A Comparative Analysis of PAPR Diminishment Techniques for Next Generation Network: LTE-MIMO to 5G

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Abstract In the wireless communication system frameworks, OFDM is an efficient and capable multicarrier modulation approach for far-off transmission of data like audio and video via radio waves. The rising requirement for high-speed and high-quality data led to the evolution of 5G mobile communication. The 5G requirements such as information rate, high spectral efficiency, low latency and complexity could be achieved using multicarrier modulation which is being researched as a piece of 5G physical layer arrangements. This paper presents the comparative analysis of PAPR diminishment techniques used in next generation networks. A simulation result shows that the performance of adjacent techniques reduces the PAPR. The accomplishment PAPR diminishment techniques is also analyzed by changing the number of transmitted symbols, oversampling factor over various OFDM sub-block lengths, number of subcarriers for different modulation techniques. The Bit error rate analysis is performed to compare performance of various systems.

Keywords Orthogonal frequency division multiplexing (OFDM) · Selective mapping method (SLM) · Bit error rate (BER) · Peak to average power ratio (PAPR)

1 Introduction

Third era (3G) versatile communication technologies actualized almost around the globe are neither ready to meet the prerequisites of the high data rates nor throughputs. Besides, voice communication in 3G relies on circuit switching technology, the same as in second-generation (2G) communication systems, rather than pure Internet protocol (IP) approach. Researchers have been trying for the next evolutionary fourth generation (4G) communication systems to give a far reaching and secure IP arrangement where voice, information and media can be offered to clients

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at “Anytime, anyplace” with higher information rates than past ages. Orthogonal frequency division multiplexing (OFDM) is the multicarrier modulation technique used within LTE, 4G signal format [1]. OFDM, orthogonal frequency division multiplex, is the simple layout used, and that is changed to offer the more than one get entry to scheme: OFDMA, orthogonal frequency division more than one get entry to with inside the downlink and SC-FDMA, single channel orthogonal frequency division more than one get entry to with inside the uplink. It has significantly progressed the overall performance as compared to preceding solutions. However, with inside the previous couple of years, the evolution of necessities and use instances posed a venture to next generation systems such as 4G and 5G which ought to be able, amongst others, to cope with the massive variety of customers and offer better information rates [2].

The current paper is organized as follows: Section 1 gives prerequisite of wireless communication standard, Sect. 2 gives literature survey of PAPR techniques and its impact on system performance. In Sect. 3, definition of PAPR and current challenges are mentioned along with reduction techniques. Section 4 presents comparative analysis of PAPR diminishment methods in SISO OFDM and MIMO models. Simulated results and its discussion are provided in Sect. 5. The conclusion is presented as Sect. 6.

2 Literature Survey

There is considerable research carried out in PAPR reduction. A complete overview of literature on MIMO OFDM for PAPR diminishment methods has been presented here.

Ben Mabrouk et al. [1] their paper has addressed a necessary condition to achieve better PAPR performance than OFDM as tone reservation and active cancellation technique.

Yi and Wang et al. [2] in their paper have addressed a technique for PAPR discount through random constellation mapping. Using random mapping methods, signals are converted to data symbols. Mapping is performed across each symbol.

Then, the candidate symbol with least PAPR is dispatched out for further communication in conjunction with its candidacy number.

Sghaier et al. [3] describe a MIMO OFDM system with blind and reduced complexity methods. High-frequency-selective channels are considered.

Boccardi et al. [5] addressed PAPR techniques with Fourier-based and Wavelet-based multicarrier communication techniques. Based on results, they categorized multicarrier modulation as high PAPR, low PAPR and moderate PAPR systems.

