Consequence of PAPR Reduction in OFDM System on Spectrum and Energy Efficiencies Using Modified PTS Algorithm

Luv Sharma and Shubhi Jain

Abstract The manuscript presents here establishing relation among energy efficiency, spectral efficiency and PAPR reduction. The results are shown by simulation over OFDM technique in MATLAB. It has been showed in results that with PAPR reduction, system can attain high SE and EE comparing with other system without PAPR reduction. Also we have evaluated the results over the clipping, filtering, PAPR reduction in OFDM, PTS4, and PTS8 algorithms. The desirable result can also be achieved using the higher order PTS algorithms. Also we have analyzed the relations with PAPR, spectrum efficiency, and energy efficiency of the OFDM Systems. The outcome using the PTS algorithm boosts the efficiency of the system by falling down the PAPR in OFDM systems.

Keywords Partial transmit sequence (PTS) · Energy efficiency (EE) · High power amplifier (HPA) · Orthogonal frequency division multiplexing (OFDM) · Peak-to-average power ratio (PAPR) · Spectrum efficiency (SE) · Input backoff (IBO)

1 Introduction

The need of high data rates in communication system is increasing very rapidly day by day. There is continuous demand for broadcast structure that can sustain such higher data rates for faster communication. On the contrary of the superior data rates there is also the requirement of the low power consumption in smart devices including smartphones, handheld computing devices, etc. It can also be said that if energy efficiency is achieved there exists a limitation of spectrum. Since spectrum resource is also very scarce and very low available for particular communication systems. Thus there is required a smart system that can comply both the energy

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efficient condition and spectrum demand to be satisfied. Thus the expected communication system required high data rate as well as highly efficient power usage. Amongst the various communication techniques for modulation and multiplexing, the OFDM system is treated to be the most efficient nowadays for achieving desirable SE and EE, multipath delay spread tolerance, power efficiency, and other important factors for a better communication system [1]. One can consider the OFDM system for the high data rates over microwave access techniques. The foremost constraint for the OFDM system is its high peak-to-average power ratio (PAPR) of broadcast signal.

Also in OFDM scheme result is superposition of several subcarriers, causing the increase in immediate power output than that of the mean power of the system. Thus, it requires HPA which is expensive and has very low efficiency. Also linearity of the system degraded resulting in distortion and degradation of SE and EE. To resolve the above problem the input backoff (IBO) of HPA must be larger than PAPR to avoid nonlinear distortion. If it is not so then this nonlinear distortion will result in reduction of the data rates. Also there exists a limitation that the power consumption increases with the increase in IBO. Now to improve the efficiency of HPA there is a major requirement of PAPR reduction resulting in power saving and thus improving the EE and SE performances of OFDM. SE and EE performances are already discussed in various literatures [2–4], so we are concerning only the method for the PAPR reduction to improve EE and SE performances. The nonlinear distortion noise is also related with the PAPR as discussed earlier so on reduction of the PAPR it will also reduce thus improving the data rates and reducing power consumption of overall communication systems [5]. There are several PAPR reduction techniques available like signal scrambling technique including selective mapping (SLM), partial transmitted sequence (PTS), interleaving technique, tone reservation (TR), tone injection (TI), and signal distortion technique includes peak windowing, envelope scaring, peak reduction carrier, clipping, and filtering [6, 7]. Amongst all the above schemes we are using the PTS scheme compared to other PAPR reduction techniques. PTS4 and PTS 8 schemes are for reducing PAPR and improving the SE and EE performances. The rest part of the paper includes review of the OFDM system, PAPR, SE, and EE, respectively. Nonlinearity and power consumption of HPA are discussed and finally the relation between PAPR reductions SE and EE derived for clipping, PTS 4, and PTS 8 schemes followed by conclusions [6].

2 About OFDM

OFDM is a generally pertinent wireless broadcast arrangement that involves towering capacity broadcast and high bit rate or information rates. The OFDM signal is the outcome of the composite signal produced by multiplexing the modulated signals [2, 4]. The conventional frequency division multiplexing (FDM) is prime basis for the technology and it is considered as advancement over this conventional

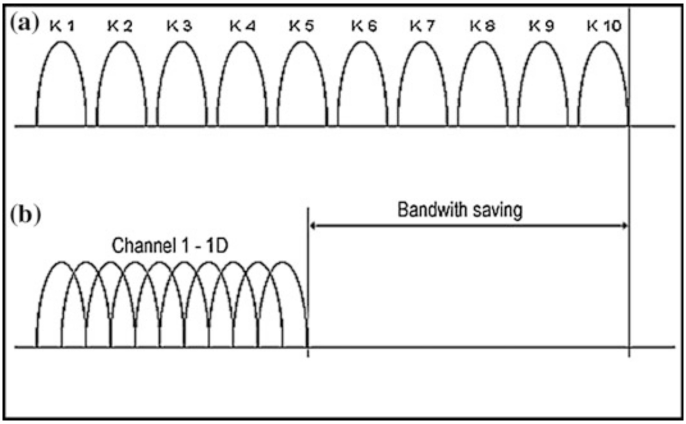

Fig. 1 OFDM spectrum

method which is adopted to hold only one signal over one conduit. The dispersive channel requires more advances and smooth transmission of signal and thus multicarrier modulation technique becomes a distinctive appearance for such transmission. The OFDM process includes a high rate data stream that is alienated into many low data streams. Further these streams are then multiplied by equivalent carrier frequency signals that are orthogonal to each other [8, 9]. The result is that the different carriers are orthogonal to each other, that is, they are absolutely autonomous of one another. This can also be achieved by placing the carrier exactly at the nulls in the modulation spectra of each other as shown in Fig. 1.

