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PAPR reduction using combined SLM & Clipping technique in OFDM system

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Abstract: Communication is one of the important aspects of life. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. Signals, which were initially sent in the analog domain, are being sent more and more in the digital domain these days. For better transmission, even single carrier waves are being replaced by multi carriers. Multi carrier systems like CDMA and OFDM are now adays being implemented commonly. In the OFDM system, orthogonally placed sub carriers are used to carry the data from the transmitter end to the receiver end. Presence of guard band in this system deals with the problem of ISI and noise is minimized by larger number of sub carriers. But the large Peak to Average Power Ratio of these signal have some undesirable effects on the system. In this paper we have focused on learning the basics of an OFDM System and have undertaken a hybrid scheme to reduce the PAPR in the system so that this system can be used more commonly and effectively.

Keywords: Orthogonal Frequency-division multiplexing (OFDM), Peak-to-average-power ratio (PAPR), Selective Mapping (SLM), Inverse Fast Fourier Transform (IFFT), Complementary Cumulative Distribution Function (CCDF), Clipping.

I. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a very popular and widely used concept in wireless communications, but it is well known to suffer from high peak to average power ratio (PAPR). There is a long list of methods that try to circumvent this effect, including selected mapping (SLM) and Clipping. The SLM is signal scrambling technique & Clipping is signal distortion technique, these are two different techniques. In this paper we present a new approach to combine SLM with clipping in order to achieve a desired PAPR while limiting the signal distortion. Here we combine both schemes in a serial manner. Theoretical analysis and simulation results show that this combination gives significant PAPR reduction.

II. OFDM SYSTEM MODEL

A. OFDM Symbol

In OFDM system, the information data symbol are passed through serial to parallel convertor and modulated using different modulation scheme like quadrature amplitude modulation (QAM), binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK) to form a complex vector of size N. For OFDM system implementation, Inverse Fast Fourier Transform (IFFT) is usually being utilized to modulate multiple sub-band signals. Here symbols are divided into N different parallel routes. The symbols in complex vector is written as:

$$X= [X0, X1, X2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. XN-1] \qquad (1)$$

After taking IFFT the OFDM symbol is represented by,

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi k \frac{n}{N}} \,; 0 \le n \le N-1$$

B. Orthogonality in OFDM

It is one of the important property of the OFDM, which efficiently uses frequency band as the subcarriers are allowed to overlap each other in the frequency domain. The orthogonality principle is used to represent the subcarriers. The N equally spaced subcarriers will be orthogonal if the frequency separation between subcarriers is Δf = 1/NTs =1/T where N.Ts is symbol duration, and rectangular windowing of the IFFT is performed. Under these conditions the subcarriers will have a sinc waveform frequency response. In the figure1 it is seen that because of the orthogonal relationship the maximum of a particular sample corresponds to a null in all other carriers, therefore eliminating the effects of interference. Mathematically orthogonality can be expressed as,

$$\int_0^{NT_s} \psi_k(t)\,\psi_l^*(t)\,dt = \begin{cases} 0, k \neq l \\ C, k = l \end{cases}$$

Where $\square_k$ (t) and $\square_l$ (t) are signals, they are orthogonal only when the above product is zero and C is constant.