3 Peak to Average Power Ratio

In OFDM, the original information which is to be transmitted consists of high power and very narrow bandwidth. This signal is divided into N parallel blocks using IFFT operation. After IFFT operation, parallel data is converted into serial with last sample and cyclic prefix (CF). Therefore, OFDM structures are acknowledged to have an excessive PAPR, as compared with single-carrier structures. In fact, the excessive PAPR is one of the maximum destructive elements within side the OFDM system because it decreases the signal-to-quantization noise ratio (SQNR) of analog-to-digital converter (ADC) and digital-to-analog converter (DAC) even as degrading the performance of the power amplifier within side the transmitter. The PAPR hassle is greater essential within the uplink because the performance of the power amplifier is essential because of the confined battery energy in a cellular terminal. High PAPR is one of the massive drawbacks of multicarrier modulations. PAPR is described as the ratio among the maximum power of the signal and its average power. The PAPR expressed as given in Eq. (1)

$$\text{PAPR} = \frac{P_{\text{peak}}}{P_{\text{average}}} = 10\log 10 = \frac{\max\left[\{|X_n|\}^2\right]}{E\left[\{|Xn|\}^2\right]} \tag{1}$$

As per Eq. (1), peak energy traits also can be defined in phrases in their magnitudes (now no longer energy) with the aid of using defining the crest factor (CF) as shown in Eq. (2);

$$\text{Pass band Condition CF} = \sqrt{\text{PAPR}} \tag{2}$$

3.1 Challenges to Mitigate PAPR Requirements

PAPR approach in OFDM has till now confronted substantial challenges related to power amplifiers used at transmitter and receiver.

As per power distribution defined by radio technologies, higher power is consumed due to high-power amplifier as shown in Fig. 1. One of the primary parameters that have an effect on all cell UE devices is their battery life. It is consequently essential to make certain financial and green energy use within the transmission and reception of signals. The complexity of the PAPR perspectives unexpectedly will increase while many digital items combat for display screen area to mark bodily entities within the dynamic perspectives of more than one fast moving roaming user.

- ***High PAPR*** and inter-carrier interference (ICI) are the two foremost issues within the implementation of an OFDM system. OFDM systems require tight frequency synchronization in contrast to single carrier systems, due to the fact that in OFDM,

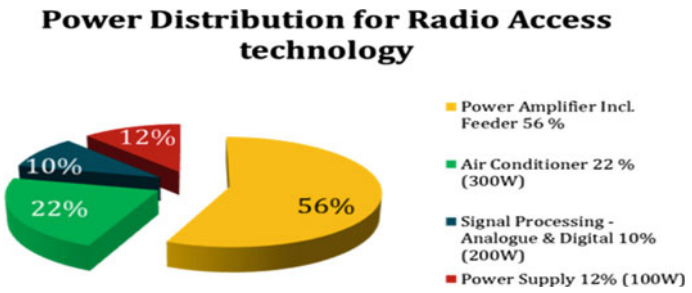

Fig. 1 Power distribution for radio access technology

the subcarriers are narrowband. Therefore, it is far touchy to small frequency offset among the transmitted and the obtained signal, which may also rise up because of Doppler Effect within side the channel or because of mismatch among transmitter and receiver nearby oscillator frequencies.

- ***Inter-service interference (ICI)*** is a main assignment inside the error-loose reception and detection of OFDM symbols.
- ***Increase within the spectral efficiency*** of wireless communication systems is one of the finest demanding situations confronted with the aid of using wireless communication engineers.
- ***Bandwidth efficiency***: The available bandwidth is scarce and costly, whereas there can be a massive call for data price created through developing the amount of subscribers and growth in multimedia applications which require big bandwidth.

3.2 PAPR Diminishment Techniques

Multicarrier modulation structures are affected by excessive PAPR. If the high-power digital equipment (HPA) is operated in this similar linear region, then the excessive PAPR does not influence the standard of the sign on the transmission. But, this example finally ends up in an excessive value in phrases of strength efficiency, normally for cellular applications and Ad hoc networks. To address the problem of high power amplifiers (HPA), this is operating in its saturation region; several strategies are familiar with cut back PAPR in OFDM structures [1, 2]. Various PAPR diminishment methods such as filtering and clipping were used initially. Furthermore, as per need of high BER achievements, selective mapping (SLM) and partial transmit sequence (PTS), tone reservation and hybrid methods are considered for PAPR diminishment. Similarly, in next generation wireless networks LTE, 5G the equipment of strategies of lowering PAPR were confined in filter bank multicarrier techniques [13].

