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# A Review of PAPR Reduction Techniques in OFDM Systems

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**Abstract** -Orthogonal Frequency Division Multiplexing (OFDM) is an efficient multicarrier modulation scheme in wireless communication. It is used in applications like 4G (fourth generation) mobile Communications, wireless networks, digital television, power line networks and audio Broadcasting. It offers both advantages and disadvantages for multicarrier transmission. The main advantages are the elimination of Inter Carrier Interference (ICI) and Inter Symbol Interference (ISI) in the signal. But OFDM's one of the main detrimental aspects are high Peak-to-Average Power Ratio (PAPR) value of the transmitted signal which highly affects the power amplifiers complexity. Several techniques to overcome and reduce PAPR such as Tone Reservation (TR), selective mapping (SLM), clipping and filtering, partial transmit sequence (PTS), etc. are proposed and implemented. Detailed description and comparisons of all techniques are discussed in this paper.

Keywords - Peak-to-Average Power Ratio (PAPR), PTS, OFDM, Inter Carrier Interference

## I INTRODUCTION

With increased demand for high quality communication services in 4G and 5G, it's been a great challenge to improve the Quality of Service (QoS) and reduces the delay time. To overcome and fulfill this requirement, a technique called Orthogonal Frequency Division Multiplexing (OFDM) is encountered. It over several outfalls like maintaining high data rate, high bandwidth efficiency, low computational complexity and eliminating multipath fading [1]. OFDM is a special case of the frequency division multiplexing (FDM), which is used by the American National Defense Department for military communications. Compared with the conventional FDM, OFDM allows the spectrums from different subcarriers that are orthogonal to be overlapped with each other, which improves the spectral efficiency of the system. The concept of OFDM techniques was first proposed by RW Chang in 1965. In 1967, Saltzberg analyzed the performance of OFDM systems. In 1970, OFDM technology was patented at the USPD and then after it was used in military communication systems. In 1971, SB Weinstern and PM Ebert employed the Discrete Fourier Transform (DFT) into the MCM. in practice, the Fast Fourier Transform (FFT) implementation of the DFT has made OFDM modulation and demodulation feasible and very successful. In the 1980s, ISI was decreased when Peled and Ruiz added cyclic prefix (CP) into the basic OFDM signals to have the orthogonality maintenance among subcarriers [1-2].

OFDM transceiver- The fundamental principle of OFDM is to split the available bandwidth into multiple sub-carriers. As the number of subcarriers increases, it gets more immune to frequency selective fading, and data rates are also increasing. However, number of sub-carriers cannot be increased arbitrarily because it increases the complex architecture of the system and symbol durations that make transmission more sensitive to the time incoherence of the channel. The problem of the intricate design of the system was handled by Weinstein and Ebert with the implementation of OFDM modulation OFDM system transmitter The incoming serial data is the information that needs to be transmitted through the channel using OFDM system. The serial data is converted into N different parallel data streams by using serial to parallel converter. These symbols can be modulated by using different modulation techniques and given to the IFFT block as an input [3]. IFFT block gives the digital time domain signal for the given input, and this parallel data is converted into serial data by using parallel to serial converter. The cyclic prefix is introduced between two OFDM symbols to cancel the effect of ISI due to channel dispersion. Now this digital time signal is converted into real time waveform with the use of digital to analog converters. The available baseband signal is up converted to an RF pass band signal with the use of a mixer or modulators.

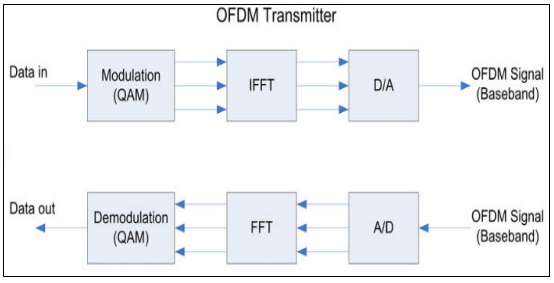

Fig.1 block diagram of PAPR Reduction Techniques

**Channel model-**The phenomenon of noise and multipath environment can be predicted by using channel model. Generation of noise can be done by adding few random data to the OFDM symbol and multipath environment can be generated by adding attenuated and delayed copies of the OFDM signal.

