

Low Complexity PAPR Reduction Technique for Coded OFDM Systems with Scrambling Approach

Darshankumar C. Dalwadi^{A*} and Himanshu B. Soni^B

Department of Electronics & Communication, University of Gujarat Technological, State Gujarat, Country India
^BG.H.Patel College of Engineering & Technology, University of Gujarat Technological, State Gujarat, Country India

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is basically a frequency division multiplexing technique which uses a multicarrier scheme. Due to the efficient behavior in multipath fading environment OFDM used in many physical wireless systems. OFDM suffers from high Peak to Average Power Ratio (PAPR) compared to the single carrier systems. In this paper we have presented a PAPR reduction technique for Coded OFDM (COFDM) systems with scrambling approach. We have evaluated channel effect with respect to the Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK) and M-ary Quadrature Amplitude Modulation (M-QAM) technique. We have derived the new analytical expression for PAPR reduction technique using Proposed method for BPSK, QPSK and M-ary QAM modulation. In this paper we have present the noble PAPR reduction technique that is based on the combination of probabilistic approach and coded approach. The proposed scrambling approach is used to scramble an input data block of the Coded OFDM symbols and transmit any one of the data block with the lower PAPR so that the occurrence of the probability of high PAPR can be reduced. In the proposed algorithm the out-of-band radiation is reduced as well as complexity of physical system is low.

Keywords: Peak to Average Power Ratio (PAPR), Coded Orthogonal Frequency Division Multiplexing (COFDM), Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature amplitude modulation (QAM).

1. Introduction

During the past decades, wireless communication has benefitted from substantial advancement in the technology and it is considered as the key enabling technique of innovative future consumer products. For the sake of satisfying the requirements of various applications, significant technological achievements are required to ensure that wireless devices have appropriate architectures suitable for supporting a wide range of services delivered to the users (R. W. Chang *et al.*, 1996; J. Zhang *et al.*, 2007).

OFDM has developed for a popular scheme for wideband digital communication, whether wireless or over wire cable like copper wires, it is used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access (E. Simon *et al.*, 2011; Y. Yu *et al.*, 2012).

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters (T. Jiang *et al.*, 2012). Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals

rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate intersymbol interference (ISI) and utilize echoes and time-spreading (that shows up as ghosting on analogue TV) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement (R. Price, 1958). This mechanism also facilitates the design of Single Frequency Networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

In an OFDM system the one of the problem is high peak values of the signals in the time domain due to the number of subcarriers are accumulated through an IFFT block (T. Jiang *et al.*, 2004). Because of this high PAPR value, it reduces the Signal to Quantization Noise Ratio (SQNR) of ADC and DAC while reduces the efficiency of the power amplifier in the transmitter. So, the main objective in the OFDM system is to reduce this PAPR value (M. F. Naeiny *et al.*).

PAPR reduction techniques are classified into the different approaches: Clipping technique, coding technique, probabilistic technique, adaptive predistortion technique, and DFT-spreading technique (O. Muta *et al.*, 2004; Y.-J. Kim *et al.*, 2009). In this paper, we have

*Corresponding author **Darshankumar C. Dalwadi** is a Research Scholar and **Himanshu B. Soni** is working as Principal

presented the noble technique that is based on combination of probabilistic technique and coding technique that is we have presented scrambling technique on coded OFDM. The proposed algorithm minimizes the PAPR value and the overall OFDM system does not suffer from out-of-band interference and it causes no distortion.

In this paper, we have simulated the Bit Error Rate performance with respect to the Signal to Noise Ratio for different modulation technique like QPSK, 16-QAM, 32-QAM, 64-QAM and 128-QAM. We have compared the results of PAPR reduction technique with results of without PAPR reduction technique.

2. Peak to Average Power Ratio (PAPR)

In this section we have discussed the basics of PAPR and also we have discussed the PAPR for different types of modulation technique like BPSK/OFDM, QPSK/OFDM and M-ary QAM/OFDM.

