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A PERFORMANCE OF A NEW HYBRID PTS-CCPAB PAPR REDUCTION TECHNIQUE IN OFDM TRANSMITTERS

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ABSTRACT

A hybrid method for reducing Peak-to-Average Power Ratio (PAPR) in multi-carrier systems such as Orthogonal Frequency Division Multiplexing (OFDM) by a combination of the partial transmit sequence (PTS) technique and cascade clipping peak amplifying bottom (CCPAB) method is proposed in this study. The PTS approach is a widely-accepted method for improving PAPR statistics. CPAB is a process to be performed by clipping peaks and amplifying bottoms of OFDM signal by controlling thresholds *A* and *B*. However, a combination of PTS and CPABto carry out a new hybrid PTS-CCPAB approach at Transmitter side requires a balance of the reduction level to the performance of PAPR reduction. Too much reduction in PAPR leads to degradation of the transmitted signal. PAPR decreases by reducing A and increasing B, but at the expense of signal power. The computer simulation is used in system tests, which show that the controlling is possible for the reduction to realize the acceptable PAPR performance. The PTS-CCPAB is a guaranteed method to achieve the desired level of the PAPR reduction. Therefore, the proposed method improves system performance regarding PAPR reduction and capabilities to be used for OFDM.

Keywords: orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), partial transmit sequence (PTS), clipping peaks amplifying bottoms (CPAB).

1. INTRODUCTION

Multi-carrier systems, such as orthogonal frequency division multiplexing (OFDM), are significantly affected by peak-to-average power ratio (PAPR). However, a high PAPR inherent in OFDM transmitted signal envelopes occasionally drives high-power amplifiers to operate in the nonlinear region of their characteristic curve.

Many techniques have been developed to reduce performance degradation resulting from the PAPR problem that is inherent in the transmitter of OFDM systems;however, each technique has its advantages and disadvantages (Pradabpet *et al*. 2013). Thepeak power of the signal that causes high PAPR problem at the transmitter side can be up to *N* times the average power (where *N* is the number of subcarriers). Several reported techniques, as the clipping and filtering, provides high complexity and suffer from various problems,including both out-of-band and in-band distortion expansion (Rahmatallah and Mohan 2013). Rahmatallah proposed companding method with low complexity, good distortion, and spectral properties; however, the signal distortion methods havea limited range of PAPR reduction. Advanced techniques, such (PTS) partial transmit sequence,(SLM) selected mapping, and coding, also havebeen a real reduction of PAPR(Al-dalakta 2012).

2. RELATED WORKS

2.1. OFDM transmitter description

In the transmitter of OFDM systems, a block of *N* symbols is formed with each symbol modulation;*N* is the number of subcarriers, wherein the OFDM transmitted signal is given by

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x[k] \exp(\frac{j2\pi nk}{N}), \qquad 0 \le k \le N-1. \quad (1)$$

In typical transmitters of an OFDM system, the value of *N* is large; hence, OFDM signals are approximated by a Gaussian distributed signal. This condition implies that some samples have a high probability of generating significant peaks, which leads to drawbacks and high PAPR problem.The construction of an OFDM transmitter with someobstacles and the expected solution that can be applied to address such barriers presented in Figure-1 (Braun, 2014).

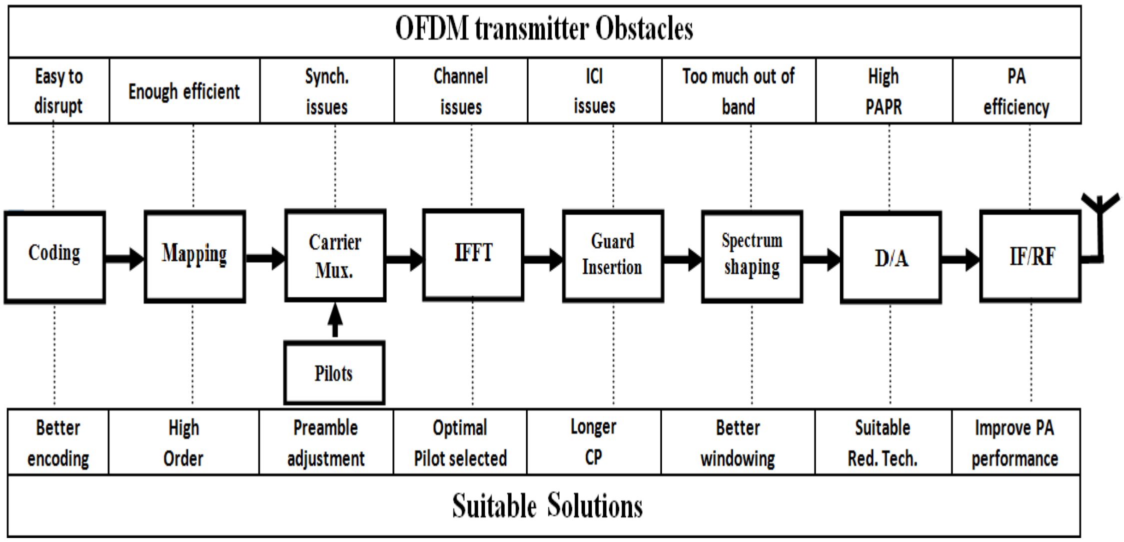

Figure-1. Baseband of OFDM transmitter and drawbacks(Jaber *et al.*, 2015a).

