

PAPR Reduction in OFDM Using Combinational Approaches

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Abstract: The article evaluates the performance of combinational approaches for peak power reduction in Orthogonal Frequency Division Multiplexing (OFDM) system. Here, two intelligent combinations have been presented using constellation extension and scrambling techniques. The principle of these combinational approaches is to use Partial Transmit Sequence (PTS) and Approximate Gradient Project (AGP) schemes simultaneously in an OFDM standards in serial and parallel structure. At the end, simulation results show that these two combined approaches reduce the PAPR as compared to conventional techniques and also maintain the Bit Error Rate (BER) performance of the system especially at low Signal to Noise Ratio (SNR). Moreover, the proposed parallel approach maintains the data rate and reduces the computational complexity in compared to PTS scheme.

Keywords: Constellation extension, OFDM, PAPR and scrambling.

I. INTRODUCTION

In current scenario, Multi-Carrier Modulation (MCM) has been adopted in several communications based standards. Due to need of high data rate transmission, researchers put focus on Orthogonal Frequency Division Multiplexing (OFDM) which is special form of MCM. Therefore, nowadays numerous standards use OFDM as main backbone in various communication systems e.g. Digital Video Broadcasting (DVB), and Long Term Evolution (LTE) [1]. It has been observed in the OFDM that entire spectrum carries parallel data through sub-channels which easily alleviated the problem of multipath propagation [2].

On the contrary, one of the major disadvantages of OFDM is high Peak-to-Average Power Ratio (PAPR). The PAPR affects the efficiency of Digital-to-Analogue Converter (DAC), introduces non-linearity in High Power Amplifier (HPA), increases spectral spreading (in-band ripples and out-of-band

radiation) and allows Bit Error Rate (BER) degradation. In literature, a variety of techniques are proposed for PAPR reduction. Such as clipping, coding [3], tone injection, tone reservation [4], null subcarrier switching [5], Selected Mapping (SLM) [6], Partial Transmit Sequence (PTS) [7], Project Onto Convex Set (POCS), and Approximate Gradient Project (AGP) [8, 9]. Generally, these techniques are compared on the basis of PAPR reduction, BER performance, computational complexity and side information. The PTS technique shows less PAPR than other methods but undergo low data rate due to the requirement of side information at the receiver. On the other hand, a smaller amount of computations are required by AGP method. Therefore, combinational approaches are proposed to overcome the drawback of individual methods. In Section II, PAPR is formulated for OFDM system model. The proposed reduction techniques along with algorithm are presented in Section III. Results and computational analysis are discussed in Section IV and V respectively. At last, the conclusion is elaborated in Section VI.

II. OFDM MODEL

An OFDM is a Frequency-Division Multiplexing (FDM) scheme with large number of independent closely spaced orthogonal subcarriers used to carry data on several parallel data streams or channels. The transmitted envelop of N subcarrier OFDM, generated using Inverse Fast Fourier Transform (IFFT) [1], is expressed as follows:

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X[K] e^{j2\pi kn/N}; \quad 0 \leq n \leq N-1 \quad (1)$$

This transmitted envelop of OFDM signal gets fluctuations due to high peaks of N times of the average power [1, 2] which is generated by the IFFT summation of N subcarriers. Large peak power distorts the signal especially when transmitter contains non-linear devices such as power amplifiers. Therefore, for distortion less transmission of OFDM signal ratio of peak to average power should be minimized. The ratio of maximum peak power and average power of the OFDM envelop is termed as PAPR and formulated as following:

$$PAPR\{x[n]\} = \frac{\max_{0 \leq n \leq N-1} [x[n]^2]}{E[x[n]^2]} \quad (2)$$

where, $E[\cdot]$ in (2) represents the expectation operator and calculates the average power of the OFDM envelop. In this paper, all the computations have been done in frequency domain because IFFT is a unitary transformation and computation for PAPR has been carried out in terms of Complementary Cumulative Distribution Function (CCDF) [6].

In this work, proposed PAPR reduction approaches have been validated by selecting the IEEE 802.11a wireless LAN (WLAN) [10] and IEEE 802.16e wireless (WiMAX) [11] standards as examples. The IEEE 802.11a mandates 52 data and 12 null subcarriers [10], on the other hand, IEEE 802.16e requires 200 data and 56 null subcarriers [11].

