# An Efficient Approach of Peak to Average Power Ratio Reduction in OFDM Using CAP-PT Method

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*Abstract* - **An Orthogonal Frequency Division Multiplexing (OFDM) system has been proposed as a standard for the mobile communication systems. Despite the advantages of OFDM signals like high spectral efficiency and robustness against ISI, the OFDM signals have some disadvantages which the main one is the high peak to average power ratio (PAPR). The reason of high PAPR is that in the time domain, the OFDM signal is actually sum of many narrowband signals. At some time instances, the sum of these narrowband signals may be large and at the other time may be small, which means that the peak of the signal is much larger than the average value. This high PAPR signal when transmitted through a nonlinear power amplifier creates spectral broadening and also an increase in the dynamic range of the digital to analog converter (DAC). The result will be an increase in the cost of the system and reduction in efficiency. Hence, the technique to overcome this problem in OFDM systems is necessary. The existing method doesn't have high capability of PAPR reduction with significant high Bit Error Rate (BER) degradation. Hence this proposed CAP-PT (Clipping, Amplification and Peak Windowing/ Partial Transmit) method combines the effect of clipping the peak signals and amplifies the signals that have low amplitude. Out of band radiations which is caused by clipping is suppressed by peak windowing process. Then followed by partial transmit which reduces in band distortions. The PAPR reduces to the great extent without BER degradation. Simulation results demonstrate that the proposed CAP-PT method yields the better performance than the existing methods.**

*Keywords :* **OFDM, PAPR Reduction, Multicarrier Transmission, Clipping, Amplification, Peak Windowing, Partial Transmit**

## 1 Introduction

OFDM is one of the Multicarrier Modulation (MCM) techniques for 4$^{th}$ Generation (4G) wireless communication. This technique is very attractive technique for high-speed data transmission used in mobile communication, digital terrestrial mobile communication, Digital Audio Broadcasting (DAB), Digital Video Broadcasting Terrestrial (DVB-T), Wireless Asynchronous Transfer Mode (WATM), Modem/ADSL [1]. OFDM has many advantages such as robustness in frequency selective fading channels, high spectral efficiency, immunity to inter-symbol interference and capability of handling very strong multipath fading [2].

But OFDM is having major drawback of a high Peak-to-Average Power Ratio (PAPR) [3-4]. This causes clipping of the OFDM signal by the High Power Amplifier (HPA) and in the HPA output producing nonlinearity. This non-linearity distortion will result in-band distortion and out-of-band radiation. The in-band distortion causessystem performance degradation and the out-of-band radiation causes adjacent channel interference (ACI) that affects systems working in neighbor band. Hence the OFDM signal may have In-band and Out-of-band distortion which degradation of Bit-Error Rate (BER) performance. One solution is to use a linear power amplifier with large dynamic range. However, it has poor efficiency and is expensive too.

## II. Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a Multicarrier Transmission technique which divides the available spectrum into many carriers each one being modulated by a low data rate stream. OFDM is similar to Frequency Division Multiple Access (FDMA) in that the multiple user access is achieved by sub-dividing the available bandwidth into multiple channels, which are then allocated to users. This is achieved by making all the carriers orthogonal to one another, preventing interference between them.

In FDMA each user is typically allocated a single channel which is used to transmit all the user information. The bandwidth of each channel is typically 10-30 kHz for voice communication. However, the minimum required bandwidth for speech is only 3 kHz. The allocated bandwidth is made wider than the minimum amount required to prevent channels from interfering with one another. This extra bandwidth is to allow for signals of neighboring channels to be filtered out and to allow for any drift in the center frequency of the transmitter or receiver. In a typical system up to 50% of the total spectrum is wasted due to the extra spacing between channels. This problem becomes worse as the channel bandwidth becomes narrower and the frequency band increases. Time Division Multiple Access (TDMA) overcomes this problem by using wider band width channels which are used by several users. The subcarriers in an OFDM signal are spaced close as is theoretically possible which maintain orthogonality between them.

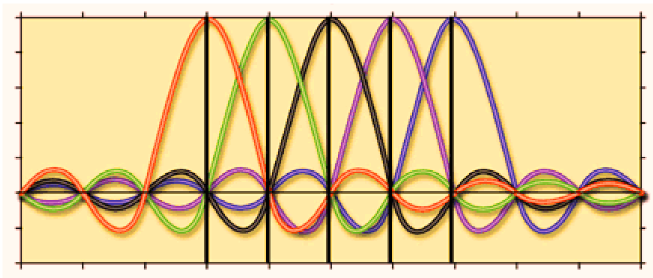

Fig. 1 Orthogonality of subcarriers

The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing them to be spaced as close as theoretically possible.

