American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-1, pp-108-117
www.ajer.org
Research Paper Open Access

Performance Analysis of OFDM Signal Using BPSK and QPSK Modulation Techniques

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ABSTRACT: *High data-rate is desirable in many recent wireless multimedia applications. Traditional single carrier modulation techniques can achieve only limited data rates due to the restrictions imposed by the multipath effect of wireless channel and the receiver complexity. Orthogonal Frequency Division Multiplexing (OFDM) is a potential candidate to fulfill the requirements of current and next generation wireless communication systems. However, Peak-to-Average Ratio (PAPR) and Intercarrier Interference (ICI) are two major challenges in implementing an OFDM system. In OFDM systems use cyclic prefix insertion to eliminate the effect of ISI. In this paper we represent the OFDM signal generation technology using two different modulation techniques step by step and compared them. Here, we also analysis the PAPR performances of two OFDM signals which are generated by using two modulation techniques.*

Keywords: *BER, B-PSK, OFDM, PAPR,Q-PSK .*

I. INTRODUCTION

Orthogonal Frequency-Division Multiplexing (OFDM) is a multi-carrier digital modulation scheme, which uses closely-spaced large number orthogonal sub-carriers. Each sub-carrier is modulated with low symbol rate, maintaining data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The fundamental principle of OFDM originates from the paper by Chang [1], and over the years a number of researchers have worked on this technique [2]-[7]. Despite its conceptual elegance, its use was initially limited to military systems, such as KINEPLEX, KATHRYN and ANDEFT [8] due to its implementation difficulties. Weinstein and Ebert's proposal to use the Discrete Fourier Transform (DFT) to perform the subcarrier modulation with a single oscillator [5] was a pioneering effort. Ebert, Salz and Schwartz demonstrated the efficacy of Cooley-Tukey fast Fourier transform (FFT) algorithm to further reduce the computational complexity of DFT [9], thereby making it possible to utilize the OFDM technique in commercial communication systems. Its use in commercial systems started with a number of wire-line standards, which included High bit rate Digital Subscriber Lines (HDSL) [10], Asynchronous Digital Subscriber Lines (ADSL) [11], and Very high speed Digital Subscriber Lines (VDSL) [11], to support a throughput upto 100Mbps. Thereafter, it has been utilized by wireless standards like DAB [12] and WLAN [13], [14], DVB [15] and WMAN. In WMAN applications, OFDM is considered for the Worldwide Interoperability for Microwave Access (WiMAX) implementation via IEEE 802.16d, a, e [16], [17] standards. OFDM is also being considered for 3GPP Long term Evolution (LTE) and 3GPP LTE-Advanced. Undoubtedly, OFDM can be a potential air interface candidate for future generation high speed wireless communications systems [18]-[21].

OFDM systems use cyclic prefix insertion to eliminate the effect of ISI and require a simple one-tap equalizer at the receiving end. OFDM brings in unparalleled bandwidth savings, leading to higher spectral efficiency. These properties make OFDM system extremely attractive for high speed wireless applications [8]. In OFDM systems different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier.

In this paper we demonstrate the concept and feasibility of an OFDM system, how OFDM signal generates, details of BPSK and QPSK modulation technique and also investigate its performance using two modulation techniques considering PAPR.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

The demand for high speed wireless applications and limited RF signals bandwidth is increasing day by day. New applications are emerging, not just in the wired systems, but also in the wireless mobile systems. At present, only low rate data services are available for mobile applications. However, there is a demand for high data rates for multimedia applications. In single carrier system, the symbol duration reduces with an increase in data rate and therefore the effect of Inter symbol Interference (ISI) becomes more severe. ISI, in wireless communication systems, is produced due to the memory of dispersive wireless channels [22]. As a general rule, the effect of ISI on error performance of the system is negligible, as long as the delay spread is significantly shorter than the duration of one transmitted symbol [18],[23]. This implies that the symbol rate supported by the communication system is practically limited by ISI. If the data rate exceeds the upper limit of data transmission over the channel, a mechanism must be implemented in order to combat the effects of ISI. Channel equalization techniques can be used to suppress the echoes caused by the channel. But such equalizers pose difficulties in real-time systems operating at several Mbps speed with compact, low-cost hardware. Multicarrier modulation techniques come to rescue in such situations.

Multicarrier modulation, and especially OFDM, is one of the promising candidates [8] that employ a set of subcarriers in order to transmit the information symbols in parallel over the communication channel. It allows the communication system to transmit the data at a lower rate on multiple subcarriers and the throughput of multicarrier system remains equal to the single carrier system. This allows us to design a system supporting high data rates, while maintaining symbol durations much longer than the channel delay spread, thus simplifying the need for complex channel equalization mechanism and can easily combat the effect of ISI[18], [19].