III. PROPOSED TECHNIQUES

In this paper, two intelligent techniques have been proposed for the minimization of PAPR in OFDM system. Firstly, constellation technique which minimizes the PAPR by extending signals space in the proper direction. Second, phase optimization technique which scrambles the OFDM symbols, multiplies with phase factors and selects one of them with minimum PAPR. In fact, in constellation technique signal spacing is done frequency-domain whereas in phase optimization technique OFDM symbols are scrambled in time-domain [12, 13]. In this article, two contributions have been presented by using combination of these two conventional PAPR reduction techniques. First, serial combination of PTS and AGP, also known as probabilistic constellation extension (PCE) technique [13], which provides constellation extension preceded by phase multiplication on the same OFDM symbol as illustrated in Fig. 1.

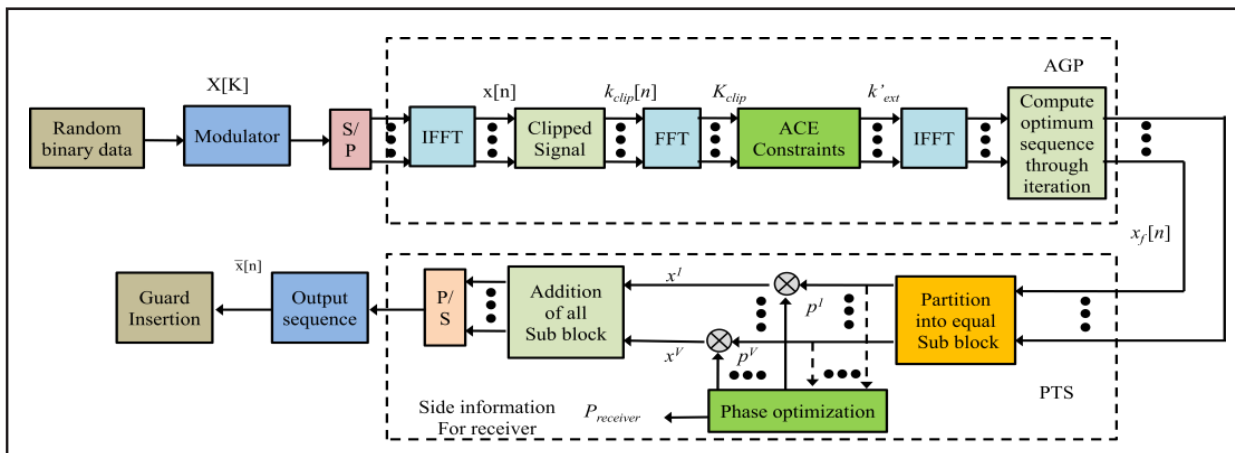


Fig. 1: Block Diagram of PCE Technique

On the other hand, in second contribution parallel combination of PTS and AGP is presented which divides input sequence into two equal halves, as shown in Fig. 2, and their peak powers are

computed and compared consequently. Symbols with less peak power are fed to PTS block and others are moved toward AGP block.

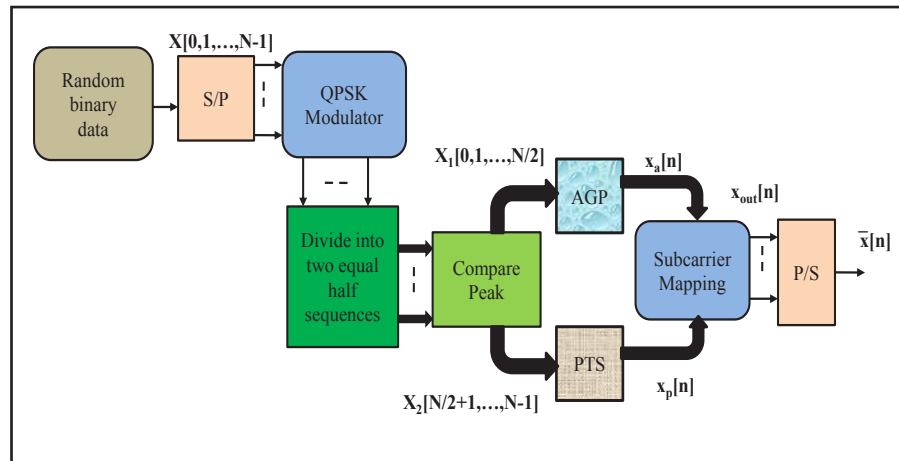


Fig. 2: Block Diagram of PAGC Technique

Finally, output sequences of both the blocks are combined as per position. This approach is also known as Partial Approximate Gradient Constellation (PAGC) [14]. Overall steps