2.1 Definition of PAPR

Consider a baseband PAM signal for a complex data sequence $\{\alpha[m]\}$:

$$\tilde{p}(t) = \sum_k \alpha[m]h(t - kT_s) \tag{1}$$

Where $h(t)$ is a transmit pulse for each symbol and T_s is the symbol duration. For PAM transmitter output of the passband quadrature modulator is represented as,

$$p(t) = \sqrt{2} \operatorname{Re}\{(\tilde{p}_I(t) + j\tilde{p}_Q(t))e^{j2\pi f_c t}\} \tag{2}$$

Where $\tilde{p}_I(t)$ and $\tilde{p}_Q(t)$ denote the in-phase and quadrature components of the complex baseband PAM signal $\tilde{p}(t)$ respectively.

PAPR is the ratio between the maximum power and the average-power of the complex passband signal $p(t)$, that is,

$$\text{PAPR}\{\tilde{p}(t)\} = \frac{\max|\operatorname{Re}(\tilde{p}(t)e^{j2\pi f_c t})|^2}{\operatorname{Mean}\{|\operatorname{Re}(\tilde{p}(t)e^{j2\pi f_c t})|^2\}} = \frac{\max|p(t)|^2}{\operatorname{Mean}\{|p(t)|^2\}} \tag{3}$$

The above power characteristics can also be described in terms of their magnitudes by defining the crest factor (CF) as,

$$\text{Passband condition: Crest Factor} = \sqrt{\text{PAPR}} \tag{4}$$

2.2 PAPR of different modulation techniques

In the PSK/OFDM system with N subcarriers, the maximum power occurs when all of the N subcarrier components happen to be added with identical phases. Assuming that $\operatorname{Mean}\{|p(t)|^2\} = 1$, if the results in $\text{PAPR} = N$, that is, the maximum power equivalent to N times the average power.

We note that more PAPR is expected for M-QAM with $M > 4$ than M-ary PSK. Meanwhile, the probability of the occurrence of the maximum power signal decreases as N

increases. For example, suppose that there are M^2 OFDM signals with the maximum power among M^N OFDM signals in M-ary PSK/OFDM system. Accordingly, the probability of occurrence of the largest PAPR is $M^2/M^N = M^{2-N}$, which turns out to be 4.723×10^{-39} in the case of QPSK/OFDM with $N = 64$ subcarriers.

2.3 Input Back-Off and Output Back-Off

Figure 1 shows the input-output characteristics of high power amplifier (HPA) in terms of the input power P_{in} and the output power P_{out} .

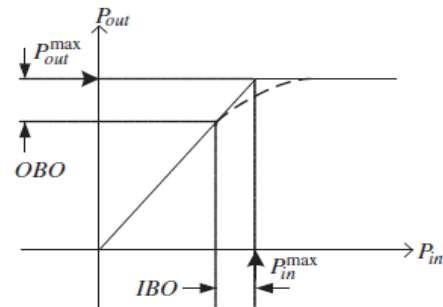


Figure 1: Input-Output characteristic of an HPA

As shown in figure 1, the input power must be backed off so as to operate in the linear region. Therefore, the nonlinear region can be described by IBO (Input Back-Off) or OBO (Output Back-Off):

$$\text{IBO} = 10 \log_{10} \frac{P_{in}^{\max}}{P_{in}}, \text{OBO} = 10 \log_{10} \frac{P_{out}^{\max}}{P_{out}} \tag{5}$$

Note that the nonlinear characteristic of HPA, excited by a large input, causes the out-of-band radiation that affects signals in adjacent bands, and in-band distortions that result in rotation, attenuation, and offset on the received signal.

2.4 PAPR Reduction Techniques

PAPR reduction techniques are classified into the different approaches: clipper technique, coder technique, stochastic technique, adaptive predistortion technique, and DFT-spreading technique.

2.4.1 Clipper Technique

The clipper technique employs clipping or nonlinear saturation around the peaks to decrease the PAPR value. It is simple to implement, but due to clipping approach in-band and out-of-band interferences are increased and it destroy the orthogonality among the subcarriers.

