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BER and PAPR Analysis of OFDM for Various Level of Quadrature Amplitude Modulation

Manish Singh
Manish0162@gmail.com

Sandeep Agrawal
sandeep1006@yahoo.com

Abstract – **To achieve better performance using multi carrier modulation one should make the subcarriers to be orthogonal to each other i.e. known as the Orthogonal Frequency Division Multiplexing (OFDM) technique. But the great disadvantage of the OFDM technique is its high Peak to Average Power Ratio (PAPR). This paper is based on analysis of bit error rate (BER) and peak to average power ratio (PAPR).**

Keywords – **Modulation, OFDM, BER, PAPR.**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.

In OFDM data is transmitted simultaneously through multiple frequency bands. It offers many advantages over single frequency transmission such as high spectral efficiency, robustness to channel fading, immunity to impulse interference, and the capability to handle frequency-selective fading without resorting to complex channel equalization schemes. OFDM also uses small guard interval, and its ability to combat the ISI problem. So, simple channel equalization is needed instead of complex adaptive channel equalization.

Orthogonal frequency division multiplexing (OFDM) signals have a generic problem of high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of the OFDM signal. The drawback of the high PAPR is that the dynamic range of the power amplifiers (PA) & digital-to-analog (D/A) converters required during the transmission and reception of the signal is higher. As a result, the total cost of the transceiver increases, with reduced efficiency.

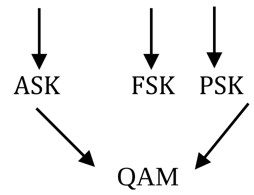
Digital Modulation

In digital modulation, an analog carrier signal is modulated by a digital bit stream (discrete signal). Digital modulation methods can be considered as digital-to-analog conversion, and the corresponding demodulation or detection as analog-to-digital conversion. The changes in the carrier signal are chosen from a finite number of M alternative symbols (the modulation alphabet).

Most fundamental digital modulation techniques are described below:

- In the case of PSK, a finite number of phases are used.
- In the case of FSK, a finite number of frequencies are used.
- In the case of ASK, a finite number of amplitudes are used.
- In the case of QAM, a finite number of at least two phases, and at least two amplitudes are used.

$$v(t) = V sin(2\pi \,.\, ft \,+\, \theta)$$



(1)

Referring to equation (1), if the information signal is digital and the amplitude (V) of the carrier is varied proportional to the information signal, a digitally modulated signal called amplitude shift keying (ASK) is produced. If the frequency (f) is varied proportional to the information signal, frequency shift keying (FSK) is produced, and if the phase of the carrier (θ) is varied proportional to the information signal, phase shift keying (PSK) is produced. If both the amplitude and the phase are varied proportional to the information signal, quadrature amplitude modulation (QAM) results.

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ASK, FSK, PSK, and QAM are all forms of digital modulation.

Peak-to-Average Power Ratio

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal.

The major disadvantages of a high PAPR are:

- Increased complexity in the analog to digital and digital to analog converter.
- Reduction is efficiency of RF amplifiers.

In other words PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. The PAPR of OFDM is defined as the ratio between the maximum power and the average power, The PAPR of the OFDM signal $X(t)$ is defined as:

$$PAPR = \frac{P_{peak}}{P_{average}} = \frac{max[|x_n|^2]}{E[|x_n|^2]} \quad (2)$$

Where x_n = An OFDM signal after IFFT (Inverse Fast Fourier transform)

E [.] = Expectation operator, it is an average power.

The complex baseband OFDM signal for N subcarriers represented as

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi n \Delta f t}, \ (0 \le t \le NT) \quad (3)$$

Bit Error Rate (BER)

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.

$$BER = \frac{No.\ of\ bit\ errors\ recieved}{Total\ number\ of\ bits\ transmitted} \quad (4)$$

Signal-to-Noise Ratio (SNR)

Signal-to-noise ratio (SNR or S/N) is a measure that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power. The ratio is usually measured in decibels (dB). A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

In other words, signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal):

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (5)$$

II. Methodology

Figure 1 shows a baseband transceiver structure for OFDM utilizing the Fourier transform for modulation and demodulation. Here the serial data stream is mapped to complex data symbols (PSK, QAM, etc.) with a symbol rate of $\frac{1}{T_s}$. The data is then T_s demultiplexed by a serial to parallel converter resulting in a block of N complex symbols, X_0 to X_{N-1}. The parallel samples are then passed through a N point IFFT (in this case no oversampling is assumed) with a rectangular window of length $N.T_s$, resulting in complex samples x_0 to x_{N-1}. Assuming the incoming complex data is random it follows that the IFFT is a set of N independent random complex sinusoids summed together. The samples, x_0 to x_{N-1} are then converted back into a serial data stream producing a baseband OFDM transmit symbol of length $T = N.T_s$.

