Simulating the Performance Characteristic of Passband Modulation Techniques in MATLAB Environment

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Abstract

Now days, digital communication systems become complex and sophisticated. Not all vendors, if any, can understand the system and components of system that represent different modulation techniques, line and block coding, multiplexing and multiple access.

They need the conclusion about which of modulation techniques is the suitable for transmission and in the same time can save the power and bandwidth.

Engineers can study and analyze the modulation techniques and then compare between them to give such conclusion using modeling and simulation.

MATLAB is a high level mathematical language for technical computing.

In this paper we use MATLAB environment as simulation software to give on display a clear result that used to compare between two digital Passband modulation techniques BPSK and QPSK, and pinpoint the performance of the two techniques over selected parameters.

Keywords: simulation, modulation, performance parameters, MATLAB

1. Introduction

Nowadays, digital modulation techniques are the most widely used in communication systems. We need to achieve higher data rates in limited bandwidth of spectrum to improve the performance of transmission.

A great deal of interest for a digital Passband digital transmission system that is bandwidth efficient with low signaling rate and high data rate and provide low Bit Error Rate (BER) at a relatively low Signal to Noise Ratio (SNR). Various digital modulation schemes are well described in different literatures but cannot fulfill actual requirement in different kind of varying environment until studded and analyzed.

Recently, a large number of research papers which study the modulation techniques were published. In (Masud, 2010), authors have investigated the performance analysis of M-ary modulation techniques when the digital communication system is subjected to Additive White Gaussian Noise (AWGN) and multipath Rayleigh fading in the channel. The study has been performed by using MATLAB program for the simulation and evaluation of BER and SNR for W-CDMA system models. It shows that the analysis of quadrature phases shift key and 16-ary quadrature amplitude modulations which are being used in wideband CDMA system, Therefore, the system could go for more suitable modulation technique to satisfy the channel quality, thus can deliver the optimum data rate to mobile user.

The paper (Samson, 2013) analyzed the performance of different passband modulation techniques in AWGN channel and multipath fading channel. This study examined the inherent attributes of the digital modulation to overcome the channel impairments and was carried out to understand the contributions of channel characteristics to effective wireless communication and made comparison between the two channels. The BER for simulated modeled channels agreed with the theoretical results. It was found that the performance of 64-QAM is better compared to other passband modulation schemes in AWGN Channel. It was also observed that the BER is higher in frequency selective channel as compared to the AWGN channel and was also observed that multipath fading

channel characteristic limits the data rate in wireless communication.

Authors in (Hemant, 2014) have presented the impact of various modulation parameters towards the modulation and demodulation processes. In addition, it has been proven that MATLAB simulation environment can play an important role towards the understanding of subject matter.

In (Rashmi, 2011), a general theoretical approach in studding various M-ary modulation schemes using MATLAB taking the BER as the measure of performance when the system is affected by AWGN and multipath Rayleigh fading channel is developed. Based on these performances a desirable modulation scheme is simulated that provides low BER at low received SNR, performs well in multipath and fading conditions, occupies a minimum of bandwidth and is easy and cost effective to implement in modern communication system.

In (Virendrakumar, 2014), (Tharakanatha, 2013), (Xiaolong, 2008), authors are implementing various binary and M-ary modulation schemes in MATLAB by using different SIMULINK tool boxes.

An efficient and effective methodology for teaching digital and analog modulation types to undergraduate students enrolled in an Information Technology program which does not require a strong foundation in mathematics as in the case of engineering program is provided in (Boulmalf, 2010). The implemented approach utilizes MATLAB program, SIMULINK, and Communication Blockset to simulate digital modulation techniques avoiding the derivation of mathematics formulations and without complex coding.

Research paper contains introduction to the subject with literature review. Section 2 introduces MATLAB software and environment. 3^d section presents the simulation of modulation and demodulation process in BPSK and QPSK using MATLAB environment. Sections 4-7 devoted for the performance parameters, data rate, bit error rate, capacity, PSD respectively. Finally, conclusion and literature references are included.

2. MATLAB Software and Environment

MATLAB is a mathematical computing environment with 4th generation programming language and interactive environment that enables engineers to perform intensive calculations based tasks very simply. Developed by Math works (http://www.mathworks.com), MATLAB allows matrix manipulation, plotting of functions and data in tables and curves, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. MATLAB has been widely adopted in the academic community, industry and research centers. It was originally written to provide easy access to LINPACK and EISPACK software packages (Gilat, 2004), (www.mathworks.com/products/simulink), (Quarteroni, 2006), (Ferreira, 2009), (Leon, (2001). The MATLAB software provides the researchers with a large collection of toolboxes and modules for a variety of applications in many fields of interest.