2.1 OFDM Signal Generation Technology:

OFDM is a method of encoding digital signal data on multiple carrier frequency and it takes several low data rate frequency channels and then combined them into one high data rate frequency channel. In OFDM data are modulated to time signal and can be generated using Q-PSK, D-PSK, B-PSK etc. Symbols are divided into different frames so that data can be modulated frame by frame during modulation. Figure 1 represents an OFDM transmitting a receiving system.

One requirement of the OFDM transmitting and receiving systems is that they must be linear. If any non-linearity appears then it will cause interference between the carriers as a result of inter-modulation distortion. This will introduce unwanted signals that would cause interference and impair the orthogonally of the transmission [8].

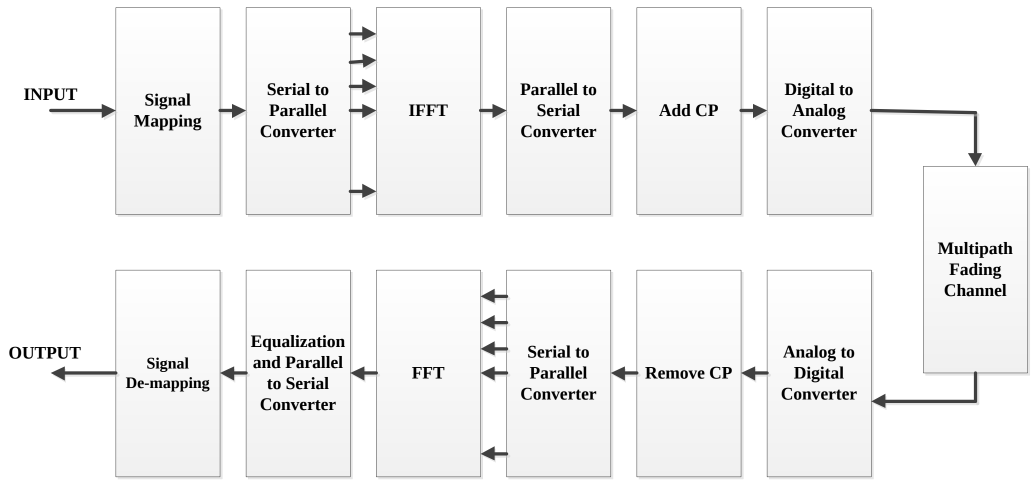


Figure 1: OFDM Transmitter and Receiver.

In terms of the equipment to be used the high peak to average ratio of multi-carrier systems such as OFDM requires the RF final amplifier on the output of the transmitter to be able to handle the peaks whilst the average power is much lower and this leads to inefficiency. In some systems the peaks are limited. Although this introduces distortion that results in a higher level of data errors, the system can rely on the error correction to remove them.

2.2 Data on OFDM

Transmitted data of an OFDM signal is spread across the carriers of the signal and each carrier taking part of the payload. This reduces the data rate taken by each carrier. The lower data rate has the advantage that interference from reflections is much less critical. This is achieved by adding a guard band time or guard interval into the system. This ensures that the data is only sampled when the signal is stable and no new delayed signals arrive that would alter the timing and phase of the signal.

2.3 Benefits of OFDM

There are many advantages of OFDM system for next generation wireless communication.

- High spectral efficiency
- Resiliency to RF interference
- Lower multi-path distortion
- Makes efficient use of the spectrum by allowing overlap.
- By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems are.
- Eliminates ISI and IFI through use of a cyclic prefix.
- Using adequate channel coding and interleaving one can recover symbols lost due to the frequency selectivity of the channel.
- Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
- It is possible to use maximum likelihood decoding with reasonable complexity.
- OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions.
- Is less sensitive to sample timing offsets than single carrier systems are.
- Provides good protection against co channel interference and impulsive parasitic noise.

III. OFDM SIGNAL GENERATION USING DIFFERENT PHASE SHIFT KEYING (PSK) TECHNIQUES

In this paper we showed how to generate an OFDM signal which has maximum data rate with minimum bandwidth requirement. Our main task is to coding an OFDM signal using MATLAB and here we used different phase shift keying methods (BPSK & QPSK) to generate and evaluate OFDM signals.

