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# BER and SER Based Performance Analysis of BPSK and QPSK Modulation Schemes with OFDM in Rayleigh Fading Channel

Authors

**Neha Mukul[1], Shailendra Singh Pawar[2], Mohd. Sarwar Raeen[3]**

[1]Electronics and Communication, All Saints' College of Technology
Bhopal, M.P.
[2]Electronics and Communication, All Saints' College of Technology
Bhopal, M.P.
[3]Electronics and Communication, All Saints' College of Technology
Bhopal, M.P.

**Abstract**

*BER is a key property of the digital communication system. Various types of modulation methods are used in the digital information transmission system. BER can be demarcated as the number of received bits of a data stream over a communication channel that can be affected due to noise, interference and distortion or bit synchronization errors. OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected. The BPSK digital modulation technique for OFDM system over AWGN and Rayleigh fading channels. From comparison we can observe that the OFDM- BPSK modulation has no any specific advantage over a conventional BPSK modulation scheme in AWGN channel but OFDM-BPSK modulation in AWGN channel has great advantage over OFDM-BPSK modulation in Rayleigh fading channel. The performance of BER of BPSK over AWGN and Rayleigh channel is compared. Simulation of BPSK signals is carried with both AWGN and Rayleigh channel. The work provides link level performance analysis of non-line of sight QPSK-OFDM data transmission over Rayleigh fading channels. Two scenarios have been considered in this thesis. Firstly, the performance of BPSK-OFDM and QPSK-OFDM over the AWGN and Rayleigh channel was obtained.*

**Keywords:** *OFDM,QPSK,BPSK,AWGN,RAYLEIGH CHANNEL*

## 1 INTRODUCTION

### 1.1 An overview of wireless channel model

In digital communication theory the most frequently assumed model for a transmission channel is the additive white Gaussian noise (AWGN) channel. However, for many communication systems the AWGN channel is a poor model, hence the need to resort to more precise and complicated channel models. One basic type of non-Gaussian channel, which frequently occurs in practice, is the fading channel. A typical example of such a fading channel is the mobile radio channel, where the small antennas of portable units pick up several multipath reflections. As a result, the mobile channel exhibits a time varying behavior in the received signal energy, which is called fading. In the communications literature, most often we encounter two types of fading definitions for the mobile radio channel, and they are called large-scale fading and small scale fading. Large-scale fading usually is defined as the average signal power attenuation or path loss due to motion over large areas. This depends on the presence of obstacles in the signal path, on the position of the mobile unit and its distance from the transmitter.

## 2. Fading

### 2.1 Rayleigh fading

Rayleigh fading is a model that can be used to describe the form of fading that occurs when multipath propagation exists. In any terrestrial environment a radio signal will travel via a number of different paths from the transmitter to the receiver. The most obvious path is the direct, or line of sight path. However there will be very many objects around the direct path. These objects may serve to reflect, refract, etc the signal. As a result of this, there are many other paths by which the signal may reach the receiver. When the signals reach the receiver, the overall signal is a combination of all the signals that have reached the receiver via the multitude of different paths that are available.

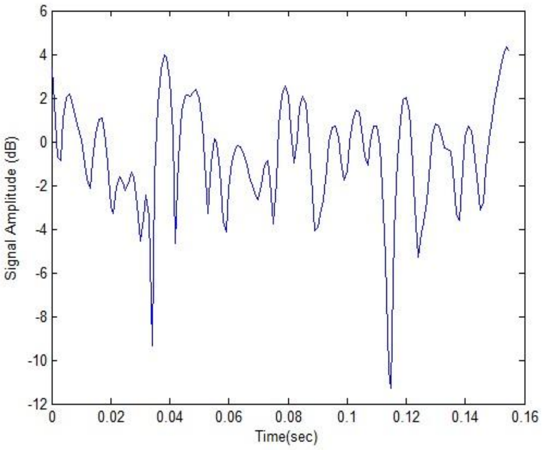



**Fig 2.1** A typical Rayleigh fading envelope

**Table 2.1:** Cumulative Distribution for Rayleigh distribution

| Signal level (dB about median) | % Probability of Signal Level Being less than the value given |
|---|---|
| 10 | 99 |
| 0 | 50 |
| -10 | 5 |
| -20 | 0.5 |
| -30 | 0.05 |

