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PAPR Reduction Techniques in Multi-Carrier Waveforms

[1]Mohit Kumar Sharma and [2]Arun Kumar

[1]Department of Electronics & Communication Engineering, JECRC University

[2] Department of Electronics & Communication Engineering, JECRC University

E-mail: [1]mohitkumar.sharma@jecrcu.edu.in, [2]arun.kumar@jecrcu.edu.in

ABSTRACT

Currently, the orthogonal frequency division multiplexing (OFDM) technique is employed for the transmission of wireless signals in 4G. The efficiency of the amplifier used in OFDM is largely affected due to high power requirements. Peak to average power ratio (PAPR) is a major limitation in OFDM waveforms. Several methodologies were introduced to reduce this problem. However, in reducing the PAPR, the complexity of the overall systems is compromised. In this paper, we projected various methods to reduce the PAPR in OFDM. The simulation results reveal that the hybrid algorithm shows better performance as compared to other techniques.

Keywords: OFDM, PAPR, BER, SLM, PTS

1. INTRODUCTION

Multiple Access Techniques (MAT) can be classified as Orthogonal Multiple Access (OMA) and Non- Orthogonal Multiple Access (NOMA). The basic difference between OMA and NOMA technologies are, in OMA a user can use the orthogonal resource in a particular time slot, frequency range, and by a specific code to avoid interference with other users whereas, in NOMA multiple users can exploit the resource simultaneously with high spectral efficiency. However, there will be interference among users at receivers [1-2]. OFDM is one of the most significant and widely used methods having many advantages over previous technologies such as high spectral density and tolerance of multipath fading channels. OFDM reduces Inter-symbol Interference (ISI) and Inter-Channel Interference (ICI) with the help of a cyclic prefix. Despite having many advantages, there are still some issues with the existing OFDM technology such as a high peak to average power ratio (PAPR) [3-4]. PAPR is a relationship between the peak power of the transmitted signal and its average power. The ratio of those two parameters becomes the expression of PAPR. The high value of PAPR causes non-linear distortions to a power amplifier, which results in degradation of execution such as deformations and high bit error rate (BER). A decrease in the average power of the signal may be regarded as a solution; however, this will likewise cut down the signal to interference ratio (SNR). For this reason, it is preferable to reduce the peak power of the signal so that the power amplifier can function effectively [5]. Distortions in the power amplifier can be eliminated by means of the power retraction method. However, these methods will limit the power efficiency of the overall system. The power amplifier usually works close to the saturation zone in order to balance the power consumption [6].In the recent years, various techniques were implemented to reduce the value of PAPR like clipping, clipping & filtering, the partial transmission scheme (PTS) [7]. There are some other reduction techniques such as Dummy Sequence Insertion (DSI), Tone-reservation and Tone-injection (TR & TI), Interleaving, and Selective mapping (SLM) [8]. This paper introduces a novel hybrid technique to improve the BER and PAPR performances of the overall system. In DSI, A dummy sequence is placed in the input before the IFFT (Inverse fast Fourier Transform) stage to lower the peaks of OFDM signal. There are multiple ways to insert the sequences in the input such as Complementary sequence insertion, Correlation sequence insertion, all zero insertion and all one insertion sequence. Despite the method used, the insertion process will take place before the IFFT. The transmission of the signal is only allowed if the PAPR is less than the prescribed limit before the parallel to serial conversion stage for a particular value of dummy sequence, otherwise a feedback mechanism is used to repeat the process for the selection of new dummy sequence. The most significant part of DSI is that it does not need any side information that's why the complexity of the receiver is reduced and hence improved BER can be achieved which is not the case in various methods like PTS and SLM [9]. In TI & TR, the subcarriers are reserved for the reduction of PAPR and called Peak reduction tones (PRT). In this algorithm, the receiver and transmitter must able to locate the PRT's. Although this method reduces the value of PAPR to a large extent however, there is a drop in data rate and excessive power is required for the transmission that's why not a suitable scheme for advance waveforms. TI is a process to cover the loss of data rate by inserting a tone in the same frequency band) [10]. Interleaving procedure is analogous to the SLM. The phase sequence is replaced by the interleaver, used in a device that reorders a block of N symbols and forms a new block doing one on one mapping. After the modification of all the blocks, the minimum PAPR symbol is selected and transmitted. At the receiver's end, the estimation of the side information is required, considered as one of the drawbacks of the method. The reduction in PAPR depends on the design and the number of interleaver [11].

