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PAPR Reduction in OFDM System Using Modified Selective Mapping Scheme

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation scheme, which is widely used in various wireless communication systems and standards due to its high data rate, high spectral efficiency and robustness to multipath fading channel. However, peak-to-average ratio (PAPR) reduction and intercarrier interference (ICI) cancellation are two major challenges in implementing an OFDM system. High PAPR results from large envelope fluctuations in OFDM signal which requires a highly linear power amplifier (PA). Power amplifiers with large linear range are bulky, costly and difficult to manufacture. Therefore, various PAPR reduction techniques have been proposed in literature to reduce the PAPR of OFDM signal. In OFDM system the subcarriers are narrowband and require tight frequency synchronization between the transmitting and receiving ends. Selected mapping (SLM) is an efficient peak-to average power ratio (PAPR) reduction scheme without signal distortion in orthogonal frequency division multiplexing (OFDM) systems. Therefore, it can be applied to mobile consumer electronics that are sensitive to high PAPR because of the limitation of the linear area of a power amplifier. However, enormous inverse fast Fourier transforms (IFFTs) are needed for the sufficient PAPR reduction performance, which cause the mobile devices with SLM scheme to become quite complex and reduce battery power consumption. In this paper, we propose a new SLM scheme that replaces the additional IFFT operations with a conversion of the other candidate OFDM signal. Simulation results show that the proposed scheme significantly reduces the computational complexity, while it obtains the better PAPR reduction performance than the other PAPR reduction scheme.**

***Index Terms*— OFDM, SLM, ISI, PAPR, IFFT**

I. Introduction

OFDM is one of the multicarrier modulation (MCM) technique for 4 th Generation (4G) wireless communication. This technique is very attractive technique for high-speed data transmission used in mobile communication, Digital terrestrial mobile communication, Digital Audio Broadcasting (DAB), Digital Video Broadcasting terrestrial(DVB-T), wireless asynchronous transfer mode (WATM), Modem/ADSL.[1] OFDM has many advantages such as robustness in frequency selective fading channels, High spectral efficiency , immunity to inter -symbol interference and capability of handling very strong multipath fading.[2] But OFDM is having major drawback of a high Peak-to -Average Power ratio(PAPR)[3-4].This causes clipping of the OFDM signal by the High power amplifier(HPA) and in the HPA output producing non-linearity. This non-linearity distortion will result in-band distortion and out-of-band radiation. The in-band distortion causes system performance degradation and the out-of-band radiation causes adjacent channel interference (ACI) that affects systems working in neighbor band. Hence the OFDM signal may have In-band and Out-of-band distortion which degradation of Bit-error-rate (BER) performance. One solution is to use a linear power amplifier with large dynamic range. However, it has poor efficiency and is expensive too.

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II. REDUCTION TECHNIQUES

At present, there are many PAPR reduction techniques of OFDM. The first is distortion technique, such as clipping, companding and so on. This technique is simple, but it is inevitable to cause some performance degradation. The second is coding technique [5]. It is an efficient method to reduce the PAPR for a small number of subcarriers, but it is inefficient transmission rate significantly for a large number of subcarriers. The third kind is probabilistic technique or the redundancy technique which is including selective mapping (SLM) and the Partial transmit sequence (PTS).[6-7] we used SLM Technique to reduce PAPR which give better performance as compare to PTS Selective mapping technique is main focus of this paper. Combination of DQPSK with SLM not only reduces the complexity at receiver but also it reduces PAPR of OFDM signal.

The paper is organized as follows section 2 gives PAPR reduction techniques. An overview of the PAPR of OFDM System in section 3. Brief description of SLM technique in section 4. OFDM USING SLM technique in section 5. Proposed Modified SLM scheme in section 6,Simulation results are presented in section 7. Finally conclusion is in section 8.