**OFDM receiver-** At the receiver end, the received OFDM signal is down converted using the demodulator and sampled with analog-to-digital converters to obtain the digital time domain signal. The digital time domain signal is demodulated by using FFT, and the data that is transmitted can be extracted by using symbol demapper [4].

**Characteristics** -OFDM has several features which attract developers to design various standard applications. Even OFDM exhibits numerous advantages over the family of conventional serial modem schemes which are as follows:

**A. Implementation complexity**: The complexity is significantly lower comparing to the single carrier system for a specified delay spread.

**B. Robustness against narrow band interference**: An interferer can destroy the communication link in single carrier while a small number of sub carriers get affected in multicarrier.

**C. Spectral efficiency:** The behavior of orthogonality accommodated a large number of sub carrier in a very narrow spectral region thus increases the spectral efficiency.

**D. Immunity against frequency selective fading:** Each subcarrier has narrow bandwidth in comparison to overall bandwidth of the signal. It converts a frequency selective fading channel into several nearly flat fading channels.

## II RELATED WORK

**Tanairat Mata et.al (2018) et.al** Because of the significant loss in signal quality, a high PAPR is widely known as a severe problem in the OFDM system, especially in the non-linear channel. Many PAPR reduction strategies have been developed to address this issue as a result of this rationale. One of the PAPR reduction techniques that can successfully enhance PAPR performance is the Partial Transmit Sequence (PTS) scheme. However, the computing cost of the procedure would grow as the number of symbol clusters in the ideal PAPR value for a PAPR reduction process rose. To address this issue, this work offers a PAPR reduction technique for OFDM systems based on an enhanced PTS with Artificial Bee Colony (ABC) algorithm. The suggested scheme's potential capacity is PAPR reduction performance with minimal computing complexity, resulting in improved signal quality in the OFDM system. The suggested scheme's outstanding PAPR reduction performance with minimal computational complexity has been confirmed by computer simulations in this study [1].

**Azlina Idris et.al (2018)-**In Malaysia, the fourth generation (4G) communication technology, Orthogonal Frequency Division Multiplexing (OFDM), is widely utilized. Even if its current performance is adequate, the system can always be improved. Peak to Average Power Ratio is a fundamental flaw in the OFDM system (PAPR). High PAPR can degrade system performance and require more power at the receiving end, which is the user's phone. As a result, researchers devised Filtered Orthogonal Frequency Division Multiplexing (F-OFDM) to address issues with OFDM. The performance of OFDM and F-OFDM in terms of PAPR will be ignored in this study work. PAPR reduction was accomplished using two approaches from block coding: Arithmetic code and Reed-Solomon code. The mathematical methodology was shown to be more suited for usage as a PAPR reduction method when both strategies were examined. This is due to the fact that math can lower PAPR by up to 18.5 percent. Aside from that, two modulation techniques will be utilized to compare the effect and performance of OFDM and F-OFDM [2].

**Thota Sravanti et.al (2017)-** the biggest drawback of Orthogonal Frequency Division Multiplexing (OFDM) is its high Peak-to-Average Power Ratio (PAPR). Manufacturing High Power Amplifiers (HPA) with high peaks is challenging and expensive. There has been several PAPR reduction strategies developed, with Partial Transmit Sequences (PTS) being the most effective. The evaluation of OFDM system, Preceded PTS OFDM system, and various pre coding methods such as Discrete Fourier Transform (DFT) Precoded PTS OFDM, Discrete Hartley Transform (DHT) Precoded PTS OFDM, and Walsh-Hadamard Transform (WHT) Precoded PTS OFDM for M-QAM is examined in this paper for enhanced PAPR reduction[3].

