International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V68I11P201

Volume 68 Issue 11, 1-8, November 2020

Testing of a Novel Tone Reservation technique for reduced PAPR of Zero Tail DFT-s-OFDM Signals Using TR Clipping

Pathuri Lavanya [1], Penke Satyanarayana [1], Mohammad Mohatram [2]

[1]*Department of Electronics and Communication, Koneru Lakshmaiah Education Foundation, Vijayawada, Andhra Pradesh*

[2]*Department of Electrical and Electronics Engineering, Global College of Engineering and Technology, Muscat, Oman;*

[1]pathurilavanya39@gmail.com

Abstract **-** *Contemporary investigation on ZT DFT spread orthogonal frequency division multiplexing, an extension to standard DFT spread orthogonal division frequency multiplexing deprived of external guard band but with an internal guard band. Its trailing tail that is of low power is designed with the nature of inertness to the delay spread in the path of the communication channel. This notable useful characteristics of Zero tail DFT Spread OFDM has attracted academics and scholars for extending this single carrier waveform on par with its 5G candidates to be deployed for Fifth Generation (5G) standards. Nevertheless, inadequacies that arises due to sharp peaks that hinders the working of high power amplifiers at the transmitter side, which causes erogenous peak powers must mitigate. Consequently, this work, a hybrid PAPR scheme is recommended, which incorporates an optimized Tone Reservation (TR) clipping technique. This recommended design decreased a significant correlation amongst the candidate signals. The specific goal in this paper for reducing PAPR in the Zero Tail Discrete Fourier spread OFDM signal is frequency optimization. Firstly, zero tailing introduced in this technique substitutes conventional IFFT with IDFT for reserved tones. Secondly, the TR is executed in a single iteration. The projected technique generates exceptional reduction in PAR values way ahead of similar research results.*

Keywords — *Zero-tail Discrete Fourier Transform-spread OFDM, Tone Reservation Peak to Average Power Ration, Iterative Clipping*

I. INTRODUCTION TO OFDM

Decreased usage energy at the Base Stations (BS) marks the chief fundamental impediment in the communication sector now. Research states that only 80 percent energy is used to operate the cellular network when working at full capacity. The crude reality, macro base stations have a fundamental function to perform to maintain the overall power performance of the antenna (Tx) chain because the Power Amplifier(PA) stands out as the most power-consuming element drawing 55 – 60% of the total power used at the base station [1-3]. Amplifier power efficiency can be improved through three procedures. This first method involves the transmission system. Modification of the architecture of the transmitter is the prime focus. Many approaches were introduced, such as the Kahn technique, envelope monitoring, parallel architecture, linear amplification with nonlinear components (LINC), and Doherty amplifiers. These techniques have a significant rise in hardware architecture complexity that is a big downside. Focus on signal processing is the second approach. Even in the absence of power amplifier's development in the design, the transmission throughput in terms of power gets improved due to the implementation of techniques that resolve the peak to average power ratio (PAPR) problem in the discrete spread systems. That enables PA to operate with lower back-off, thereby enhancing power performance. The third method considers network dimensioning. Energy output gets improved, working with tinier cells with more economical processing capacity than cells with more coverage areas. In fact, performance of the high-power amplifiers could be very well increased by implementing a combination of all the methods alluded to above. Focusing on some approaches concerning PAPR mitigation is the prime goal in this paper. PAR reduction reduces variations in transmitted data to run the high-power amplifiers (HPA), to operate them to the fullest when confined in the saturation zone where it delivers maximum power output. Primary objective concerning the entire research effort within this field aims at the integration of improved PAPR reduction strategies to benefit the communication sector.

A number of research works emerged definitely prefer certain PAPR reduction methods are classified considering their complex computation and structural intricacies involved, BER efficiency, loss in data rate, transmitted power. Tone Reservation (TR) stands out as the most common distortion less method which incorporates signal addition. Tone Reservation mostly introduced in the next-gen television transmission system (DVB-T2) in the terrestrial domain. Specified subcarriers are stored as tones for peak reduction (PRT) that not deployed for user data is transmitted save set aside for peak reduction; therefore, it gets its name. Such methods are distinct due to the compliance, not necessitating the demand for the transfer of side information of phase like signal probability techniques and are highly effective. These Tone Reservation methods are classified into four categories: firstly, TR gradient-based methods consisting of clipping followed by filtering, secondly, secondly, TR gradient-based methods wherein clipping is succeeded by peak cancellation, thirdly, TR optimized techniques and fourthly, hybrid TR techniques. Determination of the number and the method in which tones (PRT) are reserved for peak reduction and the optimum target clipping stage evaluates the efficiency of the TR techniques involving. The optimum configuration of PRTs would have the highest reduction in PAPR, consequently. Finding an ideal PRT set is a nondeterministic polynomial enigma; furthermore, that is unsolvable for the tones conceived in functional systems. Nonetheless, the time-domain gradient-based approach that includes both filtering and peak cancellation is first, it is low complex; second, it reduces the mean strength of the signal; third large iterations are required for obtaining an adequate reduction. As the basic concept of a gradient-based approach is the clipping accompanied by filtering or clipping after peak cancellation. The design iteratively snips the OFDM signal below the marked threshold, followed by filtered and peak cancellation.