3.1 Modulation and Demodulation

Analog phase modulation is used less commonly than frequency modulation, but digital phase modulation is used in many devices. Types of digital phase modulation include BPSK, QPSK and DPSK. In digital phase modulation, the phase of the carrier wave is modified by being assigned appropriately to one bit of the information bits.

BPSK: 1-symbol 1-bit composition, where the level of the 1 and 0 information signal is changed to a 1 or -1 dipolar NRZ signal and the phase of the carrier wave is assigned 0 or π.

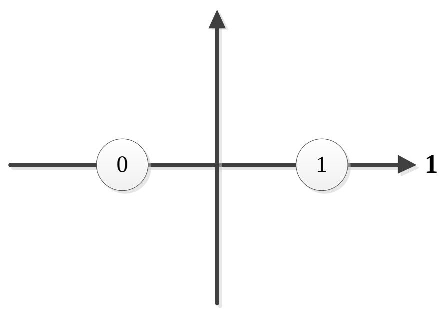
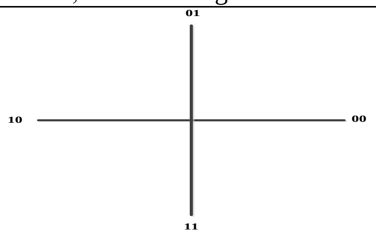


Figure 2: Constellation Diagram of BPSK

QPSK: 1-symbol 2-bit composition, where 2 bits and 4 statuses are assigned to the carrier wave phases π/4, 3π/4, 5π/4, and 7π/4. If this line of thinking is extended, PSK with eight or sixteen values is possible.

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit (2 bits)



Constellation Diagram of QPSK

Figure 3: Constellation diagram of each phase modulation and phase transition.

3.1.1 Basic Theorem of Digital Phase Modulation and Demodulation:

3.1.1.1 BPSK modulation:

In BPSK modulation, the level of the modulating signal (code 0, 1) is changed to a dipolar NRZ signal, and the signal and carrier wave are multiplied with a mixer. The modulating signal spectrum is shifted directly to the carrier frequency.

BPSK modulation changes the phase of the carrier wave C(t) proportionally to the message signal. The carrier wave C(t) is a sine wave with the following properties.

$$C(t) = A_c . \cos(2\pi . F_c . t + \phi_c)$$

The phase of the carrier wave C(t) changed by 0 degrees or 180 degrees by BPSK with regard to the 1-bit 2-status information, resulting in the following formula.

$$S_{psk}(t) = A_c . \cos\{2\pi . F_c . t + \phi_c + \pi . m(t)\}$$

When the initial phase of the carrier wave is $\phi_c = 0$;

$$S_{psk}(t) = A_c . \cos\{\pi . m(t)\} . \cos(2\pi . F_c . t)$$

If p(t) = cos{π.m(t)}, then the BPSK modulated wave Spsk(t) is multiplied by a squarer as follows:

$$S_{psk}(t) = p(t) . C(t) = p(t) . A_c . \cos(2\pi . F_c . t)$$

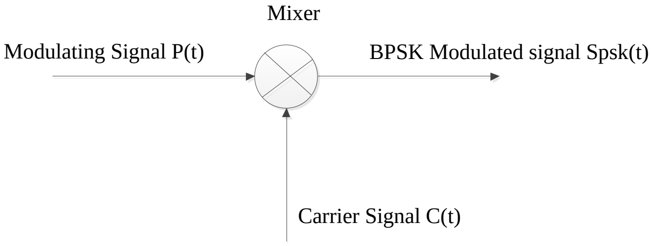


Figure 4: BPSK Modulator

The modulating signal p(t) follows the information signal m(t)(0 or 1), taking the values 1 and -1.

3.1.1.2 BPSK demodulation:

BPSK modulated signal is being demodulated by a synchronous detection system. It uses a modulator to multiply the received signal and regenerated carrier wave. The frequency and phase of the regenerated carrier wave must be synchronized with the carrier wave used on the transmitting end. If multiplication is performed with a regenerated carrier wave that is not synchronized, the amplitude level may vary, the signal polarity may be reversed, and many errors may occur, making it unusable. Frequency multiplication and other methods are used to regenerate the carrier wave.