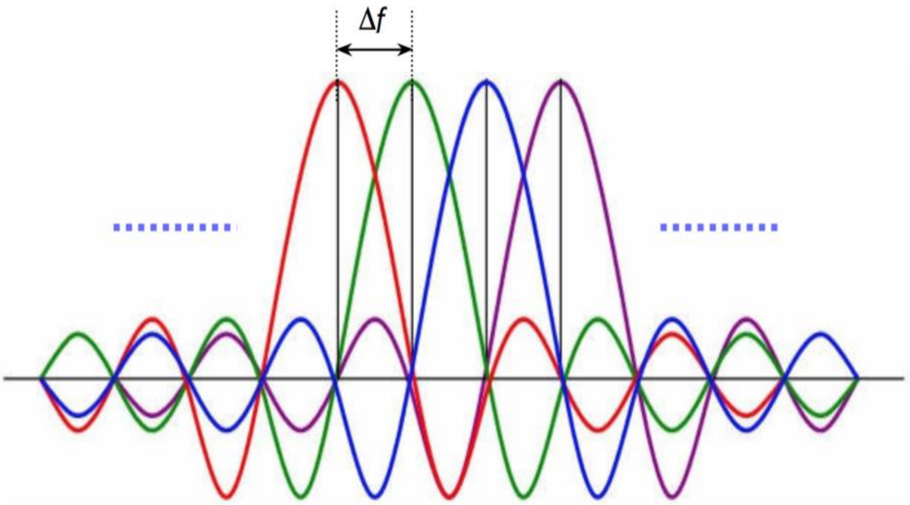

Fig. 1 Orthogonality in 4 subcarriers of an OFDM system

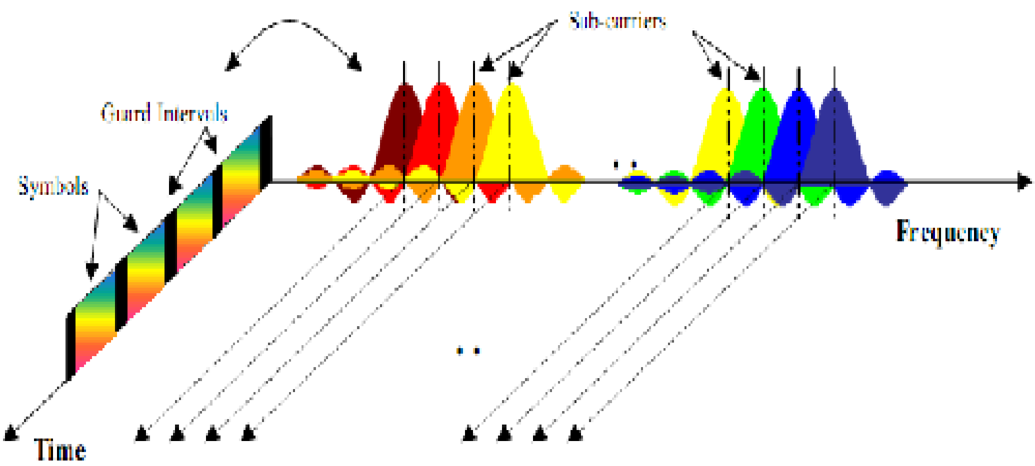

Fig. 2 Frequency & Time domain representation of OFDM signal

C. Block diagram of OFDM system

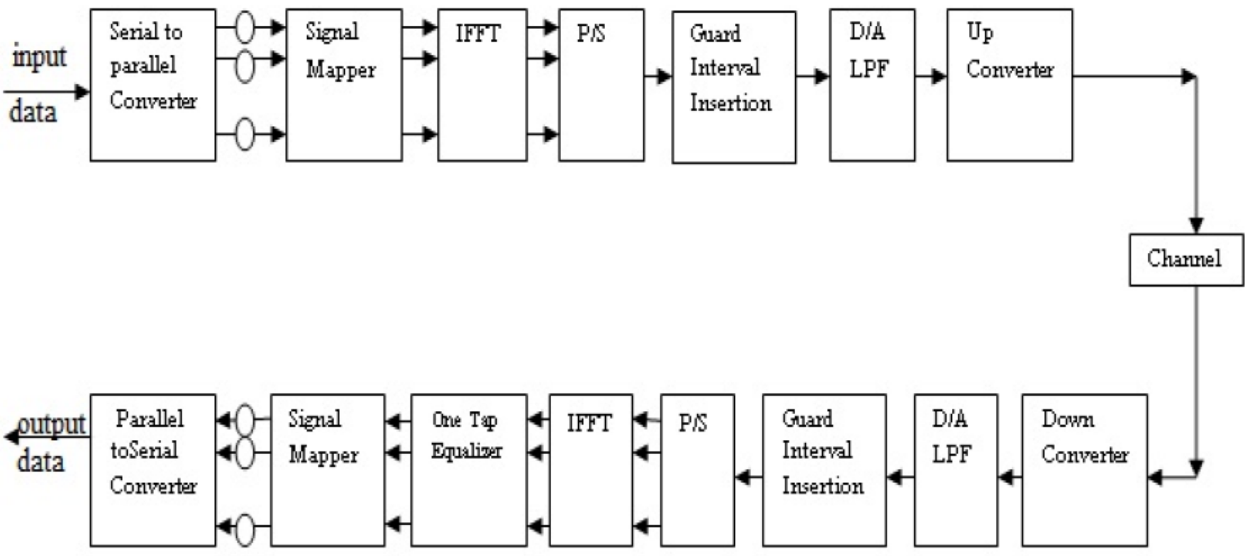

Fig. 3 General Architecture of an OFDM Transceiver system

Figure 3 shows a typical system block diagram for an OFDM system. The serial input data stream are converged to N parallel sub channels and mapped with a selected modulation scheme (signal mapped), which will result in N sub channels contain an information in complex number form. These complex values are sent to the N channel IFFT. Then signal is converted back to a serial sequence again by using a P/S device. The function of the guard interval is to reduce the effect of ISI caused by multipath propagation. Finally, the signal is converted to an analog signal and up converted to suite for the transmission. At the receiver, a reverse procedure is used to demodulate the OFDM signal with the FFT block. In the OFDM system, only a simple equalizer, a single tap equalizer, is needed at the receiver to take out the ISI.

D. PAPR Definition

In the discrete time domain, an OFDM x_n signal of N subcarriers can be expressed as,

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi k \frac{n}{N}} ; 0 \ \leq n \leq N-1$$

Where X_k ; k = 1, 2,…….,N -1, input symbols are modulated by BPSK, QPSK or QAM and n is the discrete time index. The PAPR of an OFDM signal is defined as the ratio of the maximum to the average power of the signal, as follows,

$$PAPR(x) = 10 log_{10} \frac{max|x_n|^2}{E|x_n|^2}$$

Where E {.} denotes expected value operation and $x = [x_1, \ x_2, x_3 \ldots\ldots\ldots\ldots, x_{N-1}]^T$

III. REDUCTION TECHNIQUE