But then again results in slow convergence speed. A deep and systematic research considering research articles implementing modern tone reservation methods, in nearly two decades published in IEEE journals are discussed in Fig. 1 and Fig.2. Tone Reservation (TR) technique recommended by Tellado et al. [2] where a simple gradient algorithm employs a little subcarrier set termed Peak Reduction Tones (PRTs) to produce peak cancellation during PAPR reduction, is devoid of IFFT/FFT. Time-Domain Kernel Matrix (TKM – TR), an uncomplicated gradient technique, is introduced in [3], it has a more straightforward structure than AS-TR. However, absence of suppression in peak regeneration worsens its reduction distinctly with low clipping thresholds. Reference [4] proposes an active set real-baseband algorithm to generate a minimum PAR solution set. Works in [5] states, an adaptive-scaling algorithm (AS-TR) that computes the first iteration clipping noise; yet, added IFFT/FFTs are required in each repetition. Genetic algorithm (GA-TR) [6,7] proposed claims to have lower computational complexity to

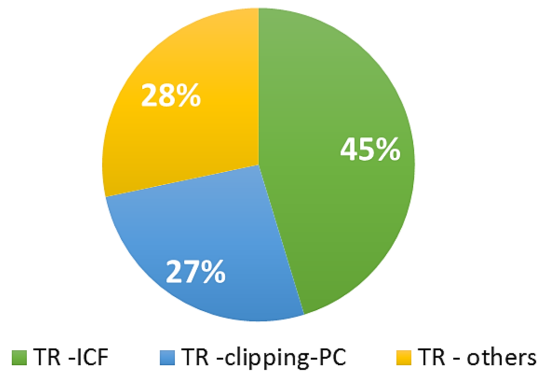


Fig. 1. Research works based on optimized TR to reduce PAPR in OFDM

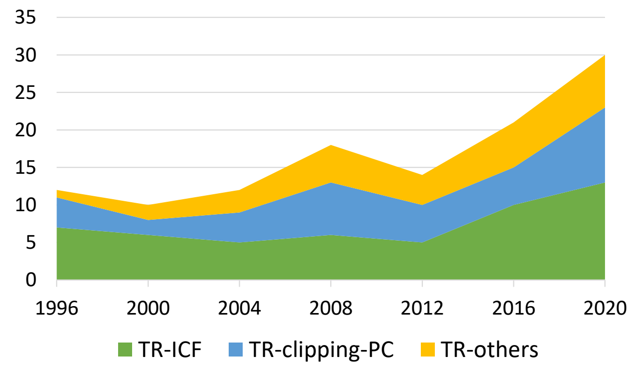


Fig. 2. Research trends over the years to reduce PAPR using optimized TR techniques

select a nearly optimal PRT set with adaptive clipping control. On the same lines, many approaches have been developed namely, efficient tone reservation method with null subcarriers **(**TRNS) [8], least-squares approximation **(**LSA-TR) [9,10], a suboptimal algorithm for peak-windowing of residual noise [11], search scheme based on parallel tabulation [12] to obtain almost perfect peak reduction tone set, deep learning algorithm utilizing tone reservation network [13], DSI-Based [14] subcarrier group modulation claims spectral efficiency, Guard Interval [15] algorithm proposed to enhance TRNS optimization further, selective mapping of partial tones **(**SMOPT**)** [16], and Adaptive All pass filte**r (**AAPF**)** [17] to improve the performance of the tone reservation. Similarly, TR algorithms with clipping followed by peak cancellation have been extensively incorporated in research. They include CC-TR technique that is deployed using filtered clipping noise [18] to reduce the PAPR.

Random search technique [19] offers lower PAPR with a natural structure. It deploys a deterministic algorithm using a cyclic difference set. Similar to other research techniques deployed to enhance Tone Reservation are Curve Fitting peak-canceling technique (CF-TR) [20], novel