**Funmilayo B et.al (2017)-**the pilot-assisted (PA) approach for peak-to-average-power-ratio (PAPR) reduction in optical orthogonal frequency division multiplexing is presented in this work with a unique

theoretical characterization (O-OFDM). In optical wireless communications, the two systems studied are direct-current biased O-OFDM (DCO-OFDM) and asymmetrically clipped O-OFDM (ACO-OFDM). The time-domain signals of DCO-OFDM and ACO-OFDM are Gaussian and half-Gaussian, respectively. To rotate the phase of U data symbols within a PA O-OFDM frame and choose the frame with the least PAPR, the PA method employs P iterations of a pilot sequence. The PAPR distributions of the PA DCO-OFDM and ACO-OFDM systems are therefore characterized using order statistics. For high P, the PA method reduces PAPR more effectively, but at the cost of additional complexity. We can find P that provides a decent PAPR reduction gain using the theoretical framework we've created. The impacts of PAPR reduction on average optical and electrical signal power are investigated in a theoretical analysis. The PA approach reduces the optical energy per bit to noise power spectral density E b(opt) /N 0 ratio needed to satisfy the goal bit-error-rate in an additive white Gaussian noise channel, according to the results. Analytical and computer modelling findings for the PA O-OFDM signal accord extremely well[4].

**Sergey N et.al (2017)-**the challenge of combining the PAPR reduction algorithm with techniques to minimize band interference in OFDM-signals in order to increase channel capacity under complex signal interference conditions is considered. In comparison to inconsistent implementation of TR algorithm and ways to decrease band interference, joint application of TR algorithm with reserved tones placed at band interference frequencies increases channel capacity. It is shown that reserved tones placed densely reduce the Peak-to-Average Power Ratio (PAPR) as compared to OFDM signals without TR[5].

**Yves Louet et.al (2018)-**this study presents simulation findings for determining a transmitter's realistic power budget by considering several post-OFDM waveforms as well as a nonlinear high-power amplifier (HPA). The waveforms utilized include Orthogonal Frequency Division Multiplexing (OFDM), Weighted Overlap and Add OFDM (WOLA-OFDM), and Block-Filtered OFDM (BF-OFDM), which are all combined with a Peak to Average Power Ratio (PAPR) technique (Selected Mapping) to improve HPA efficiency. The PAPR reduction gain and the total power budget of the transmitter have a clear optimal point, according to simulation findings[6].

**Ning Li et.al (2019)-**In orthogonal frequency division multiplexing (OFDM) systems, high peak-to-average power ratios (PAPR) are an issue. Hadamard-based selected mapping (HSLM), which employs Hadamard code as the phase sequence in selected mapping (SLM), is a promising method for lowering PAPR. However, for each data block, it is necessary to convey side information (SI) to the receiver, which reduces bandwidth efficiency. We propose a modified PAPR reduction technique termed semi-Hadamard based selective mapping (semi-HSLM) in this article, which decouples the phase information matrix into a phase rotation matrix for PAPR reduction and a SI matrix for side information concealment. We built a cyclic shift matrix as the SI matrix and suggested a semi-hadamard matrix generating method to create the phase rotation matrix. The semi-HSLM saves half of the phase storage and has superior PAPR reduction performance when compared to the regular HSLM[7].

**Mohamed Mounir et.al (2017)-**Because of its ability to deal with frequency selectivity, Orthogonal Frequency Division Multiplexing (OFDM) is utilized in high data rate wireless applications. However, OFDM has an issue with a high Peak-to-Average Power Ratio (PAPR). High PAPR signals necessitate a Power Amplifier (PA) with a large Input-Back-Off (IBO), which decreases PA efficiency. Small IBO, on the other hand, degrades BER and increases out-of-band (OOB) radiation. Various PAPR reduction methods have been documented in the literature. The simplest is intentional clipping, which has a high deterministic PAPR reduction gain. In this work, it will be demonstrated that purposeful clipping exacerbates the problem and that it cannot be utilized in the receiver without Iterative Clipping Noise Cancellation (ICNC). ICNC, on the other hand, makes the receiver's computational complexity higher than the transmitter's, therefore its best employed in uplinks (ULs)[8].