2.4.2 Coder Technique

The coder technique is to select a particular code words that minimize or reduce the PAPR. In this technique there

is no distortion and there is no out-of-band radiation, but it suffers from bandwidth efficiency as the code rate is reduced. It also suffers from complexity for encoding and decoding, especially for a large number of subcarriers. Golay code, Reed Muller code and Hadamard code can be used in this approach.

2.4.3 Stochastic Technique

The stochastic technique is to scramble an input data block of the OFDM symbols and transmit one of the data block with the lowest PAPR so that the probability of occurrence of high PAPR can be reduced. This technique does not suffers from the out-of-band power, the spectral efficiency decreases and also the complexity of the system increase as the number of sub carriers increases.

2.4.4 Adaptive Predistortion Technique

The adaptive predistortion technique can compensate the nonlinear effect of a High Power Amplifier (HPA) in OFDM systems. This technique automatically modifies the input constellation with the minimum hardware requirement (Random Access Memory and memory lookup encoder).

2.4.5 DFT-Spreading Technique

The DFT-spreading technique is to spread the input signal with DFT, which can be subsequently taken into IFFT. This technique reduces the PAPR of OFDM signal to the level of single-carrier transmission. This technique is applicable for mobile terminals in uplink transmission. It is known as the Single Carrier-FDMA (SC-FDMA), which is adopted for uplink transmission in the 3GPP LTE standard in the recent market.

3. Distributions of OFDM signals

In this section we have discussed the basics of OFDM signals and also we have discussed the effect of different types of rich channel like Rayleigh, AWGN reference channel on OFDM signals.

3.1 OFDM Basics

It is a Frequency-Division Multiplexing (FDM) scheme used as a digital multi-carrier modulation method. Figure 2 shows the basic block diagram of OFDM system. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access.

3.2 Block Diagram of OFDM System

Figure 2 shows the end-to-end block diagram of an OFDM system in which the discrete-time signal $\{x(n)\}$ after IFFT at the transmitter can be expressed as

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{j2\pi nk/N} \tag{6}$$

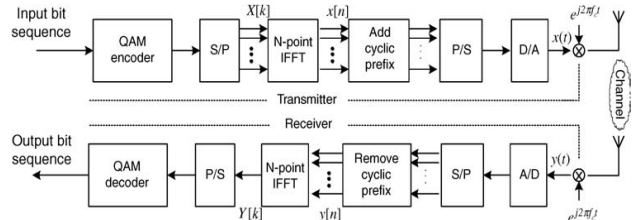


Figure 2: Block diagram of OFDM system

for a sequence of PSK or QAM-modulated data symbols, $\{X[k]\}$. In other words, $x[n]$ is given by adding the N different time-domain signals $\{e^{j2\pi nk/N}\}$, each of which corresponds to the different orthogonal subcarriers, the k th one modulated with data symbol $X[k]$.

3.3 Bit Error Rate of OFDM Scheme

The analytical expression form M -ary QAM signalling in AWGN and Rayleigh channels are respectively given as,

$$Pe = \frac{2(M-1)}{M \log_2 M} Q\left(\sqrt{\frac{6E_b \log_2 M}{N_0(M^2-1)}}\right) \tag{7}$$

for AWGN Channel

$$Pe = \frac{M-1}{M \log_2 M} \left(1 - \sqrt{\frac{3\gamma \log_2 M / (M^2-1)}{\frac{3\gamma \log_2 M}{(M^2-1)} + 1}} \right) \tag{8}$$

for Rayleigh Fading Channel

Where γ and M denote E_b/N_0 and the modulation order, respectively, while $Q(\cdot)$ is the standard Q function defined as,

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2} dt \tag{9}$$

4. Proposed Method to Reduce PAPR

The proposed technique partitions an input data block of N symbols into W disjoint sub-blocks as follows:

$$Y = [Y^0, Y^1, Y^2, Y^3, \dots, Y^{W-1}]^T \tag{10}$$

Where Y^i are the sub-blocks that are consecutively located and also are of equal size.