When the received signal is regenerated, the result is as follows.

$$S_{psk}(t) . C(t) = p(t) . A_c . \cos^2(2\pi . F_c . t) = p(t) . A_c . \frac{1}{2}\{1 + \cos(4 . \pi . F_c . t)\} \qquad (1)$$

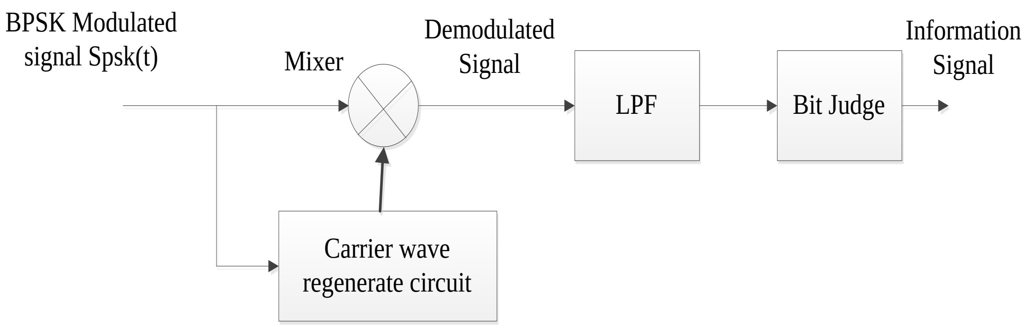


Figure 5: BPSK demodulator

The second term in the braces is an unwanted component, so LPF processing is performed to recover the signal component only.

$$\langle S_{psk}(t) . C(t) \rangle_{LPF} = \frac{A_c}{2} p(t) \qquad (2)$$

3.1.1.3 QPSK modulation:

With QPSK, 2 bits of the information signal can be expressed with 1 symbol. The constellation of QPSK is shown in the figure 6. As shown in the figure below, information is assigned to the π/4, 3π/4, -π/4 and -3π/4 phases of the carrier wave as 00, 01, 10 and 11 respectively.

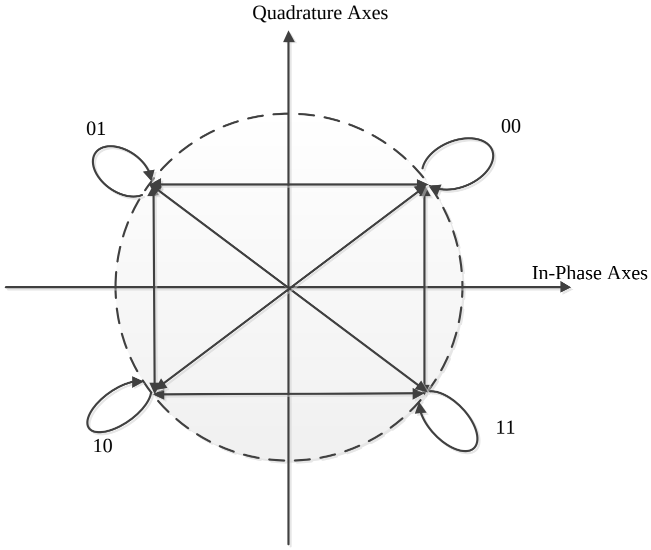


Figure 6: QPSK constellation Diagram

QPSK modulation can be expressed as changing the phase of the I and Q carrier wave C(t) proportionally to the information signal. The carrier waves Ci(t) and Cq(t) are sine waves with the following properties.

$$C(t) = A_c . \cos(2\pi . F_c . t + \phi_c) \quad (3)$$

As in the figure 7, QPSK modulation is achieved by multiplication of the I and Q components of the dipolar NRZ modulating signal and the I and Q carrier waves with a mixer based on the information, and adding the two signals. The information signal is divided into an I component signal and Q component signal by the P/S conversion unit and both are input in the mixer.

$$C_i(t) = A_c . \cos(2\pi . F_c . t) \quad (4)$$

$$C_q(t) = A_c . \sin(2\pi . F_c . t) \quad (5)$$

$$S_{qpsk}(t) = P_i(t) . C_i(t) + P_q(t) . C_q(t) = P_i(t) . A_c . \cos(2\pi . F_c . t) + P_q(t) . A_c . \sin(2\pi . F_c . t) \quad (6)$$