There are numbers of techniques are available to reduce the PAPR, in this paper we focus combination of two techniques namely SLM & Clipping. But we also study these techniques individually.

A. Clipping

It is signal distortion technique is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed.

$$R(n) = \begin{cases} R(n), & for R(n) \leq \gamma \\ \gamma \;, & for\ R(n) > \gamma \end{cases}$$

The algorithm is based on clipping the amplitude of OFDM signal that exceeds threshold value say (γ). The amplitude of signals exceeding clipping threshold value (say γ) is clipped and the signals having amplitudes less than amplification threshold value is kept as it is. The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise. This distortion falls in both in band and out of band. On the other hand spectral efficiency is hampered by out of band radiation. Out of band radiation can be reduced by filtering after clipping but this may result in some peak re growth. A repeated clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several iteration of this process.

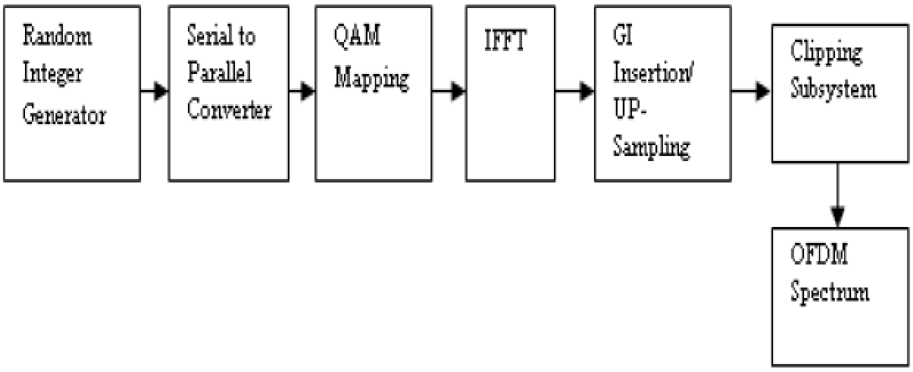

Fig. 4 General Architecture of Clipping

In the figure 4 we can get the OFDM spectrum by taking different values of threshold.

B. Selective Mapping

It is signal scrambling technique. SLM scheme is one of the initial probabilistic approaches for reducing the PAPR problem, with a goal of making occurrence of the peaks less frequent, not to eliminate the peaks. In selected mapping (SLM) method a whole set of candidate signals is generated representing the same information, and then the most favourable signal as regards to PAPR is chosen and transmitted. This method is distortion less method as it does not clip original signal. The side information about this choice needs to be explicitly transmitted along with the chosen candidate signal. The block diagram of SLM is shown in figure 5.