III. THE PAPR OF OFDM SYSTEM

Theoretically, large peaks in OFDM system can be expressed as Peak-to-Average Power Ratio, or referred to as PAPR, in some literatures, also written as PAPR. It is usually defined as [10]:

$$PAPR = \frac{P_{peak}}{P_{average}} = 10\log_{10}\frac{\max\ [|x_n|^2]}{E[|x_n|^2]}$$

Where P_{peak} represents peak output power, $P_{average}$ means average output power. $E\cdot$ denotes the expected value, x_n represents the transmitted OFDM signals which are obtained by taking IFFT operation on modulated input symbols X_k. Mathematical, x_n is expressed as:

$$x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k\ W_N^{nk}$$

For an OFDM system with N sub-carriers, the peak power of received signals is N times the average power when phase values are the same[5]. The PAPR of baseband signal will reach its theoretical maximum at (dB) =10log N. For example, for a 16 sub-carriers system, the maximum PAPR is 12 dB. Nevertheless, this is only a theoretical hypothesis. In reality the probability of reaching this maximum is very low. Fig. 3.1 shows the amplitude characteristic of an OFDM system with 16 sub-carriers. According to the graph, it can be seen that the maximum magnitude of the OFDM signals is less than the upper limit value 16 and corresponding PAPR is also lower than the theoretical maximum 12dB.

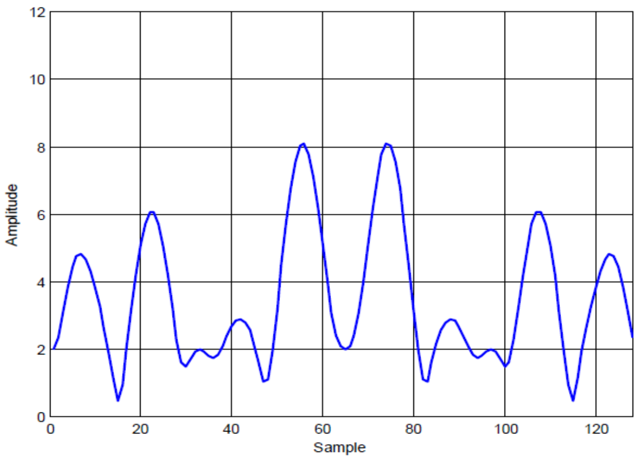


Fig 3.1: An OFDM signal waveform in time domain

The special case happens when signal sub-carriers are modulated by symbols which have the same initial phase. Assuming that input binary sequence contains „1" for the whole sequence. After PSK constellation mapping and IFFT operation, instant power reaches its theoretical maximum. Fig. 3.2 shows the result when input binary sequence contains 16 „1" , denoted by [1111111111111111]. In this scenario, the maximum amplitude reaches the value of 16. The PAPR can be calculated from (dB) =10log N and in this case it is 12dB.

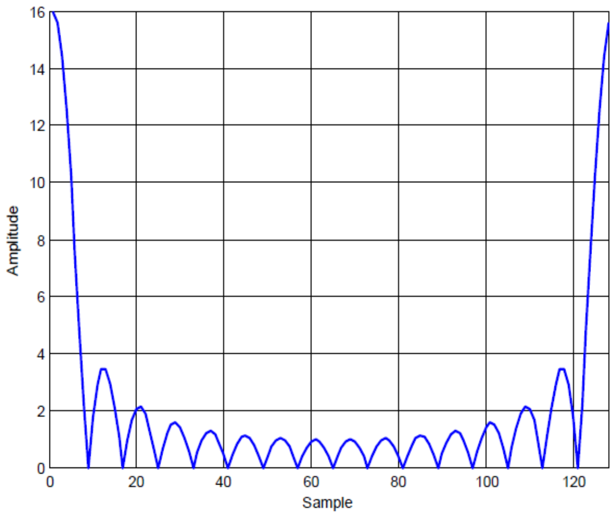


Fig 3.2: High PAPR when Sub Carriers are modulated by same symbol

By observing the simulation result in Fig. 3.2, we can make a conclusion that the amplitude of OFDM signal reaches its peak value when the input data sequence has a larger consistency. At the same time, the maximum PAPR value will be reached as well.

Another commonly used parameter is the Crest Factor (CF), which is defined as the ratio between maximum amplitude of OFDM signal s t and root-mean-square (RMS) of the waveform. The CF is defined as [5]:

$$CF\left(s(t)\right) = \frac{\max\ [|s(t)|]}{E[||s(t)|^2|]} = \sqrt{PAPR}$$

In most cases, the peak value of signal x t is equals to maximum value of its envelope (t). However, it can be seen from Fig. 3.1 that the appearance of peak amplitude is very rare, thus it does not make sense to use max x t to represent peak value in real application[6]. Therefore, PAPR performance of OFDM signals is commonly measured by certain characterization constants which are related to probability.