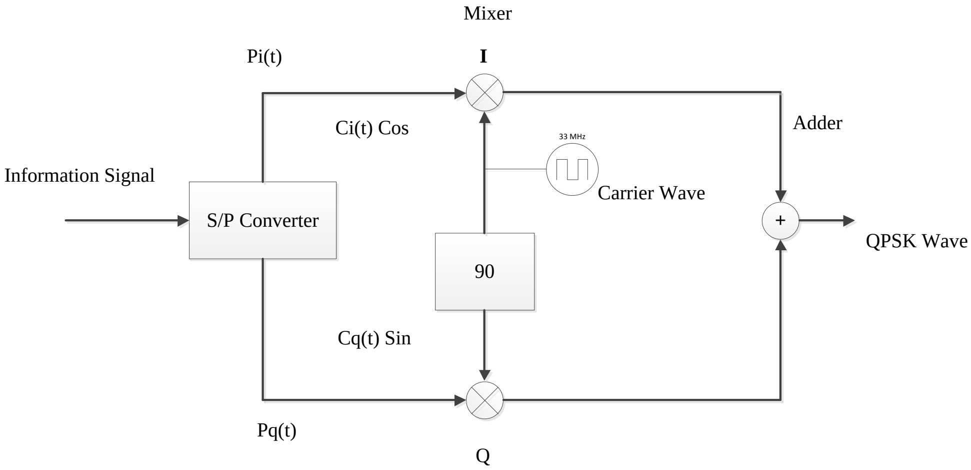


Figure 7: QPSK Modulator

3.1.1.4 QPSK demodulation:

In QPSK demodulator the received signal is multiplied by a reference frequency generators (cos(ωt)) and (sin(ωt)) on separate arms (in-phase and quadrature arms). The multiplied output on each arm is integrated over one bit period using an integrator. A threshold detector makes a decision on each integrated bit based on a threshold. Finally the bits on the in-phase arm (even bits) and on the quadrature arm (odd bits) are remapped to form detected information stream. For quadrature arm the below architecture remains same but sin(ωt) basis function must be used instead.

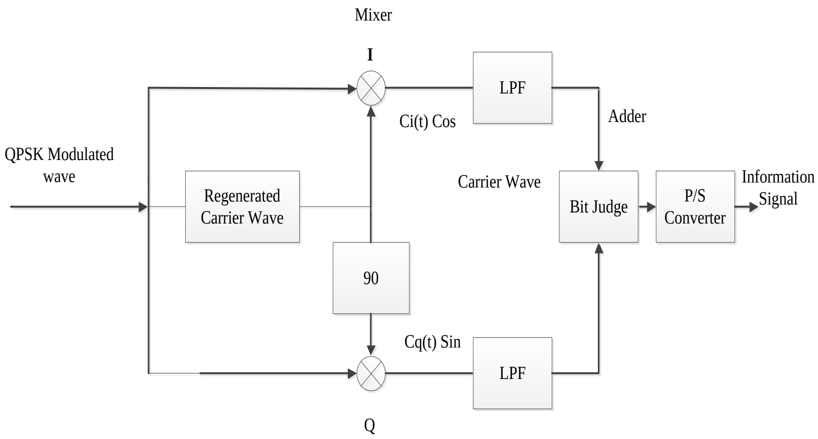


Figure 8: QPSK Demodulator

IV. SIMULATION AND RESULTS

To analysis the OFDM signal we assume some common data in table 1.

Table 1: Some common data to generate OFDM signals

Number of bits per channel extended	64 extended to128
Number of subcarrier channel (M)	4
Total number of bits to be transmitted at the transmitter (n)	256
Size of each OFDM block to add cyclic prefix	16

Different Steps are performed in MATLAB to generate OFDM signal using different phase shift keying method. First we generate a random message signal. Figure 1 represents a random message signal. After that the message signal is converted in to two forms using two PSK (BPSK & QPSK) techniques which shown in figure 10 & 11, then we generate two OFDM signal for two different modulated signals, shown in figure 12 & 13. Finally we generate the PAPR performance of two OFDM signals which represents in figure 14.