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The SLM technique is considered to be the best PAPR reduction techniques for OFDM. SLM technique is comparatively better than all other techniques since it reduces the PAPR without any distortion. In this method, there are phase sequences which need to be sent to the receiver before the communication process [12]. In [13] DSI algorithm is used for the reduction of PAPR, for simulation purposes, the BPSK method is considered and the length of dummy sequences are 8 and 16. The subcarriers are 64 for various levels of the PAPR threshold. It is observed that for CCDF = 10^{-3}, PAPR is reduced to 9dB. In [14], the hybrid method namely SLM & Clipping was introduced to minimize the peak power of the OFDM system. The simulation result reveals that the suggested algorithm reduced the peak power to 0.4 dB at CCDF of 10^{-2} as compared to the original value of 8.9 dB. In [15], the projected method used SLM design and was able to minimize the PAPR to 2.3 dB at CCDF of 10^{-3}. Hence it was concluded that the throughput of the system is better than the existing algorithms. In [16], a modified interleaving technique is proposed which is capable of using the advantages of MIMO systems. The author emphasizes those areas where PAPR needs to be reduced. It is observed that the increase in the number of subcarriers enhances the PAPR of the systems. The peak power is reduced to 0.5 dB at the CCDF of 10^{-2}. The BER 10^{-3} was obtained at the SNR of 7.5 dB for interleaved systems. In the projected work, the BER and PAPR performance is enhanced as compared to the existing methods. It is seen that the system suffers from distortion due to the need for side information [16].

The contributions of this projected work are given below:

- This paper comprehensively analyses peak power reduction algorithms for OFDM structure.
- It is observed that the conventional PAPR algorithm shows poor performance for advanced waveforms.

2. PAPR

PAPR is one of the most significant limitations of multicarrier techniques.

The inverse Fourier transform of OFDM signal is given by [17]:

$$x(k) = \frac{1}{N}\sum_{i=0}^{N-1} X(i)e^{+j2\pi ki/N} \qquad (1)$$

Where $X(i)$= information symbol; N= no of samples or subcarriers.

Average Power of the signal is defined by:

$$E[|x(k)|^2] = \frac{b^2}{N} \qquad (2)$$

Here we have assumed that the symbols are considered to have a magnitude such as +b.

$$Peak\ Power = b^2$$

Mathematically we can see that if number of subcarrier increase then the PAPR is going to increase even more.

Mathematically, PAPR is defined as [18]:

$$PAPR_o = \frac{max[|p(t)|]^2}{E\,[|p(t)|]^2} \qquad (3)$$

Where p (t) is the peak of the OFDM signal's and E is the expectation operator. The PAPR in dB is expressed as:

$$PAPR_o(dB) = 10\ log_{10}\frac{max[|p(t)|]^2}{E\,[|p(t)|]^2} \qquad (4)$$

For the characterization of PAPR, Complementary Cumulative Distribution Function (CCDF) method is the most commonly used method. CCDF graph shows the behavior of signal at a certain power level. Mathematical expression for CCDF is given by [19]:

$$CCDF = 1 - (1 - exp^{PAPR_o})$$

3. PAPR TECHNIQUES

In this section, Schematics and characteristics in brief are discussed for the various PAPR reduction techniques mentioned above.

A. *Dummy Sequence Insertion (DSI)*

As secondary information exchange (SI) is not required, this technique becomes one of the most important in reducing the PAPR. In this method, we append dummy bits to the symbols until the minimum PAPR is reached [9]. This is illustrated below in Fig. 1.

B. *TR and TI*

The schematic is given below in fig. 2 [10].In this method, PAPR signal generated by the addition of sub-carriers and the complexity of this technique is reduced integrating it with Clipping and Filtering methods. In spite of many advantages, the high computational complexity is the biggest problem of the given technique. Schematic of above said technique is given below [12].

C. *Interleaving*

The main advantage of this technique is the high bit rate and simple structure and less complexity. In this technique, a number of the interleaver blocks are used to minimize the high power. However, there is a synchronization problem in this design. A schematic of interleaving technique is shown below in fig. 3 [11].