### 2.2 Rayleigh Multipath Channel Model

When there are large numbers of paths, applying Central Limit Theorem, each path can be modelled as circularly symmetric complex Gaussian random variable with time as the variable. This model is called Rayleigh fading channel model. A circularly symmetric complex Gaussian random variable is of the form,

Z=X+jY ...... (a)

where real X and imaginary Y parts are zero mean independent and identically distributed Gaussian random variables.

For a circularly symmetric complex random variable Z,

E[Z]=E[$e^{j\theta}Z$]=$e^{j\theta}E[Z]$

The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance,

$\sigma^2 = E[Z^2]$

The magnitude |Z| which has a probability density,

P(z)=$\frac{x}{\sigma^2}\frac{-x^2}{e^{2x^2}}$ $\quad z \geq 0$

It is called a Rayleigh random variable. This model, called Rayleigh fading channel model, is reasonable for an environment where there are large numbers of reflectors. The channel is modelled as n-tap channels with each the real and imaginary part of each tap being an independent Gaussian random variable. The impulse response is,

h(t)=$\frac{1}{\sqrt{n}}[h_t(t-t_1)+h_2(t-t_2)+\cdots+h_n(t-t_n)$ (b)

Where, $h_t(t-t_1)$ is the channel coefficient of the first tap, $h_2(t-t_2)$ is the channel coefficient of the second tap and so on. The real and imaginary part of each tap is an independent Gaussian random variable with mean 0 and variance 1/2. The term $\frac{1}{\sqrt{n}}$ is for normalizing the average channel power over multiple channel realizations to 1.

### 2.3 BPSK Modulation

BPSK is the simplest form of PSK. It uses two phases which are separated by 180° and so can also be termed 2-PSK. For BPSK modulation the channel can be modelled as

$y = ax + n(13)$ (c)

where, y is the received signal at the input of the BPSK receiver, x is the modulated signal transmitted through the channel , a is a channel amplitude scaling factor for the transmitted signal usually 1

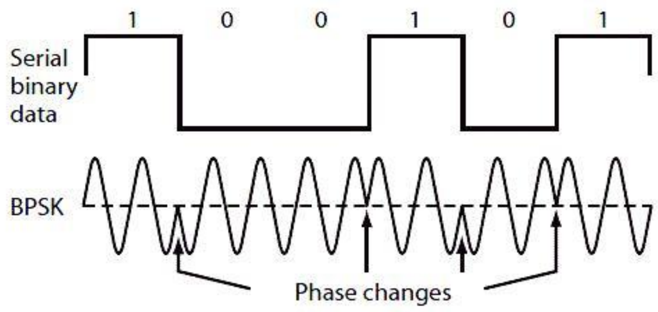



**Fig 2.2** In Binary phase sift keying a binary 0 is $0^0$ while a binary 1 is $180^0$

'n' is the Additive Gaussian White Noise random variable with zero mean and variance $\sigma^2$. For AWGN the noise variance in terms of noise power spectral density ($N_0$) is given b,

$\sigma^2 = \frac{N_0}{2}$ (d)

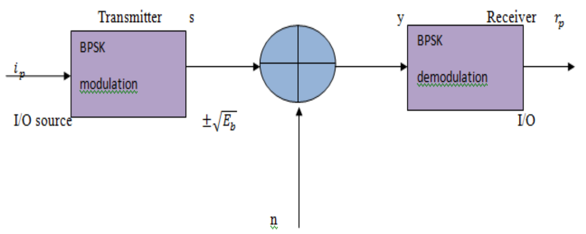



**Fig 2.3** Block Diagram of BPSK transmitter-receiver

The theoretical BER for BPSK modulation scheme over an AWGN channel is given by

$p_b = \frac{1}{2}\text{erfc}(\sqrt{\frac{E_b}{N_0}})$ (e)