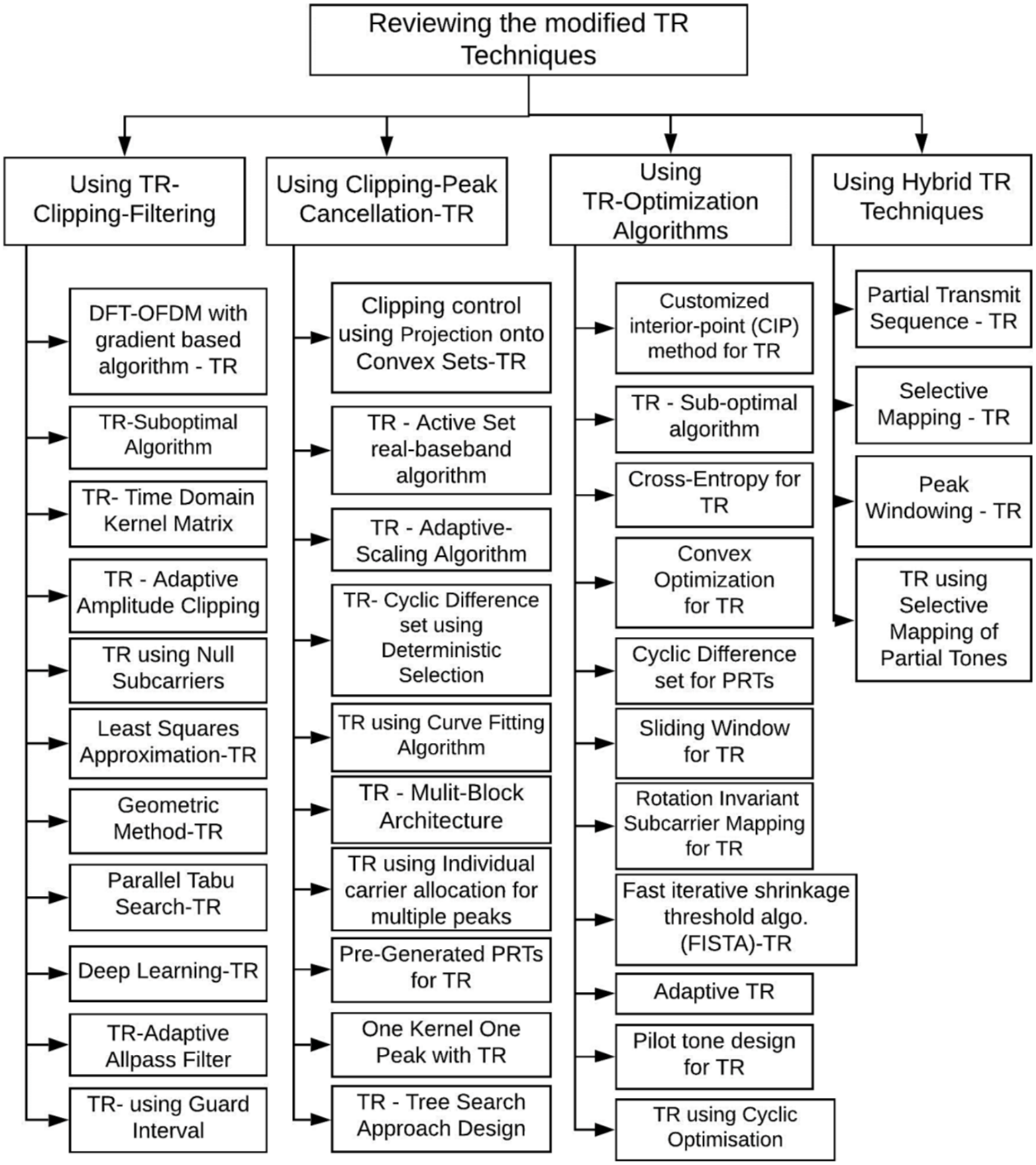


Fig. 3. Optimization techniques implemented with TR in abid to reduce PAPR

multiblock (MB) TR scheme (MB-TR) [21] that exploits overlapping structure and obtain clipping noise taking into consideration the adjacent data blocks. Tree-search approach [22] based on the principle of sphere decoding and encoding. Cyclic optimization clipping level [23] and peak-canceling signal. One kernel one peak (OKOP) [24], pre-generated peak canceling signals [25], Individual carrier and grouped allocation for multiple peaks (GICMP/ICMP) [26]. Other TR optimization techniques include customized interior-point method (IPM) [27], CE - TR cross-entropy [28] using simple gradient algorithm for optimal PRT set, implementing cyclic difference set [29], second order cone programming convex optimization SOCP [30], sliding window tone reservation (SW-TR) [31], multi data block PTS and TR methods [32], pilot tone design [33] that replaces FFT with DFT for reserved tones. In contrast, various optimizations techniques have also been added such as the adaptive tone reservation Scheme [34] that is further applied for multi-Stage TR in the research work of [35]. Two additional research works included in this extensive literature review includes fast iterative shrinkage-threshold process (FISTA) [36] for optimal peak-cancelled signal, Rotation Invariant Subcarrier Mapping (RISM) [37] to reduce PAPR in OFDM systems for TR. Fig. 3 systematically picturizes the various optimization techniques involved with TR. The present article describes a superior TR clipping technique that accomplished the PAPR reduction in a single iteration in time domain. It was specially developed for ZT DFT-s-OFDM output signal to minimize peak to average power (PAR), provides advanced efficiency with reduced technical sophistication. Primarily focused on the TR framework, the whole report introduces a different framework which could reduce hardware overhead and energy consumption.

As in proposed architecture, the Fast Fourier Transform is substituted by the discrete Fourier Transform, because it deals with the number of allocated tones that are lower than those of the subcarriers. In order to significantly reduce the sophistication of the TR structure, single iteration is deployed in a bid to reduce the large multiplication operation with basic ones. Experimental analysis in terms of improvement of both complementary cumulative distribution function (CCDF) and bit error rate (BER) that are two major performance indicators for analyzing PAPR, shall be done only with sequentially incorporating Tone Reservation post clipped Zero Tail DFT spread OFDM signals. The results will then be monitored and evaluated. Simulation outcomes show increased efficiency in the reductions of peak to average power and BER with almost same technical complexity as that of the OFDM signal. The article is structured in the following sequence. Section 2 discusses the tone-reservation methodology incorporated to the OFDM framework. Section 3 presents the fundamental topics leading to the motivation to implement the projected technique. Section 4 deals with the in depth description of the proposed method. Section 5 describes the simulation results implemented to evaluate the proposed systems. Section 6 concludes the research findings by proposing probable future research directions in this domain.