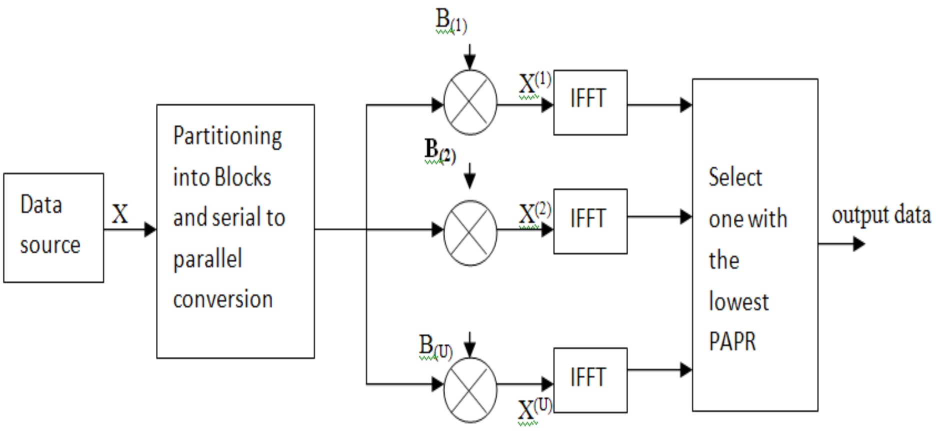

Fig. 5 Block Diagram of SLM technique

The OFDM data block represent in equation 1 is multiplied by element with phase sequences present in equation 2.

$B_U(t) = [b_u,0, bu,1, b_u,2, \ldots\ldots\ldots\ldots\ldots\ldots\ b_u,N\text{-}1,]^T$ Where u = 1, 2, 3, ……….,U. ……………..(2)

To make the U phase rotated OFDM data blocks.

$Xu (t) = [Xu,0, Xu,1, Xu,2,\ldots\ldots\ldots\ldots\ Xu,_{N-1},]$ Where $X_{u,m} = X_m.b_{u,m}$, $m = 0, 1, 2, \ldots\ldots\ldots.N-1.$

All U phase rotated OFDM data blocks represent the same information as the unmodified OFDM data block provided that the phase sequence is known. After applying the SLM technique to X.

$$x_u(t) = \frac{1}{N}\sum_{m=0}^{N-1} X_m\, b_{u,m} e^{j2\pi f_m t}, \quad 0 \le t \le NT$$

The PAPR is calculated for U phase rotated OFDM data blocks by,

$$x_u(t) = \frac{\max\limits_{0\le t\le NT} |x_u(t)|^2}{\frac{1}{NT}\int_0^{NT} |x_u(t)|^2 dt}$$

Among the phase rotated OFDM data blocks, the one with the lowest PAPR is selected and transmitted.

IV. Proposed Methodology

A. Block Diagram of combine SLM & Clipping

We propose to combine the signal scrambling (SLM) & signal distortion techniques (Clipping) serially to get better PAPR reduction in comparison with individual methods.

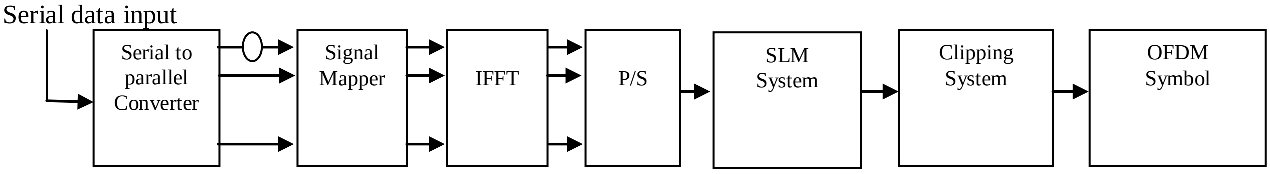

Fig. 6 Block Diagram of SLM-Clipping Hybrid method

In the figure 6, there is a serialization of SLM & Clipping system, the signal which is chosen from SLM system is clip to some threshold level so that PAPR in combine scheme is reduced as compared to individual technique. This can be shown by using CCDF function.