2.2. Peak to Average Power Ratio (PAPR)

The high PAPR of an OFDM signal is one of the biggest problems in OFDM systems in wireless communication. A high PAPR reduces the efficiency of a power amplifier, which leads to the lossof its orthogonality feature, particularly for OFDM systems between subcarriers.Thus, it also generally degrades the performance of OFDM system, as well as those of high-complexity analogue-to-digital (ADC) and digital-to-analogue (DAC) systems. Moreover, a high PAPR has two significant disadvantages.Firstly, it increases complexity in a DAC/ADC circuit; second, it reduces the efficiency of radio frequency amplifiers(Jiang and Wu, 2008). Based on the process of central limit theorem for a large number of subcarriers, the peaks and baseband of an OFDM signal are statistically random. Assuming that the samples are mutually uncorrelated, and the probability of PAPR exceeds a limit threshold, γ can be obtained by:

$$\text{Probability}\{PAPR>\gamma\}=[1-(1-e^{-\gamma})^{N}], \text{ where } \gamma>0. \quad (2)$$

Equation calculates PAPR:

$$PAPR=\frac{(x_k^{\,2})_{\max}}{E\{x_k^{\,2}\}}, \quad 1\le k\le N, \quad (3)$$

Over the years, many techniques have been proposed to address the high PAPR problem in multi-carrier modulation systems. In particular, different PAPR reduction techniques for OFDM systems have been developed. The major drawback of OFDM systems is their large PAPR about the acceptable ratio. Consequently, the transmitter requires a highly linear range process to amplify the transmitted signal to be able to receive it without clipping it. Such process is also necessary to design ADC and DAC devices with low demands on dynamic range and precision; otherwise, OFDM signals will be exposed to nonlinear distortion, which will result in high PAPR, signal interference, and degradation in system performance (Hasan, 2012; Rahmataallah, 2010). PAPR techniques are grouped into five categories.

(i) **Signal distortion:** peak windowing, companding technique, envelope scaling, peak reduction carrier, clipping, and filtering.

(ii) **Signal distortion less:** Firstly, coding techniques involved numerous methods such as block coding techniques, permutation sequences, cyclic coding, dummy sequences insertion, pseudo-noise coding, turbo coding, and Golay sequences. Secondly, multiple signaling and probabilistic techniques such as interleaving method, trellis shaping, active constellation extension, orthogonal pilot sequences, neural networks, dynamic symbol pairing technique, carrier-by-carrier partial response signaling, and linear phase rotation vector technique.

(iii) **Pre-distortion methods:** tone reservation, tone injection, and pre-coding or pulse shaping).

(iv) **Probabilistic (scrambling) methods:** SLM and PTS.

(v) **Hybrid techniques:** techniques that consist of two combined methods, such as PTS with a clipping method.

2.3. PTS Technique

The PTS method reduces PAPR in OFDM signals. These techniques can exhibitexcellent PAPR reduction performance of OFDM signals. However, an exhaustive search over all combinations of allowed phase factors is required, which results in high complexity. The PTS technique is similar to SLM because most of the drawbacks of PTS also involve computational complexity [e.g., search complexity for the optimal phase factor and more than one inverse fast Fourier transform (IFFT) blocks] and low data rate [e.g., required side information (SI)]. Therefore, researchers have decreased complexity

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by avoiding SI calculations(Yang *et al*. 2006). In (Al-dalakta, 2012), many differences were identifiedconcerning computing the complex nature of PTS and SLM methods. PTS techniques were determined to exhibit less complexity than SLM technique. Numerous techniques have been proposed to reduce PAPR and computational load by improving conventional methodssuch as those presented in(Yang *et al*. 2006; Wang and Liu 2011).

Theconventional PTS block diagramis characterised in Figure-2. Hence, block input data, which comprise symbols, is partitioned into M disjoint sets $d(m)$, $m = 0, 1, \ldots M-1$ and zero-padded to the left and right to obtain the following:

$$d^{(m)} = \left[0^{1\times mN/M}\ , \{d\}_{mN/M}^{(m+1)N/M-1}, 0^{1\times[N-(m-1)N/M]}\right] \qquad (4)$$

