Abstract—Multicarrier modulation systems i.e. orthogonal frequency division multiplexing (OFDM) performs better than single carrier systems. The major advantage of OFDM system over the single carrier system includes the better performance in fading phenomena of multipath environment. OFDM system has a drawback which is high Peak to Average Power Ratio (PAPR). This paper gives the comparative analysis of effects of different modulation schemes (i.e. binary phase shift keying (BPSK), quadrature phase shift keying (QPSK) and M-quadrature amplitude modulation (M-QAM) technique) w.r.t. peak to average power ratio (PAPR).

Keywords—OFDM, Peak To Average Power Ratio, BPSK, QPSK, 16-QAM, CDF Plots.

I. INTRODUCTION

OFDM, a multicarrier modulation scheme of wireless communications because of its high immunity for multipath fading & high spectral efficiency [1]. OFDM is a combination of schemes like modulation and multiplexing. In this scheme a high data stream is divided into different low data streams that are subsequently modulated into various carriers (orthogonal). Orthogonality of the subcarriers prevents ISI [2],[6]-[8]. OFDM provides various advantages such as immunity for frequency selective fading and narrow band interference, it provides improved spectral efficiency than FDM & it maintains orthogonal relationship between carriers [5]. Hence OFDM provides the better data carrying capacity in comparison with FDM using the same bandwidth. Peak to average power Ratio (PAPR) is considered as one of the major challenge in almost all advanced radio access techniques like OFDM and Multi carrier CDMA etc. Its limiting factor is high PAPR that is the outcome of the nature of modulation [1]. PAPR is calculated from the peak-amplitude of the waveform divided by the average value of the waveform.

Today major challenge in telecommunication is to convey as much information as possible through limited spectral width. Orthogonal frequency division multiplexing (OFDM) introduces the concept of allocating more traffic channels within limited bandwidth of physical channel. In this technique the available bandwidth is divided into a number of channels over which the traffic is transmitted simultaneously. In frequency division multiplexing (FDM) a guard band is provided between individual channels, which separates the spectrum of different channels, and enables a practical band pass filter to detect individual channel. But the situation is completely different in OFDM where spectrums of adjacent channels are overlapped which resembles adjacent channel interference, but interference is avoided by maintaining orthogonal relation between subcarriers [9]. In first step the incoming single high speed data stream is converted to low speed multiple data streams parallel to each other. Output of each parallel line is modulated with orthogonal carriers; therefore transmitted signal is a vector sum of orthogonal modulated carriers. This will results in a large peak to average power ratio. So the dynamic range of devices must be high.

II. PEAK TO AVERAGE POWER RATIO

CREST factor or peak-to-average ratio or peak-to-average power ratio is a measurement of a waveform that is calculated from the peak amplitude of the waveform isolated by the root mean square value of the waveform. PAPR is actually a measure of the factor that how much irregularity in signal amplitude peaks has occurred [1]. If we consider N modulated data symbols from a particular signaling constellation, \( X_k = (X_0, X_1, \ldots, X_{N-1}) \), over a time interval \([0, T]\), the OFDM symbol can be written as:

\[
x(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi f_k t}
\]

Where: \( f = 1/T \). Replacing \( t = nT_b \), where \( T_b = T / N \), we arrive at the discrete time version given by:

\[
x(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi k n / N}
\]

The PAPR of the signal, \( x(t) \), is then given as the ratio of the peak instantaneous power to the average power, written as:

\[
PAPR = \frac{|x(t)|^2}{\langle |x(t)|^2 \rangle}
\]
Where $E[.]$ is the expectation operator. Here two different types of modulation quadrature amplitude shift keying (QPSK) and 16-quadrature amplitude modulation are discussed. We will see the effect on PAPR [4].

III. QUADRATURE AMPLITUDE MODULATION (16-QAM)

Because of its very high spectral efficiency, multilevel quadrature amplitude modulation is an impressive modulation technique for broadband communications. 16-QAM has recently proposed and studied for various non-adaptive and adaptive broadband systems [4]. The need of multimedia applications and services demands an increasing frequency range in broadband systems. High-speed data rate is reliable for communications over insufficient channel bandwidth that is one of the main challenges of harsh wireless environments that push the achievable spectral efficiency far below its theoretical limits [3]. Now, 16-QAM as one of the efficient modulation scheme for the transmission of high data traffic without the need of increasing bandwidth in wireless systems.

In 16-QAM the data bit stream is converted into small data bit streams and assigning each bit stream a different symbol. Where each symbol defines a constellation point for the data signal streams. Such as in a 16-QAM bit streams are applied to different constellation points [3]. Each constellation point tells about a various phase and amplitude as clear from the graph in Fig.1. In the graph the constellation points that are for 16-QAM are represented using Gray Coding technique.

IV. BINARY PHASE SHIFT KEYING MODULATION (BPSK)

BPSK (also called PRK, Phase Reversal Keying, or 2PSK) is the easiest form of phase shift keying. Binary phase shift keying relates to . In BPSK the plane is divided into two parts 180 out of phase therefore it can be represented by 2-PSK. In BPSK the constellation point could be both on real or imaginary axis, but here in Fig.2 we are taking them at real axis by using grey code [4].

V. QUADRATURE PHASE SHIFT KEYING MODULATION (QPSK)

QPSK is also known as quaternary PSK, 4-PSK, quadri-phase PSK, or 4-QAM. The root concepts of QPSK & 4-QAM are different, but the resulting modulated waves match exactly. QPSK is related to so it uses four constellation points. QPSK is able to encode two bits per symbol [11]-[12]). The mathematical analysis b/w QPSK & BPSK reveals that QPSK doubles the data rate retaining the original bandwidth, or maintains the BPSK data rate but use half the bandwidth used by BPSK.
VI. RESULTS OF COMPARATIVE ANALYSIS OF BPSK, QPSK & 16-QAM

For

\[ \text{nfftsize} = 64, \text{subcarrierIndex} = [-26:-1 1:26], \]
\[ \text{nBitPerSymbol} = 52, \]

It is evident from the graph given in Fig.6 that PAPR axis has intermediate values for these specifications but the result of BPSK is best among all of them. The 16-QAM and QPSK shows approximately equal results.

For

\[ \text{nfftsize} = 64, \text{subcarrierIndex} = [-5:-1 1:5], \]
\[ \text{nBitPerSymbol} = 10 \]

It is clear from the graph given in Fig.7 that axis has lower values for these specifications but the result of BPSK is best among all of them. The 16-QAM and QPSK shows approximately equal results.

VII. CONCLUSION

We analyzed effects of various digital modulation techniques on PAPR in OFDM and compared their
characteristics. In case of intermediate values of number of bits per symbol and nFFT size the graphical results shows that PAPR due to BPSK is less as compared to 16-QAM and QPSK the last two techniques shows approximately same results. Whereas in case of lower and greater values of nFFT and number of bits per symbol the PAPR decreases and increases correspondingly but even then the results of BPSK is better as compared to other two techniques.

REFERENCES