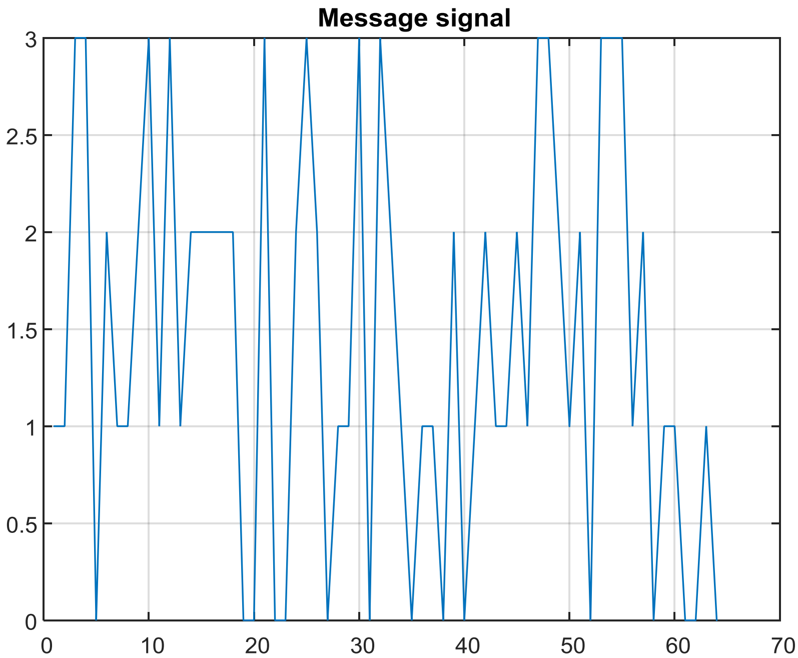


Figure 9: Message Signal

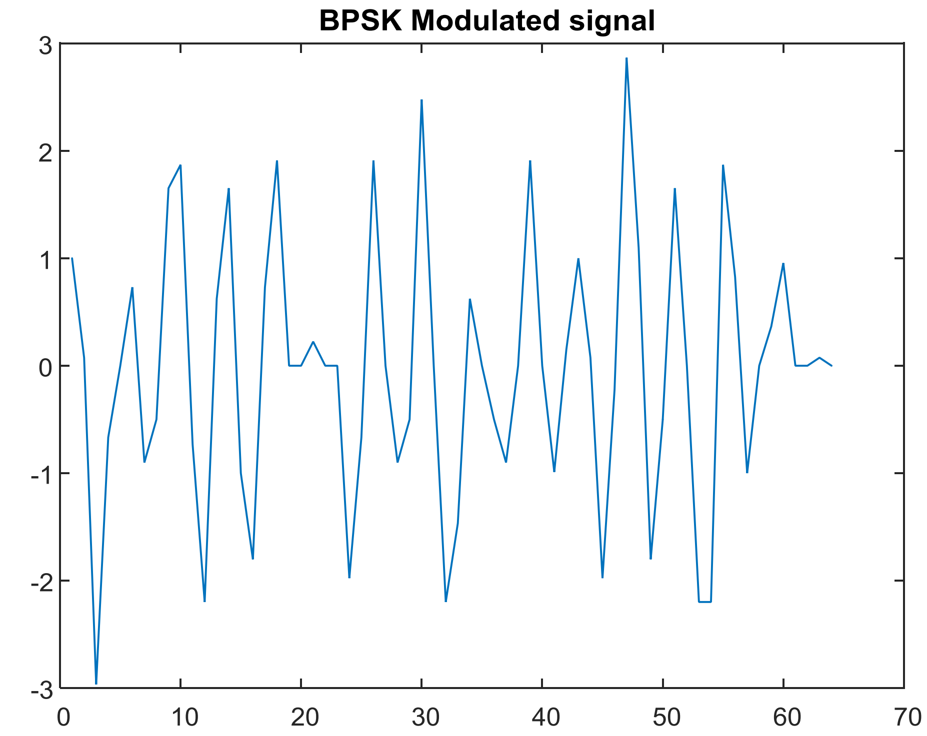


Figure 10: BPSK modulated Message signal

