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LOW COMPLEXITY PARTIAL SLM TECHNIQUE FOR PAPR REDUCTION IN OFDM SYSTEMS

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ABSTRACT-Orthogonal frequency division multiplexing (OFDM) has a great demand in digital modulation technique which make use of multiple carriers that are mutually orthogonal to each other over a given time interval. OFDM can be used in many recent and emerging broadband wireless communication systems like Wi-MAX, digital audio and terrestrial TV broadcasting and future 4G/ LTE systems. The main loss of OFDM system is high peak- to-average power ratio (PAPR) of the transmitted signal, so system is susceptibility to nonlinear amplification.Active Constellation Extension, Tone Reservation, Companding, and Partial Transmit Sequence etc. are some of the PAPR reduction techniques with high computational complexity. In this paper, partial SLM with time domain and frequency domain approaches are used to reduce the computational complexity and produce a better PAPR perfomance in OFDM systems than the other techniques. Also, computer simulation results show that proposed Partial SLM with time domain have less complexity and high speed than the frequency domainmethod but the PAPR perfomance of both the methods have almost the same.

Keywords- [OFDM, Peak-to-average power ratio, Complementarycumulative distribution function, PTS, SLM.]

1. INTRODUCTION

By the increasing demand of this generation, longing for high speed communication has a greatest importance. Different multicarrier modulation techniques are possessed to meet these demands. One among them is OFDM, a better solution for obtaining high data rate transmission in frequency selective fading radio channels [1] [2]. The Fundamental rule of OFDM is, high data rate streams are divide into multiple low data rate streams which are transmitted concurrently over a number of subcarriers. OFDM has established a wide variety of applications in digital transmission involves digital audio and video broadcasting, digital subscriber line and wireless local area network, WiMAX etc. On account of its multicarrier nature, it has high PAPR that can cause undesirable saturation in the power amplifier leading to in-band distortion and out-of band radiation.

Various researchers have been recommended a number of PAPR reduction techniques which includes Tone reservation [3][4][5], Tone Injection [4][6], Companding [7], Active Constellation Extension [8][9], Bit or Symbol Interleaving [10][11], Partial Transmit Sequence [12][13], Selective Mapping [14][15]. Most commonly used technique is SLM due to its distortionless nature, but the computational complexity is high since it requires bank of inverse fast Fourier transform (IFFT) operations [16].

A low-complexity PAPR reduction scheme has been proposed in [16],where three frequency domain operations are used, namely, frequency domain cyclic shifting, frequency domain complex conjugate and frequency domain sub-carrier reversal operations are take up to shuffle the sub-carriers to increase the PAPR divergence of the candidate signals.Hence to circumvent the multiple IFFTs, these frequency domain operations are converted into time domain operations. Along with these frequency domain operations, sub-carrier partitioning and re-assembling processes are essential to achieving low complexity time domain equivalent operations.

This paper introduces a different architecture for reducing PAPR in OFDM system with a lower computational complexity than the SLM scheme at the same time maintains a better PAPR reduction perfomance. SLM scheme use only the frequency domain phase rotation operation but the proposed method use the Partial SLM scheme in which time domain operations, namely, time domain phase rotation, cyclic shifting, complex conjugate, subcarrier set Reassembling, time domain reversal operations and frequency domain operations, namely, frequency domain cyclic shifting, frequency domain phase rotation, frequency domain complex conjugate, frequency domain subcarrier reversal operations are performed. Hence produces a better PAPR reduction with low complexity.

The rest of this paper is organized as follows. Section II briefly describes the PAPR problem in OFDM. Section III and IV describes the proposed PAPR reduction method in frequency domain and time domain operations. Simulations are performed in section V. Lastly conclusions and overall comparisons of the other techniques are drawn in section VI.

2. PAPR PROBLEM IN OFDM

PAPR is defined as the ratio of the maximum power of a sample in a given OFDM transmit symbol to the average power of that OFDM symbol. In a multicarrier system PAPR occurs, when the different sub-carriers are out of phase with each other. At any instant they have different phase values with reference to each other. At the same time when these points attain the maximum value, unexpectedly the output envelope raises that cause a spike in the output envelope. Hence the peak value of the system is very large as compared with the average of the system. This ratio of peak to average value is referred to as peak-to-average power ratio. Hence the high power amplifier in the transmitter is sensitive to operate in non-linear region which causes nonlinear distortions and spectral spreading.