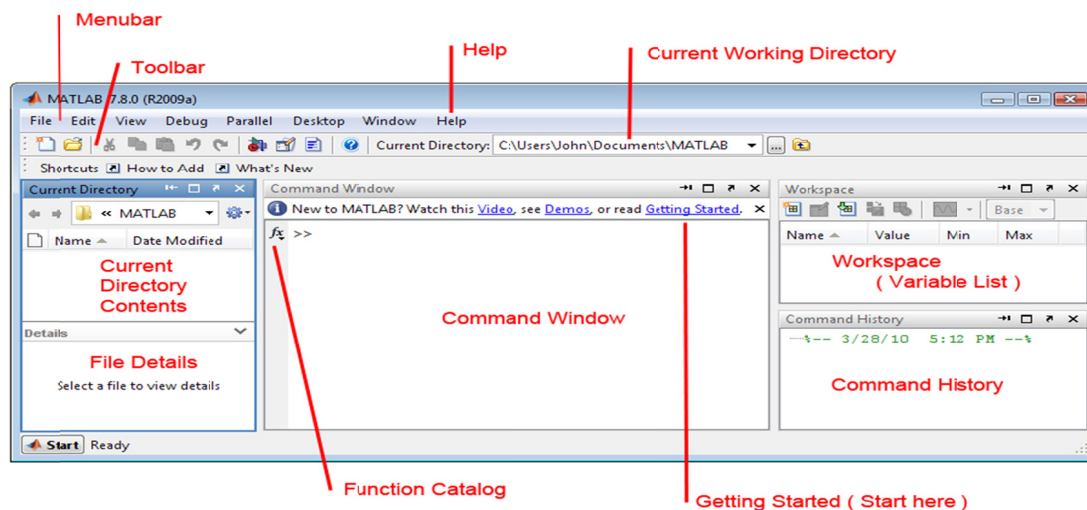Figure 1 demonstrates the basic MATLAB work environment and commands.

Figure 1. The MATLAB work environment

3. Simulation of Modulation and Demodulation

Here, to demonstrate the simulation using MATLAB environment we compare two will-known and basic passband modulation techniques BPSK and QPSK. These methods are still used in different modern communication systems.

3.1 BPSK Technology

BPSK modulation is a basic technique used in various wireless standards such as CDMA, Imax (16d, 16e), WLAN 11a, 11b, 11g, 11n, Satellite, DVB and cable modem. BPSK considered to be more robust among all the modulation schemes due to the 180° difference between two constellation points. Hence it can with stand severe amount of channel conditions or channel fading. It is used in OFDM and OFDMA to modulate the pilot subcarriers used for channel control.

Different channels are used for specific data transmission in cellular systems. The channels used to transmit system related information which are very essential are modulated using BPSK modulation.

BPSK is less susceptible to error than ASK, also is more efficient to use of bandwidth (higher data rate is possible). BPSK modulation and demodulation code was written in MATLAB environment. The result of running this program is shown in figure 2.
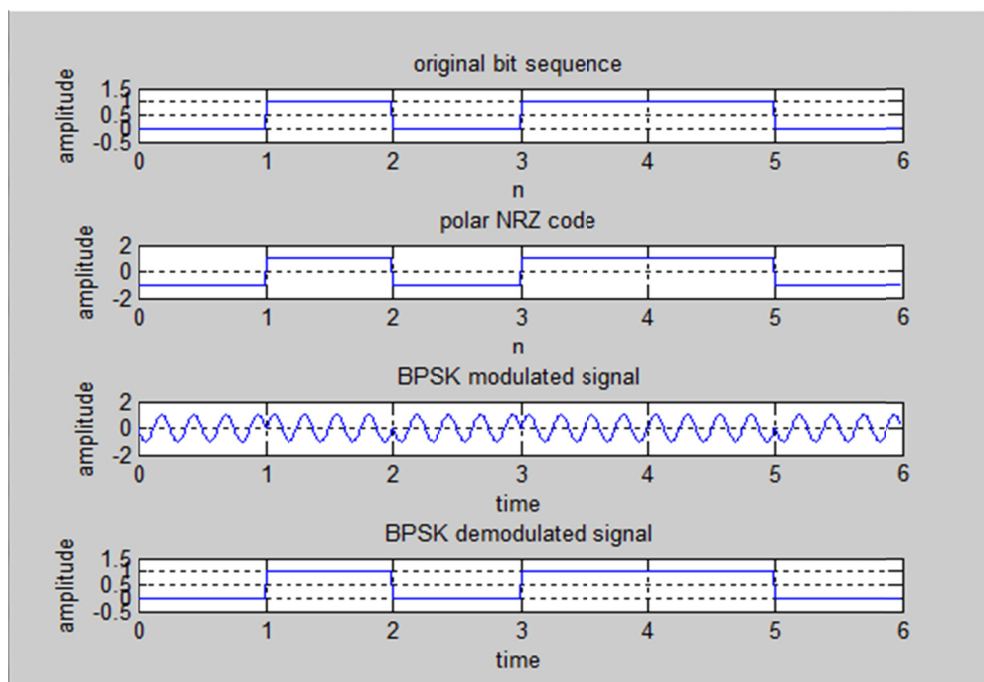