The block diagram of proposed technique for PAPR reduction as shown in figure 3.

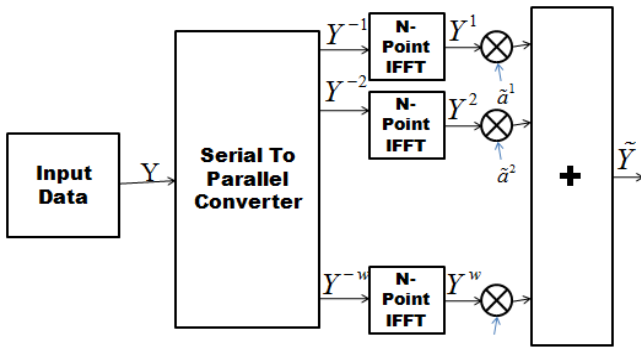


Figure 3: Block diagram of proposed technique for PAPR reduction

In proposed technique scrambling is applied to each sub-block. Then each partitioned sub-block is multiplied by a corresponding complex phase factor $a^w = e^{j\phi^w}$, $w = 1, 2, 3, \dots, W$, subsequently taking its IFFT to yield,

$$y = IFFT \left\{ \sum_{w=1}^W a^w Y^w \right\} = \sum_{w=1}^W a^w \cdot IFFT \{ Y^w \} = \sum_{w=1}^W a^w y^w \quad (11)$$

Where $\{y^w\}$ is referred to as a transmitter sequence.

The corresponding time-domain signal with the lowest PAPR vector can be expressed as,

$$\tilde{y} = \sum_{w=1}^W \tilde{a}^w y^w \quad (12)$$

In this paper, we have present complementary cumulative distribution function of PAPR for a various modulation technique using proposed technique as the number of sub-block varies.

5. Results and discussion

Here, in this paper we have present the technique which minimize the peak to average power ratio value using low complexity. In the proposed method complexity is very low. We have calculated received power value with respect to the various OFDM sub-blocks. In this section we have discussed the results with respect to the various modulation technique like BPSK/OFDM, QPSK/OFDM, 16-QAM/OFDM, 32-QAM/OFDM, 64-QAM/OFDM and 128-QAM/OFDM.

Figure 4 to figure 9 represents Complementary Cumulative Distribution Function (CCDF) value versus input decibel value for BPSK, QPSK, 16-QAM, 32-QAM, 64-QAM and 128-QAM types of modulation techniques respectively.

Figure 4 to figure 9 represents CCDF value with respect to the without peak to average power reduction technique as well as for with peak to average power reduction technique. In peak to average power reduction technique, the five different types of sub-blocks are used ($v=1, v=2, v=4, v=8$ and $v=16$).

From figure 4 to figure 9, we say that as we increased the number of sub-blocks the CCDF value is decreased. The simulated CCDF results are shown in table 1.