II. CONVENTIONAL TONE RESERVATION TECHNIQUE

The whole technology involves the collection of reserved tones. With such a method, reserved tones not designated to transport information could be used to reduce PAPR. Such approach is being used for the transport of multicarrier. Each approach relies on the strength of the tones. The benefit of this tone reservation is quite optimistic that no procedure is required at the end of the receiver. Furthermore, it is not necessary to transmit the additional features as side information along with the carrier frequency. The tone reservation technique reserves C tones for PAPR reduction and the remaining X tones for data transmission. Tone reservation ratio $R = C/X$ is very small. $\hat{x}(t) = x(t) + c(t)$. Here $0 \le t \le T$. The block diagram of the structure of conventional Tone Reservation is shown in Fig.4. Then, the peak to average power ratio of resultant Zero Tail DFT spread OFDM waveform would be denoted by following equation.

$$PAPR\,\{x_c[N]\} = 10\log_{10}\frac{\max\limits_{iT\le t\le(i+1)T}|x(t)+c(t)|^2}{E|x(t)|^2} \qquad (1)$$

Addition of peak reduction symbol C, the time-domain symbol of $x + c = Q(X + C)$ has a lower PAPR of x. Where $X = [x_0, x_1, \dots, x_{N-1}]^T$ time-domain oversampling OFDM signal and must compute the vector c that minimizes the maximum peak value, i.e.

$$\min_{c}\|x + c\|_\infty = \min_{\hat{C}}\left\|x + \hat{Q}\hat{C}\right\|_\infty \qquad (2)$$

Where $c(t)$ represents the tones assigned to reduce impulsive peaks. The manner in selecting the different PRTs as a set and the no of PRTs selected for the provided Zero Tail DFT spread OFDM signal, are the criteria for generating optimal reduction in burst peaks. Conversely, DFT-s-OFDM system fares better performance in reducing PAPR than that achieved using ZT discrete fourier transform spread OFDM. However Zero Tail DFT spread OFDM signal structure features overlapped adjacent data blocks. Consequently, incorporating regular TR scheme to reduce the PAPR limits the performance output. Therefore, iterative clipping followed by filtering needs to be implemented.

III. ANALYSIS OF CLIPPING AND FILTERING

The clipping stands out as the simplest technique for reducing PAPR. This technique beholds the main objective to clip the sections of the amplitude of the data waveform greater than the pre-defined threshold level A. This technique is very well appreciated for its supremacy to efficiently reduce the power variation. Sometimes this technique is iteratively repeated until the desired performance output is met, or till the signal gets completely below the threshold. Clipping represents the category of signal distortion techniques. The high amplitude peak of the Zero Tail DFT spread OFDM signal envelope gets clipped in the time domain. However, there exists a certain drawback as there is a possibility for increase in bit error rate if clipping level exceeds a certain limit, requiring a great need for a proper tradeoff factor maintain the PAPR reduction and the increase in BER level to the original information.

Level A, also called as A_{thres}, is decided on the basis of the manner in which reserved-tone set is chosen. Research states that an ideal reserved-tones are obtained in random selection of tones. The signals that cross the threshold level A causes clipping noise $f(t)$ or clipping pulse to be more specific clipping pulse. Rate at which the signals cross the level can be formulated as $\lambda_A = \sqrt{\pi/6}\ (AN/\sigma T)e^{-A/2\sigma^2}$. Typically, the mean no of level crossing in an OFDM signal can be formulated as $\bar{N}_p = E\{N_p\} = \lambda_A T$. The corresponding pulse duration τ of the clipped signal follows the Rayleigh ransom variable having the probability density function (pdf).

$$p(\tau) = \frac{\pi\tau}{2\bar{\tau}^2} e\left(-\frac{\pi\tau^2}{\mathbf{4}\,\bar{\tau}^2}\right) \tag{3}$$

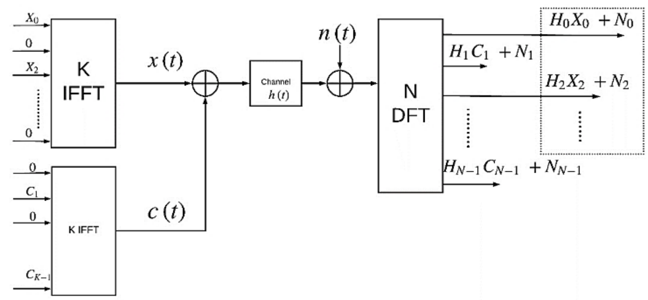


Fig. 4 Block diagram of TR

A. Filtered followed by Clipping

Noise generated during the clipping greatly affects both the data subcarriers and reserved tones. In the former case, they are preserved for PAPR reduction whereas in the latter case they are filtered to prevent Out of band radiation (OOB) which would further cause Inter carrier Interference (ICI). Low pass filter suitably deployed to filter the generated noise after clipping brings greater efficiency in the system, where $\omega_c = 2\pi f_c = 2\pi\, N_r/2T$. The cumulative clipping noise that is filtered can be denoted as

$$\hat{f}(t) = \sum_{i=1}^{N_p} \hat{f}_i(t) \tag{4}$$

Linking $\hat{f}_i(t)$ and $f_i(t)$, we conclude firstly, both reach the peaks at the same time $t = 0$. Secondly, both follow the same phase in the pulse duration. Thidly, duration of $f_i(t)$ is much wider and of lesser height than $\hat{f}_i(t)$.

