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PAPR Reduction in Weighted OFDM system and it's BER Analysis

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Abstract –**There has been a tremendous growth in the wireless communication industry. In the new information age, high data rate and strong reliability features are becoming the dominantly factor for a successful deployment of commercial networks. OFDM is a new wireless broadband technology has gained great popularity for its capability of high rate transmission and its robustness against multi-path fading and other channel impairments. As during a transmission OFDM system faces a high peak to average power ratio due to the independent modulated subcarriers. In a system PAPR problem and ICI interference are two major issues that faced by a developer during an implementation of OFDM system. In wireless communication system many multicarrier modulation techniques are available in the market but OFDM is the best option which provides high spectral efficiency, less vulnerability to echoes, it is less complex to implement and there is less non – linear distortion in the system. It is extremely used in various communication systems because of its advantages but when this system is going to implement a major problem is appear at the transmitter end means that when the system is ready to transmit an OFDM signal, the system's amplifier worked in a nonlinear region due to the high peak to average power ratio. The complications are increases with analog to digital and digital to analog converters in the system due to this peak to average power ratio of a signal and it also reduces the efficiency of the RF power amplifier. For this problem many researchers work on this and give many techniques to reduce the peak of transmitted signal along with this it also reduces the range of multi carrier transmission. Whatever reduction technique is used in the system it should prevent spectral growth and the transmitter amplifier should be operate in linear region. For choosing the reduction technique to keep all the point in a mind for better communication with minimum PAPR in the OFDM system and in this project we choose weighting scheme as a PAPR reduction technique.**

Keywords – **OFDM, PAPR, IFFT, BPSK, QPSK, Amplitude Clipping, Weighted ODFM, BER.**

I. Introduction

Recently there is a highly demand for multimedia data services which give us a life in the age of 4th generation wireless communication system. By using of multimedia data service, where the users are in large number with bounded spectrum and this modern digital wireless communication system has a requirement to adopt a technology which is bandwidth efficient and which is robust against multipath channel environment and that technology is known as multi- carrier communication system [1], [2]. It provide high speed data rate at minimum cost for many users as well as with high reliability by using advance digital multicarrier wireless communication system. If we talk about single carrier system it requires the entire communication bandwidth but in multicarrier system the available communication bandwidth is divided in many sub-carriers. In the multicarrier system each sub-carrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These positive features of multicarrier technique encourage us to study Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a platform for all 4G wireless communication systems due to its huge capacity in terms of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility.

Advance technologies become an effectively supporting technology in wireless multimedia with widely different origin in computing, telecommunication, entertainment and publishing or can say that from smaller things to the bigger things working smoothly and fast just because of these technologies. New applications are emerging not in wired communication but in mobile communication also. Now a days, there is a highly demand of the wireless multimedia broadband system in both public and private sector. In multimedia communication, a demand for high speed, high quality digital mobile portable transmission and reception is emerging all around the globe [2]. For a multipath environment simple digital system do not work very well and multimedia communication has large demands on bandwidth and Quality of service (QoS) compared to what is available today to the mobile user [1], [3]. The radio environment is not a suitable candidate for this requirement due to many reflected waves and other

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effects. By using of adaptive equalization at the receiver could be the solution but there are practical issues in operating this equalization in real time at several mbps with low cost hardware. Then a promising candidate introduces to eliminate the need for the complex equalizer i.e. the Orthogonal Frequency Division Multiplexing (OFDM), a multicarrier modulation technique.

For several high frequency applications like KINEPLEX, ANDEFT and KATHRYN [4] during world-war II (1939-1945) OFDM based systems were used but it is true at that time OFDM system was not highlighted like as today's point. An idea was given by Weinstein and Ebert [5] that these large numbers of coherent demodulators can be replaced by IDFT and DFT algorithm which worked as modulation and demodulation respectively in the system. Another important contribution in the OFDM system was Cyclic Prefix introduced by the Ruiz and Peled [6], [7].