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D. *SLM*

SLM technique is one of the most common techniques used to reduce the PAPR in OFDM systems. In this method, a phase sequence is used. Modified input sequences are obtained by multiply the existing input signals with the phase sequences. The input sequence, which has a minimum value of PAPR, is then selected and transmitted. However, the complexity of the system is an issue in SLM design [12]. The schematic of the SLM method is shown in the fig .4 [12].

E. *DSLM –CT*

In this hybrid DSLM-CT, Circular transformation (CT) is used, to figure out the peak power. Before applying CT, we use the phase sequence method in the proposed design. This hybrid DSLM-CT technique works very well as the simulation results are very effective and better than the existing reduction techniques. The Schematic for this hybrid DSLM-CT technique is given in fig. 5 [17].

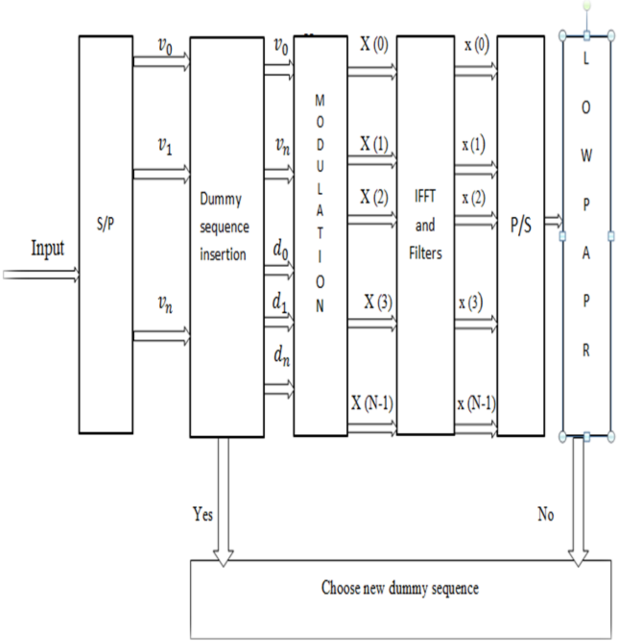

Fig .1 Dummy sequence insertion block diagram [9]

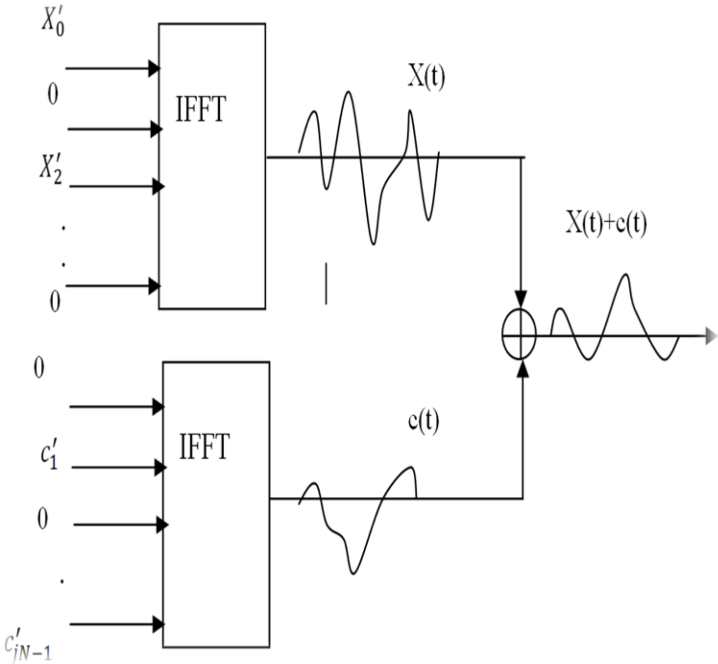

Fig 2. Structure of TI and TR [10]