For BPSK modulation schemes the symbol energy is given by

$E_S = R_c E_b$ (f)

where $E_S$=Symbol energy per modulated bit (x), $R_c$ is the code rate of the system if a coding scheme is used. In our case since no coding scheme is used $R_c$ =1. $E_b$ is the Energy per information bit. Assuming Es=1 for BPSK (Symbol energy normalized to 1)

$\frac{E_b}{N_0} = \frac{E_s}{R_c N_0}$ (g)

From the above equation the noise variance for the given $\frac{E_b}{N_0}$ can be calculated as

$\sigma^2 = \left(2R_c \frac{E_b}{N_0}\right)^{-1}$ (h)

For the channel model random function in Matlab is used to generate the noise term. This function generates noise with unit variance and zero mean. In order to generate a noise with sigma σ for the given Eb/No ratio , use the above equation , find σ, multiply the 'random' generated noise with this sigma , add this final noise term with the transmitted signal to get the received signal. Now, the BER for BPSK in a Rayleigh fading channel is defined as Eb/N0 can be represented as,

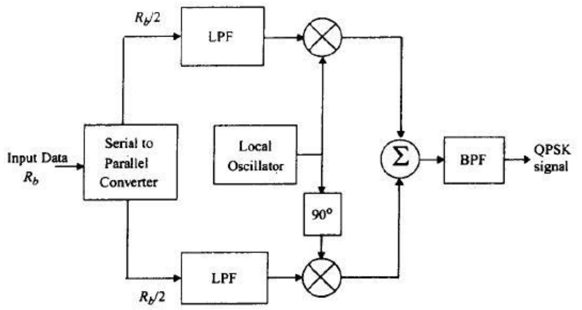
$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{E_b/N_o}{E_b/N_o+1}}\right)$ (i)

Since there is only one bit per symbol that is why the BER for BPSK both in AWGN and Rayleigh fading channel is also defined only intern of the symbol error rate.

### 2.4 QPSK Modulation and Demodulation

There are different modulation schemes that can be used to modulate the data:-namely BPSK,QPSK,FSK,etc. In space communication power is severely limited. FSK is not generally used as it would require very high bandwidth to modulate our data resulting in very low bandwidth efficiency. Higher constellation QAM also can't be used in our case as that would require very high

C/N ratio. The choice is between QPSK and BPSK. The advantage of BPSK is that it requires the lowest C/N ratio. The drawback is that the data rate achieved using BPSK is very low. QPSK is basically two BPSK links operating on the same channel with their carriers in phase quadrature. Therefore the BER of a QPSK remains the same as BPSK. At the same time the data rate is doubled. The only penalty we pay is in terms of C/N ratio. QPSK requires 3 dB more C/N ratio than BPSK. This project demands high date rate without losing much on bandwith and power. Because of these tradeoffs is decided on using QPSK modulation scheme for the raw data received from the rover. The following block diagram shows a simplified QPSK modulator and demodulator.




QPSK modulation and demodulation

## 2.5 OFDM system

OFDM has the property that it combines the modulation and multiplexing techniques to improve spectral efficiency. A transmission channel is divided into many smaller sub channels or subcarriers. The subcarrier frequencies and spacing are chosen so they are orthogonal to one another. Their spectra won't interfere with one another, then, so no guard bands are required. Most broadband systems are subject to multipath transmission. Conventional solution to multipath is equalizer in the receiver but for high data rates equalizers are too complicated. With OFDM there is a simple way of dealing with multipath which makes use of relatively simple DSP algorithms. OFDM solves the problem of multipath by transmitting the data in parallel with longer symbol period and by cyclic prefix to reduce Inter Symbol Interference. In OFDM parallel data streams are used as inputs to an IFFT.

