & (c) and also the result of BER in this Figure.

Table 5.1. Result of OFDM

System	Result in DB
PAPR of normal OFDM	49.2233
PAPR of modify OFDM	35.1996

The Energy Efficiency and Spectrum Efficiency developed with four techniques in this graph such as Clipping, PTS 4, PTS 8 and New OFDM in terms of bits/joule and bits/s/Hz. These techniques are simple and low complexity techniques. Clipping technique is used like the time domain OFDM signal magnitude and has the non linearity and may cause of in band distortion and out band radiation. This technique is used to the recovery of the receiver signal. We calculated EE is 6.2400 bits/joule and the SE is 3.5399 bits/s/Hz by clipping technique. PTS 4 have the no of subcarrier of a signal is 4 and the phase weight is 2 and the phase factor lies between 1 to -1. We calculate Energy efficiency 1.1099bits/joule and the Spectral efficiency is 4.2300bits/s/Hz by this technique. PTS8 have the 8 subcarriers then the energy efficiency is 4.1199 bits/joule and the Spectrum efficiency is 4.2300bits/s/Hz.

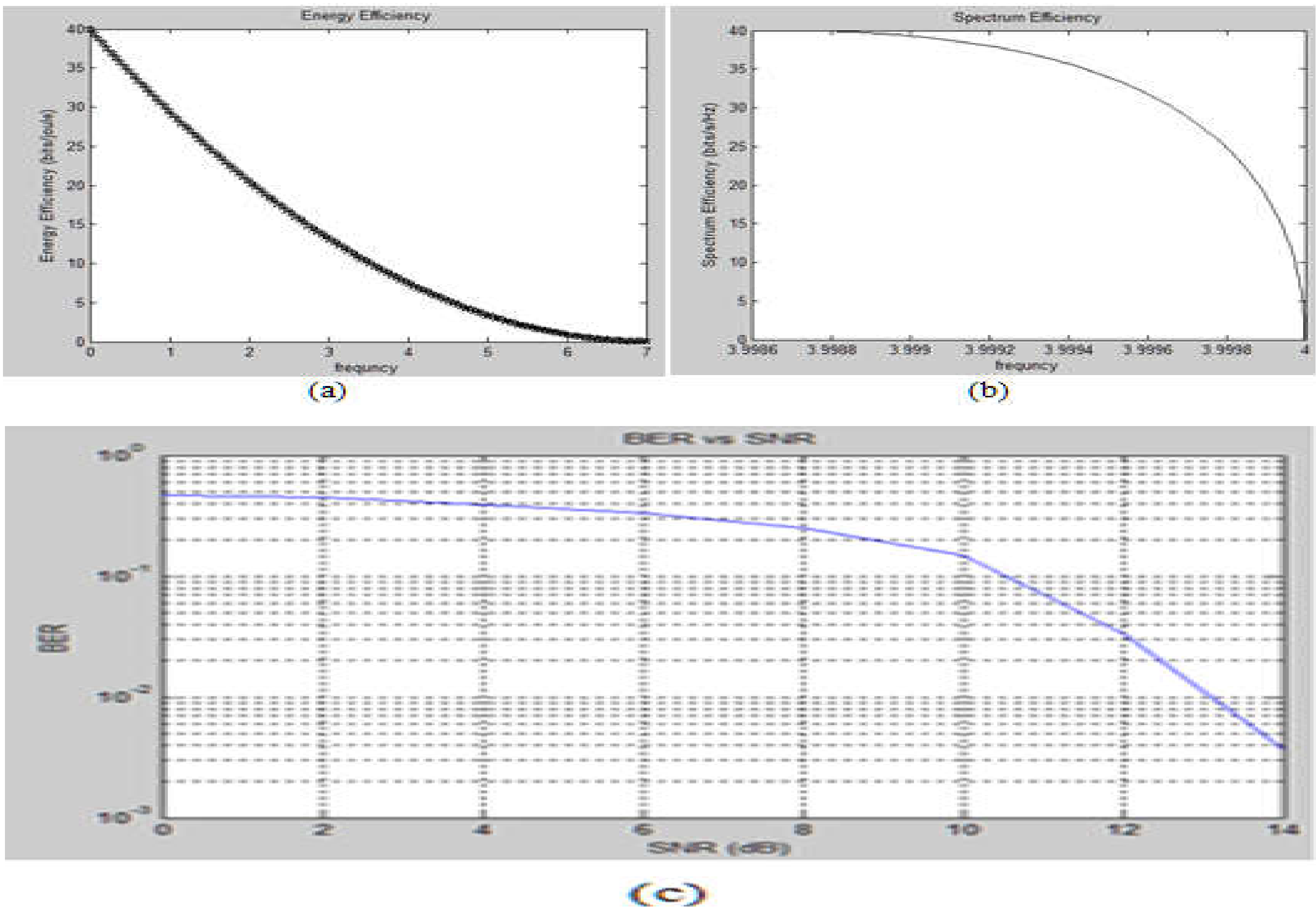

Figure 3. (a). Energy efficiency (b) Spectrum efficiency (c) BER vs SNR graph

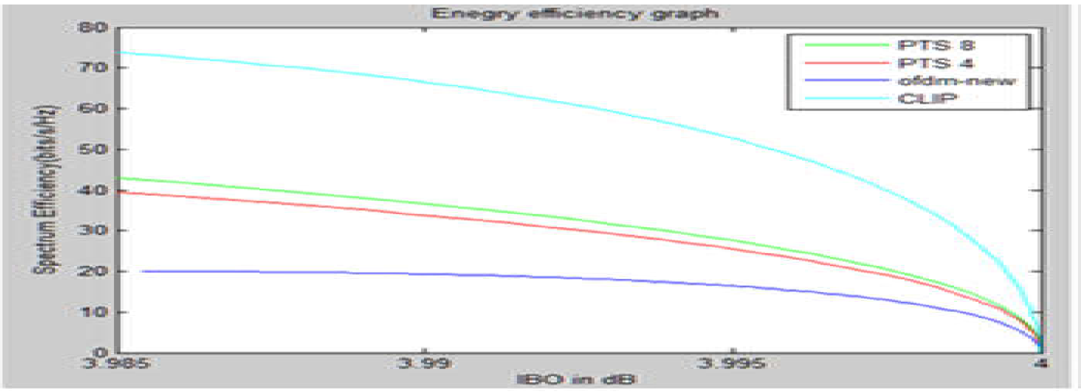

Figure 4. Spectral efficiency

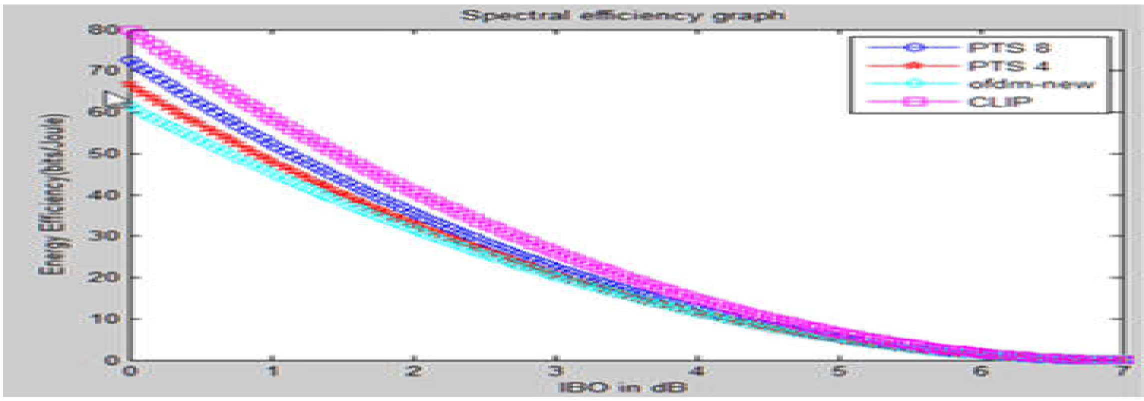

Figure 5. Energy Efficiency