In an OFDM system Orthogonality plays an important role in OFDM system and is defined as the integral of the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. It can be mathematically represented as-

For the case of continuous time:

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)dt = 0 \qquad (1)$$

For the case of discrete time:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right)\cos\left(\frac{2\pi km}{N}\right)dt = 0 \qquad (2)$$

Where n and m are two different integers of the different signals, f0 is the fundamental frequency of the subcarriers and T is the time period over which we have taken integration. The block diagram of an OFDM system is shown in Figure 1.

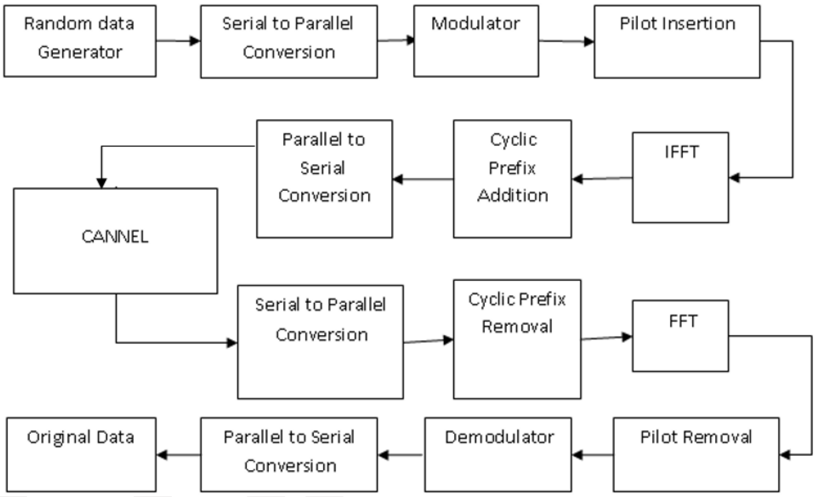

Figure 1: Block diagram of OFDM

OFDM has several attractive features which make this technology more advantageous for high speed data transmission over other data transmission techniques [5]. These features includes-

- High Spectral Efficiency
- Robustness to channel fading
- Immunity to impulse interferences
- Flexibility

OFDM system is using because of its benefits there are some obstacles also like:

- OFDM signal shows very high Peak to Average Power Ratio (PAPR)
- Very sensitive to frequency errors (Tx. & Rx. offset)
- Intercarrier Interference (ICI) between the subcarriers [4].

In this paper we will discuss the problem of high PAPR associated in OFDM. We will discuss what is PAPR, how it causes problem in existing OFDM & its effect and PAPR reduction technique.

II. Peak-to-Average Power Ratio

In OFDM system the ratio of the maximum powers of transmits OFDM symbol to the average power of that OFDM symbol is known as Peak to Average power ratio. In a multicarrier transmission system when the numbers of subcarriers are out of phase with each other then it creates the situation of PAPR in the system. At every instant all subcarriers are different from each other at different phase values. This condition occurs once when simultaneously all the points achieve the highest value then the output of the amplifier cross the threshold level and gives peak level in the output signal. Due to the large independent modulated subcarriers in a system [8] arises the situation that peak value of the system is

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very high as compared to the average value of the whole system.

Impact of PAPR on the system

At the transmitter end of the radio system generally we use High Power Amplifier for obtaining maximum output power efficiency of a signal. The operating point of HPA is at saturation region or near the saturation region. By obtaining the difference in the amplitude of the signal, the nonlinear characteristic of the HPA is very weak and high differences in the amplitudes which crosses the threshold level gives high PAPR. For the linear amplification of a signal, PAPR forces the amplifier to have large back off power [9] of a system and this kind of linear working amplifier of a system has poor power efficiency. The purpose of the radio frequency HPA is that it will work in efficient manner. When power amplifier is driving near the saturation region it shows the nonlinear behaviour of a signal and due to this reason multicarrier signal become distorted and it also degraded [9]-[14]the system performance. According to the definition, PAPR is mathematically expressed as-