$$\left|\hat{f}_i(t)\right|_{max} = \alpha\tau_i |f_i(t)|_{max} \tag{5}$$

B. Iterative Clipping and Filtering

Your Iterative clipping followed by filtering may be performed to meet the required criteria. Clipping noise generated from first iteration $f_i^{(A)}(t)$ having a pulse width $\tau_i^{(A)}$ will be larger than others. The signal at the output after the first iteration $\hat{x}^{(1)}(t) \approx x(t) - \hat{f}_i^{(A)}(t)$, here $\hat{f}_i^{(A)}(t)$ denotes filtered signal of $f_i^{(A)}(t)$. Firstly, $\hat{f}_i^{(A)}(t), f_i^{(A)}(t)$ and $x(t)$ have same phase, $\hat{f}_i^{(A)}(t)$ greater than $f_i^{(A)}(t)$i.e. Filtered signal is of lower amplitude than original signal. The resultant signal $\hat{x}^{(A)}(t)$ can be approximated to $\hat{x}^{(A)}(t) \cong x(t) - \hat{f}_i^{(A)}(t)$ leading to A. Second iteration, the clipped signal $f_i^{(B)}(t)$ represents

$$f_i^{(B)}(t) = f_i^{(A)}(t) - \hat{f}_i^{(A)}(t) \tag{6}$$

To implement further iterations, the equal procedure follows. For the l^{th} iteration. Filtered clipping noise at $t_i - \tau_i^{(l)}/2 \le t \le \tau_i^{(l)}/2$ reflects the primary lobe of $\hat{f}_i^{(1)}(t)$ closer to $t = t_i$. As the lth iteration, $l \to \infty$, clipping noise $f^{(l)}(t)$ proceeds to null value, and the peak value of $x(t)$ limits itself to level A.

IV. PROPOSED TONE RESERVATION ALGORITHM

An enhanced constant-scaling tone reservation algorithm is proposed taking in view of the resource constrained environment of the communication infrastructure having a constant scaling factor $\bar{\beta}$

<u>*Step 1: Algorithm Initialization*</u>

- Clipping threshold A is selected
- Reserved tones R are randomly set.
- Scaling factor $\bar{\beta}$ is calculated

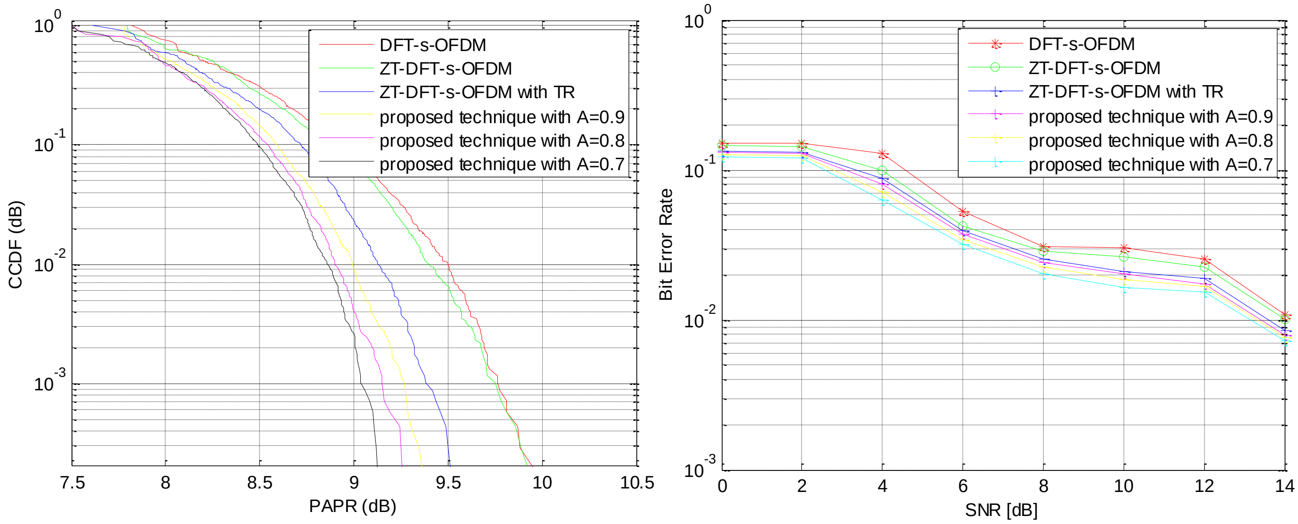
<u>*Step 2: Algorithm Initialization*</u>

- Incorporate the input symbols to PRT tones R^c
- Compute equivalent time-domain data x_n.
- If $PAR > A$, execute next step; if not proceed to the x_n and finish.
- Clip x_n to the threshold A , compute clipping noise f_n
- Firstly, convert clipped and filtered $\hat{f}_n$ to the frequency domain using DFT; $F_k = DFT\{f\}$
- Obtain filtered clipping noise F ; F_k for $k \in \mathcal{R}$
- Scaled signal C_k is obtained by $C_k = -\bar{\beta}\hat{F}_k$
- Adapt C_k in time domain c_n by incorporating IDFT in place of IFFT.
- Scaling PAPR is calculated for the resultant signal $\hat{x}_n = x_n + c_n$, and transmitted.