PAPR diminishment strategies are labeled into the various approaches: clipping approach, coding approach, probabilistic (scrambling) approach, adaptive predistortion approach and DFT-spreading approach proven in Fig. 2

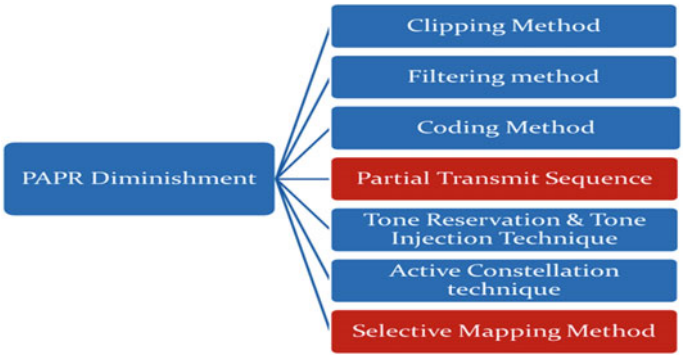

Fig. 2 PAPR diminishment methods

- *Clipping Method*: The clipping approach of PAPR diminishment is made possible within the nonlinear saturation region of a high-power amplifier across the peak envelope of the signal. The implementation of PAPR diminishment method in LTE and MIMO OFDM framework found easy, but it has in band and out of band signaling. This in-band signaling distortion results in lower BER. In the clipping method, out band distortion is reduced by using filtering techniques on another side Aliasing effect will occur in the sampling process. In the current scenario repeated, reconstructed and interactive clipping with filtering approaches are used [12].
- *Coding Method*: In this method, it employs selection of different code words that will reduce PAPR in the MIMO OFDM network. Due to use of code words reduction in in-band and out band distortion is made possible. The complexity of this method is responsible due to large loops and program size for the encoding and decoding purpose [13].
- *The Active Cancellation Technique*: In proposed method we are using clippling methods whereas high amplitude peaks are going to removed. The limitations of this method such as high conversion time and mean square error (MSE). This limitations are overcome by using proper broadcasting method and with the aid of designing suitable schooling signals [3].
- *Selective Mapping Method (SLM)*: In selective mapping method of PAPR diminishment, generation of number of OFDM symbols with lowest PAPR is achieved by representing each data blocks and transmits over a time [9]. Higher complexity and data rates in this method are increased due to use of number of IFFT blocks. Errors are increased due to loss of data blocks of data blocks in SLM method. The phase constant and input data blocks are multiplied so that alternate input symbols are generated [13].
- *Companding Technique (CT)*: A satisfactory achievement in diminishment of PAPR is possible due to companding method. This method compresses the signal at the input so it expands at the receiver so as to maintain the amplitude beneath

level as low as to achieve the maximum amplitude throughout communication [13].

- *Partial Transmit Sequence (PTS)*: This method gives advantage of achievement of PAPR diminishment of PAPR by dividing sub-block into data blocks. Rotation in phase factors achieved by rotational factor and sub-blocks. The sub-block consists of multiples of non-overlapping blocks of information. A rotation mechanism is employed in such a way that all the rotational phase factors become statistically independent of each other. A major limitation of these methods is poor spectral efficiency due to higher order complexity and filters. Similarly to the reality that it impacts the spectral performance of the system [3, 4].
- *Tone reservation method (TR)*: It is also known as peak tone reduction method. The word "Tone" refers to a set of information. In TR method, isolation of energy made for cancellation of higher peaks with a predefined set of reserved tones. The TR method gives advantage of less complexity, simple receiver design and absence of side information due to this higher spectral performance obtained [4, 9].