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]} \quad (1)$$

Where E [.] denotes expectation operator and x(t) is the continuous-time signal.

In OFDM complementary cumulative distribution function is used instead of cumulative distribution function to evaluate the performance of PAPR reduction, which helps to measure the probability that the PAPR of a certain data block exceeds the given threshold level.A CCDF curve displays how muchtime the signal devotes at or above a given power level. The power level is articulated in dB relative to the average power.

$$CCDF_{PAPR(X)} = Pr\,(PAPR(x) > \gamma) \quad (2)$$

Where γ is the threshold level.

3. PROPOSED PARTIAL SLM SCHEME IN FREQUENCY DOMAIN

In this proposal,an informalsystem has been considered based on the SLM technique called Partial SLM. In Partial SLM technique, computational complexity of partial SLM can further reduced by using time domain and frequency domain approaches. The proposed partial SLM scheme is shown in figure 3. And works as follows: the arriving OFDM sequence is distributed into number of subsequences each of length$\hat{N}$. Mapper is known after the serial to parallel converter, mapper is scattering the contents of each of the M sets out through the entire transmit frequency band so the continual symbols are not focused in any one region. This way if there is any a null in any specificarea of the band only a few of the repeated symbols would be affected. This would contribute the frequency diversity.

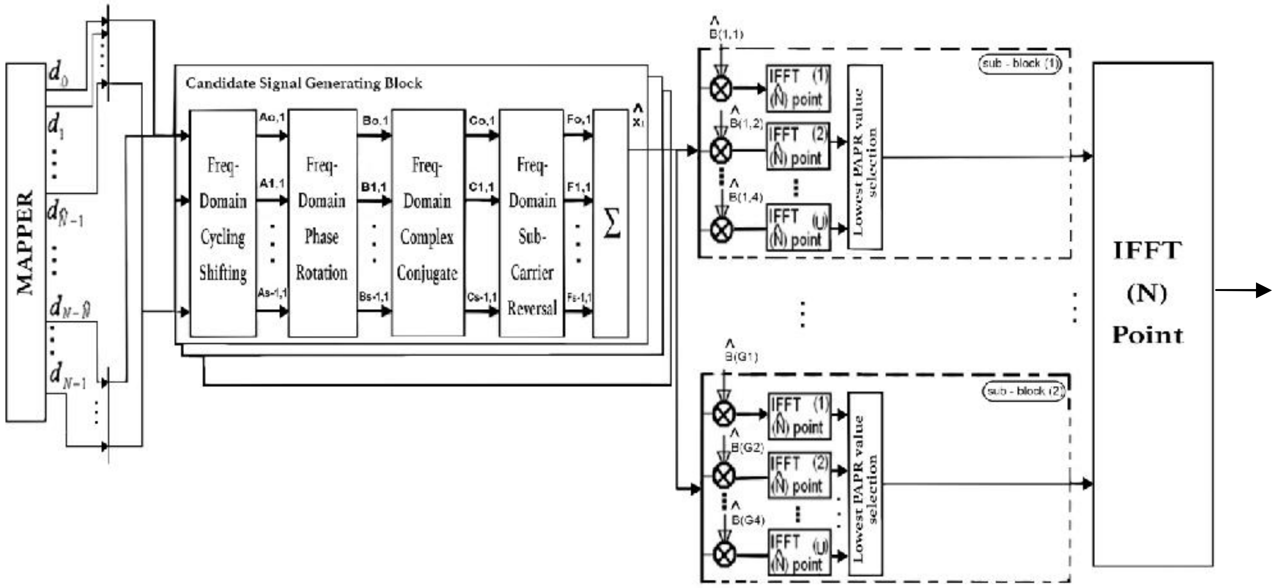

Figure 1- Partial SLM with frequency domain approaches

After thatapplying frequency domain approaches, cyclic shifting, phase rotation, complex conjugate, subcarrier reversal operations. That is the signal from the mapper goes to Candidate signal generating block. First block in the CSGB does cyclic shifting operations. Assuming that $l_{s,m}$cyclic shifts are done on X_s, the output signal is designated as $A_{s,m}s=0, 1, . . . , S - 1, m = 1, 2, . . . ,M$. Therefore, the kth element of $A_{s,m}$ is given by

$$A_{s,m}[k] = X_s[(k - l_{s,m})N],\ k = 0, 1, . . . ,N - 1 \qquad (1)$$

The second block of the CSGB implements frequency-domainphase rotation. The output of the sth sub-carrier set for the mth CSGB is denoted as $B_{s,m}$, with the kth element being given by,

$$B_{s,m}[k] = \theta_{s,m}[k] \cdot A_{s,m}[k],\ k = 0, 1, . . . ,N - 1 \qquad (2)$$

Where $\theta_{s,m}[k]$ is a complex number with a unit magnitude.

