Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrow band flat fading sub channels. Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique against the multipath fading channel for wireless communications [1]. However, OFDM faces the Peak-to-Average Power Ratio (PAPR) problem that is a major drawback of multicarrier transmission system. We will be using Selected Mapping method (SLM) to reduce PAPR, improve BER while maintain high SNR. MATLAB® simulation is used to implement the proposed model.

Keywords: BER, PAPR, QAM, SLM, SNR

I. INTRODUCTION

The demand of high data rates in wireless applications continues to grow at an exponential rate. The limited availability of spectrum makes achieving high data rates in wireless communications challenging task. For applications such a real-time video streaming, high data rates are required. High throughput is realized through tradeoffs between bandwidth, power, and system complexity. Today most mobile wireless system are using digital modulation techniques, in which information is converted to bits and mapped onto a carrier frequency to be transmitted over a wireless channel. The choice of digital modulation scheme is of very much importance for mobile communications systems. Modern mobile standards use adaptive modulation schemes which adjust the modulation scheme depending on the signal to noise ratio. Binary Phase shift Keying (BSPK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM) modulation techniques are used in 4th Generation Wireless System, LTE and WiMAX.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal Frequency Division Multiplexing (OFDM) is a digital modulation technique consisting of transmitting a data stream using a large number of parallel narrow–band subcarriers instead of a single wide-band subcarrier. Therefore OFDM is a combination of modulation and multiplexing with better immunity to impulse noise and inter-symbol interference (ISI), high spectral efficiency and low complexity. The principle of OFDM is to divide a high rate data-stream into lower rate data stream that are transmitted simultaneously over a number of sub carriers. OFDM sends multiple high speed signals concurrently on orthogonal carrier frequencies [1]. This results much more efficient use of bandwidth as well as robust communications during noise and other interferences. The orthogonal frequency division multiplexing (OFDM) technology gives the best BER performance under AWGN & fading channel environment. The purpose of OFDM is to convert the high speed information to low speed information stream that can be transmitted simultaneously over a large number of subcarriers.

An important drawback of OFDM based system is its high Peak-to-Average Power Ratio (PAPR) at the transmitter, requiring the use of a highly linear amplifier which leads to low power efficiency [2]. The various approaches to minimize this problem in OFDM based systems can be classified into five categories: clipping effect transformation [3], [4], coding [5], [6], frame superposition using reserved tones [7], expansible constellation point: tone injection [7] and active constellation extension [8], [9], [10], and probabilistic solutions.
A. Quadrature Amplitude Modulation:

In QAM the two waves are out of phase with each other by $90^\circ$ and are thus called Quadrature carriers—hence the name of the technique. In QAM the constellation points are arranged in a square grid with equal vertical and horizontal spacing. In Quadrature amplitude modulation ASK is combined with PSK to create a system such in which amplitude and phase both are changed at the same time. QAM is the modulation technique which conveys data by modulating the amplitude of two carrier waves [11]. With more than 8 phases the error rate becomes too high, for this the better modulation technique is required which is the QAM.

![Constellation Diagram of 16-QAM Modulation](image)

A M ary-QAM signal set, in general form, can be represented as:

$$s_i(t) = \sqrt{\frac{2E_{\text{min}}}{T_s}} a_i \cos 2\pi f_c t + \sqrt{\frac{2E_{\text{min}}}{T_s}} b_i \sin 2\pi f_c t$$

where $E_{\text{min}}$ is the energy of the signal with the lowest amplitude, $a_i$ and $b_i$ integer values. Figure 2 shows the optimal constellation diagram of a 16-QAM Scheme. In digital communication usually the data is binary, the number of points in the grid usually a power of 2 (2, 4, 8, 16…). Hence the constellation of QAM is in square shape. The most common forms of QAM are 16, 64, 128 QAM and 256 QAM.

B. Bit Error Rate (BER):

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been changed by interference, noise, bit synchronization errors and distortion. The bit error rate (BER) is the number of bits errors divided by the total number of transferred bits. The bit error probability $p_e$ is the expectation value of the BER. In communication system, the receiver side BER may be affected by transmission channel distortion, noise, bit synchronization problem, interference, attenuation, and wireless multipath fading [11]. The BER is improved by selecting strong signal strength, by selecting robust and slow modulation scheme or line coding techniques.

C. Peak to Average Power Ratio (PAPR):

Fig.3 illustrates the block diagram of an OFDM system with arrangement for transmitting signal with minimum PAPR. Baseband modulated symbols are passed through serial to parallel converter which generates complex vector of size $N$. We can
write the complex vector of size N as $X = [X_0, X_1, X_2… X_{N-1}]^T$. $X$ is then passed through the IFFT block. The complex baseband OFDM signal with N subcarriers can be written as:

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \cdot e^{j2\pi \frac{n}{N} k}, \; n=0, 1, 2… N-1$$

Here $j = \sqrt{-1}$ and the PAPR of the OFDM signal can be written as

$$PAPR = \frac{\max|X_n|^2}{E[|X_n|^2]}$$

In OFDM systems due to the presence of large number of independently modulated sub carriers, the peak value of the OFDM system can be very high as compared to the average of the whole system. This ratio of peak to average power value is termed as peak to average power ratio (PAPR) [1]. The coherent addition of N number of signals of same phase produces a peak which is N times the average signal. There are number of techniques to deal with the problem of PAPR. Some of them are amplitude clipping, clipping and filtering, coding, selected mapping, partial transmit sequence and interleaving. These techniques are used to reduce the problem of PAPR at the expense of transmit power increase, bit error rate increase, data rate loss and computational complexity increase etc.

Fig. 3: Block diagram for an OFDM system for min PAPR signal transmission

III. RESULTS

![Plot showing BER vs. SNR for different transmitted powers]

Fig. 4: Simulation results for the OFDM system model

IV. CONCLUSION

Simulation results for the OFDM system model simulated in MATLAB® are shown in fig 4. The plot shows BER vs. SNR for different transmitted powers. The proposed model has shown high values of SNR for low BER as compared to [12], e.g. for BER of $10^{-2}$ our system has shown SNR 17dB i.e., improvement by 3dB. For the above parameters the model has achieved PAPR of 7.273.

V. FUTURE SCOPE

The problem of PAPR is a big hurdle in long range as well as high power level transmission, and for improvement in PAPR the proposed work can be extended for different varying parameters such as $m$ in QAM or Turbo codes can be implemented incorporated with SLM technique.

REFERENCES