Figure 2. Simulation of Modulation and demodulation using BPSK in MATLAB

3.2 QPSK Technology

QPSK used widely in applications including CDMA cellular phone, wireless local loop, Iridium (a voice/data satellite system) and DVB-S (Digital Video Broadcasting — Satellite). QPSK is used for satellite transmission of MPEG-2 video also used in video conferencing.

With four phases, QPSK can encode two bit per symbol, to minimize the required bandwidth, twice the rate of BPSK in the same bandwidth. This may be used either to double the data rate compared to a BPSK system while the maintaining the bandwidth of the signal or to maintain the data rate of BPSK but half bandwidth needed.

As with BPSK, there are phase ambiguity problems at the receiver and differentially encoded QPSK is more normally used in practice. Another advantage of QPSK is the use of differential DQPSK. Here the phase shift is not relative to a reference phase of a signal but relative to the phase of previous two bit. The receiver does not need the reference signal but only compares two signals to reconstruct the original data.

The phase shift can always be relative to reference signal. If this scheme used, phase shift of 0 means that the

signal is in phase with reference signal. QPSK signal will then exhibit a phase shift of 45$^\text{o}$ for the data 11, 135$^\text{o}$ for 10, 225$^\text{o}$ for 00 and 315^0 for 01, with all phase shifts being relative of the reference signal.

Inter channel interference (ICI) is significantly large in QPSK. To avoid ICI QPSK requires filtering which can change amplitude and phase of QPSK waveform. QPSK requires a round 8 times its bandwidth to transmit the same power.

The disadvantage of QPSK relative to BPSK is that it is more sensitive to phase variation. Transmitter and receiver have to be synchronized very often, example by using special synchronization patterns before user data arrives or via pilot frequency as reference.

QPSK modulation and demodulation code was written in MATLAB environment. The result of running this program is shown in figure 3.