The third block of the CSGB implements a frequency-domainconjugate operation and produces an output signal $C_{s,m}$. $C_{s,m}[k] = B^*_{s,m}[k]$, $\forall k \in \Gamma_s$, where ∗symbolizes the complex conjugate operation. The fourth block performs a frequency-domainsub-carrier reversal operation on the sub-carrier sets, i.e., $F_{s,m}[k] = C_{s,m}[(-k)N]$, $\forall k \in \Gamma_s$. Finally, the *m*th candidate signal in the frequency domainis obtained by summing up the various sub-carrier sets of the corresponding CSGB, i.e.,

$\widehat{X_m} = \sum_{s=0}^{S-1} F_{s,m}$ (3)

Candidate signals are then fed into IFFT block of length $\hat{N}$ and for each sub-block conventional SLM is applied. Hence partial SLM is equivalent to the conventional SLM, the only difference is SLMapplied in individual sub-block. Without a doubt, the SLM will beapplied Gtimes and for each sub-block, there generates a Unumber of sequences from a single sub-sequence and then the signal with the lowest PAPR (partially) is nominated and stored. Theprocedure repeats until all sub-blocks are covered. Lastly, the new sequence of length N to be transmitted by concatenating all partially selected sequences. Hereafter instead of using individual IFFT blocks of length Neach, *G* number of partial SLM blocks is generated each of length$\hat{N}$. In this waythe complexity is reduced as now we have smaller IFFT sequences. Moreover, the selection of G is done under restraint,

$N = 2^r$, $G=2^p$ and $\hat{N} = \frac{N}{G}$(4)

Such that r, p are integers and r > p with p ≠ 0.

The multiplication factors are phase rotations nominatedproperly such that multiplying a complex number with these factors proceeds in rotation of that complex number to another complex number characterizing a different point in the constellation. So,

$b_n^i = e^{-j\theta_n^i}$ Where $\theta_n^{(i)} \epsilon\ [0, 2\pi)$(5)

Where θ is the angle of rotation. For signal recovery, rotation vectors are transmitted as side information.

The new length of phase rotation factors in each sub-block are given as,

$$\hat{B}^{(v,a)} = \left[b_0^{(v,a)}, b_1^{(v,a)}, b_2^{(v,a)}, \dots\dots, b_{\hat{N}-1}^{(v.a)}\right]$$

(6)

Where ‘a’ justdesignates the index of the individual rotation factors which ranges from 1 toU. It is noticed that the number of rotation factors used in each sub-block in the PartialSLM method relics the same (i.e. U) but the length of individual rotation factor is$\hat{N}$.

4. PROPOSED PARTIAL SLM SCHEME IN TIME DOMAIN

In case of partial SLM with time domain approaches, time domain equivalent operations are performed after doing the IFFT operations. The proposed partial SLM with time domain approaches is shown in figure 2 and explains as follows: the incoming OFDM sequence is divided into number of subsequences each of length $\hat{N}$. Each subsequence is delivering into an IFFT block of length$\hat{N}$ and conventional SLM is adapted in each sub block. Then time domain equivalent operations were performed. The first block in the CSGB performs time domain phase rotation which is same as the frequency domain cyclic shifting operation.The second block of the CSGB performs a time-domaincyclic shifting operation, i.e., the time-domain equivalent ofthe frequency-domain phase rotation operation. Therefore, thenth element of the output signal $b_{s,m}$ has the form

$b_{s,m}[n] = as[(n - w_{s,m})N]$, $n = 0, 1, . . . ,N - 1$(7)

Where $w_{s,m}$ denotes the number of cyclic shifts of the *s*thsub-carrier set for the *m*th CSGB.