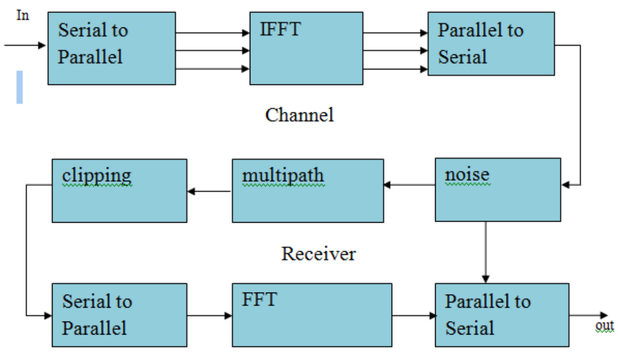



**Fig 2.4** Block diagram of OFDM

## 3. METHODOLOGY

In this paper we simulated Bit error-rate performance using MATLAB. Bit-error-rate testing requires a transmitter, a receiver, and a channel. Bit error-rate performance is usually depicted on a two dimensional graph. The ordinate is the normalized signal-to-noise ratio (SNR) expressed as Eb /N0: the energy-per-bit divided by the one-sided power spectral density of the noise, expressed in decibels (dB). Here, in this paper we simulate the BPSK and QPSK modulation and OFDM-BPSK and OFDM-QPSK modulation in AWGN and Rayleigh channel. The aim of this work is MATLAB implementation for modulation system. The design specifications are verified using MATLAB. We obtain a theory and a simulation result.

1 Simulation model

The attached Matlab simulation script performs the following:

(a) Generation of random binary sequence

(b) QPSK/BPSK modulation i.e. bit 0 represented as -1 and bit 1 represented as +1

(c) Assigning to multiple OFDM symbols where data subcarriers from -26 to -1 and +1 to +26 are used, adding cyclic prefix,

(d) Convolving each OFDM symbol with a 10-tap Rayleigh fading channel. The fading on each symbol is independent. The frequency response of fading channel on each symbol is computed and stored.

(e) Concatenation of multiple symbols to form a long transmit sequence

(f) Adding White Gaussian Noise

(g) Grouping the received vector into multiple symbols, removing cyclic prefix

(h) Converting the time domain received symbol into frequency domain

(i) Dividing the received symbol with the known frequency response of the channel

(j) Taking the desired subcarriers

(k) Demodulation and conversion to bits

(l) Counting the number of bit errors

(m) Repeating for multiple values of Eb/No

2.Simulation System Model

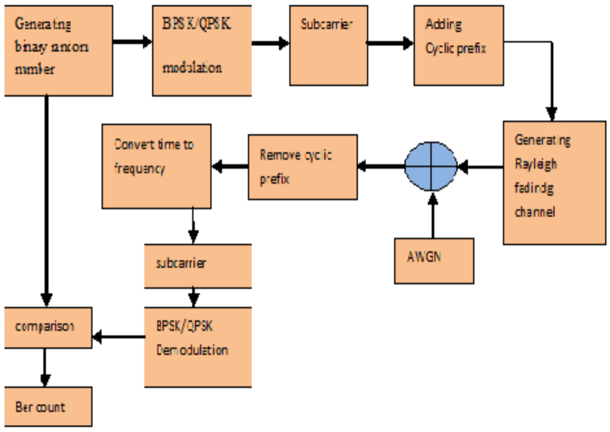



**Fig 3.1** Simulation model of OFDM

## 4.RESULT AND DISCUSSION

**Simulation and results**

OFDM system parameters used for simulations

| Parameter | Value |
|---|---|
| FFT size. nFFT | 64 |
| Number of used subcarriers. nDSC | 52 |
| FFT Sampling frequency | 20MHz |
| Subcarrier spacing | 31205kHz |
| Used subcarrier index | {-26 to -1, +1 to +26 } |
| Cyclic prefix duration, Tcp | 0.8us |
| Data symbol duration, Td | 302us |
| Total symbol duration, Ts | 4us |
| Modulation method | BPSK,QPSK |