**Nishant Sharan et.al (2019) -**Inter symbol interference occurs in VLC systems as data rates grow (ISI). For high-speed data flow, it is desirable to decrease the high ISI by employing the appropriate modulation approach. OFDM (orthogonal frequency division multiplexing) is a good modulation scheme for reducing ISI. In a multipath environment, OFDM in a VLC system allows for high data rates while maximizing the available LED modulation bandwidth. However, the optical OFDM (O-OFDM) system has a high peak-to-average power ratio, which is a concern (PAPR). Because of LED chip warming and signal clipping distortion, the PAPR problem in a DC-biased O-OFDM (DCO-OFDM) system causes nonlinearities and system deterioration. For PAPR reduction, this work proposes a combined technique including a preceding matrix and the Mu-law commanding method. This hybrid approach is demonstrated to be an appealing option for achieving a favorable trade-off between PAPR and system bit error rate (BER)[9].

**Yoedy Moegiharto et.al (2019) et.al -**The OFDM system has been used by high-speed digital communication systems, and one of its advantages is that it has good bandwidth efficiency and high performance. The Peak to Average Power Ratio (PAPR) of the OFDM is high, which is a significant drawback. A high PAPR OFDM signal necessitates the use of a power amplifier with a broad dynamic range to handle the signal; if this need is not met, nonlinear distortion will result, degrading OFDM performance. An optimization technique is suggested to overcome nonlinear distortion in the Power Amplifier (PA). The system combines the PAPR reduction technique of Partial Transmit Sequence (PTS) with predistortion. PTS is a PAPR signal reduction method that keeps signals out of the PA saturated area. PA's linear range is also extended using the predistortion method. BER will be used to assess system performance. The results demonstrate that the performance of the combined PTS-predistortion approach is superior to that of PTS alone. The combined PTS-pre distortion approach can increase BER performance to 10 -7 at 11 dB SNR, compared to 10 -3 at SNR 30 dB for systems without predistortion[10].

**Badis Lekouaghet et.al (2020)-**the major source of nonlinearity in orthogonal frequency division multiplexing (OFDM) systems is the Peak-to-Average Power Ratio (PAPR). As a result, the focus of this study is on establishing a novel PAPR reduction method, with a particular focus on the selective mapping (SLM) technique, which has been shown to be one of the most effective techniques. Two phase sequences for SLM are used in this context, including rows of normalized Riemann matrix (RM) and diagonal elements of the modified RM. The rows of the symmetric Toeplitz matrix are then used to suggest new phase factors. To evaluate the performance of the suggested technique, the evaluation is carried out using the complementary cumulative distribution function (CCDF) as a metric. In compared to other well-known SLM methods in the literature, simulation results show a substantial reduction in PAPR impact when the suggested phase variables are used [11].

**Ryohei Iwasaki et.al (2018)-**a high peak-to-average power ratio is a disadvantage of an orthogonal frequency division multiplexing (OFDM) transmission (PAPR). For PAPR reduction, a preceding technique is suggested. A low PAPR signal is created using this approach by multiplying a sequence and data symbol vector with a matrix. Even when a new matrix is created by a different parameter, the PAPR decrease obtained by this approach remains constant. Another approach for lowering PAPR is using partial transmits sequences (PTS). Subcarriers in an OFDM signal are divided into clusters using the PTS technique. After that, phase rotations are applied to each cluster's time-domain signals, and the OFDM signal with the lowest PAPR is chosen. Due to linear processing, this approach does not result in non-linear distortion. Increasing the PAPR reduction necessitates a large number of clusters and phase rotations, which adds to the calculation overhead. We explain in this study how these techniques may be used to reduce the PAPR even further. The suggested technique reduces PAPR better than the PTS or preceding methods individually, according to this article. We also show that, like the PTS approach, increasing the number of candidate signals in the proposed method can enhance the PAPR decrease. In addition, the suggested technique can significantly reduce the number of candidate signals required to accomplish the same reduction [12].