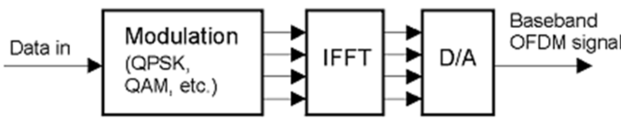


Fig.2 OFDM transmitter

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. Fig.2 shows the transmission of OFDM signal. The orthogonal carriers required for the OFDM signal can be easily generated by setting the amplitude and phase of each frequency bin, then performing the IFFT. Since each bin of an IFFT corresponds to the amplitude and phase of a set of orthogonal sinusoids, the reverse process guarantees that the carriers generated are orthogonal.

### III Related Works

Several algorithms [5-9] have been proposed to handle this PAPR problem. However, none of these algorithms have produced significant reduction of PAPR in OFDM systems. A simple Encodable/Decodable OFDM QPSK proposed in [7] used Reed-Muller code with QPSK. This could reduce the PAPR but it could not be used with higher order signal constellations. OFDM PAPR reduction by a rotation of redundancy bit position in subblock code word scheme was proposed in [8]. In this method the redundant bit positions of subblock code words are rotated and the lowest PAPR codeword is chosen by a feedback scheme However, the side information for bit position is required. Companding transform [9] compresses as large signal while enhancing a small signal that can achieve a desired PAPR but with a significant increase in the bit error rate (BER). Selective Mapping (SLM) [10, 11] is based on the creation of P different signals from the original input data vector. The tone reservation method, also called Peak-Reduction Carriers reserves a set of subcarriers to create the PAPR reduction signal c(t), while the tone injection method makes use of so-called expanded constellation diagram [12].

### IV. The PAPR of OFDM System

An important limitation of OFDM is that it suffers from a high Peak-to-Average Power Ratio (PAPR) resulting from the coherent sum of several carriers. This forces the power amplifier to have a large input backoff and operate inefficiently in its linear region to avoid intermodulation products. High PAPR also affects D/A converters negatively and may lower the range of transmission. The PAPR of OFDM is defined as the ratio between the maximum power and the average power. The PAPR of the OFDM signal X(t) is defined as

$$PAPR = \frac{P_{peak}}{P_{average}} = \frac{\max\left[\,|x_n|^2\right]}{E\left[\,|x_n|^2\right]} \qquad (1)$$

Where $x_n$ = An OFDM signal after IFFT (Inverse Fast Fourier transform)
E[.] = Expectation operator, it is an average power.

### V. Proposed Method

This method is simple but efficient algorithm for PAPR reduction by using CAP-PT (Clipping, Amplification and Peak Windowing / Partial Transmit method. Fig.3 depicts the block diagram of proposed CAP-PT model.

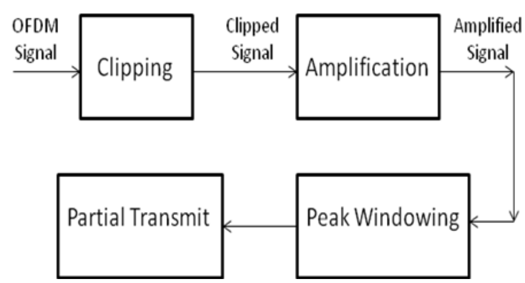


Fig.3 Block Diagram of Proposed CAP-PT model

The algorithm is based on clipping the amplitude of OFDM signal that exceeds threshold value say (A). The amplitude of signals exceeding clipping threshold value (say A) is clipped and the signals having amplitudes less than amplification threshold value say (say B) is amplified to threshold level. PAPR is calculated for clipped signal and compared with that of the original PAPR of OFDM signal. Clipping can be performed by clipping the complex envelope of OFDM signal. Probability of clipping is defined as

$$CCDF = Pc = p\ \{A < x < \infty\}$$
$$= e^{-A/(2\,\sigma 2)} \qquad (2)$$

where, A is clipping level and $\sigma^2$ is variance of x

Taking in on both sides we get,

$$-2 \ln(CCDF) = PAPR \text{ (or)} \qquad (3)$$
$$A^2 = -\ln(\ CCDF)\ \sigma^2 \qquad (4)$$

Above equations gives the relation between CCDF and PAPR. This concludes that with decrease in PAPR the CCDF increases and vice versa.