We enter [0 0 0 1 1 1 0] as an original sequence to the simulation program and taking in to account the Gray code we got the result as shown in figure 3.
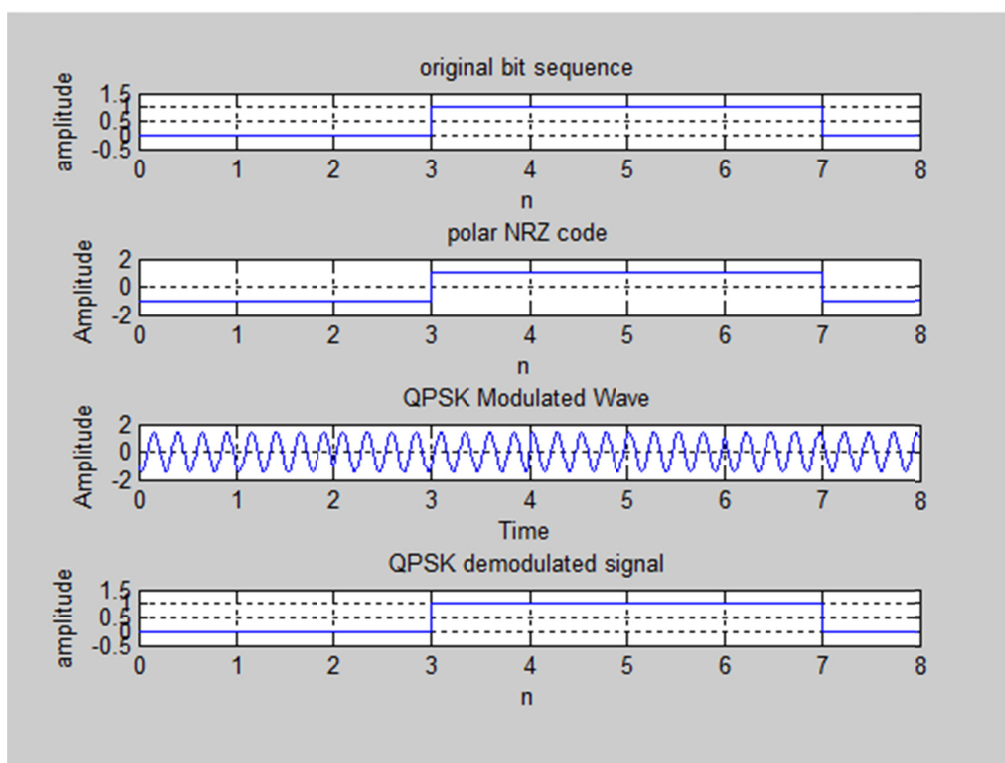

Figure 3. Simulation of Modulation and demodulation using QPSK in MATLAB

4. Nyquist Data Rate

Data rate is a parameter associated with the rate of data transferred between two or more computing or telecommunicating devices. Bit rate describes how much binary digits or bits can be transferred in a given time, normally in one second. Mostly data rate is measured in Mbps. Data rate is proportional to the bandwidth of communication channel not to information signal bandwidth. If the bandwidth is high, data rate will be also high.

In our situation we assume that the bandwidth is the same for BPSK and QPSK channels. According to the formula $R_b = 2B \times \log_2 L$, where L is the number of levels. In QPSK L is larger than the in BPSK, this leads to make the bit rate of QPSK larger than BPSK.

The Data Rate code of QPSK and BPSK was written in MATLAB environment, a part of which shown below. The result of running this program confirms the above idea and shown in figure 4.

```
BW=1:30
Rb_B=log2(2)/2.*BW*10^6
Rb_Q=log2(4)/2.*BW*10^6
plot(BW,Rb_B,'-rs')
hold on
plot(BW,Rb_Q,'-b*')
grid on
legend('BPSK','QPSK')
xlabel('BW (MHz)')
ylabel('Rb (bps)')
title('Bandwidth Vs. Data rate')
```

From figure 4, we can see that at the same bandwidth for example at 10 MH$_Z$, QPSK shows twice superiority on BPSK in data rate
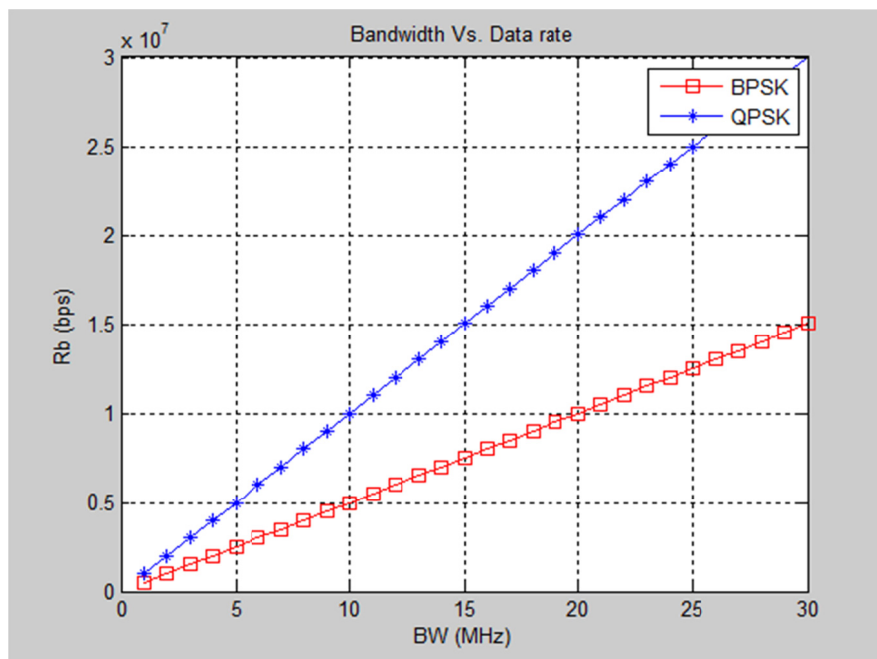

Figure 4. Data rate for BPSK and QPSK in MATLAB

5. Bit Error Rate

In digital transmission, the number of bit errors is the number of received bits of over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.