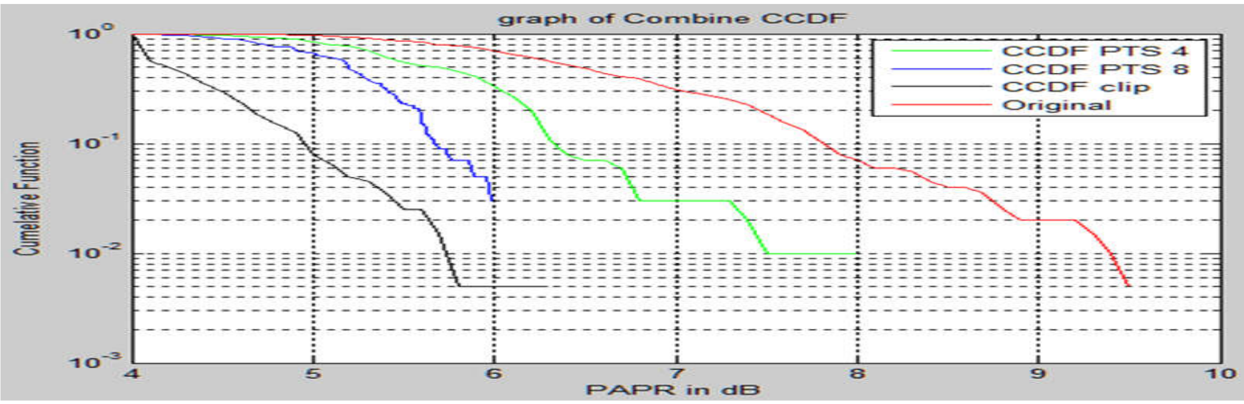

Figure 6. CCDF of PAPR

Whenever clipping effects on the BER to cut the amplitude of the signal and increasing the complexity of the PTS that is propositional to the EE that will be reduce to improve the EE&SE. There is one condition is satisfied that given as:

$$PAPR < N+1 \quad \text{…………. (13)}$$

PTSNEW have the 64 no. of subcarriers, 1 oversampling, 4 pilot symbol, 128 no of bits, 80 Hz bandwidth and using the M=2^b QAM modulation type. All techniques results are represented in table no.1 and Figure 3,4

CCDF is known as the factor to illustrate the peak power information of digitally modulation OFDM signal.

Table 2. Results of all techniques

PAPR Technique	EE in bits/joule	SE in bits/s/Hz
PTS8	4.1199	7.7800
PTS4	1.1099	4.2300
PTSNEW (OFDMNEW)	6.3199	9.5800
Clipping	3.5399	6.2400

CCDF is used to provide the data as regards in percentage of OFDM signal to have PAPR over a particular altitude. In the second chapter we already understood about the real and imaginary part of the OFDM signal. The Complementary cumulative distribution function (CCDF) of PAPR with OFDM with N subcarrier is that:

$$\mathrm{CCDF}(\gamma_0) = \Pr\,(\mathrm{PAPR}(x[n]) > \gamma_0) \quad \text{................ (14)}$$

In the Figure: 5 show that CCDF of OFDM signal for various factor (N) with QAM modulation and the no of subcarrier is 64 at the simulation. If the N>4 then the CCDF of PAPR is less. It can be easily observed from the figure. PAPR is proportional to the no. of the subcarriers of OFDM system. We are simulate the CCDF for the three technique like clipping, PTS 4, PTS 8 with the 64 no of subcarrier, 0.01 amplifier gain, 1 oversampling, and the no of symbol for PTS4 is 4 and the PTS8 is 8 and the no. of bits is 1k with adding 0.792 noise. The graph of clipping, PTS8 and the complete graph of CCDF are given that:

Conclusion

In this paper, we have analyzed the Energy efficiency and Spectral efficiency with four techniques like: Clipping, PTS4, PTS8 and PTS NEW in OFDM systems with class-A HPA. With the PAPR reduction, the power efficiency of the HPA is improved, and the nonlinear distortion noise caused by the HPA is reduced. Thus, compared with the original OFDM systems without PAPR reduction, the OFDM systems with PAPR reduction can achieve higher data rate with lower power consumption. Therefore, both the SE and EE performances can be improved by reducing the PAPR of the OFDM signals. We have analyzed the comparative study of the OFDM with the related techniques.

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