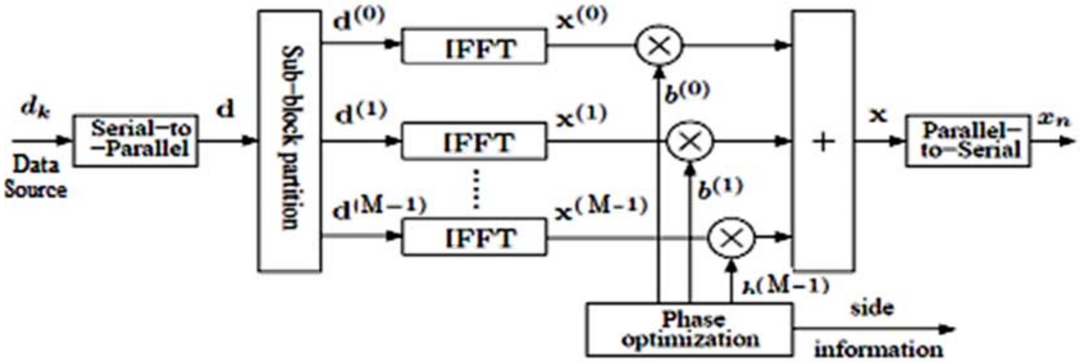

Figure-2. The conventional PTS block diagram (Al-dalakta 2012).

The time-domain vectors$\mathbf{x}^{(m)}$are obtained by implementing an N-point IFFT on every disjoint set. Moreover, samples $x_n^{(m)}$ in time–domain can be described as follows:

$$x_n^{(m)} = \frac{1}{\sqrt{N}} \sum_{q=0}^{N-1} d_q \ e^{j2\pi qn/N}, \quad n = 0, 1, \ldots, N-1; \qquad (5)$$

Where d_q, $q = 0, 1, \ldots, N-1$ are the input symbols or the discrete time index modulated by phaseshift keying or quadrature amplitude modulation (QAM). Consequently, complex weighting phase factors, that is, $b(m) = \{\pm1, \pm j\}$, are multiplied to the scramble IFFT outputs. Therefore, M signals are added in time-domain to produce the overall samples as:

$$x_n = \sum_{m=0}^{M-1} b^{(m)} x_n^{(m)} \qquad (6)$$

This scheme provides the minimum PAPR value by selecting the optimal combination of phase factors and transmitting these factors as SI (Al-dalakta 2012).

2.4. Clipping technique

One of the most straightforward methods is repeated clipping and filtering, which appears adequate in handling the problem experienced by current systems. No old or new method is included. Moreover, this technique is the most famousfor OFDM systems (Jaber *et al*. 2015). The amplitude variation of an OFDM signal and its peaks exceed the threshold value, as shown in Figure-3.

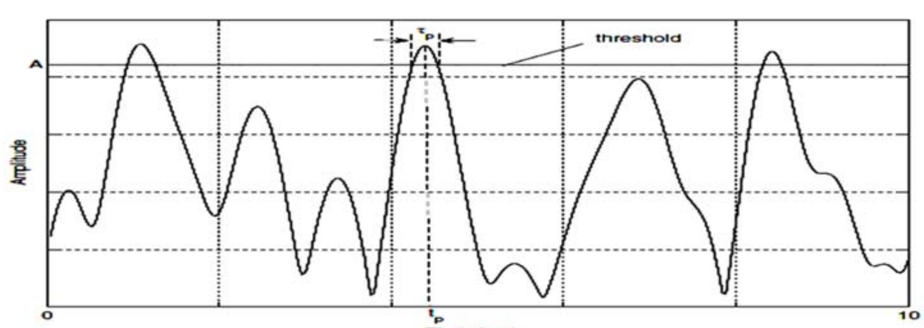

Figure-3. Clipping peaksof OFDM signal.

The disadvantages of the clipping technique include causing a distortion in the OFDM signal and significant high degradation in system performance. This method also imposes out-of-band overlapping of signals in neighbouring channels as a result of out-of-band noise. A filtering process can quickly reduce out-of-band noise, but the effect of such process influences in-band signals is a high-frequency component when clipping is performed at the Nyquist sampling rate. Conducting filtering after clipping may mitigate out-of-band noise at the cost of the amplitude of a signal. Filtered signal may go over the given threshold of clipping (Li and Cimini, 1998).

Other methods, however, have been determined to mitigate the effects of the amplitude clipping process, such as the iterative clipping and filtering process proposed by Zhu (Zhu *et al*. 2013). In this previous study, clipping and filtering were regarded as procedures for adding an extra signal to the original signal.

PROPOSED METHOD

As shown in Figure-4, automatically selected vectors (weights) after the cascade clipping peak amplifying bottom (CCPAB)are applied to OFDM signals. The new hybrid PAPR reduction technique is implemented by combining CPAB and PTS methods. In hybrid PTS - CCPAB method, deciding on the optimum vector from the vectors supposed through random phase rotations is important. The best selection of thresholds can satisfy the better PAPR reduction among the supposed vectors. For example, PAPR is decreased when M increased. However, calculation of the cost may be considerably higher, which indicates that additional modification may be implemented on the proposed hybrid PTS–CPAB algorithm. In this technique, the simulation program attains a better trade-off between PAPR and performance processes by selecting *A* and *B* values, as well as candidate vectors of phase rotations in an optimization unit.