## III PEAK-TO-AVERAGE POWER RATIO

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. At each instant they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to Average Power Ratio. As demand of high transmission rate is increasing day by day parallel transmission using multi-carrier is becoming a need of hour and OFDM is a promising candidate for various application such as Wireless Local area Networks (WLAN), Digital Video Broadcast (DVB), Digital Audio Broadcast (DAB), 4-G pertaining to its high band-width efficiency and its immunity towards ISI and delay spread [11],[12],[13]. OFDM avoids ISI problem by sending many low speed transmissions simultaneously with addition of cyclic prefix. However high peak to average power ratio is a major problem associated with OFDM system, this leads to increased complexity of analog to digital converter ,digital to analog converter and reduced efficiency of the RF power amplifiers. The transmit signals in an OFDM system can have high peak values in the time

domain since many subcarrier components are added via an IFFT operation. Therefore, OFDM systems are known to have a high PAPR (Peak-to-Average Power Ratio), compared with single-carrier systems [14], [15]. When high PAPR OFDM signal pass through a nonlinear device such high power amplifiers (HPA), it 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. So a large back-off in input OFDM power is required to force the operation in linear region of HPA. Such HPA with large dynamic range are quite expensive and increase overall cost of the system. By reducing PAPR we reduce the overall cost as well as complexity of various components in the OFDM system. The amount of PAPR reduction is proportional to the number of phase weighting factor. If the number of phase weighting factor is large, the number of parallel addition processor and the number of phase weighting factor sequences are searched to find the optimum combination of phase weighting factors will be increased incorporating huge complexity in the system. Then we cannot assume that the candidate signals are independent in PTS. The correlation among candidate signals deteriorates the PAPR reduction performance in PTS. The correlation among candidate signals is governed by two factors-one is the sub-block partition style as described in [6] and the other is the value of phase weighting factor set. So it is possible to alter these two factors to produce candidate signals with diminished correlation, so as to prevent degradation of the PAPR reduction performance.

**PAPR Reduction Techniques -**There are number of techniques have been used to overcome the problem of high PAPR in the OFDM system. Various techniques to minimize the PAPR are. I. Signal Scrambling Techniques a) Selective Mapping (SLM) The most promising technique is the selective mapping technique because no distortion is introduced and yet reduce the PAPR. In this technique the signal at the input is divided into many sub-blocks. The signal with least or minimum PAPR is selected from different phase sequence that contain same information at transmitter. The index to be selected is called side information index. The transmitter uses side information so that receiver can make uses of that side information to predict which signal is selected.[4][7]

## b) Block Coding Technique

It is the easiest method which we used to overcome the peak to average power ratio (PAPR). The basics idea behind this method is to overcome PAPR by applying different blocks code and codeword's. This method is applied to reduce the problem of peak to mean envelope power ratio. During the codeword's selection many point should be kept in mind, such as m array phase modulation technique, types of codes rate and also error correction and error decoding.[4]

## c) Tone Reservation (TR)

Tone reservation is the simplest way to minimize the PAPR. In this scheme reversing a small fraction of tone lead the large amount of reduction of PAPR with simple operation at the transmitter side. Some set of tones are reserved in this technique. In tone reservation side information and other additional operation are not required, so there is no complexity at the destination end.[8]

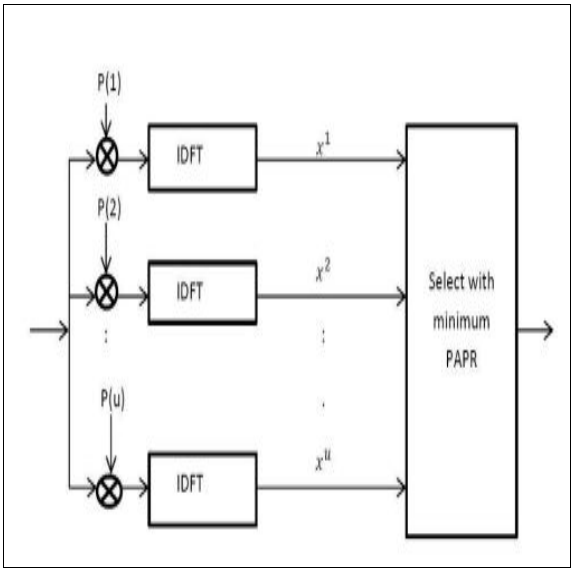


Fig.2 block diagram of PAPR Reduction Techniques

## d) Linear Block Code (LBC)

This is an error correcting code. This technique allows more efficient encoding and decoding algorithms as compared to other codes. Linear block codes are basically used in forward error correction and for transmitting symbols or bit on the communication channel. This is also the modification of selective mapping schemes. In this technique transmitted signal with least PAPR used scrambling code. This technique provide better performance than SLM scheme.[9]