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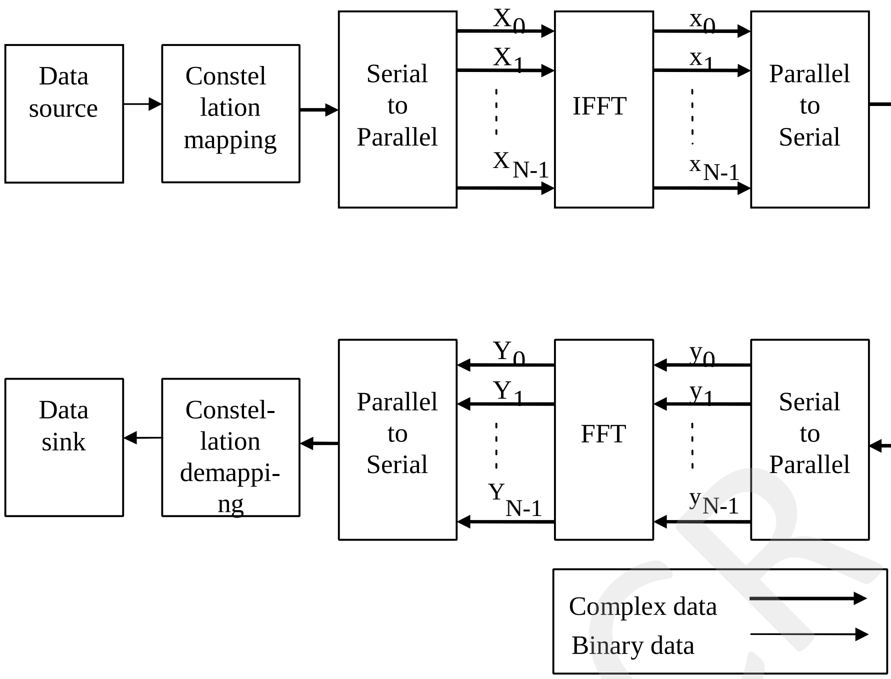

Figure 1: Basic OFDM transmitter and receiver pair utilizing Fourier transform

A Cyclic Prefix (CP), which is a copy of the last part of the samples is appended to the front of the serial data stream before Radio Frequency (RF) up conversion and transmission. The CP combats the disrupting effects of the channel which introduce Inter Symbol Interference (ISI).

In the receiver the whole process is reversed to recover the transmitted data, the CP is removed prior to the FFT which reverses the effect of the IFFT. The complex symbols at the output of the FFT, $Y_0 \,..\, Y_{N-1}$ are then decoded and the original bit steam recovered.

Mathematically the demodulation process (assuming no CP and no channel impairments) using the FFT is equation (1):

$$Y_{m,k} = FFT\{x_{m,n}\}$$

$$= \frac{1}{N}\sum_{n=0}^{N-1} x_{m,n} e^{-j2\pi nk/N}$$

$$= \frac{1}{N}\sum_{n=0}^{N-1}\sum_{d=0}^{N-1} X_{m,d} e^{j2\pi n(d-k)/N}$$

$$= \frac{1}{N}\sum_{d=0}^{N-1} X_{m,d} \sum_{n=0}^{N-1} e^{j2\pi n(d-k)/N}$$

$$= \frac{1}{N}\sum_{d=0}^{N-1} X_{m,d}\, N\delta[d-k]$$

$$= X_{m,k} \quad (5.1)$$

III. SIMULATION AND RESULTS

Simulations are done with MATLAB 2010.