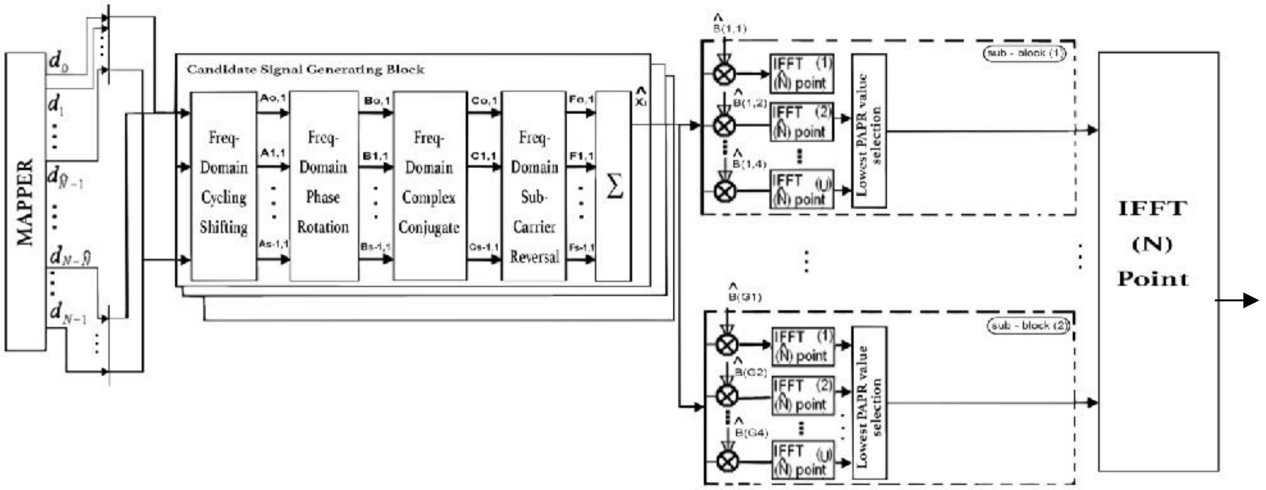

Figure 2- Partial SLM with time domain approaches

The third block in figure 2 performs the time-domain complexconjugate action, same as the operation ofthe frequency-domain complex conjugate process, then the n^{th} element of the output signal $C_{s,m}$ has the form

$C_{s,m}[n] = b_{s,m}[n]$ or $b^{*}_{s,m}$ $[(-n)N]$ (8)

Before performing the time domain reversal operation, subcarrier sets endures the re-assembling operations. Hence,the fourth block of the time-domain CSGB implements a sub-carrierset re-assembling functionconsists of twosteps. Firstly, the S HPM sub-carriersets $\Gamma_{s,}$ $s = 0, 1, . . . , S - 1$ $(S = U \cdot V)$, are united to obtain V DPM sub-carrier sets $\bar{\Gamma}_{\bar{s},}$ $\bar{s} = 0, 1, . . . , V - 1$.

The $\bar{s}^{th}$ DPM sub-carrier set is gainedby joining the outputs of time-domain complex conjugateoperations. Secondly, sub-carrier sets are combined to form a single sub-carrier set while leaving $\bar{\Gamma}_{s=0}$ and $\bar{\Gamma}_{s=v/2}$ unaffected. The sub-carrier set re-assembling block ofthe suggested time-domain architecture uses the time-domainrepetition property in order to diminish thecomputational complexity.

After the sub-carrier set re-assembling process, time-domain signal reversal process is implemented. On the basis of the complex conjugate operation, the system aimlesslyselects whether or not to achieve the reversal operation. Lastly, the m^{th} candidate signal is attained by adding overall signals of the m^{th}CSGB. By generating the M candidate signals, the signal with thelowest PAPR is nominated for transmission.

5. SIMULATION AND RESULTS

Simulation of BER with SNR of PAPR reduction techniques and OFDM The simulation of BER of the proposed techniques and other PAPR reduction technique were plotted. Figure 3 shows the BER perfomance of various PAPR reduction techniques including the proposed technique. SNR versus BER graph has been determined using MATLAB. It is clear from the graph that PAPR reduction techniques companding and clipping have high BER when comparing with the other techniques. PAPR reduction techniques SLM with frequency domain and time domain have SNR of 16dB and 17dB to maintain a BER of 10^{-4} respectively. But the proposed technique partial SLM with time domain have SNR around 13dB to maintain a BER of 10^{-3} and partial SLM with frequency domain have SNR around 11dB to maintain a BER of 10^{-2}. Hence BER of partial SLM with frequency domain have low BER comparing with the other techniques.