3.3 MIMO-OFDM System

In rapid-velocity next generation wireless communication, OFDM may be implemented to convert frequency-selective MIMO channels into parallel flat MIMO channels in multipath fading surroundings; additionally, excessive statistics price sturdy transmission may be achieved via way of means of lowering the hassle of the receiver [2]. A maximum transmitting antenna such as (1×1, 2×2, 4×4) antenna systems is used [5, 10]. An enter facts bit circulate is provided into space-time coding, then modulated via way of means of OFDM and eventually fed to antennas for transmission of information signal. At receiver side, early detection of information signal is made by using detectors blocks so that exact signal is recovered. Time space encoding and pace time decoding used at transmitter and receiver side, respectively [3]. Figure 3 shows the basic configuration of a MIMO-OFDM system.

PAPR is the most immediate power normalized via means of the average power among all possible signal patterns. Hence, we define $\text{PAPR}_{\text{MIMO}}$ is the maximum of all PAPER related to N_t MIMO path; hence, we have

$$\text{PAPR}_{\text{MIMO}} = \text{PAPR}_i \tag{3}$$

An excessive dynamic variety HPA has low energy efficiency. The energy may want to store with the aid of using lowering PAPR as shown in Eq. (3). This energy saving is carried out in the sort of manner to offer an instantaneous correlation with the favored common output energy.

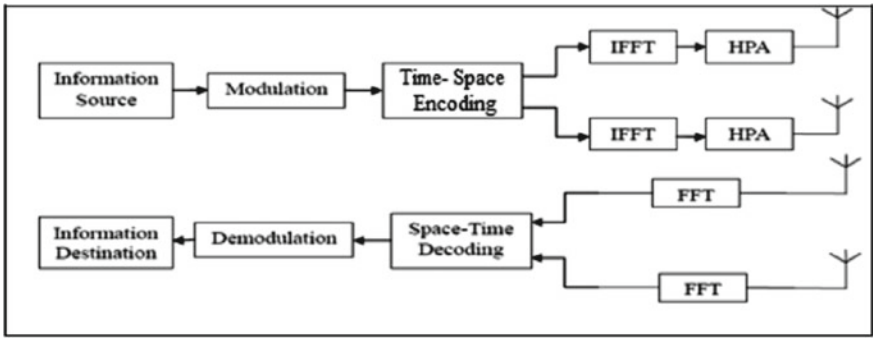

Fig. 3 Configuration of MIMO OFDM system

4 Comparative Analysis and Simulation Results of PAPR Diminishment in MIMO OFDM

In proposed method of research we are considering following parameters of OFDM such as shown in Table 1.

The said system uses Rayleigh selective fading channel with the parameters shown in Table 1. In this work, spatial multiplexing with N_t independent streams of data symbol on each antenna is considered; hence, the waveforms on different antennas are not couples in any way to avoid ISI.

The PAPR is calculated by using Eq. 1 and complimentary cumulative distribution function CCDF. The BER performance of MIMO OFDM for different transmitted symbols such as 64,128 7 1024 over QPSK, 16QAM, BPSK modulation techniques [represented in Figs. 4, 5 and 6]. The detection performance of all PAPR diminishment techniques, i.e., effects on BER is irrelevant as the various PAPR diminishment methods mentioned.

Hence, the waveform generated at the transmitter side is simulated to measure the PAPR. The comparative analysis is thoroughly done for single antenna SISO (single input single output) and MIMO antenna, including comparison with methods. BER performance of SISO OFDM for different transmitted symbols such as 64, 128 and 1024 over QPSK, 16QAM and BPSK modulation scheme is shown in Figs. 4, 5 and 6.