## e) Partial Transmit Sequence

It is the most efficient technique to reduce PAPR. In this technique, blocks of data is partitioned into no overlapping sub-blocks. This technique is the modified technique of selective mapping scheme. There are three partitioning

methods for PTS scheme: adjacent, interleaved and pseudorandom. Pseudorandom partitioning provide better PAPR performance among all these schemes.[8][9]

### f) Inter Leaving Technique

In this technique interleavers are used for the purpose of generation of multiple OFDM signal and same information is transmitted by the signal. It is a device that runs on a block of symbol and rearranges them in a specifics way. In this adaptive techniques is also overcome the complexity. Adaptive interleaving is used as an early terminating threshold. As the searching process is terminated the value of PAPR reaches below the threshold value these low threshold force the adaptive interleaver to search for all interleaving sequence. As compared to PTS this technique is less complex.

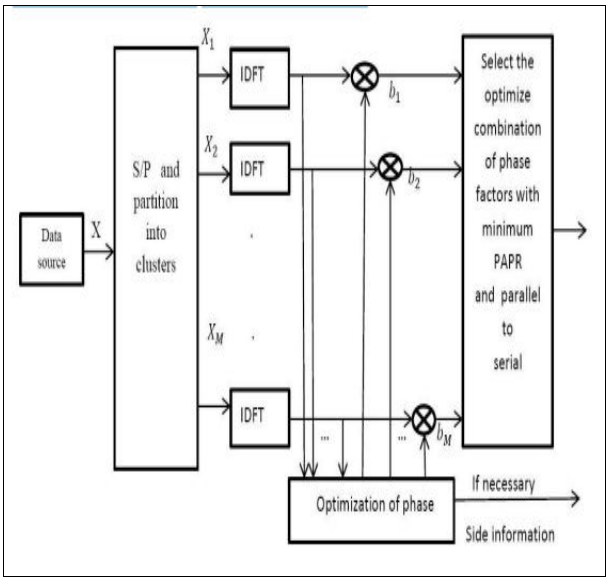


Fig.3 block diagram of Partial Transmit Sequence

### Signal Distortion Techniques Clipping and Filtering

It is the simplest technique to to minimize the PAPR .In this high amplitude peaks signal are clipped before passing the signal is passed from the power amplifier. For this clipper is used which limit the signal up to determined level called as clipping level. It is a non-linear process, which result in the formation of in-band and out of band distortion. We cannot remove in-band distortion by using filtering, whereas out of band distortion can be removed by filtering and improve the performance of BER. By the use of clipping and filtering algorithm, more PAPR can be minimized than that of direct clipping.[9]

### b) Peak Windowing

This technique is almost similar to that of clipping technique, but it provides better performance due to the addition of self interference and increased bit error rate (BER). This result in out of band distortion increased. In this technique, different windows are multiplied with large signal peaks such as Gaussian shape window, cosine, Kaiser and hamming window. The size of window should be narrow as possible otherwise it will increase bit error rate (BER).[4]

## IV CONCLUSION

In this paper, we have analyzed and compared eight PAPR reduction techniques. Among above analyzed techniques, it was found out that from present techniques no technique is fully effective in reduction of PAPR and is the best for the OFDM system. As before choosing the appropriate PAPR technique, various other factors like maintaining data rate, computational complexity, BER, signal power should also be taken into acknowledgement. So, it is suggested to propose peak to average power ratio (PAPR) reduction scheme and design a network/model supporting it for OFDM systems after comparing existing conventional methods..

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