IV. SLM TECHNIQUE

This is an effective and distortion less technique used for the PAPR reduction in OFDM. The name of this technique indicates that one sequence has to be selected out of a number of sequences. According to the concept of discrete time OFDM transmission we should make a data block considering N number of symbols from the constellation plot where N is the number of subcarriers to be used. Then using that data block U number of independent candidate vectors are to be generated with the multiplication of independent phase vectors[8]. Let us consider X is the data block with X (k) as the mapped sub symbol (i.e. the symbol from the constellation). Where k = {0, 1, 2 ...N − 1}. Let the uth phase vector is denoted as B $^{(u)}$, where u = {1, 2 ...U}. The uth candidate vector that is generated by the multiplication of data block with the phase vector is denoted as X $^{(u)}$. So we can write the equation to get the kth element of uth candidate vector as

$$X^{(u)}(k) = X(k)\ \ B^{(u)}(k)$$

Then by doing IFFT operation to each candidate vector we will obtain U number of alternative OFDM signals, so the nth symbol of uth alternative OFDM signal can be written mathematically as

$$x^{(u)}(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X^{(u)}(k)\ e^{j\left(\frac{2\pi nk}{N}\right)}$$

So out of the U number of alternative OFDM signals the signal having minimum PAPR is to be selected for transmission[8]. Let that selected OFDM signal is denoted as $x^{(\bar{u})}(k)$. This selected mapping (SLM) technique is known as the classical SLM.

V. OFDM USING SLM

The generation of sufficient candidate OFDM signal sequences causes high computational complexity because of the IFFT operation of each candidate sequence. Therefore, it is desirable to reduce the number of IFFT operations. The generation of sufficient candidate OFDM signal sequences causes high computational complexity because of the IFFT operation of each candidate sequence[5]. Therefore, it is desirable to reduce the number of IFFT operations. The block diagram for this technique is shown below

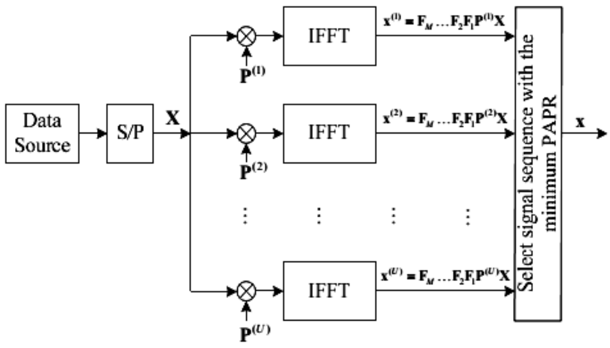


Fig 5.1 Block Diagram of SLM technique

In the SLM scheme, statistically independent symbol sequence $S^{(u)}$. $1 \le u \le U$, is generated by multiplying the input data symbol sequence $X = [X_1\ X_2 \ldots\ldots X_{N-1}]^T$ and the phase rotation matrix $P^{(U)}$, $1 \le u \le U$, where U is the number of candidate OFDM signals. Therefore $S^{(u)}$ can be expressed as

$$\mathbf{S}^{(u)} = \left[S_0^{(u)}\ S_1^{(u)} \ldots S_{N-1}^{(u)}\right]^T = \left[P_0^{(u)} X_0\ \ P_1^{(u)} X_1\ \ldots\ P_{N-1}^{(u)} X_{N-1}\right]^T = \mathbf{P}^{(u)}\mathbf{X}$$

Where

$$\mathbf{P}^{(u)} = \begin{bmatrix} P_0^{(u)} & 0 & \cdots & 0 \\ 0 & P_1^{(u)} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{N-1}^{(u)} \end{bmatrix}.$$

The elements of $P^{(u)}$ can be generated by complex number $P_k^{(u)} = e^{j\theta_k^{(u)}}$ where $\theta_k^{(u)} \in [0, 2\pi)$, $0 \le k \le N\text{-}1$.

To simplify the system we assume that the elements of $P^{(u)}$ use binary or quaternary elements, i.e., {ȼ1} or {ȼ1, ȼj}. After the IFFT operation of $S^{(u)}$, a set of candidate OFDM signals $X^{(u)}$, $1 \le u \le U$, can be expressed as

$$\mathbf{x}^{(u)} = \mathbf{F}_M \ldots \mathbf{F}_2 \mathbf{F}_1 \mathbf{P}^{(u)} \mathbf{X}$$

Where $\mathbf{F}_i$, $1 \le i \le M$, is the $N \times N$ symmetric matrix representing the i^{th} stage of the IFFT. Finally, the OFDM signal with the lowest PAPR is selected for transmission among $\mathbf{x}^{(u)}$, $1 \le u \le U$. Fig5.1 shows the block diagram of the SLM scheme.