Table 1 LTE parameter

Frequency range	2.4–5 GHz
Bandwidth	1.25 MHz
FFT size	128,256
Number of transmit symbol	64,128,1024
Modulation type	QPSK
Spacing frequency	30 MHz

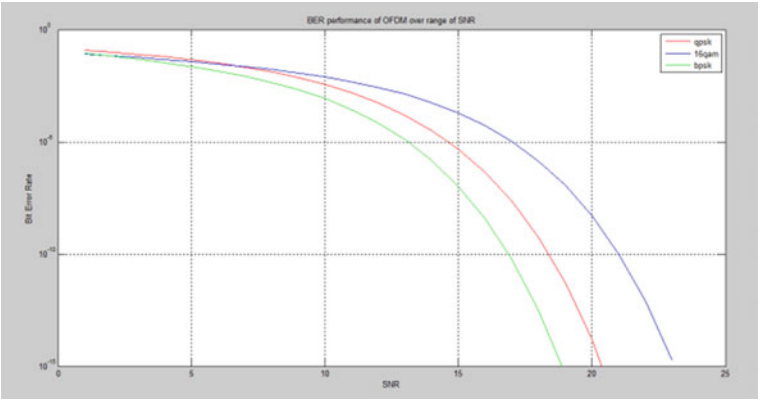

Fig. 4 BER performance for transmitted symbols = 64

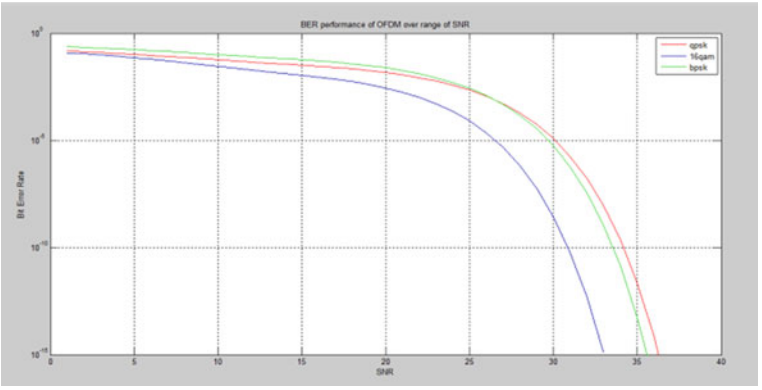

Fig. 5 BER performance for transmitted symbols = 128

Figure 4 shows BER performance of MIMO OFDM over 64 symbols with QPSK modulation techniques. The SNR at BER 10^{-15} is equal to 23.25 dB with QPSK modulation.

Figure 5 gives SNR at BER 10^{-15} is equal to 36 dB with QPSK modulation and highest SNR is achieved by using proposed system across all existing methods.

Figure 6 shows BER performance of MIMO OFDM over 64 symbols with QPSK modulation techniques. The SNR at BER 10^{-15} is equal to 70 dB with QPSK modulation.

After constructing the MATLAB-simulated version for above-mentioned PAPR diminishment methods, overall performance of the system is evaluated with distinctive strategies motioned in this work. The MATLAB simulation performed with modified PTS with respect to original OFDM and old PTS method.

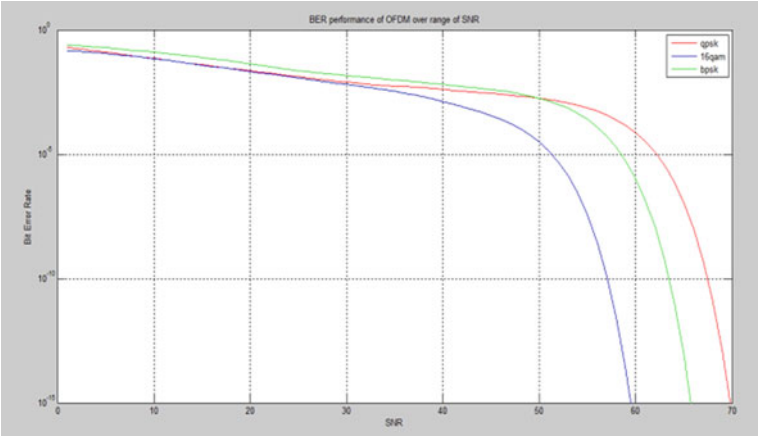

Fig. 6 BER performance for Transmitted symbols = 1024

The CCDF curve for the case of single antenna OFDM with $N = 64$, QPSK and 16QAM modulation orders are shown in Fig. 7. The CCDF of modified PTS here is improved and PAPR of 5.1, whereas normal OFDM has high PAPR 10.8 as shown in Fig. 7. Since it is approximated that with modified PTS 50%, reduction in PAPR is possible.