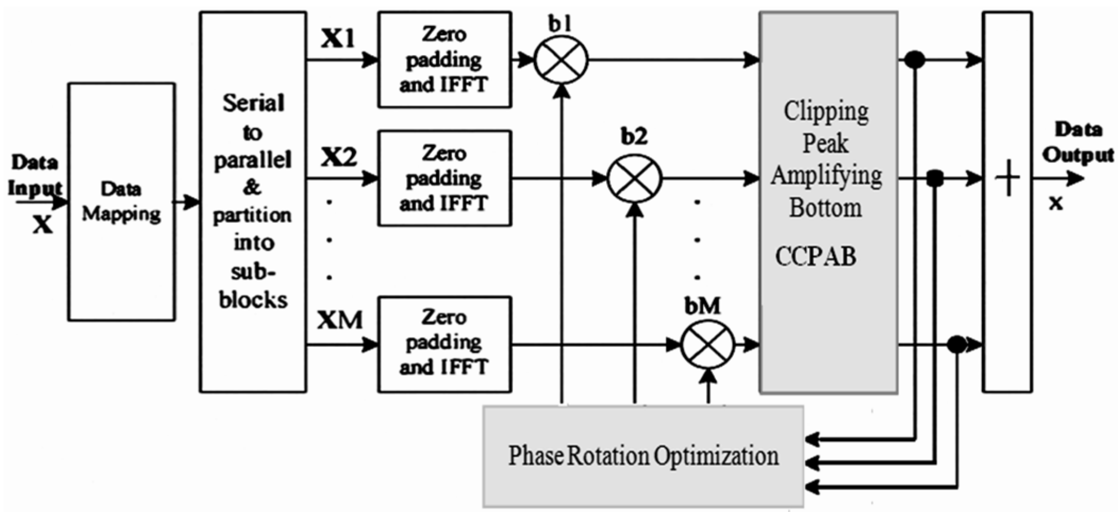

Figure-4. The transmitter of OFDM system with hybrid of *PTS-CCPAB.*

In the proposed method, by using PTS, the sequence of input data is rearranged first. An input data block $\{X_n, n = 1,2,3, ..., N\}$ is defined as a vector,

$X = [X_1\ X_2\ X_3 \ldots X_N]^T$

It can represent by $\{X_m, m = I,2,3, ..., M\}$.

$$X = \sum_{m=1}^{M} X_m \quad (7)$$

So IFFT is implemented as,

$$X_m = IFFT\ \{ X_m\} \quad (8)$$

By applyingphase, rotations to satisfy an optimization of the combined weights in the PTS. The sequences are as,

$$x = \sum_{m=1}^{M} b_m x_m = [x(1)\ x(2)\ ,.......\ x(N)], \quad (9)$$

Where the weights of the phase rotation are $\{b_m, m= 1,2,3, ..., M\}$ for each sub-block. PAPR can be minimizedthrough an exhaustive search to select the appropriate combinationofcorrespondingphase and sub-blocks. PTS requires SI bits, that is, log2 W^{M-1}toretrievedataby the receiver (Pradabpet *et al*. 2013).

The model of the CPAB method is shown in Figurie-5. A proposed PAPR reduction method comprises the two methods above and naturally exhibits the advantages of both to obtain a small PAPR. However, the number of sub-blocks increases; hence, the calculated cost of the selection must be considerably larger.

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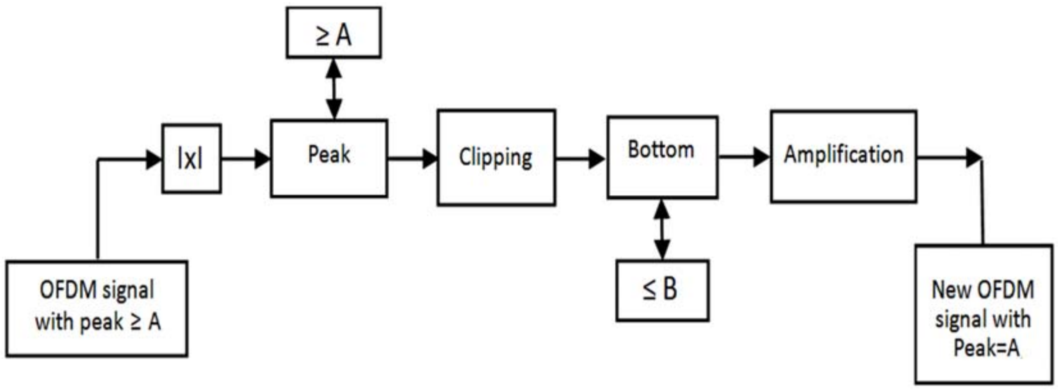

Figure-5.*CPAB* method blocks diagram.