involved in PCE and PAGC techniques are also illustrated by the flow charts shown in Fig. 3 and Fig. 4 respectively.

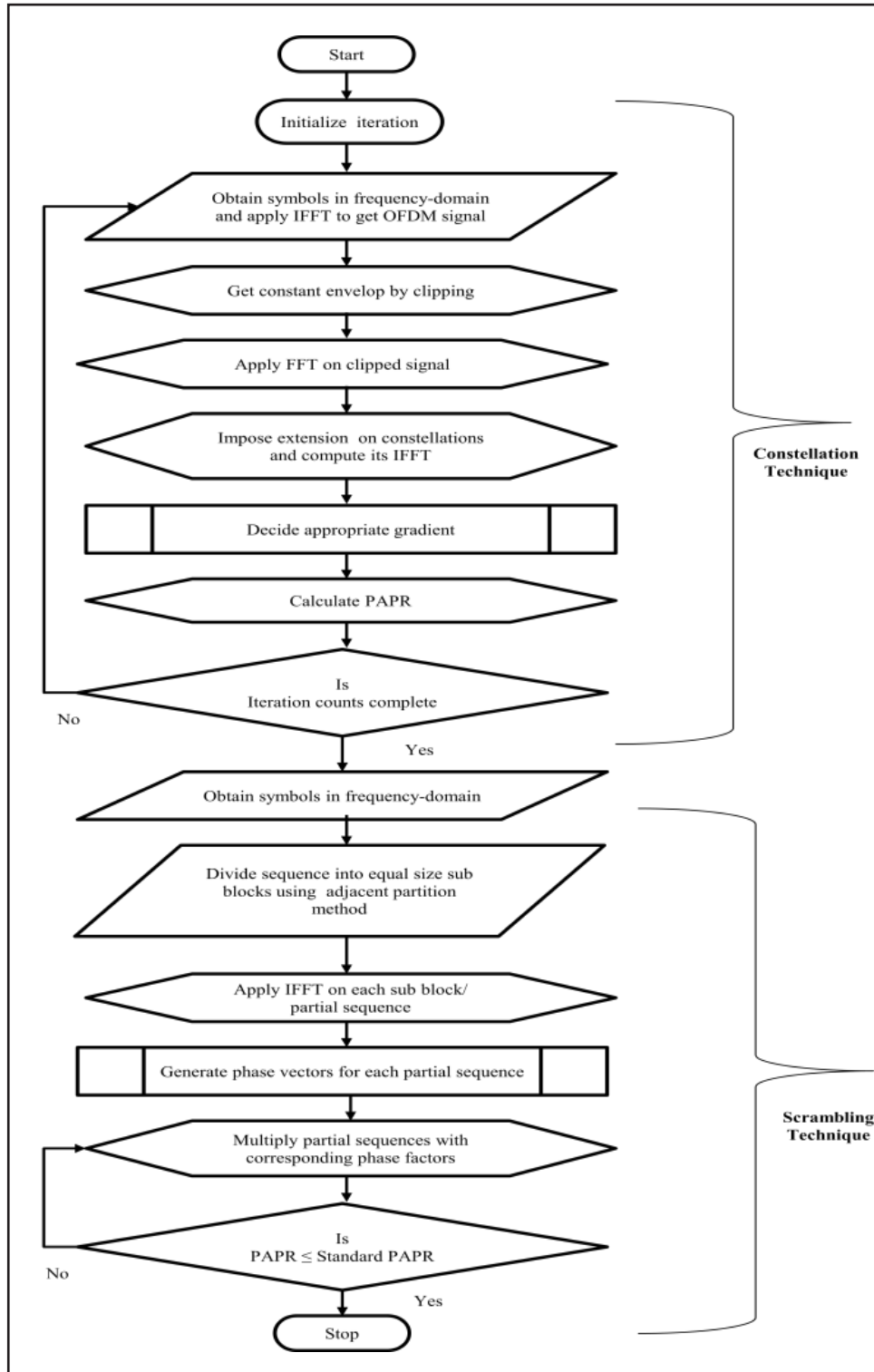


Fig. 3: Flow Chart Diagram of PCE Technique

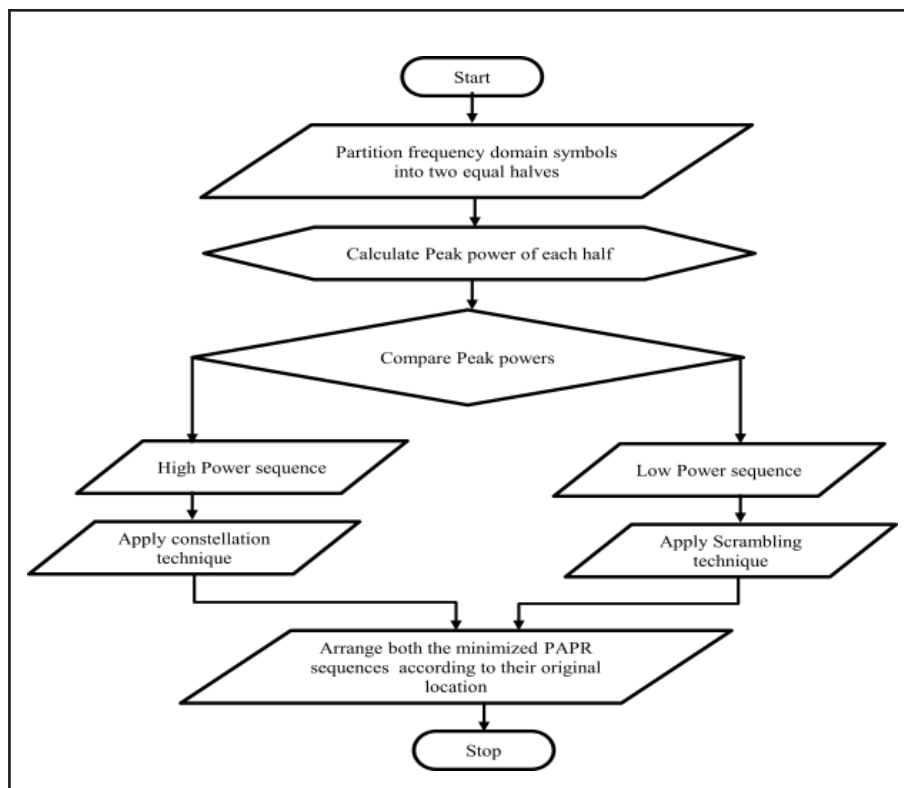


Fig. 4: Flow Chart Diagram of PAGC Technique

IV. RESULTS AND ANALYSIS

Approximately 20,000 QPSK modulated OFDM symbols are used to validate the proposed methods in MATLAB environment. The PTS model utilizes four sub blocks, whereas two iterations employed in AGP technique. Approximately 0.5 dB and 1 dB less PAPR is observed in proposed techniques compare to conventional methods as shown by Fig. 5(a) and

Fig. 5(b) respectively. In general, BER performance is analysis in the presence of Additive White Gaussian Noise (AWGN). The proposed techniques clearly maintain BER similar to conventional techniques as confirmed by Fig. 6(a) and Fig. 6(b). The combinational schemes also preserve spectral spreading as conventional techniques depicted in Fig. 7(a) and Fig. 7(b). It is because of smaller in-band ripples as well as less out-of-band radiations in particular frequency band.