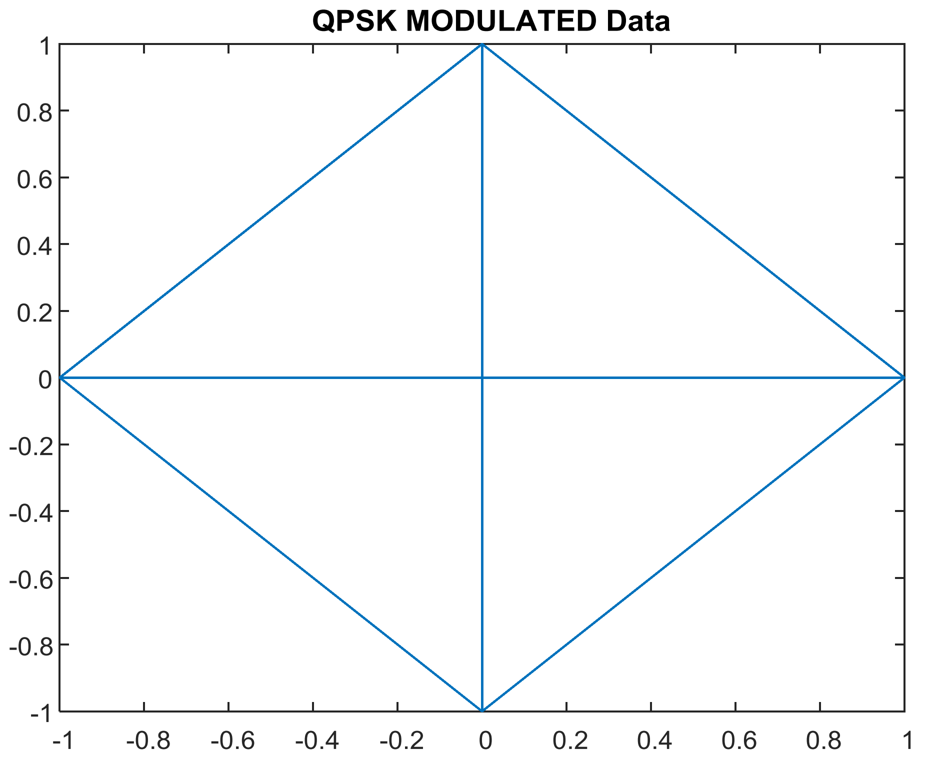


Figure 11: QPSK modulated Message signal

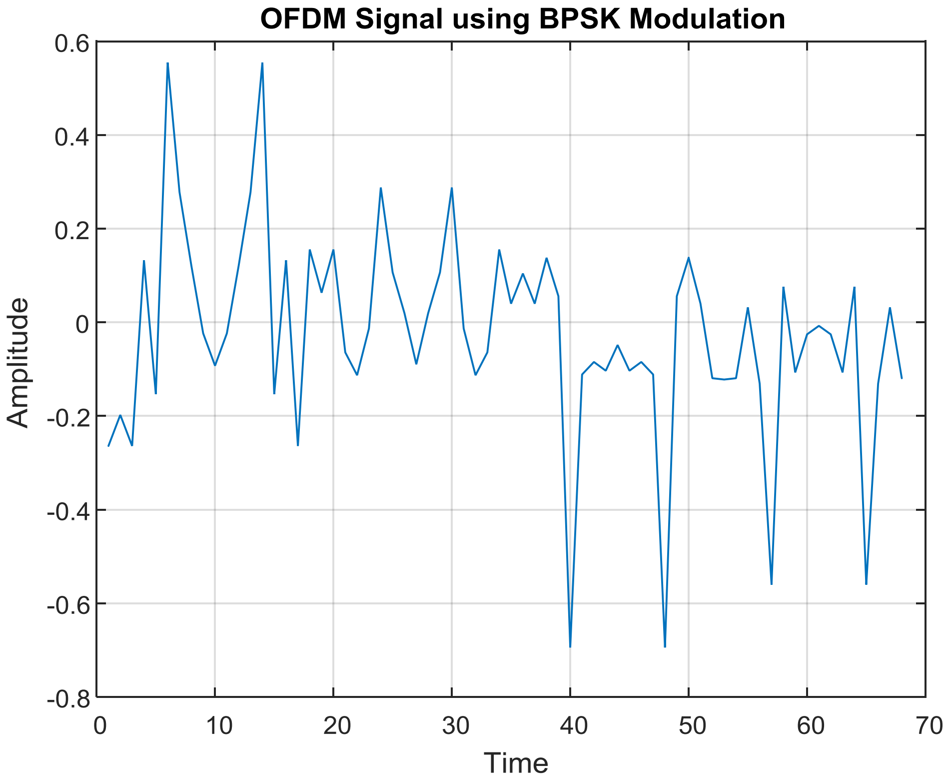


Figure12: OFDM signal using BPSK modulation Technique.