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]} \qquad (3)$$

Or

$$PAPR\ in\ dB = 10log10\ \frac{max|x(t)|^2}{E[|x(t)|^2]} \qquad (4)$$

III. Amplitude Clipping and Filtering Method

The simplest reduction technique which is mostly used by the developers is Amplitude clipping and filtering method. In this method the high peaks of a signal is clipped at the transmitter end and the clipped signal is again reconstruct at the receiver end [8]. For clipping a signal the level is decided by the developer means that only those signals will be clipped whose amplitude are above the threshold value [14] and the rest signals are able to pass without clipping.

$$B(x) = \begin{cases} x & |x| \le A \\ Ae^{j\theta(x)} & |x| > A \end{cases} \qquad (4)$$

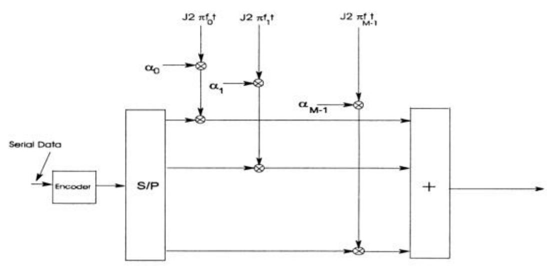
B(x) represents the amplitude value of a clipped signal, x represents the amplitude of original signal and A denotes the threshold level.

By using this amplitude clipping and filtering method a problem is observed by the observer that due to the clipping of a signal distortion is obtained in the system and it is predict as another way of noise added in the system. There is an in – band and out – of – band distortion but out-of-band distortion can be reduced by applying a filtering method. Yet in-band is present in the system and it can't be reduce by the filtering method. Out-of-band distortion is reduced by filtering but it will blocked the spectral efficiency and during the filtering it re-growth some peaks of a signal. Therefore to solve this problem repeated filtering and clipping process [9] is done in the system. In this iteration process is done to set the amplitude levels which decide the threshold level.

IV. Weighted OFDM Method

As we know that PAPR problem is faced by the system at the transmitter end it means before a transmitting an OFDM signal message is distorted, if we apply some weight to keep the peaks at the threshold level so the system will face less PAPR. In this project we are using weighted OFDM signal as PAPR reduction technique and it is proposed to reduce PAPR without any distortion. In this proposed scheme firstly we taken a bandlimited signal by which we can apply weight on each discrete OFDM signal and then OFDM signal is composed with the weighted discrete data before passing in a high power amplifier. At the receiver end the original OFDM signal can be easily recovered back just by removing applied weight. If we are concerned about a time so it required a time to transmit the weighted OFDM signal is just similar to time duration of the original OFDM signal. Weighted OFDM signal gives less PAPR as compare to the amplitude clipping and filtering method and the bit-error-rate performance of the weighted OFDM system is better than the clipping and filtering method [14].

The proposed scheme is much simpler than the amplitude clipping and filtering method. As in the serial data transmission the data is transmitted as a train of serial pulses but in the multicarrier transmission system transmission of each bit is sequence of N modulated data of different subcarriers. Weighted OFDM technique is similar to the conventional OFDM technique but the difference is that each carrier is weighted by a real weighting factor α_m [15] where the value of is depends on number of subcarriers as m = 0, 1, 2…, N-1.



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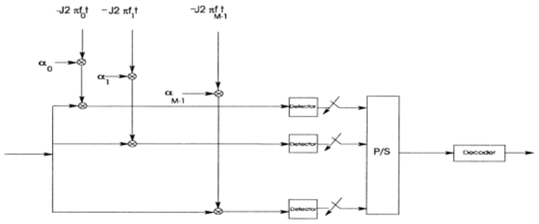

Figure 2 Block diagram of weighting Multicarrier system

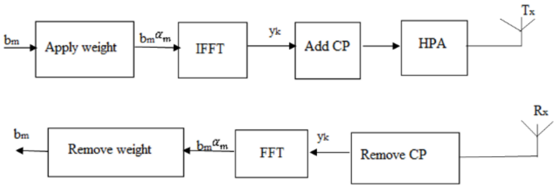

Figure 3 Block diagram of a Proposed Method

In this scheme we can used Gaussian function, Rectangular function, Bartlett function, Raised cosine function, half sine function and Sinc functions as weighted function. In our project we consider a sinc function as weighting function for proposed method.

$$\alpha(x) = \frac{1-\text{sinc}(x)}{\pi^2 x^2} \quad (6)$$

A signal α is a band limited with bandwidth of π and it has no zero on the real line. The weighted OFDM signal is represented as:

$$x(t) = \sum_{i=-\infty}^{\infty} \sum_{m=0}^{M-1} b_m(i)\alpha_m e^{j2\pi\frac{m}{T}(t-iT)} \quad (7)$$

α_m = represents a real weighting factor in above equation.