As mentioned, in proposed work, OFDM symbol generation for LTE network with frequency range 2.4–5 GHz is shown in Fig. 8.

Figure 9 shows band-limited spectrum with frequency spacing 30 MHz for MIMO

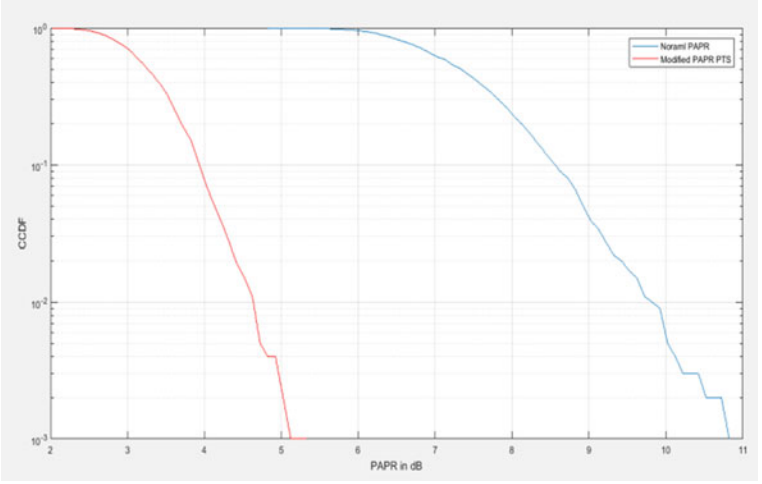

Fig. 7 CCDF functions of modified PTS scheme

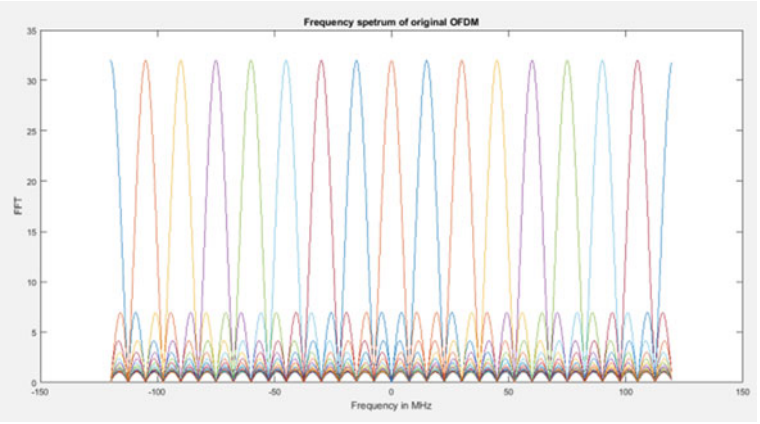

Fig. 8 OFDM frequency spectrum

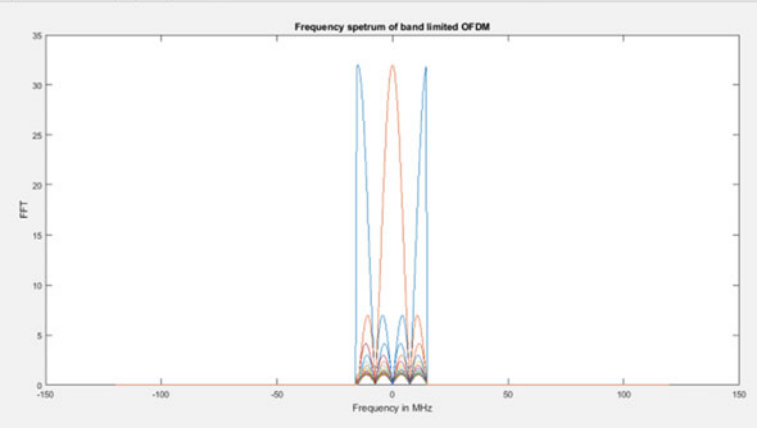

Fig. 9 OFDM band-limited spectrum at 30 MHz

OFDM. This means that each subcarriers are spaced with 30 MHz; due to this, inter symbol interference is reduced.