VI. Proposed SLM Scheme

Many additional OFDM signal sequences must be generated in order to achieve sufficient PAPR reduction performance in the conventional SLM scheme. However, the generation of sufficient candidate OFDM signal sequences causes high computational complexity because of the IFFT operation of each candidate sequence. Therefore, it is desirable to reduce the number of IFFT operations[7]. Unlike conventional SLM scheme, in which each additional input symbol sequence is applied to an IFFT separately, a conversion of the first candidate OFDM signal replaces the IFFT operations of the other candidate OFDM signals, which reduce computational complexity significantly. Fig.6.1 shows the block diagram of the proposed SLM scheme.

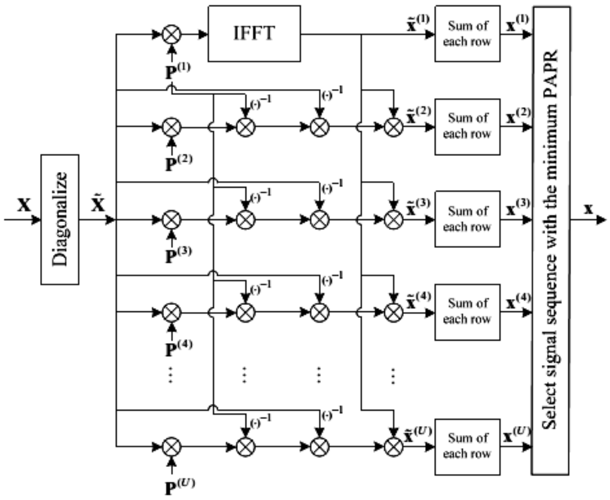


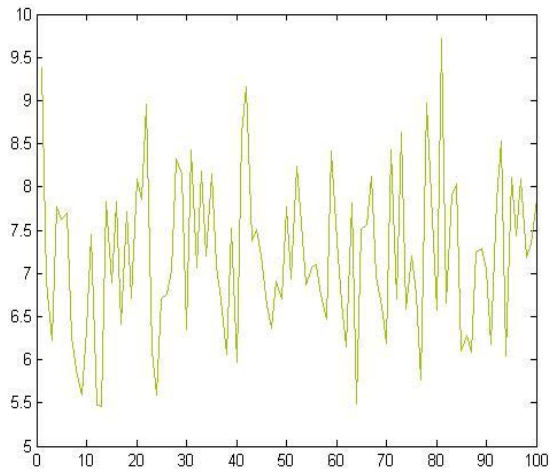
Fig 6.1: Block Diagram of Proposed SLM Scheme

VII. SIMULATION PERFORMANCE

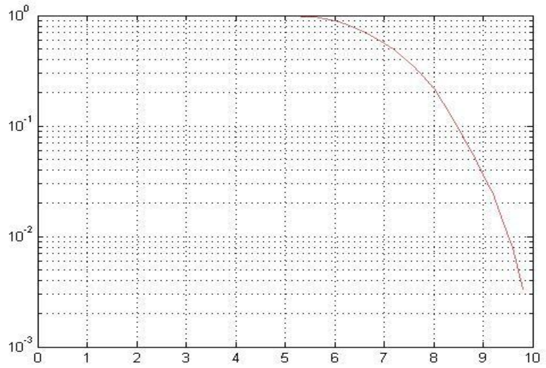
In this part, an evaluation of factors which could influence the PAPR reduction performance is performed using Matlab simulation. Based on the principles of SLM algorithm, it is apparently that the ability of PAPR reduction using SLM is affected by the route number *M* and subcarrier number *N*. Therefore, simulation with different values of *M* and *N* will be conducted.

A. Simulation Result I without Clipping and Selecting Method

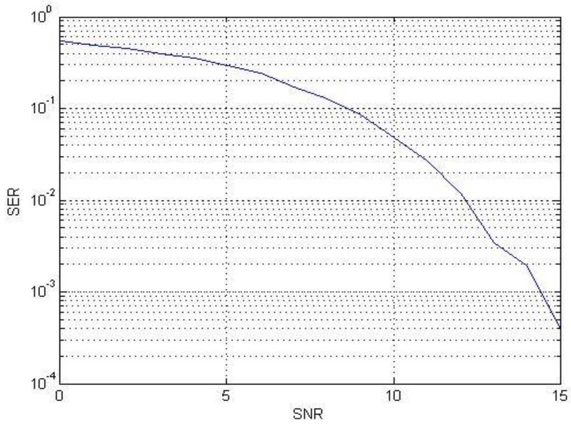
This is a script file without clipping and selecting method .In this case, we set the number of OFDM signal frame *M* equals to 8, the number of bits and number of symbols are 52 and 100 respectively.PAPR value is reduced up to 7.2042 with the help of quadrature amplitude modulation technique.