$b_m(i)$ = data of the N subcarrier which is modulated by the BPSK, QPSK or etc.

V. PAPR OF WEIGHTED OFDM SYSTEM

The basic aim of our project to calculate PAPR and reduces its effect from the system. In this section we calculate PAPR after applying a weight on OFDM signal. From the above equation we have taken a Weighted OFDM signal with the time interval of 0≤t≤T [15]-

$$x(t) = \sum_{m=0}^{N-1} b_m \alpha_m e^{j2\pi\frac{m}{T}t} \quad (8)$$

To calculate PAPR we should know the value of maximum power and average power of a signal. So by using equation (8) we find the instantaneous power of OFDM signal and which can be describe as-

$$P(t) = |x(t)|^2 = \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} b_m \alpha_m (b_n \alpha_n) * e^{\frac{j2\pi(m-n)}{T}t} \quad (9)$$

Or,

$$P(t) = \sum_{m=0}^{N-1} |b_m \alpha_m|^2 + \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} b_m \alpha_m (b_n \alpha_n) * e^{\frac{j2\pi(m-n)}{T}t} \quad (10)$$

The average power of a signal $P(t)$ is:

$$E[P(t)] = \sum_{m=0}^{N-1} \overline{|b_m|^2}\, |\alpha_m|^2 + \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} E|b_m b_n^*| \alpha_m \alpha_n^* e^{\frac{j2\pi(m-n)}{T}t} \quad (11)$$

Here we assumed that symbols on different subcarriers independent to each other means the $E|b_m b_n^*| = \delta(m-n)$. Therefore the second term in equation (11) is equal to zero [15] then the average power becomes:

$$E[P(t)] = \sum_{m=0}^{N-1} |\alpha_m|^2 = 1 \quad (12)$$

Now PAPR of the weighted OFDM signal can be written as:

$$PAPR = \frac{Max\,\{P(t)\}}{Avg\,\{P(t)\}} \quad (13)$$

In the weighted OFDM signal, the weighting factor α_m is non uniform therefore the BER performance of a system could be reduced. So we can make it better by adding a suitable constant αk which is positive to the original weight and will give better performance of BER. So the modify weight [14] of the weighted OFDM system is:

$$\alpha_k(x) = \alpha_m(x) + \frac{k}{logN} \quad (14)$$

In the above equation N is the number of subcarriers and k is a shift parameter. In the weighted OFDM equation the weight α_m is replace by a modified weight α_k to get the modified weighted OFDM signal which is represented as:

$$Z_N(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} b_m \varphi_k(2\pi f_k) e^{j2\pi f_k t} \quad 0 \le t \le T \quad (15)$$

With the help of weighting factor weight is made to imposed on the discrete data b_m, and we obtained weighted OFDM signal and after modifying a weight we get $Z_N(t)$ as weighted OFDM signal. Now we calculate the PAPR of this transmitted OFDM signal which is represented by $Z_N(t)$ and it is given as:

$$PAPR(Z_N) = \frac{max|Z_N(t)|^2}{E(|Z_N(t)|^2)} \quad (16)$$

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VI. SIMULATION AND RESULTS

Simulation Parameters

Table 1 Simulation Parameters

Simulation Tool	MATLAB R2010b
Number of Bits	160000
Number of Subcarriers	64,128,256,512,1024
Type of Modulation	BPSK,QPSK
Weighting Function	Sinc Function
Channel	AWGN Channel

Simulation Tables

Table 2 PAPR of OFDM and reduction techniques using BPSK modulation

OFDM	6.2 dB
Weighted OFDM	1.2dB
Clipping and Filtering	5.6dB
Modified Weighted OFDM	1.4dB