Calculating PAPR with f_n requires all values of x_n to be calculated, tending it to be costly affair. Alternatively, incorporating for all satisfying $|x_n| \ge A$ greatly reduces the complexity. Also, when PAPR reduction is more important than the complexity concerned, adaptive-scaling algorithm could be another option where β differs for each OFDM symbol, here $\hat{x}_n = x_n - \beta\hat{f}_n$. Algorithmic complexity is determined with the complexity in calculating $|x_n|$ and f_n. After completion of the first iteration $\hat{N}_f = N_f - N_1 + N_2$ where N_1 represents samples less than threshold A now but N_2 denotes new peaks generated post first iteration. As $\hat{x}_n = x_n + c_n;\ c_n \ll x_n$, x_n around the threshold level A will contribute to N_1 or N_2 and usually neglected. f_n consists of $2\hat{N}_f$ real multiplications and $\hat{N}_f$ real divisions. Complexity of introduced fixed scaling algorithm is proportional to (N) , but if we consider the complication of adaptive scaling turns out to be $O(N\log_2 N)$ for achieving optimal PAR for TR technique. Considering the PAR reduction, increase in power and system complexity we recommend constant scaling technique better choice to generate better reduction in resource constraint environment where complexity matter.

V. EXPERIMENTAL RESULTS AND OBSERVATION

Sampling frequency	30.72 MHz



(a) (b)

Fig. 4. (a) CCDF of PAPR outputs of the proposed technique with Clipping ratios 0.9, 0.8, 0.7 using 16QAM modulation. (b) Performance comparison of BER using DFT-O-OFDM, Zero Tail DFT spread OFDM, Zero Tail DFT spread OFDM with TR and clipping with 16-QAM mapping over AWGN channel

This segment is important wherein it considers a 104 uniformly distributed OFDM signals in a 16-QAM modulated system with 128 subcarriers, oversampling rate L = 4 considering reserved tones T = 8 in number, tone-reservation ratio R = 6%, requires only one iteration is considered for the experimental study of the proposed technique. PAPR reduction is characterized by the performance of the BER bit error rate and the complementary cumulative distribution function (CCDF). Table 1 and Table 2 denote the experimental setup and chosen simulation parameters respectively.

Table 1. Experimental Setup

System Configuration	Details
OS	Windows 7 - Ultimate
Frequency	2.30 GHz
Software	MATLAB 2019A
Processor	Intel (R) i5 – 4200 U
Laptop	Personal HP Computer

Table 2. Simulation parameters for ZT DFT spread OFDM

Experimental parameters	Values
OFDM symbols	10000
Length of CP	4.68 μs for DFT-OFDM
Carrier frequency	2 GHz
Implemented Modulation	16 QAM
Bandwidth	20 MHz
Symbols used	14 in Discrete -OFDM 15 in ZT DFT-s-OFDM
N	1200
N_h; N_t	8 ; 84
N_{IFFT} size of IFFT	2048
N_{sh}; N_{st}	14 ; 144
Subcarriers	128
Threshold (A)	0.9, 0.8, 0.7
Oversampling factor L	4
Peakreduction tones (C)	8

Fig. 5(a) indicates a comprehensive analysis of PAPR performance improvements by Zero Tail DFT spread OFDM, Discrete Fourier transform spread OFDM, Zero Tail DFT spread OFDM with TR, Zero Tail DFT spread OFDM Tone Reservation with Clipping and peak cancellation. Suggested technique demonstrates much higher efficiency of CCDF than the current systems. When CCDF is $10^{-4,}$ while the standard Discrete Fourier Transform spread OFDM is 10.3 dB, the Zero Tail DFT spread OFDM reduces the PAPR by 0.6 dB making it to 9.7 dB. The PAPR value of Zero Tail DFT spread OFDM with TR is further lowered by 1 dB to 9.6 dB; it is observed that clipping ratio of 0.7 produced a maximum reduction in PAPR by is 0.5 dB reaching 9.2 dB, 1 dB lower than the standard Zero Tail DFT spread OFDM. It proves to be reducing PAPR in a power efficient structure when compared to similar studies from [35-37]. The methodical reduction of the bit error ratio rate (BER) depicted in Fig. 5(b), includes the presentation of the DFT spread OFDM, ZT discrete Fourier transform spread OFDM, Zero Tail-DFT-spread OFDM inclusive of TR and various levels of clipping ratio, the addition of zero tail to the discrete spread of Fourier OFDM. When BER is 10^{-4}, while the standard SNR of DFT spread OFDM is 15.5 dB, the Zero Tail DFT spread OFDM reduces the SNR by 0.2 dB making it to 15 dB. The SNR value of Zero Tail DFT-spread OFDM with Tone Reservation is further lowered by 0.5 dB to 15.5 dB; it is observed that clipping ratio of 0.7 produced a maximum reduction in SNR by is 0.5 dB reaching 14.2 dB, 1.2 dB lower than the standard ZT-DFT-s-OFDM. This improvised and proposed algorithm has proven to be have more efficient system performance than techniques applied in the works of [34-36] with almost the system complexity.