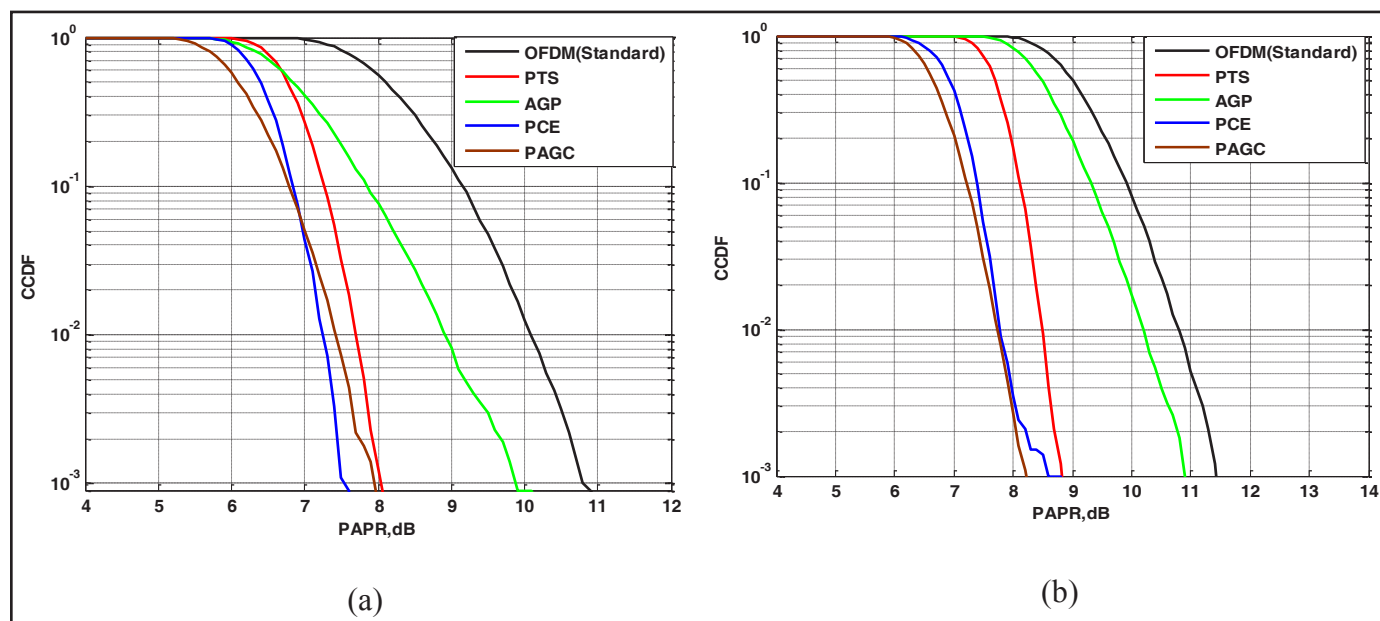


Fig. 5: CCDF Distribution for IEEE (a) 802.11a (b) 802.116e

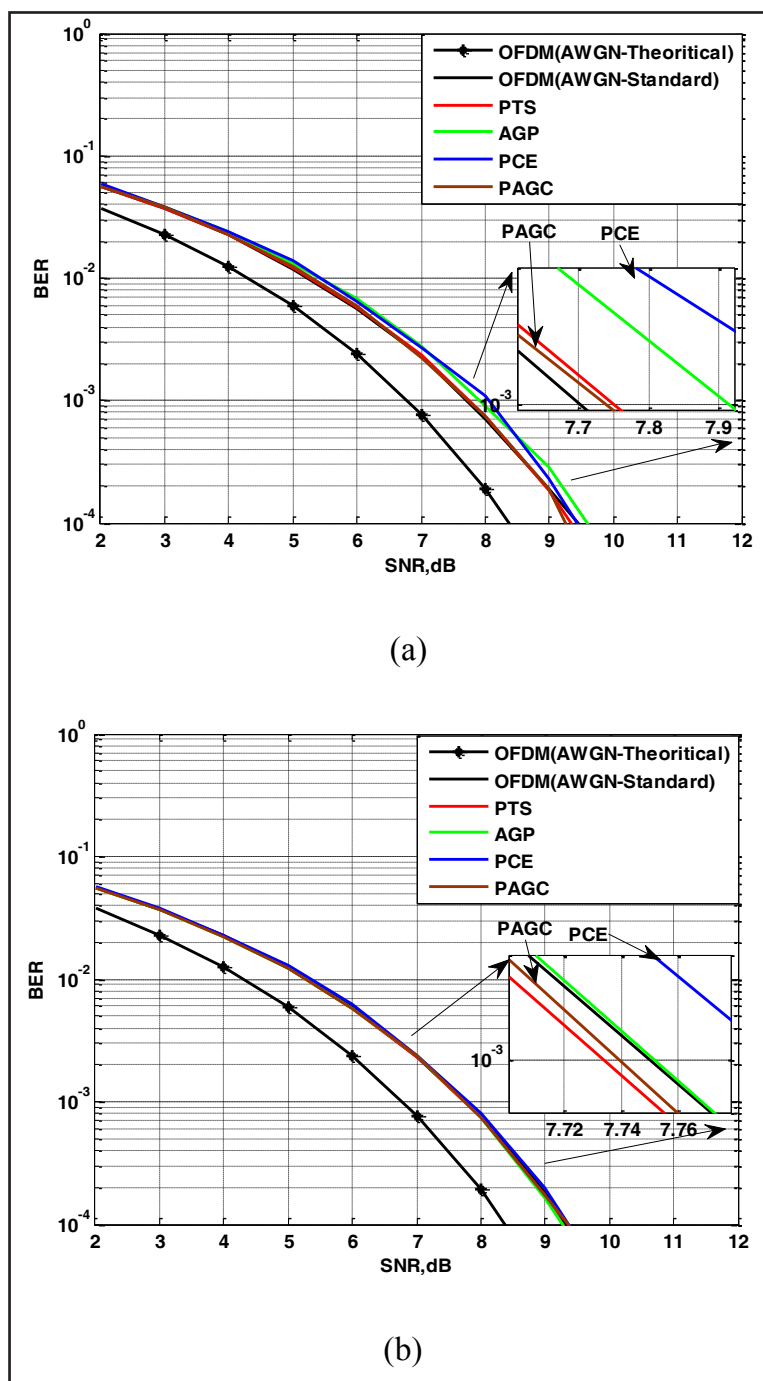


Fig. 6: BER for IEEE (a) 802.11a (b) 802.16e

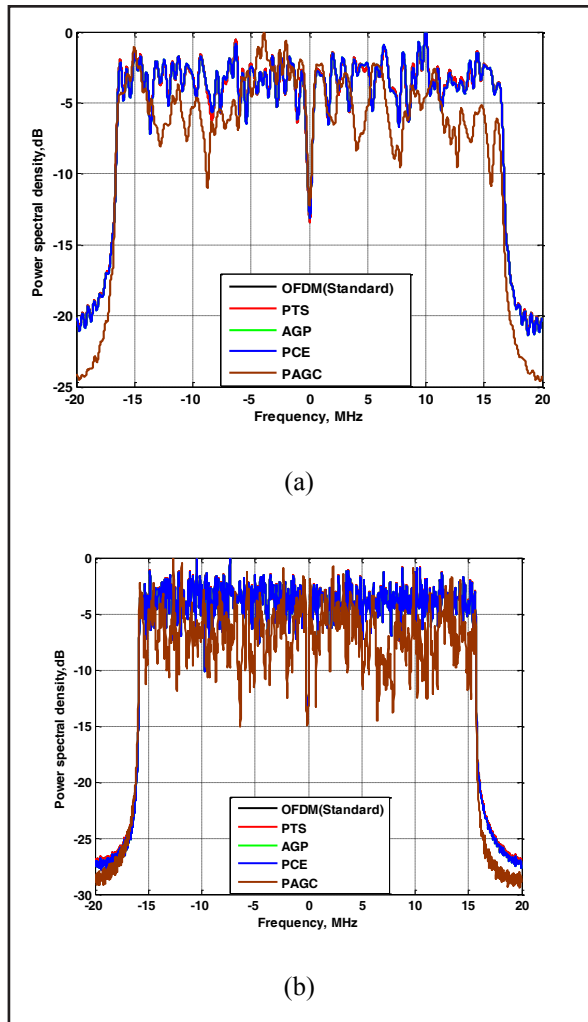


Fig. 7: Spectral Spreading for IEEE (a) 802.11a (b) 802.16e

V. COMPUTATIONAL ANALYSIS

The PCE technique requires $\{D \times (N/2) \times n\}$ complex multiplications and $\{(M + (4 \times D) + 2) \times N \times n\}$ complex additions, where D is number of sub blocks, N is number of OFDM subcarriers, n is the number of binary bit sequences and M is number of phase candidate sequences [13]. On the other hand, AGP technique utilizes $\{q \times (2 \times N) + (N/2) \times n\}$ and $\{q \times (4 \times N + N \times n)\}$ complex multiplications and complex additions respectively where q is number of iterations. Therefore, computational complexity