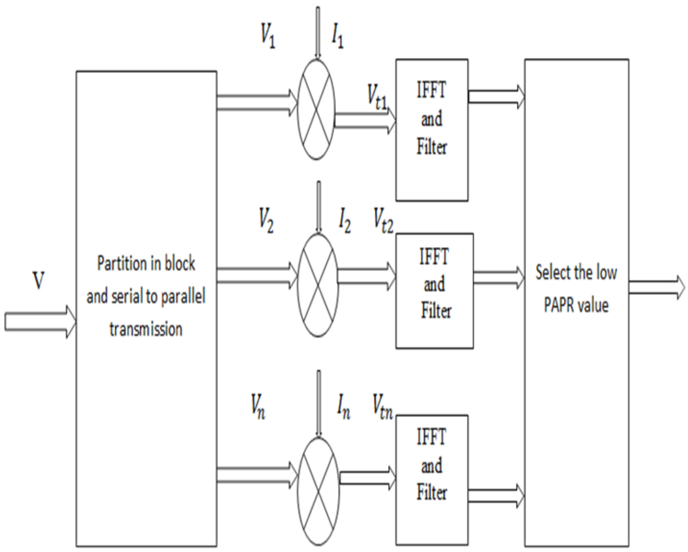

Fig 3. Schematics of Interleaving [11]

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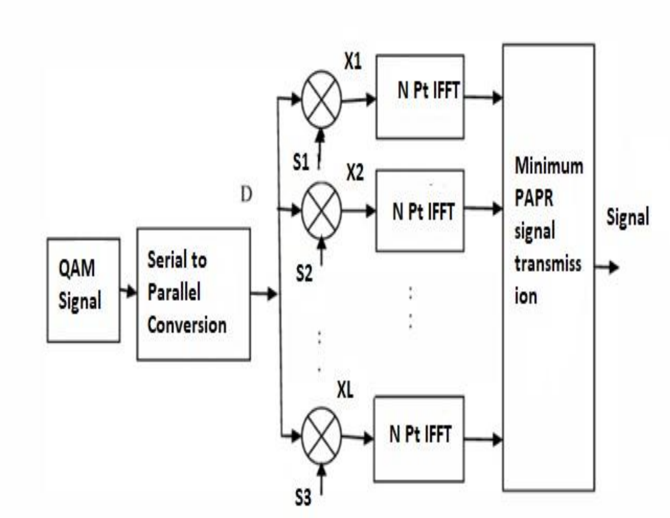

Fig 4. Selective Mapping Method [12]

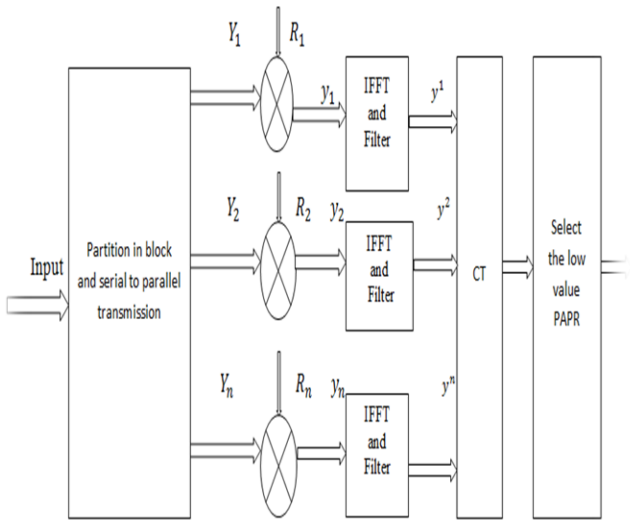

Fig 5. Hybrid DSLM-CT technique [17]

4. RESULTS

In this work, peak power minimization algorithms is studied and estimated by using Matlab-2014. We have considered an OFDM structure, 64 sub-carriers, 64-QAM, 64-FFT, and a bandwidth of 4 Mhz. Figure 6, gives the peak power estimation of the PAPR algorithms. Result reveals that the hybrid algorithm realized a gain of 3.7 dB, 2.9 dB, and 1.1 dB as compared to the DSI, TR &TI, and SLM methods. The BER estimation of the projected algorithms is illustrated in fig. 7. It is seen that the hybrid method obtained BER of 10^{-2} at the SNR of 4 dB as compared to the SNRs of 5 dB, 6.8 dB, 7.2 dB and 8.1 dB respectively.