VI. CONCLUSIONS

An evolved Tone Reservation based clipping technique for Zero Tail DFT spread OFDM that provides optimal peak to average power reduction with minimal iterations is presented in this research paper for power-efficient uplink systems. PAPR reduction primarily relies upon the following factors, firstly, the range of peak reduction tone (PRT) set secondly, the technique that decodes the peak reduction tones, and then thirdly, the determination of near-perfect clipping threshold optimal PRT must be determined such that the totality in the selection of the combination of possible PRT sets brings out exceptional PAPR reduction. PRT sets selected are obtained by in a consecutive manner, equally spaced manner and random manner. Experimental outcomes explicate that the suggested clipping control algorithm delivers immeasurable PAPR reduction despite the objective clipping rates. This TR clipping system is uncomplicated yet attractive concerning effective implementation.

REFERENCES

[1] Tani, K., Medjahdi, Y., Shaiek, H., Zayani, R., & Roviras, D. PAPR reduction of post-OFDM waveforms contenders for 5G & beyond using SLM and TR algorithms. 2018 25th International Conference on Telecommunications (ICT). (2018).

[2] A.K. Bashir, R. Arul, S. Basheer,G. Raja,R. Jayaraman, N,M,F Qureshi, An optimal multitier resource allocation of cloud RAN in 5G using machine learning, Transactions On Emerging Telecommunications Technologies. 30(8) (2019).

[3] M. V.Rao, B.T.P. Madhav, J.K.Y. Usha Devi, T. Anilkumar, B. P. Nadh, CSRR-loaded T-shaped MIMO antenna for 5G cellular networks and vehicular communications. 29(8) (2019).

[4] Wang, Y., Chen, W., & Tellambura, C., Genetic algorithm based nearly optimal peak reduction tone set selection for adaptive amplitude clipping PAPR reduction. IEEE Transactions on Broadcasting. 58(3) (2012) 462-471.

[5] Tellado, J., & Cioffi, J. (n.d.)., Efficient algorithms for reducing PAR in multicarrier systems, Proceedings. 1998 IEEE Int' Symposium on Information Theory.

[6] Krongold, B., & Jones, D., An active-set approach for OFDM PAR reduction via tone reservation, IEEE Transactions on Signal Processing. 52(2) (2004) 495-509.

[7] Luqing W, Tellambura, C., Analysis of clipping noise and tone-reservation algorithms for peak reduction in OFDM systems, IEEE Trans on Vehicular Tech. 57(3) (2008) 1675-1694.

[8] Wang, Y., Chen, W., & Tellambura, C., Genetic algorithm based nearly optimal peak reduction tone set selection for adaptive amplitude clipping PAPR reduction, IEEE Transactions on Broadcasting. 58(3) (2012) 462-471.

[9] Hu, S., Wu, G., Wen, Q., Xiao, Y., & Li, S., Nonlinearity reduction by tone reservation with null subcarriers for WiMAX system, Wireless Personal Communications. 54(2) (2009) 289-305.

[10] Guel, D., Palicot, J., & Louët, Y., Tone reservation technique based on geometric method for orthogonal frequency division multiplexing peak-to-average power ratio reduction, IET Communications. 4(17) (2010) 2065.

[11] Deumal, M., Behravan, A., & Pijoan, J. L., On cubic metric reduction in OFDM systems by tone reservation, IEEE Transactions on Communications, 59(6) (2011) 1612-1620.

[12] Wang, J., Lv, X., & Wu, W., SCR-based tone reservation schemes with fast convergence for PAPR reduction in OFDM system, IEEE Wireless Communications Letters. 8(2) (2019) 624-627.

[13] Hou, J., Ge, J., & Gong, F., Tone reservation technique based on peak-windowing residual noise for PAPR reduction in OFDM systems, IEEE Trans. on Vehicular Tech. 64(11) (2015) 5373-5378.

[14] Hou, J., Tellambura, C., & Ge, J. Tone injection for PAPR reduction using parallel tabu search algorithm in OFDM systems, IEEE Global Communications Conf (2012).

[15] Wang, B., Si, Q., & Jin, M., A novel tone reservation scheme based on deep learning for PAPR reduction in OFDM systems, IEEE Communications Letters. 24(6) (2020) 1271-1274.

[16] Hossain, M. S., & Shimamura, T., Spectrum efficient DSI-based OFDM PAPR reduction by subcarrier group modulation, IEEE Trasn on Broadcasting. 64(3) (2018) 771-777.

[17] Sohtsinda, H., Perrine, C., Bachir, S., & Duvanaud, C., Using guard interval signal to improve tone reservation method for peak-to-average power ratio reduction in orthogonal frequency division multiplexing systems, IET Signal Processing. 9(6) (2015) 476-483.