The peaks of signal upper threshold *A* are clipped to value *A*. Then, the clipped signal passes through a detector the bottoms of this signal to distinguish the values of the signal which under amplifying threshold *B*, which is amplified to *be*. Therefore, the values of *A* and *B* are carefully selected because both PAPR and the CCDF complementary cumulative distribution function depend on these values.

The output signal of IFFT block is a complex base signal. For*X*is the OFDM sampled version signals in time,and max |*X*| = A', which is equal the value that exceeds the threshold *A*. At the clipped signal, max |*X*| = *A*.It meant clipping is performed the maximum of *X* becomes *A*.

The relation between CCDF and *A*is enveloped of OFDM signals. The design of the CPAB algorithmis shown in Figure-6.

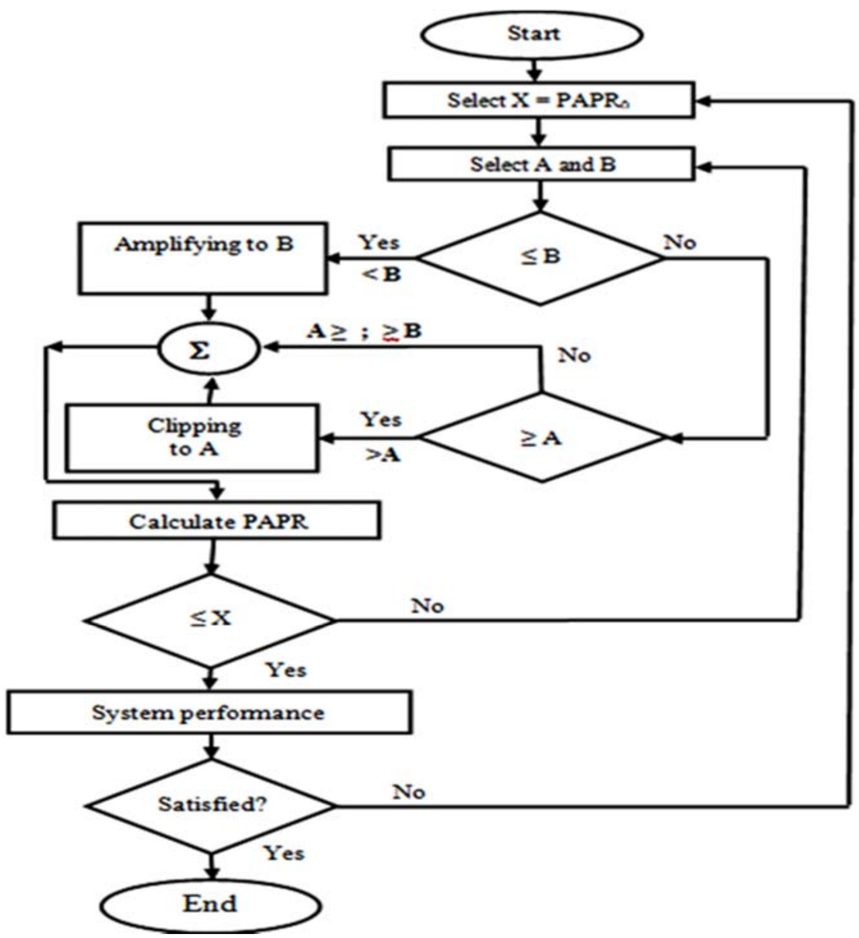

Figure-6. *CPAB* method algorithm.

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Therefore,

$$CCDF = 1 - e^{\frac{B^2}{2\sigma^2}} + e^{\frac{A^2}{2\sigma^2}}, \qquad (10)$$

Where A is the clipping threshold, B is the amplification threshold, and σ^2 is the variance of x. By substituting σ^2.

$$PAPR = -2\ln CCDF \Big/ \left[1 - \frac{B^2}{A^2}\right] \qquad (11)$$

4. RESULTS AND DISCUSSIONS

The proposed methods and their performance are validated and compared with other techniques, such as existing PTS and clipping approaches. Some parametersare used in the computer simulation, these parameters arelisted in Table 1(Wang and Liu, 2011; Pradabpet *et al*. 2013).

Table-1. Simulation parameters.

Number of sub-carriers	48
Number of pilots	4
Number of data symbol	52
Number of sub-blocks	8
Number of IFFT/FFFT size	64
FFT/IFFT interval	3.2µsec
Modulation order	16, 32, and 64
Phases rotation w=4	1, i, -1, -i
Data rate	54 Mbps
Coding rate	3/4
CP interval	0.8 µsec
Multiplexing scheme	OFDM
Channel Bandwidth	20MHZ
Central frequency	5 / 2.4 GHz
Sub-carrier spacing	312.5KHZ
OFDM symbol interval	4µsec

The details of PAPR variation compared to clipping threshold (A) and amplifying threshold (B) are provided in Figures-7(a) and 7(b). The former shows that PAPR increases with the increase in modulation order M (16, 32, 64). For 16-QAM, 32-QAM, and 64-QAM, Figure-7(a) shows the clipping threshold varies from 30% to 60% peak power value of the OFDM signal, whereas the amplifying threshold is fixed at approximately 15% of the average power value.