BER is the number of bit errors divided by the total number of transferred bits during a studied time interval.

Also the definition of bit error rate can be presented in a simple formula; the equation below is the ratio of energy consumed in bit E_b to the signal spectral noise N_0 and represent bit error rate in BPSK $BER = 0.5 \, erfc \sqrt[2]{E_b/N_0}$. For QPSK using Q parameter $BER = Q\sqrt{E_b/N_0}$. Based on these BER formulas, a code was written in MATLAB environment. The result of running this program is shown in figure 5.
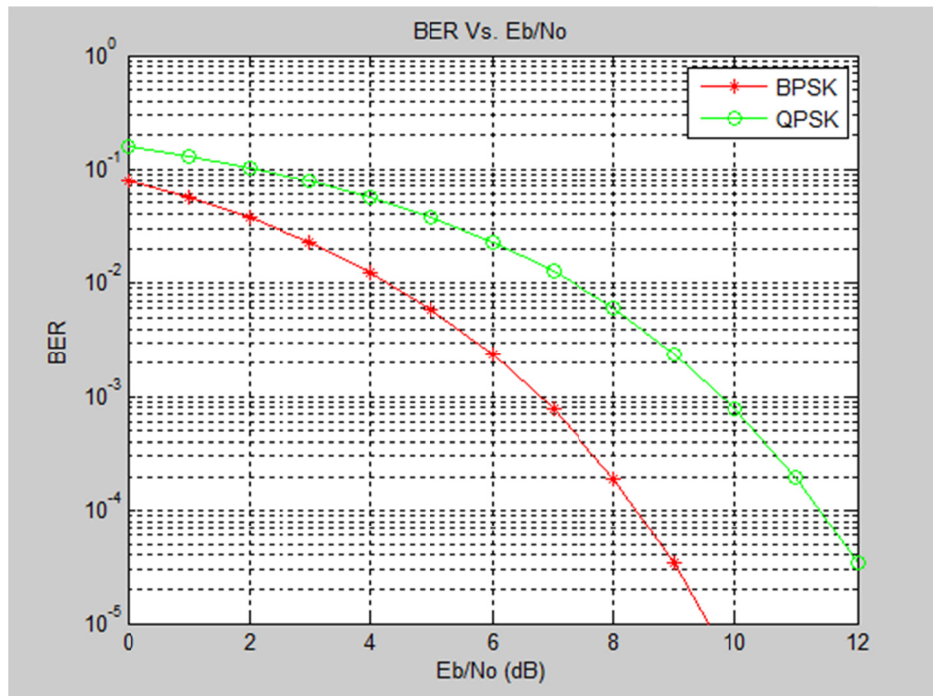
Figure 5. Bit error rate for BPSK and QPSK in MATLAB

To achieve the same BER, for example 10^{-4}, BPSK needs less energy as 8.5 dB, while QPSK needs 11.4 dB.