[18] Seungsoo Yoo, Seokho Yoon, Sun Yong Kim, & Iickho Song., A novel papr reduction scheme for OFDM systems: Selective mapping of partial tones (SMOPT), IEEE Transactions on Consumer Electronics. 52(1) (2006) 40-43.

[19] Hong, E., Park, Y., Lim, S., & Har, D., Adaptive phase rotation of OFDM signals for PAPR reduction, IEEE Transactions on Consumer Electronics. 57(4) (2011) 1491-1495.

[20] Gatherer, A., & Polley, M. (n.d.)., Controlling clipping probability in DMT transmission. Conference Record of the Thirty-First Asilomar Conference on Signals, Systems and Computers (Cat. No.97CB36136).

[21] Dae-Woon Lim, Hyung-Suk Noh, Jong-Seon No, & Dong-Joon Shin., Near optimal PRT set selection algorithm for tone reservation in OFDM systems, IEEE Transactions on Broadcasting. 54(3) (2008) 454-460.

[22] Jiang, T., Ni, C., Xu, C., & Qi, Q., Curve Fitting based tone reservation method with low complexity for PAPR reduction in OFDM systems, IEEE Comm. Letters. 18(5) (2014) 805-808.

[23] Jiao, Y. Z., Liu, X. J., & Wang, X. A., A novel tone reservation scheme with fast convergence for PAPR reduction in OFDM systems. 2008 5th IEEE Consumer Comm. and Networking Conference.

[24] Tosato, F., Sandell, M., & Tanahashi, M. Tone reservation for PAPR reduction: An optimal approach through sphere encoding. IEEE Int' Conf. on Communications (ICC) (2016).

[25] Lv, X., & Wan, Y., Efficient tone reservation peak-to-average power ratio reduction system with optimal clipping for orthogonal frequency division multiplexing systems, IET Communications. 9(17) (2015) 2070-2076.

[26] Mroué, M., Nafkha, A., Palicot, J., Gavalda, B., & Dagorne, N., Performance and implementation evaluation of TR PAPR reduction methods for DVB-T2, International Journal of Digital Multimedia Broadcasting. (2010) 1-10.

[27] Li, H., Wei, J., & Jin, N., Low-complexity tone reservation scheme using pre-generated peak-canceling signals, IEEE Communications Letters. 23(9) (2019) 1586-1589.

[28] Bulusu, S. S., Crussiere, M., Helard, J., Mounzer, R., Nasser, Y., Rousset, O., & Untersee, A., Quasi-optimal tone reservation PAPR reduction algorithm for next generation broadcasting systems: A performance/Complexity/Latency tradeoff with Testbed implementation, IEEE Transactions on Broadcasting, 64(4) (2018) 883-899.

[29] Aggarwal, A., & Meng, T. (n.d.)., Minimizing the peak-to-average power ratio of OFDM signals via convex optimization. GLOBECOM

'03. IEEE Global Telecommunications Conference (IEEE Cat. No.03CH37489).
[30] Jung-Chieh Chen, & Chih-Peng Li., Tone reservation using near-optimal peak reduction tone set selection algorithm for PAPR reduction in OFDM systems, IEEE Signal Processing Letters. 17(11) (2010) 933-936.
[31] Lim, D., Noh, H., Heo, S., No, J., & Shin, D., Construction of the near optimal PRT set using the cyclic difference set in TR scheme, IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications (2007).
[32] Zabre, S., Palicot, J., Louet, Y., & Lereau, C., SOCP approach for OFDM peak-to-Average power ratio reduction in the signal adding context, IEEE International Symposium on Signal Processing and Information Technology (2006).
[33] Lu, S., Qu, D., & He, Y., Sliding window tone reservation technique for the peak-to-Average power ratio reduction of FBMC-OQAM signals, IEEE Wireless Comm. Letters. 1(4) 268-271.
[34] Wang, H., A hybrid PAPR reduction method based on SLM and multi-data block PTS for FBMC/OQAM systems. Information, 9(10) (2018) 246.
[35] Gang Yang, Zhengjie Yang, & Jianhua Xu., PAPR reduction in the OFDM system employing tone reservation based on FFT/IFFT, International Symposium on Communications and Information Technologies.(2007).
[36] Ni, C., Ma, Y., & Jiang, T., A novel adaptive tone reservation scheme for PAPR reduction in large-scale multi-user MIMO-OFDM systems, IEEE Wireless Comm. Letters. 5(5) (2016) 480-483.
[37] Dae-Woon Lim, Hyung-Suk Noh, Hyun-Bae Jeon, Jong-Seon No, & Dong-Joon Shin., Multi-stage TR scheme for PAPR reduction in OFDM signals, IEEE Transactions on Broadcasting. 55(2) (2009) 300-304.
[38] Wang, Y., Xie, S., & Xie, Z., FISTA-based PAPR reduction method for tone reservation's OFDM system, IEEE Wireless Communications Letters. 7(3) (2018) 300-303.
[39] Rosati, S., Candreva, E. A., & Corazza, G. E., Rotation invariant subcarrier mapping over DVB-T2 reserved tones, IEEE 77th Vehicular Technology Conference (VTC Spring) (2013).