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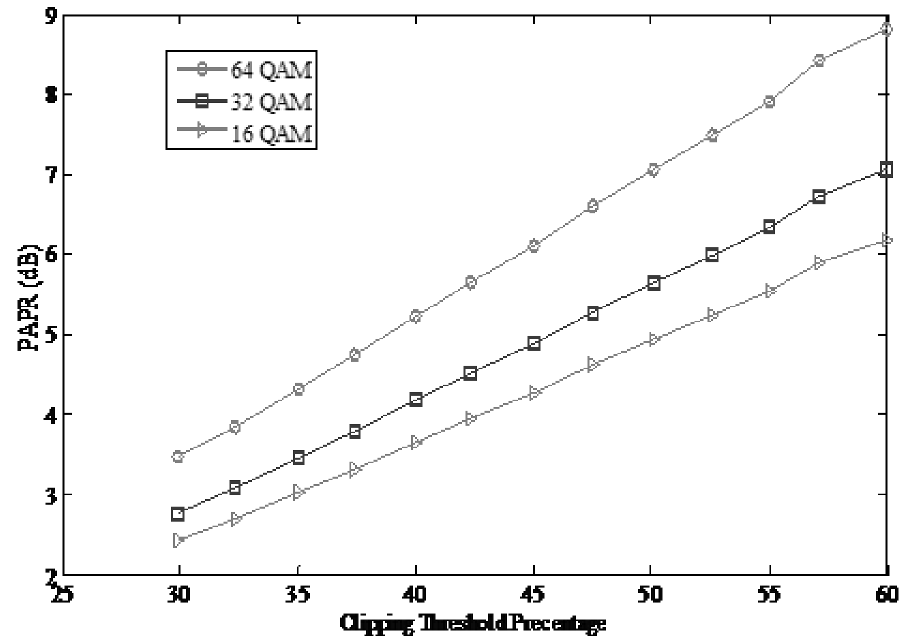
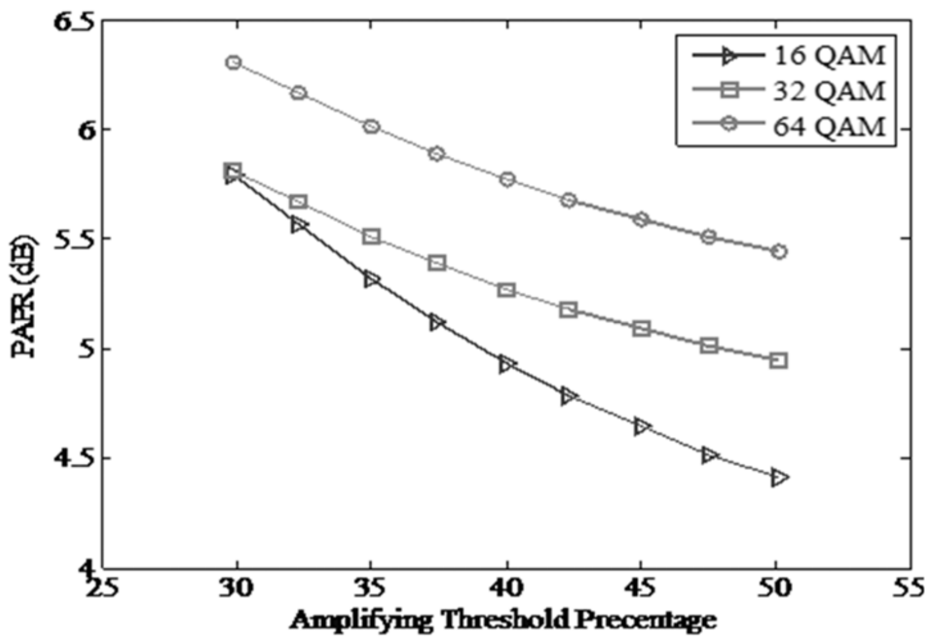


(a) The clipping threshold *A*



(b) The amplifying threshold*B*
(c)

Figure-7. PAPR vs. *A* and *B*.

Inclipping threshold (*A*) of 40% peak power, the PAPR values are 3.6, 4.2, and 5.25 dB for 16-QAM, 32-QAM, and 64-QAM, respectively.

Meanwhile, Figure-7b shows that the amplifying threshold varies from 10% to 40% average power value of the OFDM signal, whereas the clipping threshold is fixed at 40% for 16-QAM, 32-QAM, and 64-QAM.

At 35% average power amplifying threshold (*B*), the PAPR values are 5.3, 5.5, and 6 dB for 16-QAM, 32-QAM, and 64-QAM, respectively. Both figures reveal that PAPR is affected more by the selected clipping value than the amplifying value and that it depends on *M*-array modulation.