In OFDM transmission, the composite data representation slab $a = (a_0, a_1, \ldots a_{N-1})$ is conceded all the way through an N Point inverse fast Fourier transform (IFFT) accomplishing discrete time domain section to be broadcast.

The above statement concluded that the broadcast signal illustration is represented as $b_n^i = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} a_m^i e^{\frac{j2\pi nm}{M}}$

where i is the OFDM representation key, b_n^i is the data representation broadcast above m$^{\text{th}}$ subcarrier.

3 About PAPR

PAPR of OFDM signals $x(t)$ is typified as the relation flanked by the highest instantaneous power and its average power [10–12]. The PAPR representation of the time sphere model progression $b = (b_0, b_1, \ldots b_{N-1})$ is defined as

$$\mathrm{PAPR}(b) = \frac{\mathrm{Max}|b_n|^2}{\frac{E||b_n||^2}{N}} = \frac{P_{\mathrm{peak}}}{P_{\mathrm{average}}}$$

where P_{peak} represents peak output power, P_{average} means average output power, $\|.\|$ signify the norm of the enclosed vector b_n.

Since $b(n)$ is random, the PAPR is also a random variable. Therefore, complementary cumulative distribution function (CCDF) is for perpetuity that describes the statistical possessions of the PAPR in OFDM systems, i.e.,

$\mathrm{CCDF}_\lambda = \Pr\{\mathrm{PAPR} > \lambda\}$ [13–15],

where λ is a constant

The definition of the SE and EE in OFDM systems

can be written as

$$\eta_{\mathrm{SE}} = \frac{R}{B}$$

$$\eta_{\mathrm{EE}} = \frac{R}{P_{\mathrm{hpa}}}$$

4 PTS (Partial Transmit Sequence)

Partial Transmit Sequence (PTS) The PTS technique involves the participation data block of N Symbols that are partitioned into disjoint sub blocks before the signals are transmitted. Some more issue that could authorize the PAPR reduction presentation in PTS are subblock partitioning, technique of the division of the subcarriers into multiple disjoint subblocks. There are three categories of subblock partitioning method: adjoining, interleaved, and pseudorandom partitioning. The most important advantage of this PTS technique is that it is compatible with an uninformed quantity of subcarriers and any modulation format (Fig. 2) [15–18].

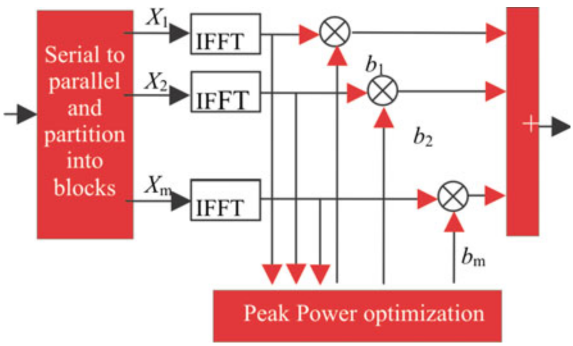

Fig. 2 Flow diagram of the PTS technique showing working of various blocks [4]

The operating point of the HPA is set as IBO (input backoff) and defined as

$$\text{IBO} = 10\log_{10}\frac{P_{\max}}{P_{\text{avg}}}$$

where $P_{\max}$ denoted the saturation input power of the HPA and P_{avg} is the average power of the input signals [19].

5 Performance Analysis

In this section, using MATLAB for simulation both theoretical analysis and numerical simulations demeanor are assessed by the effect of the PAPR reduction on EE and SE performances in OFDM systems [19]. A preassumption is considered that the circuits of the devices are unchanged and the over consumption of the other circuit devices P_c remains the same when the PAPR is reduced. Also another assumption is taken that OFDM signal is normalized as $T = 1$, and the bandwidth is $B = N$. For all simulations, quadrature phase shift keying (QPSK) employed sub-carriers $N = 64$ and SNR = 15 dB.

The phase rotation factor is {+1,−1} and No. of subblocks $V = 4$ and $V = 8$, respectively. Results from figure PAPR of original OFDM signal is 12.45, CCDF = 10^{-4},

PAPR reduction by 3.13 and 5.05 dB at $V = 4$ and $V = 8$ is achieved (Figs. 3, 4, 5, 6 and 7).