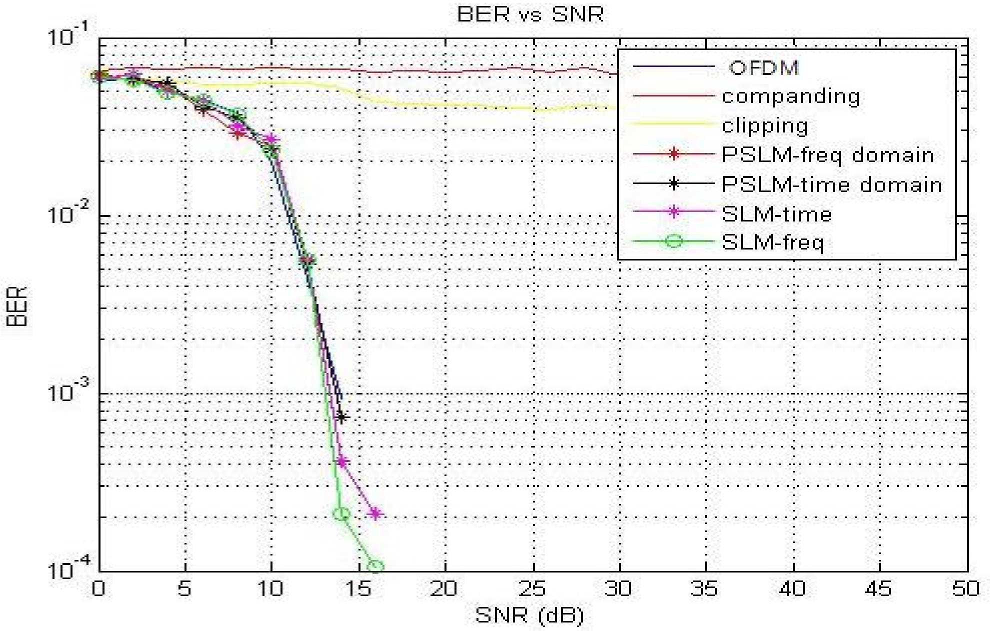

Figure 3- Comparison of BER of various PAPR reduction techniques

Simulation of PAPR of various techniques CCDF (Complimentary Cumulative Distribution Function) curves for various PAPR reduction techniques such as companding, clipping, SLM with time domain and frequency domain, partial SLM with frequency domain and time domain were plotted. Compare these results with the normal OFDM. The PAPR reduction technique clipping have highest PAPR of 9.4dB is obtained at CCDF equal to 10^{-2} which is slightly equal to the normal OFDM.

For companding technique PAPR is reduced than the clipping to a value equal to 7dB at CCDF of 10^{-2}. There is a small variation in PAPR of the SLM and partial SLM, SLM time domain and frequency domain have a PAPR of 4.4dB and 4.3dB at CCDF of 10^{-2}. But the partial SLM with time domain and frequency domain have a PAPR of 4.1 dB and 3.9 dB respectively at a CCDF of 10^{-2}. Hence, partial SLM with frequency domain has a better PAPR perfomance.

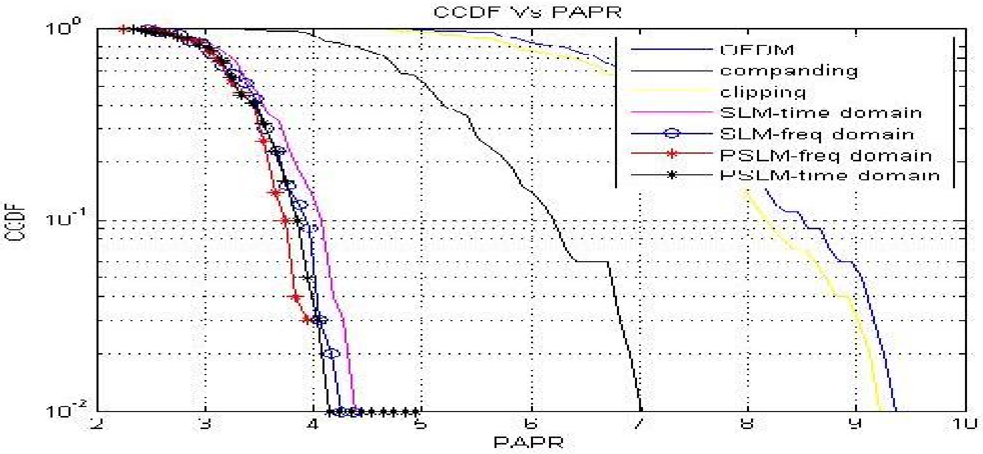

Figure 4- Comparison of CCDF perfomance for clipping, companding, SLM-time domain and frequency domain, partial SLM with frequency domain and time domain.