Also, CCDF increases with increasing modulation order (*M*) and amplifying threshold but

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decreases with decreasing clipping thresholds with a slight change in signal amplification.

By combining the two methods (clipping and amplifying), the CPAB method for PAPR reduction is investigated. The results show PAPR performance of the hybrid method provides less CCDF, as indicated in Figure-8. The amplifying technique reduces PAPR more than the clipping technique. For *An* equal to 60% OFDM peak value and the amplifying threshold *B* of 35% average power of the OFDM signal to provide a balance between system performance and PAPR reduction. Different *M*-array modulation techniques are investigated to obtain an appropriate modulation for OFDM system regarding CCDF or PAPR performances.

In general, the proposed PTS-CCPAB method reduces peak-to-bottom values to approximately 65% of the traditional value.

As shown in Figure-9, the reduction of PAPR using the PTS-CCPAB method is a better performance ascompared with those of the conventional OFDM signal (without using any PAPR reduction technique), clipping,amplifying,PTS, CPAB respectively. However, the proposed hybrid PTS-CCPAB may be required more time simulation because the complexity is high also. In short, high PAPR performance at transmitter side with great complexity will be obtained by adopting the new proposed technique of hybrid PTS-CCPAB technique.

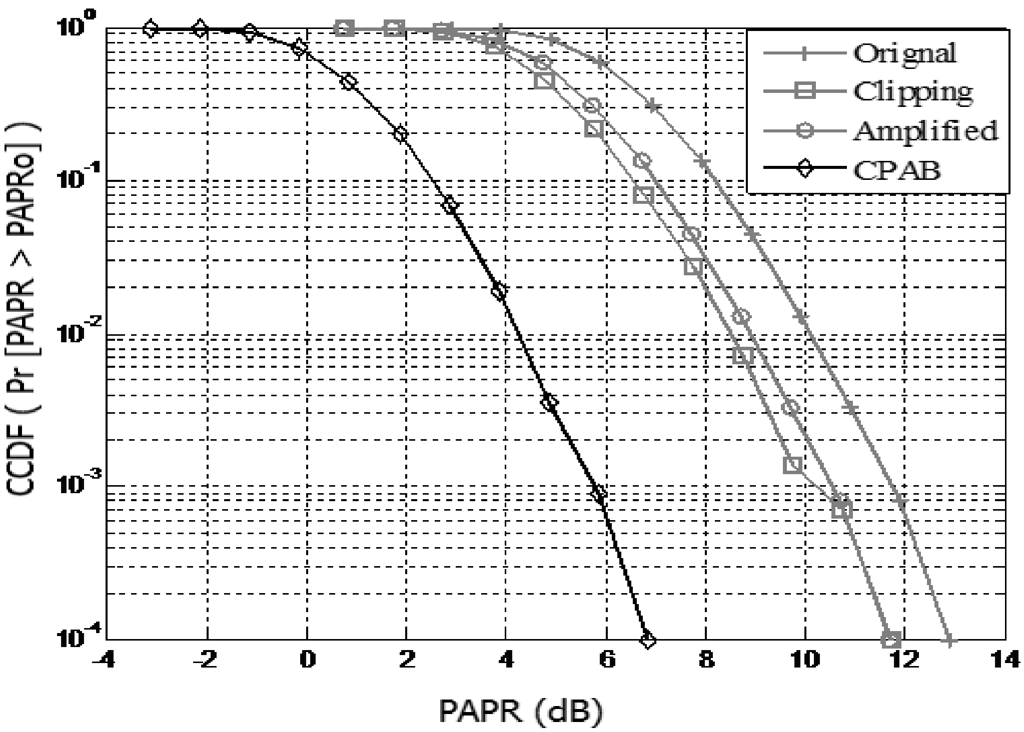

Figure-8. PAPR reduction methods comparison.