The sub-carriers are together orthogonal within the frequency domain which alleviates the results of ISI. Table 2 shows results and comparison of PAPR diminishment methods. As shown in Table 2, oversampling factor $L = 1$ is considered due to fast-fading channels in MIMO OFDM.

It is clear that with modified PTS technique, PAPR diminishment is achieved over normal OFDM for different alphabet sizes. The constellation order size of the alphabet considered is 4, 16 and 32. Simulation were performed on MATLAB with an LTE toolbox over 1000 OFDM symbols.

Figure 10 shows graphical analysis of PAPR techniques over normal OFDM

Table 2 Results and comparison with PAPR diminishment methods

Parameters	Input to MATLAB simulation model					
L factor (1–1.5)	1	1	1	1	1	1
Transmitted symbol (Power of 2)	16	32	64	32	64	128
Size of alphabet	4	4	4	16	16	32
PAPR with normal OFDM—dB	18.32	16.04	18.77	17.13	21.15	20.04
PAPR with SLM technique—dB	9.9	11.09	10.37	10.21	13.59	15.53
Efficiency of SLM	45%	30.85	32	40.34	35.73	22.49

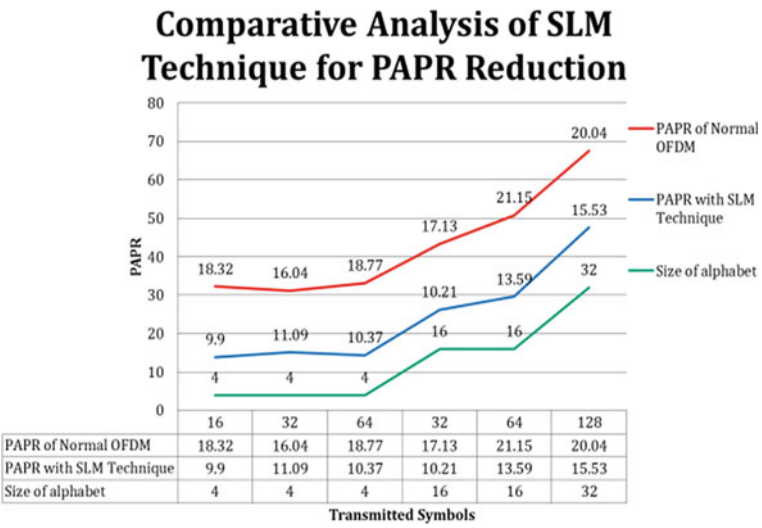

Fig. 10 Graphical analysis of SLM technique

symbolic methods and with SLM techniques. In this analysis, we used different alphabet symbols over which performance is measured. Using SLM method, PAPR of 15.53 is achieved, whereas normal OFDM methods gives high PAPR 20.04.

5 Results and Discussion

In above-presented literature survey and PAPR diminishment method, we examine numerous or many current studies in phrases of PAPR diminishment in OFDM. Using methods of Selective Mapping Method (SLM), Pratial Tranmit Sequence (PTS) and another different method used for PAPR reduction in MIMO OFDM network, this

offers regular verbal exchange and conscious from the error. In the PAPR surroundings, each method maximizes and reduces statistics associated with every alphabet symbol.

In this paper, we have analyzed different PAPR diminishment techniques, and additionally, in comparison, those are strategies for distinctive parameters in next generation wireless networks. We look at that SLM is the only approach to mitigate PAPR to a remarkable quantity and additionally enhance BER overall performance of the system. The factors influencing the PAPR were studied; this also helps to understand the LTE and 5G network. In LTE network new method incorporated to uplink multiple-access scheme of SC-FDMA has been used which is known as Single Carrier FDMA (SC-FDMA).

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