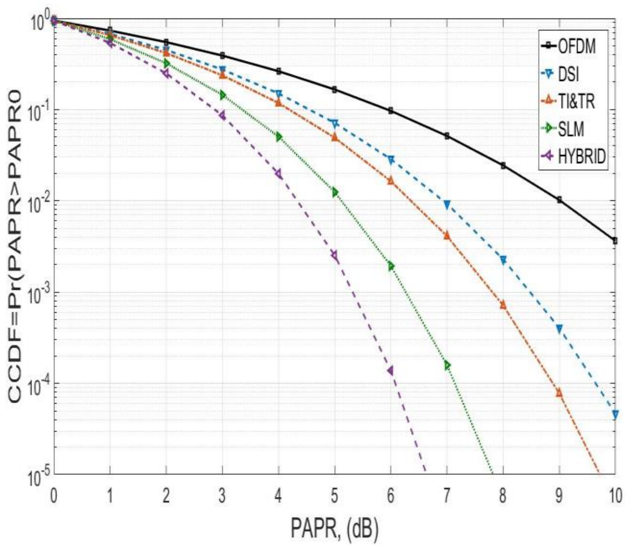

Fig 6. PAPR estimation

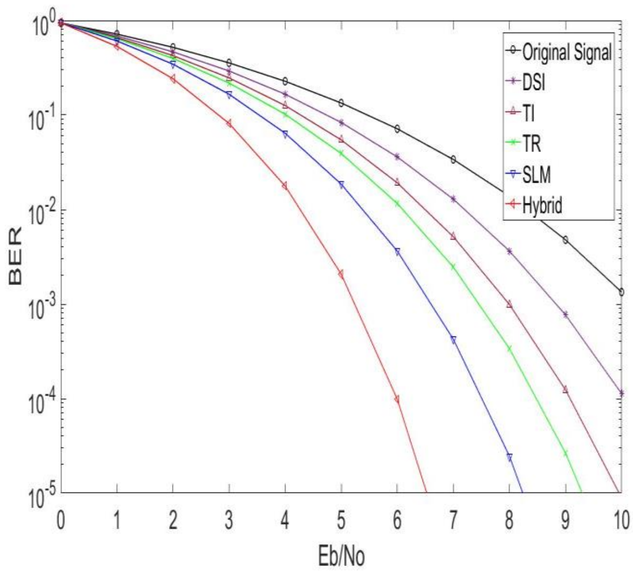

Fig 7. BER curves

Table 1 indicate the extent of computational complexities in the various PAPR reduction techniques, with mathematical expressions having N= no of subcarriers, V= sub-carriers and P= phase sequence.

Table 1 Complexity

S No	Technique	Complexity	References
1	SLM	$N(Vlog_2N)$	[20]
2	PTS	$N(l0g_2\frac{N}{4})$	[21]
3	Hybrid	$P^{N-1}V(N-1)$	[22]

5. CONCLUSION

In this article, we looked at different techniques to reduce PAPR in OFDM structures. All the techniques utilized such as DSI, Interleaving, TI & TR, and SLM has their own advantages and disadvantages as illustrated in the literature of the paper. Finally, this paper proposed a hybrid scheme to limit the PAPR to a lower level and is extensively described by simulation results and tabular differences. It is concluded that the proposed work indicates that by reducing the PAPR, the overall complexity of the system increases. The reduction of the PAPR is important for better transmission of the signals, but reaching it without increasing the complexity of the system remains a major challenge. For advanced waveforms such as 5G waveform technology, there are different techniques with innovative and hybrid methods that can achieve the results.

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AUTHOR PROFILES

Mohit Kumar Sharma received his bachelor's degree in Electronics & Communication Engineering from University of Rajasthan in 2009. He received his master's degree in VLSIDESIGN from MNIT Jaipur 2014. He is a research scholar of JECRC University.

Dr. Arun Kumar obtained his B.E, M.E and Ph.D doctorate in the field Electronics and Communication Engineering in 2009, 2013 and 2016. He has served in the field of education for over 7 years and is currently in service at JECRC University, Jaipur, India. He is the guest editor of the Book Series "Advances in Antenna, Microwave and Communication Engineering", Scrivener, John Wiley and also Editor in Chief of the Book Series "Advances in Antenna Design, Wireless Communication and Mobile Network Technology", CRC Press, Taylor and Francis. His current research interests are in the area of, 5G, OFDM, CDMA, Spectrum Sensing, Peak to Average Power Ratio, Advance Modulation Schemes, Antenna and UWB system. He is a member of IEEE. He has published more than 50+ papers (15 SCI/SCI-E + 30 Scopus Indexed Journals). He is Reviewer of many SCI and Scopus indexed international journals