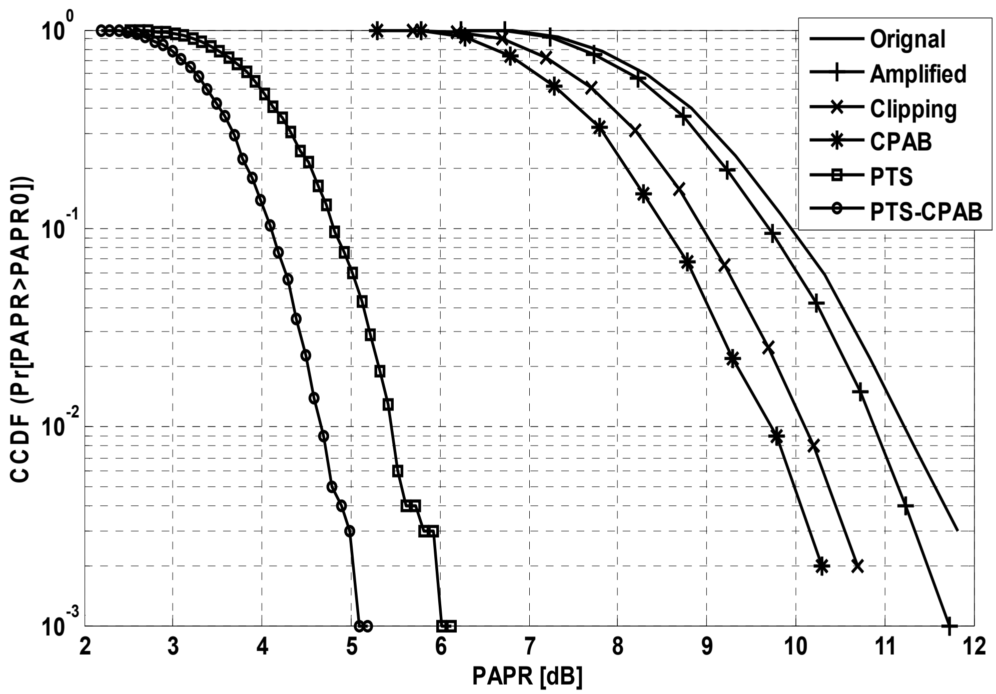

Figure-9. PAPR performance of OFDM transmitter.

5. CONCLUSIONS

This study proposes the hybrid PTS-CPAB method to address the high PAPR problem in OFDM systems. The peak clipping and amplification techniques were described for multi-carrier transmission. These methods were combined to produce the new PTS-CPAB method. In CPAB, the clipping process is independent of amplification, and the values of the clipping threshold (*A*) and the amplifying threshold (*B*) determine the value of PAPR. However, the balance between PAPR and BER is required. Also, the computation cost is considerably larger when *N*is increased. The simulation showed that the algorithm was reliable in estimating *A* and *B* selection. CCDF is dependent on *A* and *B*. A large CCDF improves power amplifier efficiency, but yields a high degradation in the transmitter performance. Therefore, the relationship between CCDF, *A*, *B* is established to maintain system performance. Moreover, the PTS-CPAB method exhibits better CCDF performances than the original OFDM signal. However, computations and complexities increase with a large number of sub-blocks. In this case, one of the optimisation methods can be used to terminate the operation as a solution.

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REFERENCES

Al-dalakta E. 2012. PAPR and ICI Reduction Techniques for OFDM Based. Newcastle University.

Braun K.M. 2014. OFDM Radar Algorithms in Mobile Communication Networks. Karlsruher Institutes für Technologie.

Hasan M. and S.S.S. 2012. An Overview of PAPR Reduction Techniques in OFDM Systems. International of Computer Application. 60(15): 33-37.

JaberA. Y., Latiff L. A., Norulhusna A., and Ahmed N. A. 2015a. Peak-to-average Power Ratio Methods to Improve the Performance of Multicarrier Modulation Systems. Research Journal of Applied Sciences, Engineering and Technology. 11(10): 1091-1102.

Jaber A. Y., Latiff L. A., Norulhusna A., Ahmed N. A.2015b. Joint Clipping and Amplifying Techniques for PAPR Reduction in OFDM Systems. pp.54-58.

Jiang T. and Wu Y. 2008. An overview: Peak-to-average power ratio reduction techniques for OFDM signals. IEEE Transactions on Broadcasting. 54(2): 257-268.

Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4446229.

Li X. and Cimini L.J. 1998. Effects of clipping and filtering on the performance of OFDM. IEEE Communications Letters. 2(5): 131-133.

Pradabpet C., Chivapreecha S. and Yimman S. 2013. The hybrid of PTS-CAPPR methods with MA for PAPR reduction in OFDM systems. In: 13thInternational Symposium on Communications and Information Technologies: Communication and Information Technology for New Life Style Beyond the Cloud, ISCIT 2013. Bangkok, Thailand: Phranakhon Si Ayutthaya Rajabhat University. pp. 680-684.

Rahmataallah Y. 2010. A Companding Scheme with Enhanced Bit Error Rate Wireless Orthogonal Frequency Division Multiplexing Systems. University of arkansas at Little Rock.

Rahmatallah Y. and Mohan S. 2013. Peak-To-Average Power Ratio Reduction in OFDM Systems: A Survey and Taxonomy. IEEE Communications Surveys and Tutorials. 15(4): 1567-1592.

Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6476061.

Wang L. and Liu J. 2011. PAPR reduction of OFDM signals by PTS with grouping and recursive phase weighting methods. IEEE Transactions on Broadcasting, 57(2 PART 1): 299-306.

Yang L. *et al.* 2006. PAPR reduction of an OFDM signal by use of PTS with low computational complexity. IEEE Transactions on Broadcasting. 52(1): 83-86.

Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=1599576.

Zhu X. *et al*. 2013. A simplified approach to optimized iterative clipping and filtering for PAPR reduction of OFDM signals. IEEE Transactions on Communications. 61(5): 1891-1901.

Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6469001.