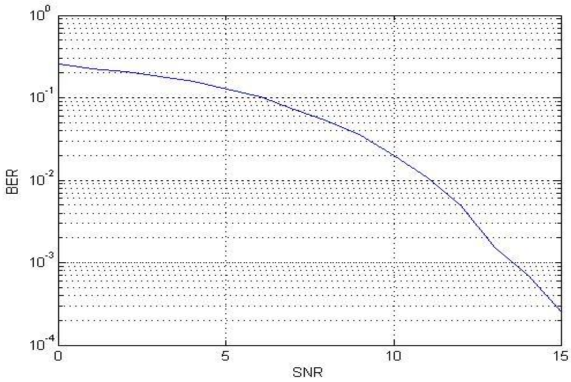
(a)



(b)



(C)

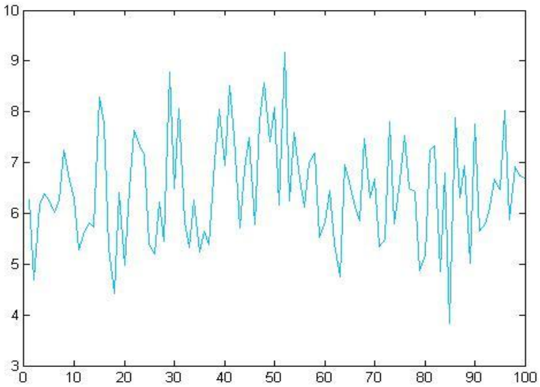


(d)

Fig7.1: Simulation Results I without clipping and selecting method (a) graph of random numbers (b)graph for the value of PAPR (C) Graph b/w SNR &SER on semi-log Scale. (d) Graph b/w SNR &BER on semi log scale

B. Simulation Result II using Quadrature Phase shift Keying Technique

This implementation is same as previous simulation but in this case the technique used for the implementation is Phase Shift Keying with OFDM signal Frame M equals to 4 , No of symbols and No of bits are 100 and 52 respectively for the reduction in PAPR value which is reduced due to this implementation from 7.2042 to 6.4612



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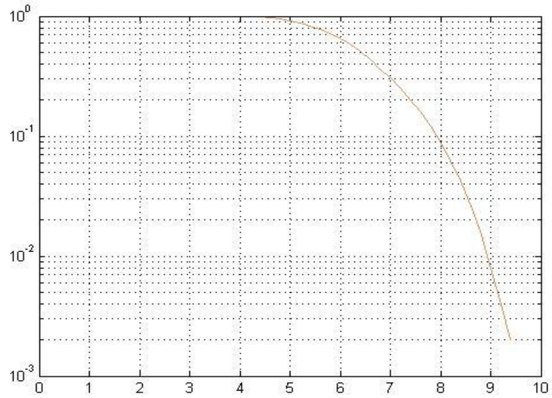

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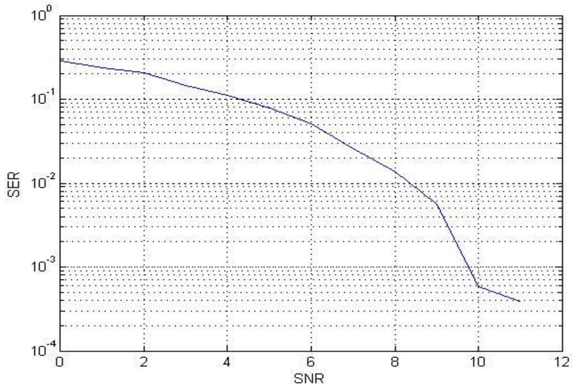