of PCE technique is the addition of computations required in both the techniques as shown in Table I. On the other side, PAGC technique needs $[D \times (N/4) \times \log_2(N/2) + q \times \{N + (N/4) \times \log_2(N/2)\}]$ of complex multiplications and $[\{M + (4 \times D) + 2\} \times (N/2) \times \log_2(N/2) + q \times \{2 \times N + (N/2) \times \log_2(N/2)\}]$ of complex additions [14].

TABLE I: COMPARISON OF COMPUTATIONAL COMPLEXITY

Complex Operations	Techniques			
	PTS	AGP	PCE	PAGC
<i>IEEE 802.11a (N = 52)</i>				
Multiplications	593	504	1097	471
Additions	24307	1009	25316	10474
<i>IEEE 802.16e (N = 200)</i>				
Multiplications	3058	2329	5386	2393
Additions	125359	4658	130017	56608

The computation time is also one of the important parameter to analyze the proposed techniques [15, 16]. This time has been from MATLAB commands scripted for the techniques taken into consideration. It is clear from the Fig. 8(a) and Fig. 8(b) that the PCE needs more computation time because AGP and PTS are run serially whereas PAGC requires less time than the conventional techniques due to parallel structure.

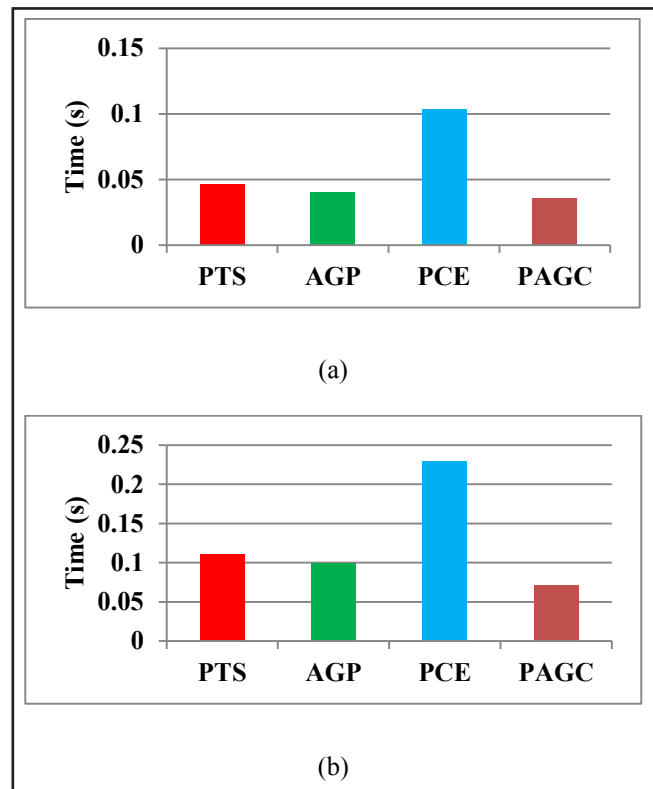


Fig. 8: Computation Time Chart (a) WLAN (b) WiMAX

VI. CONCLUSION

Two combinational approaches for PAPR reduction in OFDM system viz. PCE and PAGC are proposed. These techniques are

the series and parallel combinations of AGP and PTS methods respectively. It is found that the PCE provides lower PAPR among all the techniques while maintains BER and spectral density performances intact. On contrary, PAGC outperforms PCE in computational complexity and computation time. Moreover, it provides comparative PAPR, BER and spectral spreading to PCE technique.

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