6. Capacity and Signal to noise ratio

Signal to noise ratio is expressed as $SNR = P_{signal}/P_{noise}$. The SNR for BPSK is very low means that it provides high immunity to noise as compare to the signal floating through the medium. The capacity is calculated as $c = B \times \log_2\left(SNR + 1\right)$. Figure 6 represents SNR of BPSK and QPSK as result of running MATLAB code.
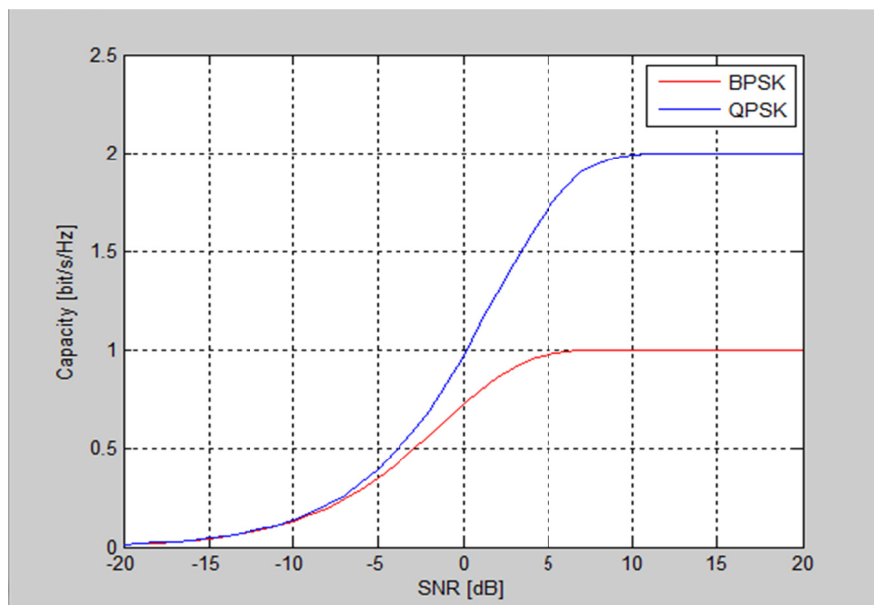

Figure 6. Capacity versus SNR for BPSK and QPSK

The capacity of QPSK is twice of BPSK at the same SNR.

7. Power Spectral Density

Power spectral density function (PSD) shows the power as a function of frequency. PSD shows at which frequencies variations are strong and at which variations are weak. Computation of PSD is done by fast Fourier transform.

The formula of PSD for BPSK modulation is $S_B\left(f\right)=2E_b Sinc^2\left(T_b f\right)$ and for QPSK modulation is

$$S_B\left(f\right)=4E_b Sinc^2\left(T_b f\right).$$

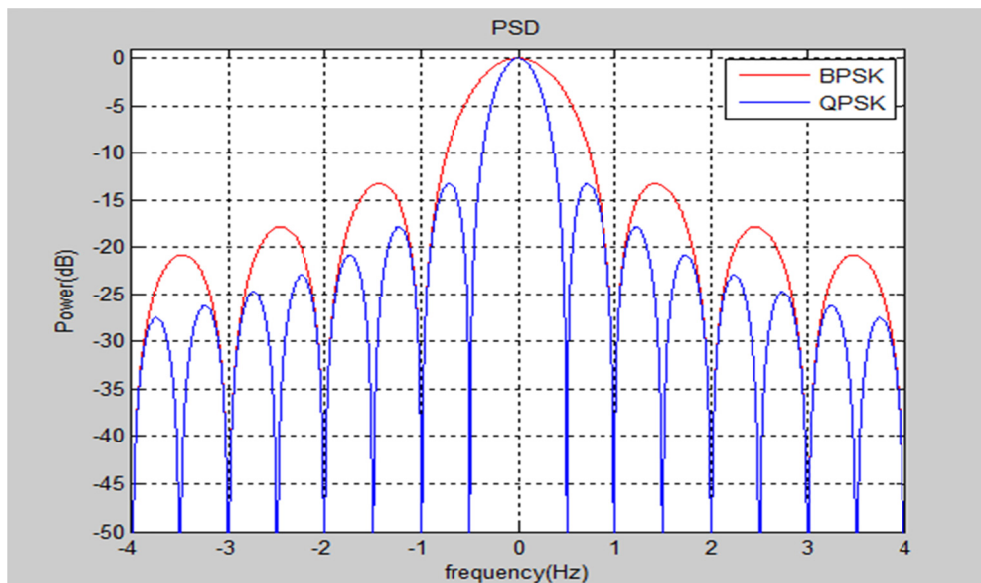Figure 7 represents PSD for BPSK and QPSK as result of MATLAB code.

Figure 7. PSD for BPSK and QPSK

8. Conclusion

In this paper, we had presented two kinds of digital modulation techniques BPSK and QPSK which are widely used in wireless communication system.

We used MATLAB for the simulation and comparison between BPSK and QPSK over a set of performance parameters. We can conclude that:

- Bandwidth and data rate of QPSK is better than BPSK.
- Bit error rate is less occurred in BPSK unlike QPSK.
- Signal to noise ratio of QPSK is better than BPSK.
- Power spectral density of BPSK and QPSK are the same.

All of these expected and theoretical results prove the suggested idea of using MATLAB environment for the simulation of passband modulation techniques.

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