Simulation of the speed curves

Figure 5shows the speed curve of SLM time domain and frequency domain, partial SLM time domain and frequency domain. It is clear that time domain has higher speed than the frequency domain for both SLM and partial SLM.

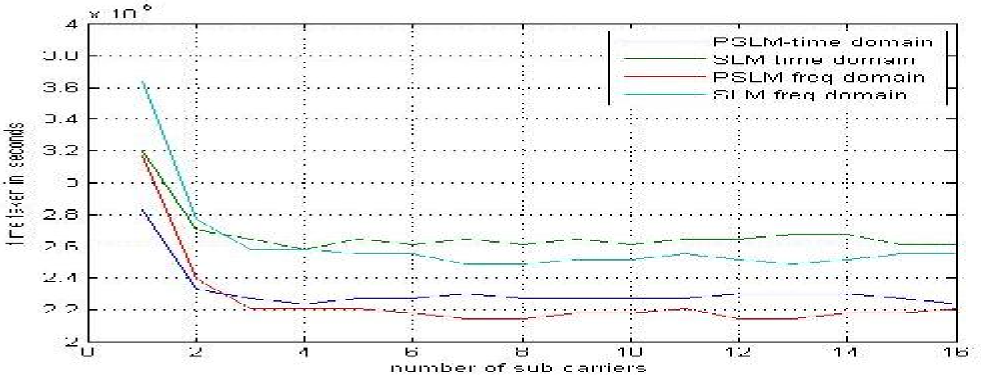

Figure 5- Speed curve of various PAPR reduction techniques

Number of Subcarriers	PAPR Reduction Techniques	PAPR (in dB)
N=16	Companding	9.4
	Clipping	7
	SLM-Time Domain	4.4
	SLM-Frequency Domain	4.3
	Partial SLM-Time Domain	4.1
	Partial SLM-Frequency Domain	3.9

Table 1- Comparison of PAPR with different PAPR reduction techniques

Technique	Complexity	Distortion	Data Loss	Power Increase
Tone Reservation[3]	Yes	No	No	Yes
Tone Injection[6]	Yes	No	No	Yes
Companding[7]	No	No	Yes	Yes
Active Constellation Extension[8]	Yes	No	No	Yes
Interleaving[10]	Yes	No	Yes	No
Partial Transmit Sequence[12]	Yes	No	Yes	Yes
Selective Mapping-Time Domain	No	Yes	Yes	No
Selective Mapping-Frequency Domain	Yes	No	Yes	No
Partial SLM-Time Domain	No	Yes	Yes	No
Partial SLM-Frequency Domain	Yes	No	Yes	No

Table 2- Overall Analysis of Different PAPR reduction Techniques

CONCLUSION

OFDM is a very prominent technique for multicarrier transmission and has developed one of the typical choices for fast data transmission over a communication channel. OFDM has several advantages; moreover it has one major drawback: that is very high PAPR. In this paper,a new technique is introduced for obtaining a better PAPR reduction perfomance.

The proposed method partial SLM with time domain and frequency domain gives a better PAPR perfomance. But the frequency domain PAPR reduction technique have high complexity produces a better PAPR reduction whereas time domain has high speed and less complexity but the PAPR reduction perfomance is almost equal to the frequency domain technique. The bit-error-rate is also plotted against the signal-to-noise ratio to understand the perfomance of the PAPR reduction techniques, the proposed technique has low bit-error rate. Hence the proposed technique gives us a better PAPR reduction perfomance with less bit-error rate and complexity than the other techniques.

However, no exact PAPR reduction technique is the finestresult for the OFDM system. Numerousfactors like loss in data rate, transmit signal power increase, BER increase, computational complexity increase should be taken into concern before selecting the proper PAPR technique.

Future scope to promote the reduction of computational complexity for the proposed techniquecan is predicted. More advanced technique can be used for avoiding the transmission of side information in the proposed technique.

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