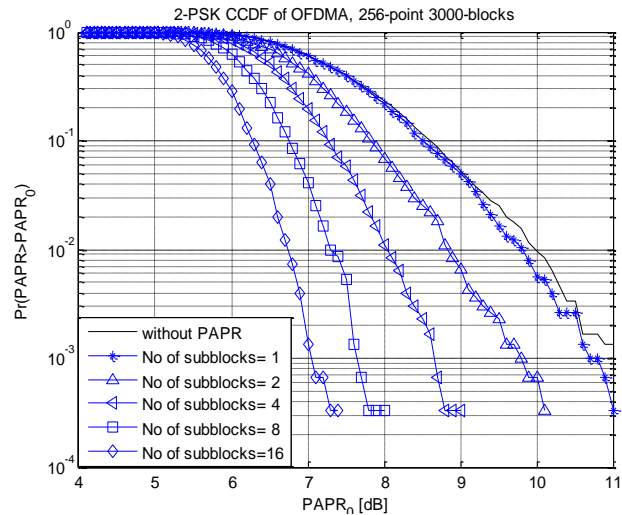


Figure 4: PAPR Reduction with respect to the BPSK/OFDM

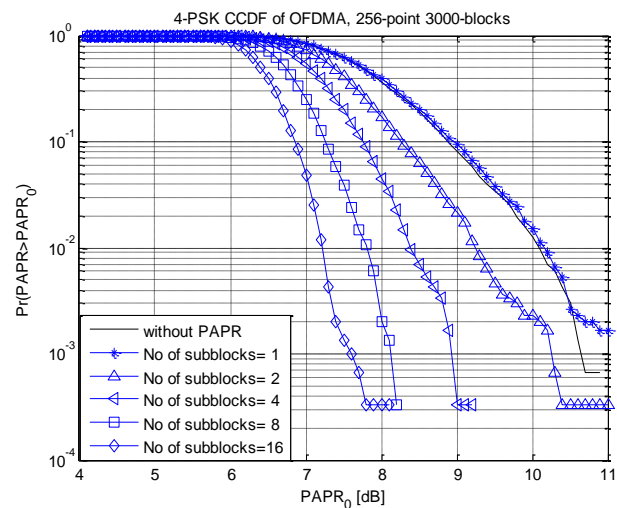


Figure 5: PAPR Reduction with respect to the QPSK/OFDM

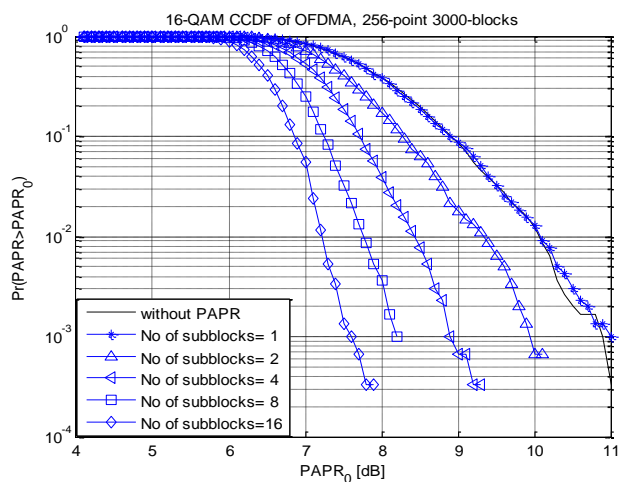


Figure 6: PAPR Reduction with respect to the 16-QAM/OFDM

Table 1: Parameters regarding Peak to Average Power Ratio (PAPR) simulation for Different modulation technique On OFDM

Modulation Technique	N-Point	No. of OFDM blocks	No. of sub-blocks	Practical CCDF (PAPR) Value at 7 dB
BPSK/OFDM	256	3000	Without Reduction	0.6117
			1	0.6043
			2	0.4147
			4	0.1967
			8	0.0410
			16	0.0013
QPSK/OFDM	256	3000	Without Reduction	0.8363
			1	0.8120
			2	0.7273
			4	0.5447
			8	0.2477
			16	0.0480
16-QAM/OFDM	256	3000	Without Reduction	0.8697
			1	0.8500
			2	0.7180
			4	0.5353
			8	0.2523
			16	0.0550
32-QAM/OFDM	256	3000	Without Reduction	0.8763
			1	0.8523
			2	0.7090
			4	0.5543
			8	0.2723
			16	0.0517
64-QAM/OFDM	256	3000	Without Reduction	0.8780
			1	0.8417
			2	0.7023
			4	0.5313
			8	0.2620
			16	0.0483
128-QAM/OFDM	256	3000	Without Reduction	0.8800
			1	0.8540
			2	0.7270
			4	0.5397
			8	0.2713
			16	0.0443