Table 3 PAPR of OFDM and reduction techniques using QPSK modulation

OFDM	15.6 dB
Weighted OFDM	1.4dB
Clipping and Filtering	8.8dB
Modified Weighted OFDM	1.6dB

Table 4 PAPR of OFDM and weighted OFDM system with different subcarriers using BPSK modulation

Number of subcarrier	OFDM (in dB)	weighted OFDM (in dB)
64	6.2	1.2
128	6.8	1.7
256	7.3	2
512	7.9	2.6
1024	8.4	4

Table 5 PAPR of OFDM and weighted OFDM system with different subcarriers using QPSK modulation

Number of subcarrier	OFDM (in dB)	weighted OFDM (in dB)
64	15.6	1.9
128	18.3	4.3
256	21.2	6.6
512	24.2	10
1024	27	14.5

Simulation Results

Figure 4 a CCDF curve represents the simulated signals that spends a time at a given power level denoted by a point in a graph. Here in the graph each point defines the probability and it depends on percentage of time that signals spend there. In the figure 4 the x-axis shows PAPR in dB and y-axis shows the point at which the level of power according to the x-axis is spend by the signals. In the above graph we can see that at point on y-axis at point 0.5 the related PAPR of OFDM signal is 6.5 dB, Amplitude clipping and filtering signal is 5.9 dB, weighted OFDM signal is 1.2 dB and modified weighted OFDM signal is 1.9 dB is obtained on the x-axis.

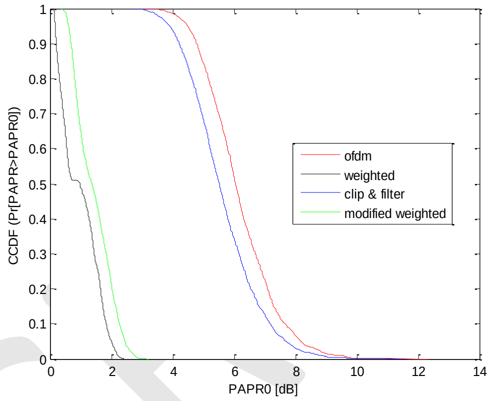

Figure 4 ccfd of different reduction techniques using BPSK Modulation

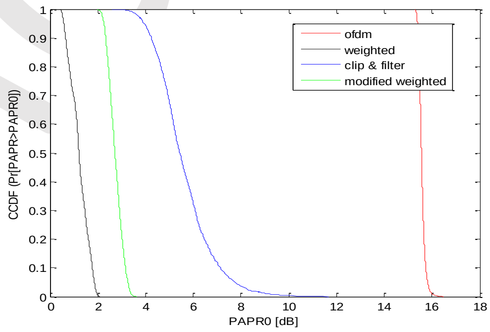

Figure 5 CCFD plot different reduction techniques using QPSK Modulation

In figure 5 CCDF curve represents the simulated signals that spends a time at a given power level denoted by a point in a graph. Here in the graph each point defines the probability and it depends on percentage of time that signals spend there. In the above figure 5 the x-axis shows PAPR in dB and y-axis shows the point at which the level of power according to the x-axis is spend by the signals. In the above graph we can see that at point on y-axis at point 0.5 the related PAPR of OFDM signal is 15.9 dB, Amplitude clipping and filtering signal is 6.2dB, weighted OFDM signal is 1.9 dB and modified weighted OFDM signal is 2.8 dB is obtained on the x-axis.

In figure 6 and figure 7 we have seen that as we increases the number of subcarriers, PAPR also increases and as we used higher oreder of

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modulation technique and increases the number of subcarriers, PAPR also increases.