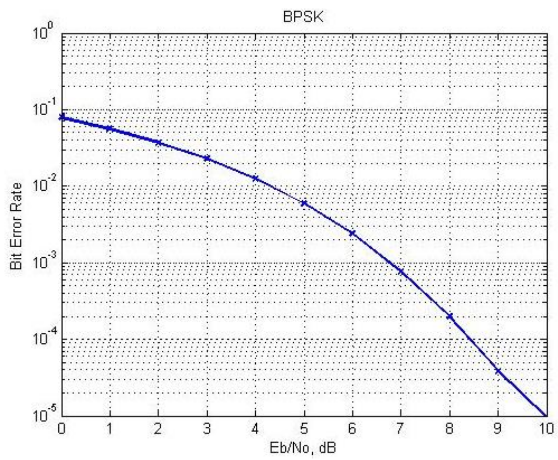

Figure 2: BER v/s SNR graph for BPSK

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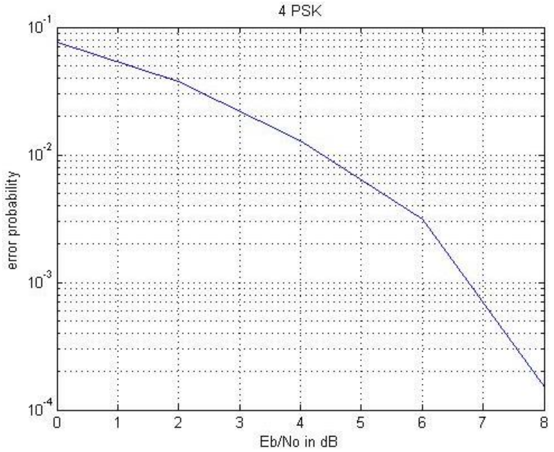

Figure 3: BER v/s SNR graph for 4-PSK

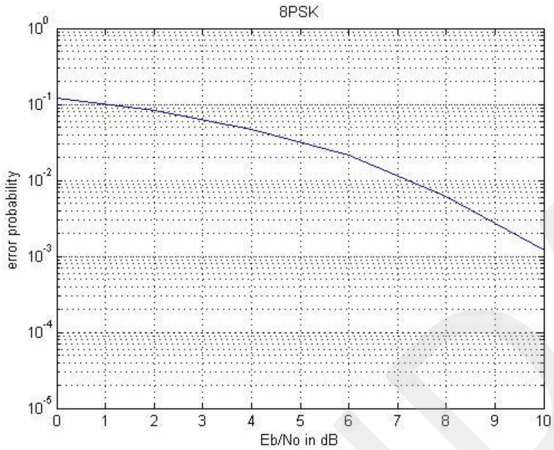

Figure 4: BER v/s SNR graph for 8-PSK

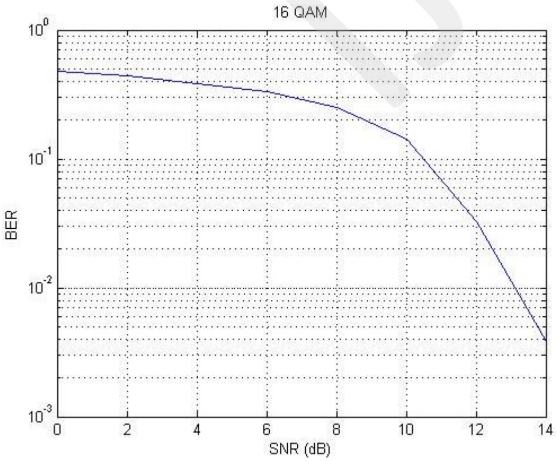

Figure 5: BER v/s SNR graph for 16-QAM

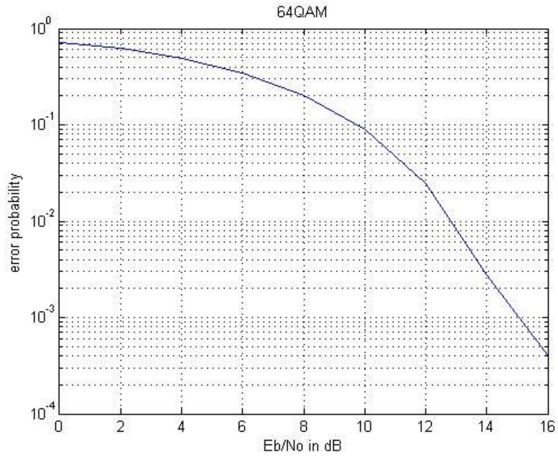

Figure 6: BER v/s SNR graph for 64-QAM

IV. Conclusion

OFDM system under different constellation points has been analyzed and observed that as increasing the constellation points, bit error rate decreased accordingly. Future research could be directed on investigating and quantifying further the influence of PAPR as a function of different modulation mapping schemes, OFDM subcarrier levels, and phasing schemes.

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