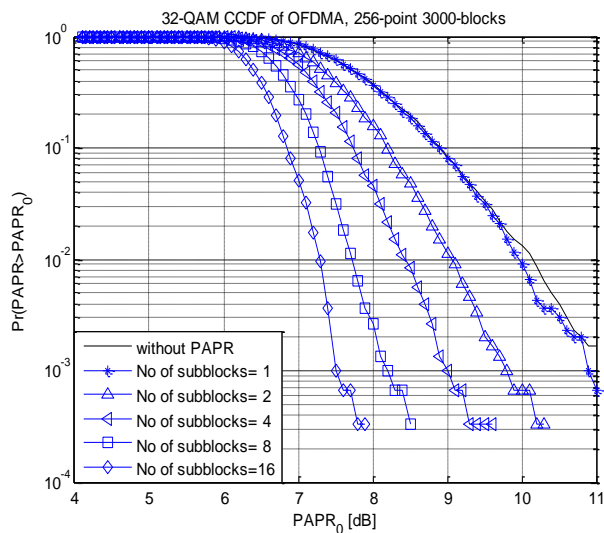


Figure 7: PAPR Reduction with respect to the 32-QAM/OFDM

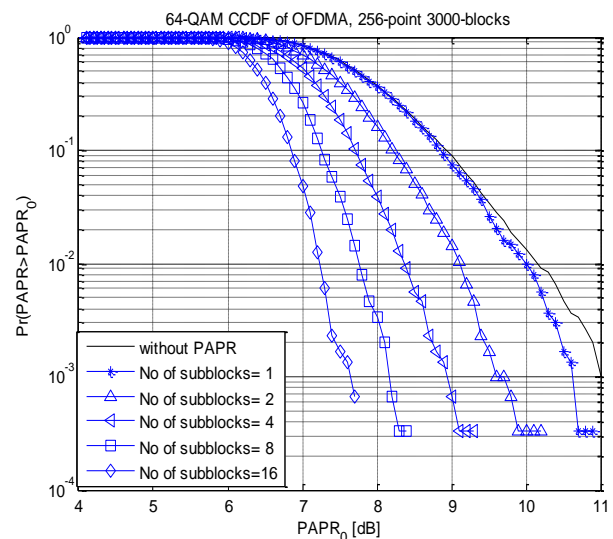


Figure 8: PAPR Reduction with respect to the 64-QAM/OFDM

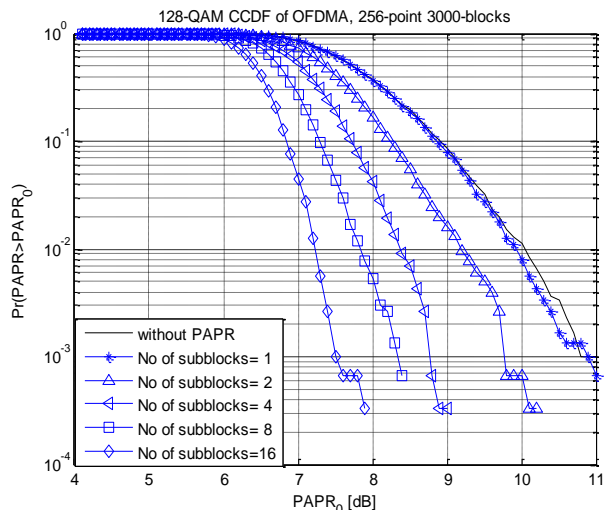


Figure 9: PAPR Reduction with respect to the 128-QAM/OFDM

Conclusion

This work was devoted to the derivation of a new analytical expression for the PAPR reduction technique for coded OFDM systems using scrambling approach with respect to the modulation technique like BPSK, QPSK and M-QAM. OFDM used in many wireless communication systems due to its efficient behavior in fading environment. OFDM suffers from high PAPR compared to the single carrier systems. The proposed algorithm is based on the combination of probabilistic approach and coded approach which reduced the PAPR value efficiently. In the proposed method the out-of-band interference is very low as well as very low complexity. From table 1 we say that as we increased the number of sub-blocks the CCDF (PAPR) value is decreased.

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