This clipping and amplification process then combines with peak windowing technique. Fig.4 shows the flowchart for clipping process. The process of peak-windowing is realized by multiplying window function from the biggest peak to the smaller peaks in the peaks exceeding fixed value level. In proposed method, peak-windowing is performed on clipped and amplified OFDM signal. Our method suppresses the out of radiation caused by clipping which results in PAPR reduction. This technique does not require a high power amplifier which increases the circuit complexity at the receiver.

Clipping Ratio (CR) at peak-windowing is defined as

$$CR = \frac{A_{max}}{\sqrt{P_{maen}}} \qquad (5)$$

Fig.5 shows the process of peak windowing. $s_{max}$ is the symbol which has the biggest peak in an iterative signal x(n). $n_{max}$ is its index. r is the iteration number. w is the window function. $A_{max}$ is the maximum amplitude after clipping and Amplification. $P_{mean}$ is the average input power of the OFDM signal before clipping.

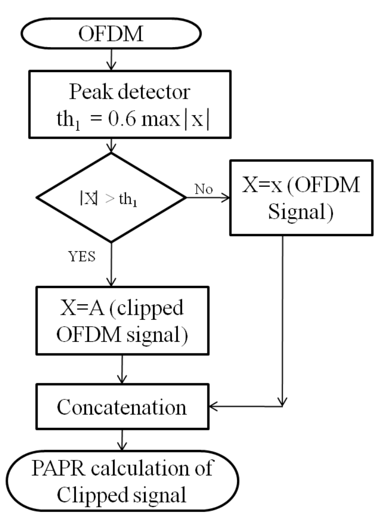


Fig.4 Flowchart for Clipping

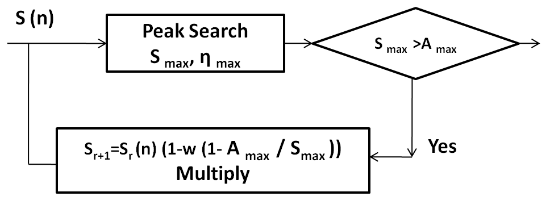


Fig.5. Process of Peak windowing

In Partial Transmit Sequences (PTS) method, the IFFT inputs symbols are divided into several frequency disjoint subblocks. The IFFT operation is performed not on the N subcarriers in total, but separately on these subblocks. The output of l-th subblock is then multiplied by so-called complex rotation factor $b_l$. The values of $b_l$ for all l are then optimized to find

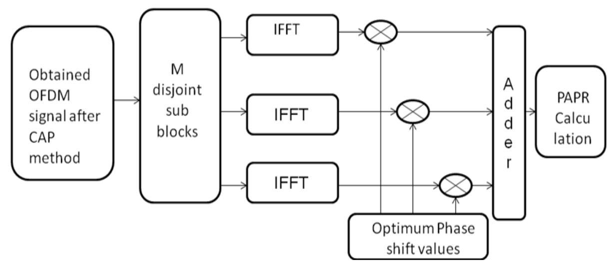


Fig.6. Block diagram of Partial Transmit

complex rotation factors resulting in the lowest symbol PAPR. This optimization has to be performed in the real time for each IFFT input symbol. The information about used complex rotation factors has to be send as a side information to the receiver. This reduces the useful data rate. The Block diagram of PT is shown in the fig.6.

Table 1 Simulation Parameters

| **Modulation** | **M-QAM, M-PSK** |
|---|---|
| Number of data subcarriers | 64 |
| Number of FFT points | 8 |
| Number of sub-blocks | 4 |
| Window function | Blackman |
| Channel Model | AWGN |

In Peak detection, components of the amplitude which exceeds fixed value is detected. Peak-detection is transferred to frequency domain by FFT. Out of band components which are generated by FFT are set to zero. Thus out of band radiations is suppressed by peak windowing. As PT is distortion less technique, it reduces in band distortion. PAPR reduced to 2.8 dB when CAP combined with PT method.

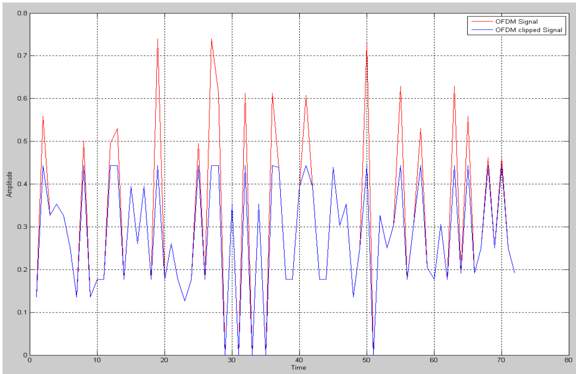


Fig.7 comparison of original and clipped OFDM signal

Comparison between different M-ary (M-QAM, and M-PSK, M=16, 32, 64) modulation technique for CAP-PT method is investigated choosing clipping threshold to be 60 % of the peak volt of OFDM signal.