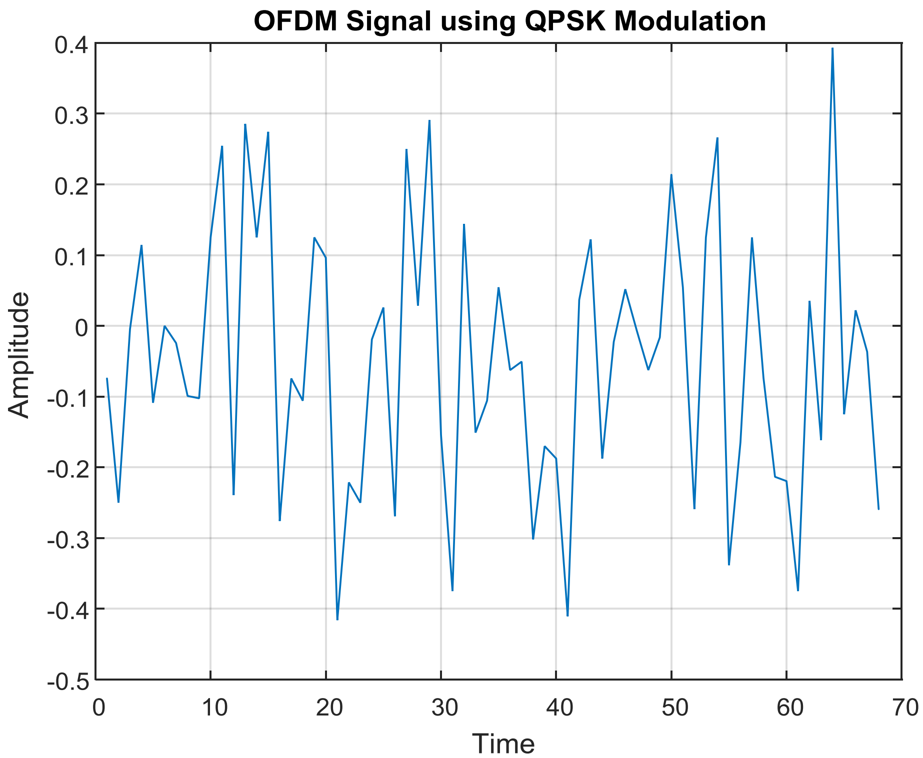


Figure 13: OFDM signal using QPSK modulation Technique.

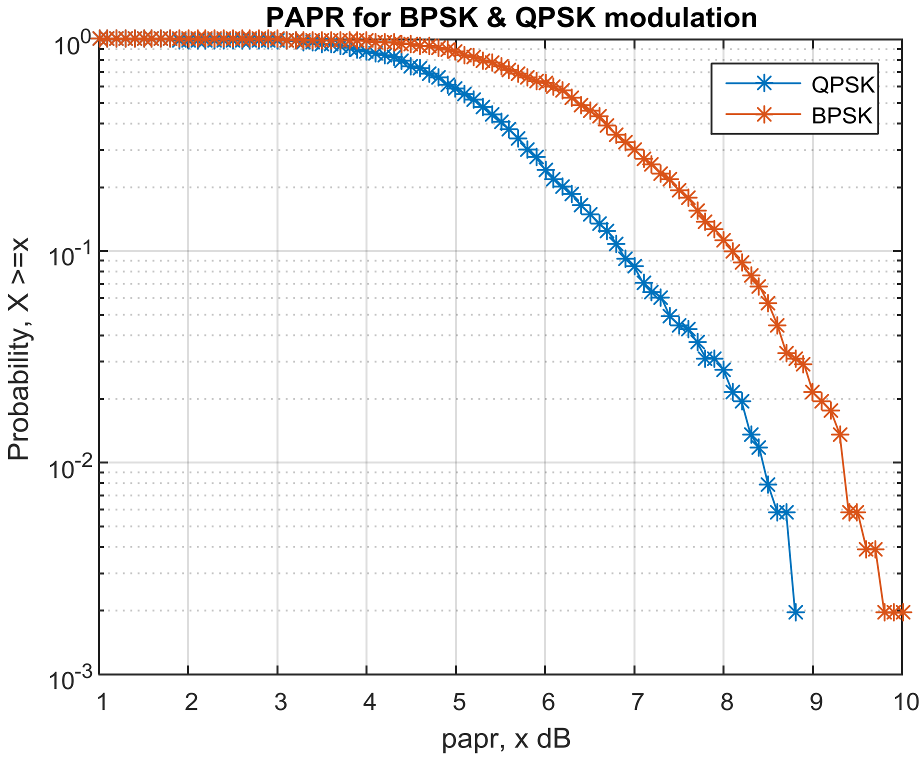


Figure 14: PAPR performance of BPSK & QPSK modulated OFDM signals.

V. CONCLUSION

OFDM is the latest multi carrier transmission techniques used in today's wireless communication system arena. In practice, OFDM signal is generated by using Inverse Fast Fourier Transform (IFFT) algorithm of sub carriers and Fast Fourier Transform (FFT) algorithm of received signal. Here conventional modulated scheme (Quadrature Phase Shift Keying, Binary Phase-shift keying) is used to generate and analyze the OFDM signal. We observed that the data rate of OFDM signal is very high with lower requirements of bandwidth. Here we evaluate two OFDM signal using two modulation techniques. The data rate of BPSK is lower than the QPSK signal but also bit error rate is lower than QPSK. The main problem of OFDM system is high peak generation which is higher in BPSK system compared to QPSK system, as well as PAPR is also higher.

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