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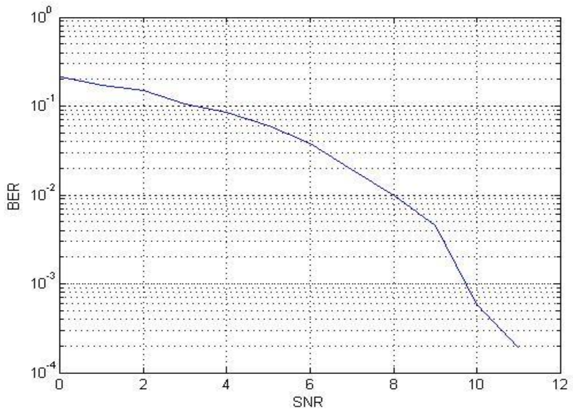
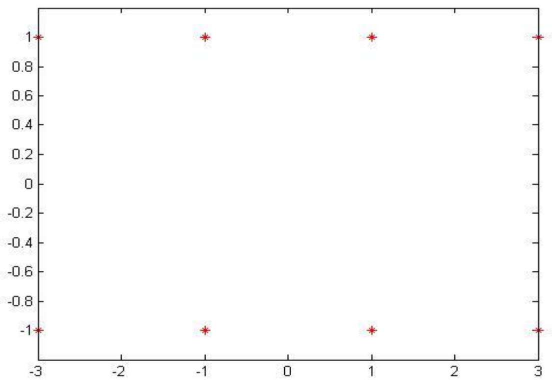


(d)

Fig 7.2:Simulation Results II (a) graph of random Numbers (b) graph for the PAPR value (c) graph b/w SNR & SER (d) Graph b/w SNR & BER n semi-log scale

C. Simulation Result III using Selective Mapping scheme

In this case implementation is done with the help of conventional selective mapping scheme for the reduction in PAPR value. Number of OFDM signal frames used in this technique is M levels equals to 8, Number of symbols and number of bits used is 50 & 84 respectively



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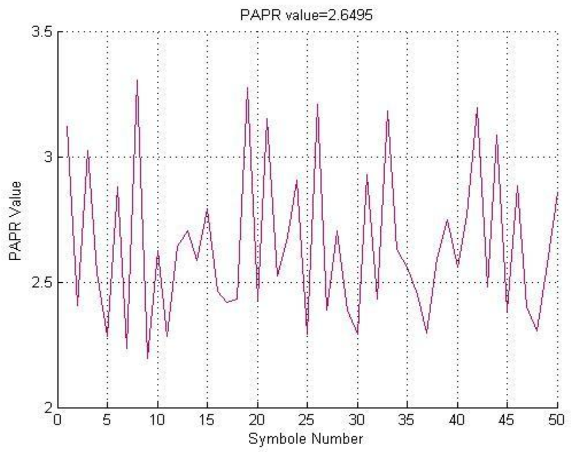

(b)

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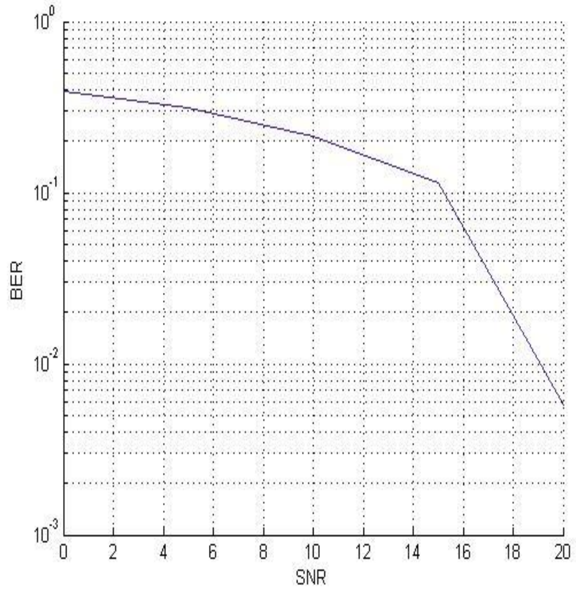
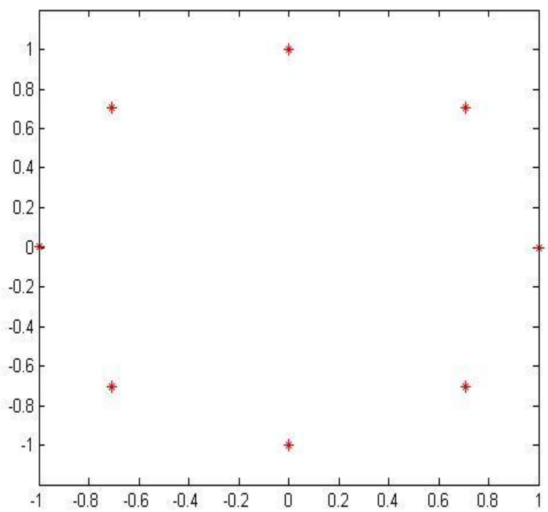