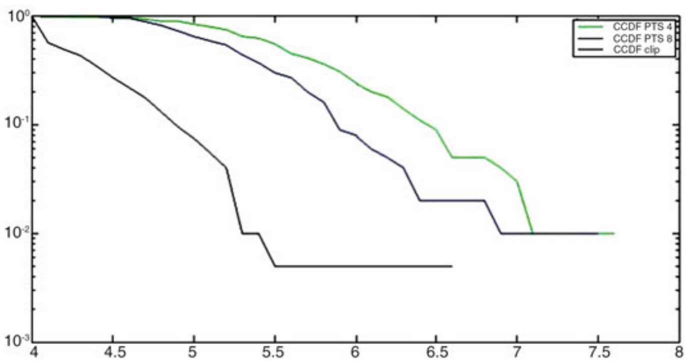

Fig. 3 PAPR lessening for the various PTS scheme taking $V = 4$ and $V = 8$

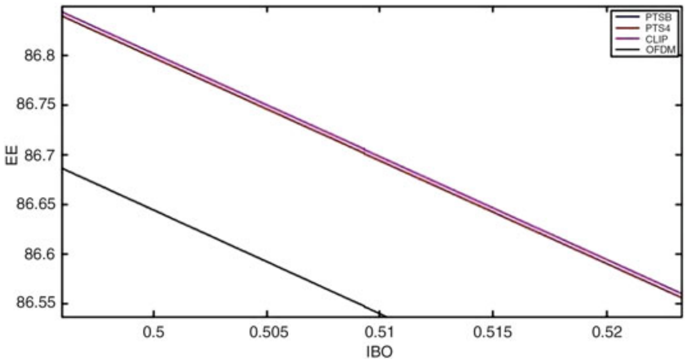

Fig. 4 Comparison of various signals for clip, PTS 4 and PTS8 techniques

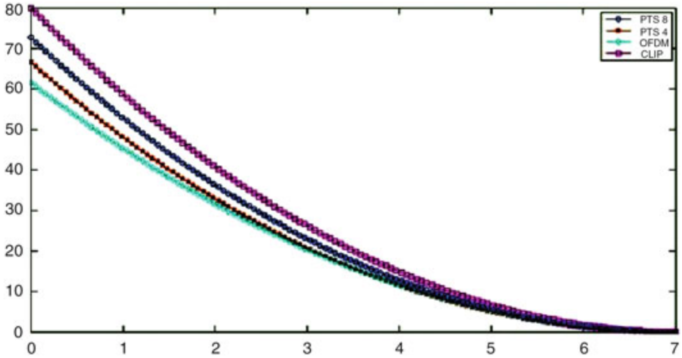

Fig. 5 EE performance with different PAPR reduction at different IBO in OFDM system

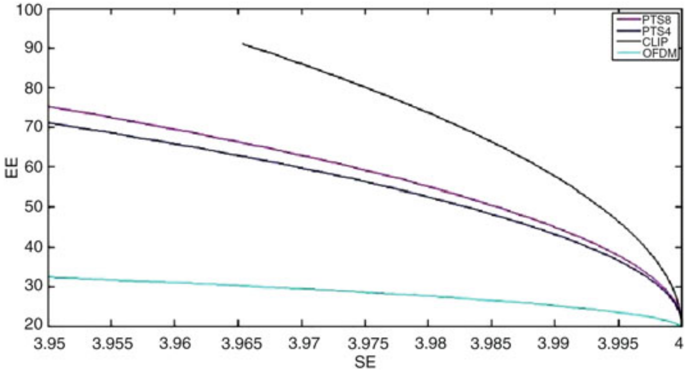

Fig. 6 Relation between SE and EE with constant P_{avg} when PAPR reduction is different

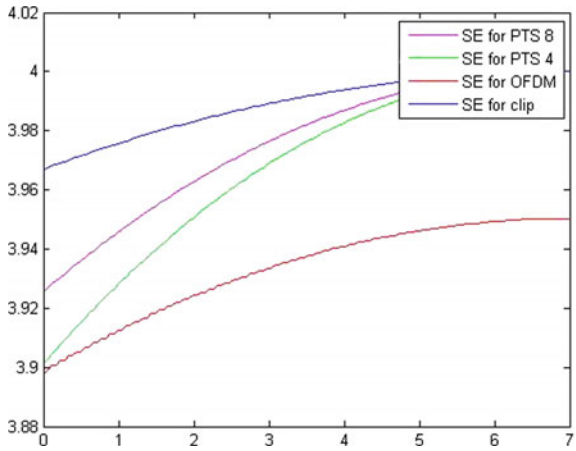

Fig. 7 SE performance with different PAPR reduction at different IBO in OFDM system

6 Conclusion

Thus in the above paper we have analyzed and studied the overall consequence of the PAPR reduction in the SE and EE in OFDM systems considering the CLASS A HIGH POWER AMPLIFIER. With the PAPR reduction, the power efficiency of the HPA is extremely enhanced, and the nonlinear distortion noise caused by the HPA is reduced to remarkable degree. Thus, the results can obtained with the comparison of the original OFDM scheme without PAPR reduction, the orthogonal frequency division multiplexing systems with PAPR reduction can achieve advanced data rate with very low power consumption. Therefore, both the SE and EE performances can be greatly improved by reducing the PAPR of the OFDM signals. Also PAPR reduction satisfies the requirement for low power in smart devices.

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