B. Complementary Cumulative Distribution Function

In the communication world, CCDF measurement proves as one of the important tool. This function provides comprehensive analysis of signal power peak. It is statistical technique that provides the amount of time, a signals spends above any given power level. However by using these plots a probability can be seen that a signal data blocks exceeds a given threshold. These CCDF plots can use to analyze the PAPR performance of the signals.

V. Results and Simulations

The results and simulation is done by using MATLAB software. Here we simulate the CCDF for original OFDM, clipping, SLM and SLM-Clipping hybrid model.

TABLE I Parameters used for simulation

Sr. No.	Simulation Parameters	Value
1	Number of Sub-carriers (N)	128
2	Modulation Type (M)	QAM-64
3	Number of Phase Sequence (U)	4
4	Clipping Threshold (th)	0.80

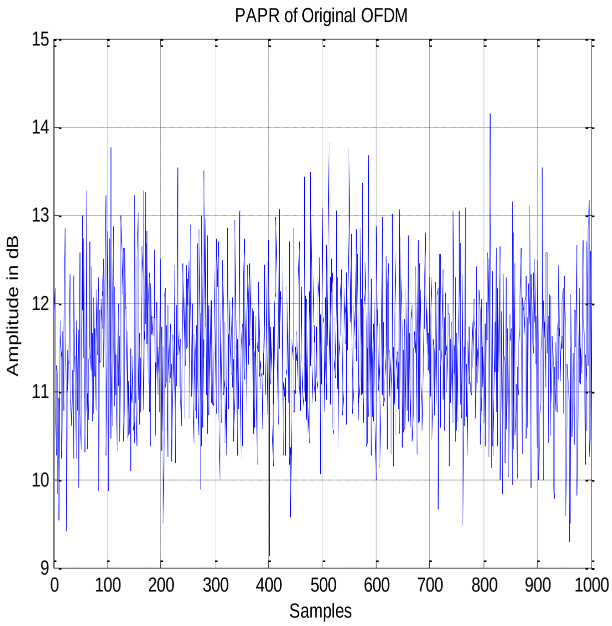

Fig. 7 PAPR of original OFDM signal

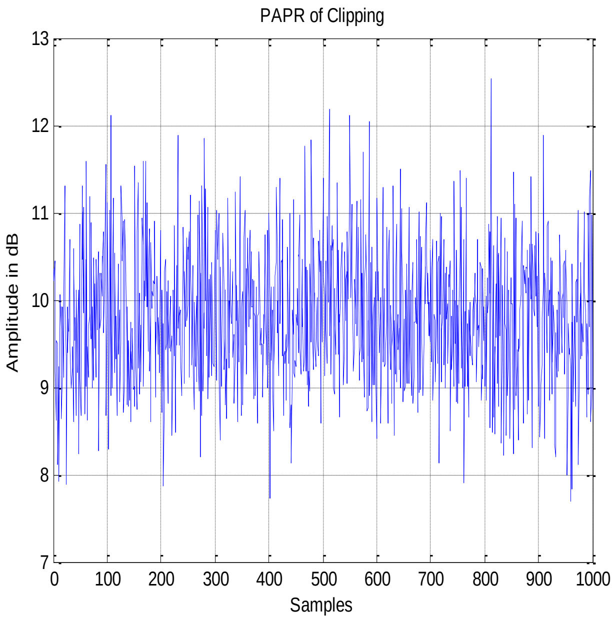

Fig. 8 PAPR of OFDM signal having clipping threshold th=0.80

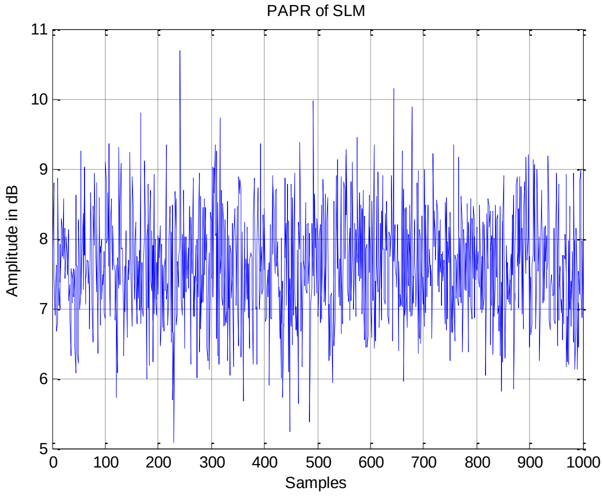

Fig. 9 PAPR of OFDM signal using SLM with U=4

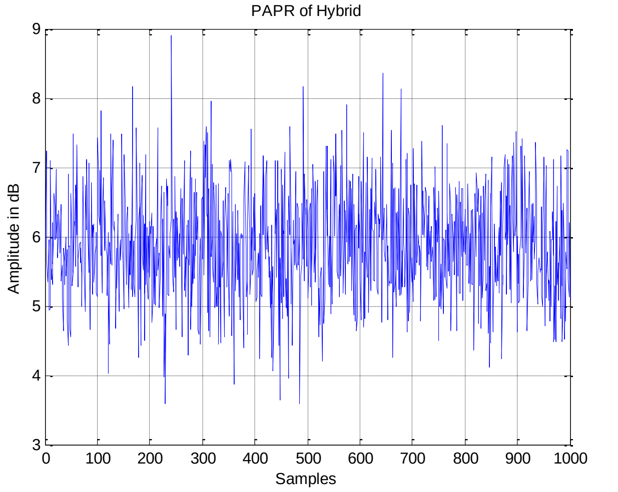

Fig. 10 PAPR of OFDM signal using hybrid method having U=4 & th=0.80

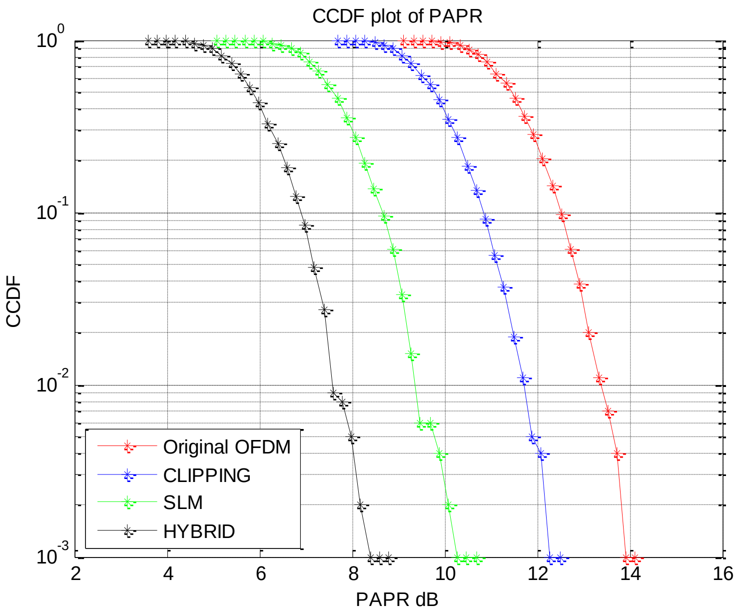

Fig. 11 CCDF Vs PAPR of OFDM signal for N=128

TABLE II Results of simulation

PAPR in dB			
Original OFDM (Without applying any technique)	Clipping with threshold th=0.80	Selective Mapping with U=4	Hybrid Method
13.9	12.3	10.3	8.4

VI. CONCLUSION

When the simulation is run for 1000 iteration for N=128 subcarriers, QAM-64 modulation, threshold level 0.80 and no of phase sequences U=4, we get the results for all the techniques which are mentioned in this paper. We see the amplitude graph of OFDM samples from figure 7 to figure 10. In these figures, PAPR of original OFDM is high. After applying different techniques like clipping, SLM & hybrid the PAPR is reduced in each case. The result for maximum PAPR in each case is shown in figure 11. From table II, where hybrid technique has lowest value, i.e. 8.4 dB, as compared to the original PAPR of 13.9 dB. So, the PAPR using hybrid method is reduced by 5.5 dB. So, the combine technique has good PAPR reduction capability compared single technique. However, no specific PAPR reduction technique is the best solution for the OFDM system. Various parameters like loss in data rate, transmit signal power increase, computational complexity increase should be taken into consideration before choosing the appropriate PAPR technique.

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