(d)

Fig 7.3: Simulation Results III Using Conventional Selective Mapping Scheme (a) Graph of random numbers (b) Graph b/w PAPR value and symbole number,PAPR is 2.6495 (c) Graph b/w PAPR and CCDF value (d) Graph b/w SNR and BER

D. Simulation Result IV using new Selective Mapping Scheme with QPSK technique

In Proposed SLM scheme the number of IFFT operation reduced for reducing the computational complexity unlike conventional SLM scheme in order to achieve sufficient PAPR reduction because of the IFFT operation of each candidate sequence .Therefore, it is desirable to reduce the number of IFFT operations. In this case, No of symbols and no of bits are same as used in previous scheme only the number of IFFT operations for each candidate sequence reduced.Finally,the value of PAPR is reduced up to 2.2006.



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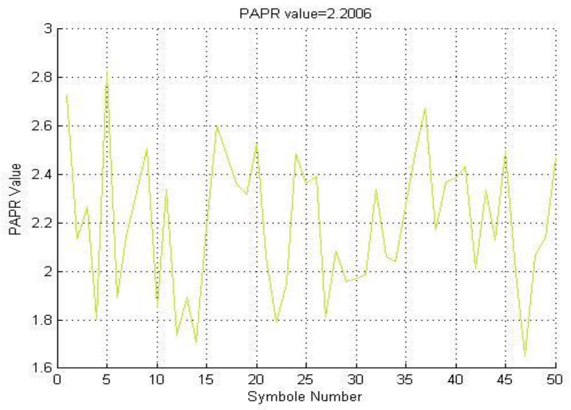

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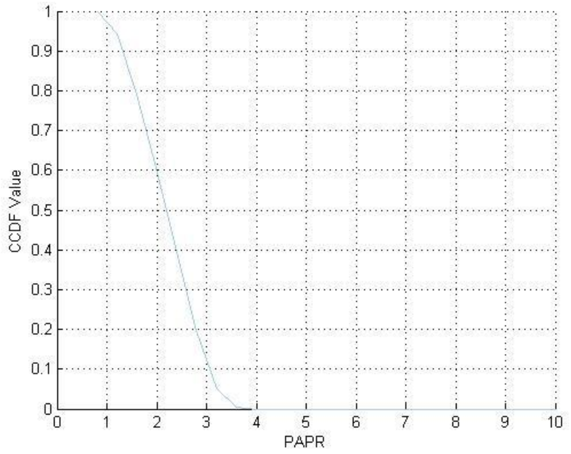

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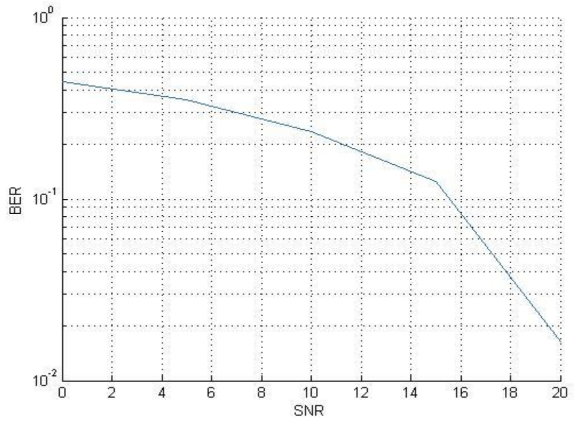

(d)

Fig 7.4:Simulation Results IV using SLM scheme with QPSK (a) Graph of random numbers (b) Graph b/w PAPR Value and symbole number,PAPR value is 2.2006 (c)graph b/w PAPR and CCDF (d) Graph b/w BER and SNR

VIII. CONCLUSION

A modified selective mapping technique is proposed in this paper to improve the performance of the OFDM system with respective PAPR. This scheme requires only one IFFT block at the transmitter. Results of simulation of modified SLM technique show that the PAPR reduction of OFDM system, which further results in high performance of wireless communication. With the rising demand for efficient frequency spectrum utilization, OFDM proves invaluable to next-generation communication systems.

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