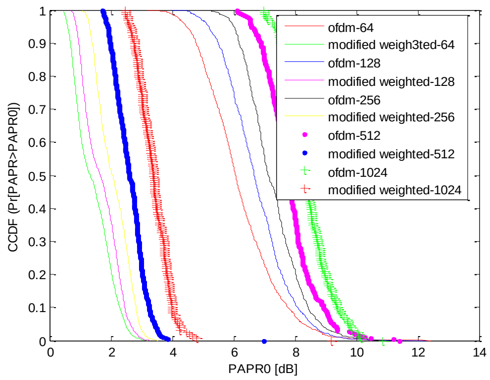

Figure 6 CCDF between OFDM and weighted OFDM with different subcarriers using BPSK Modulation

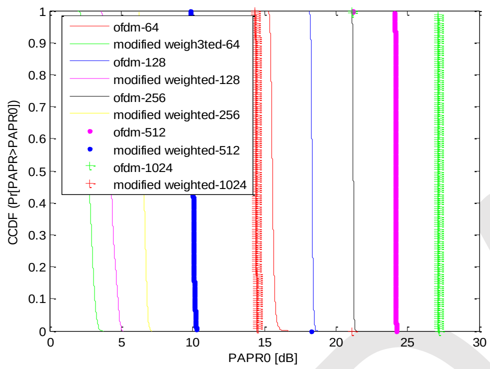

Figure 7 CCDF between OFDM and Modified weighted OFDM with different subcarriers using QPSK Modulation

From the figure 8 the graph represents the system performance over AWGN channel and BER v/s SNR graph has been determined using MATLAB. The overall system performance with using PAPR reduction techniques can be seen by this figure. By using BPSK modulation we obtained BER at 10^{-5} on SNR of 11 dB for OFDM and 13.2 dB for modified weighted OFDM and for CF is 24dB at 10^{-3}.

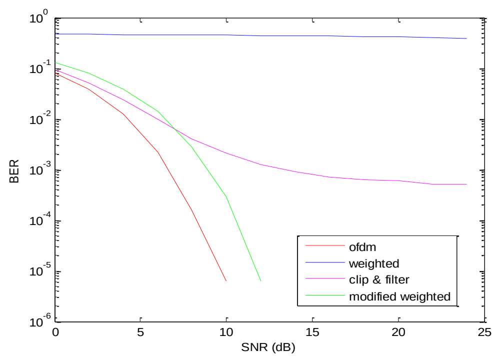

Figure 8 BER performance of OFDM system with reduction techniques using BPSK modulation

From the figure 9 we observed the system performance over AWGN channel and BER v/s SNR graph has been determined using MATLAB. The overall system performance with using PAPR reduction techniques can be seen by this figure. By using QPSK modulation we obtained BER at $10^{-0.5}$ on SNR of 24 dB for OFDM and CF and BER for modified weighted OFDM at $10^{-0.4}$ on SNR of 24dB.

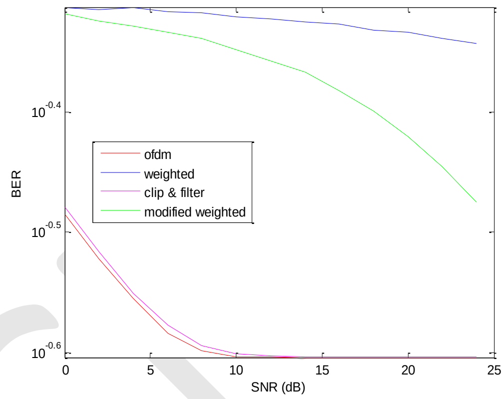

Figure 9 BER performance of OFDM system with reduction techniques using QPSK modulation

VII. CONCLUSION

In this paper we are using Weighted OFDM technique as a PAPR reduction technique for OFDM system. In this technique we can reduce PAPR at the transmitter end or we can say that we form our OFDM data which is to be transmitted in such a way that it reduces more PAPR in the transmitter end only without any distortion in the system as compare to the other PAPR reduction techniques. On the behalf of simulation results which we have done, we observed that weighted OFDM technique reduces more PAPR without any distortion as compare to the other techniques. We also observed that as we increased the number of subcarriers and used higher order modulation, PAPR also increased. The system performance is obtained by the BER v/s SNR. We observed that the used weighting factor α_m is non uniform and it reduced the BER performance. For this we added a suitable constant α which is positive to the original weight gave a better performance of BER as compare to the other techniques.

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