Fig. 8 shows the comparison between 16-PSK and 16-QAM, 32-PSK and 32-QAM, 64-PSK and 64-QAM respectively. On X-axis different modulation techniques (M-QAM, and M-PSK, M=16, 32, 64 as 1, 2, 3, 4, 5 & 6 respectively) and on Y-axis PAPR reduction (in dB) is plotted. It is observed that with increase in M (M=16, 32, 64) the PAPR increases and so does PAPR reduction. It is also observed that PSK has better performance over QAM in terms of PAPR reduction i.e. PSKs have more PAPR reduction than QAMs.

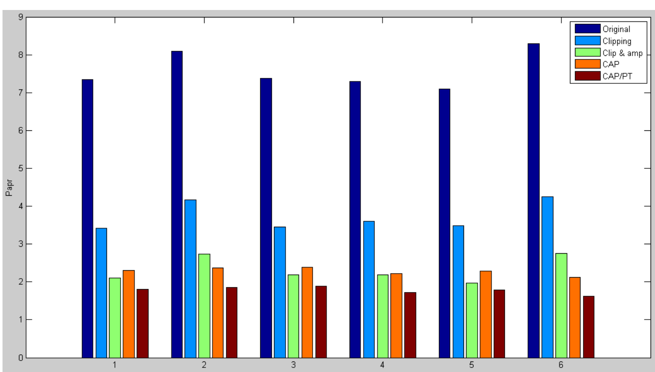


Fig. 8 Comparison between 16- QAM, 32- QAM, 64-QAM and 16 –PSK, 32-PSK, 64-PSK respectively

The value of PAPR reduction (in dB) is indicated in the figure. The conclusion drawn from this is that the PSK modulation technique is better than QAM in OFDM in terms of PAPR and QAM. To say in other way, if PSK modulation is used during generation of OFDM signal, PAPR will be less and if PAPR occurred is high( since the PAPR is dependent of the bit sequence), PAPR can be considerably decreased using CAP-PT method.

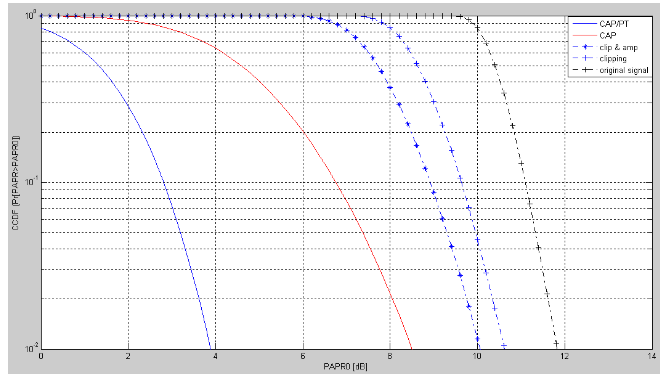


Fig. 9 Comparison of PAPR with probability of clipping of CAP-PT method

Figure 9 shows the plot of PAPR Vs complementary cumulative distributive function (CCDF) of clipping, amplification and peak windowing combined with Partial transmit methods. Table II shows that the increase in the clipping probability, PAPR decreases.

Table II Reduction of PAPR of various methods

| **Method** / **CCDF** | **Original Signal** | **Clipped Signal** | **Clipped and Amplified Signal** | **CAP** | **CAP/ PT** |
|---|---|---|---|---|---|
| 0.01 | 11.8 | 10.8 | 10 | 8.5 | 3.9 |
| 0.1 | 11 | 9.8 | 9 | 7 | 2.8 |

## VI. Conclusion And Futurework

In this paper Orthogonal Frequency Division Multiplexing (OFDM) is presented as one of best candidates for fourth generation (4G) communication system, as it can combat radio impairments very effectively with very efficient use of spectrum. But every advantage comes with some disadvantages. Different disadvantages of OFDM such as frequency synchronization, maintaining orthogonality among carriers, local oscillator offset etc.

This paper mainly focuses on one of the challenging drawback of OFDM that is high peak to average power ratio (PAPR). A new CAP-PT method is proposed in this paper. Clipping is a non-linear process and causes significant inband distortion that causes bit error degradation, outband distortion causes degradation in spectral efficiency. The drawback of clipping can be combated using peak windowing technique. Peak windowing seems to be beneficial. Partial transmit significantly reduce in band distortions with large PAPR reduction.

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