The BER performance of BPSK/QPSK digital modulation with OFDM technique over AWGN and Rayleigh fading channels, respectively. The performance of BER of BPSK/QPSK modulation has been investigated by means of a computer simulation using MATLAB. Both the AWGN and Rayleigh fading based OFDM systems are implemented using MATLAB programming and the graphical results found show the bit error rate probabilities of both the systems. The results presented show the BER/SER performance as a function of the energy per bit to noise ratio. The OFDM technique MATLAB simulations are based on 802.11a specifications that shown in table. The BER/SER performance of an OFDM system with BPSK/QPSK modulation over AWGN channel and N = 64 is shown in Figures. From the simulation result we can observe that the theoretical and simulated results of BPSK modulation over AWGN channel are the same.

In Figure 4.1 shows the BER performance of conventional BPSK modulation over AWGN channel. It can be seen that the BER performance of conventional BPSK modulation is almost same with the BPSK using OFDM over an AWGN channel. From the simulation result we can observe that the theoretical and simulated results of BPSK modulation over AWGN channel are the same.

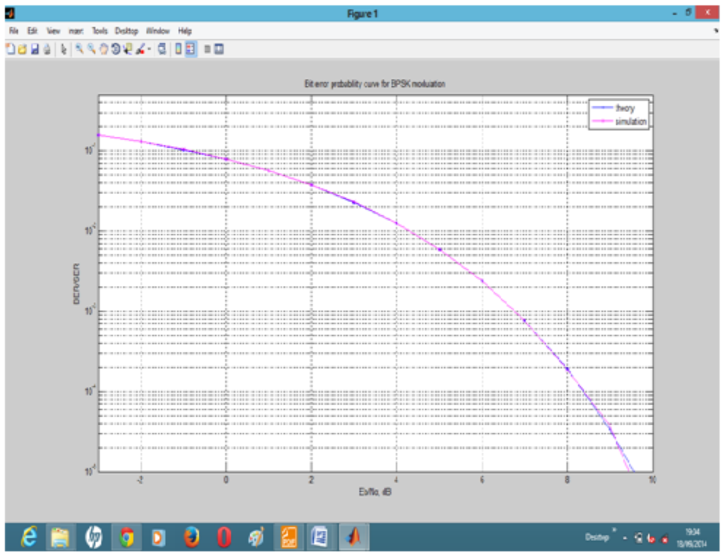


**Figure 4.1**: BER/SER curve for BPSK modulation

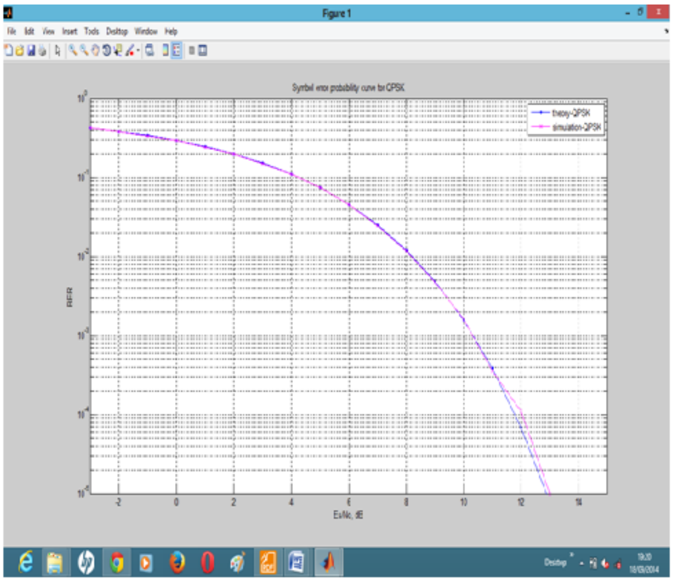



**Figure 4. 2** Ber curve for QPSK modulation

Figure 4.2 shows the BER performance of QPSK modulation over AWGN channel. It can be seen that the BER performance of QPSK is almost same with the QPSK using OFDM over AWGN channel.

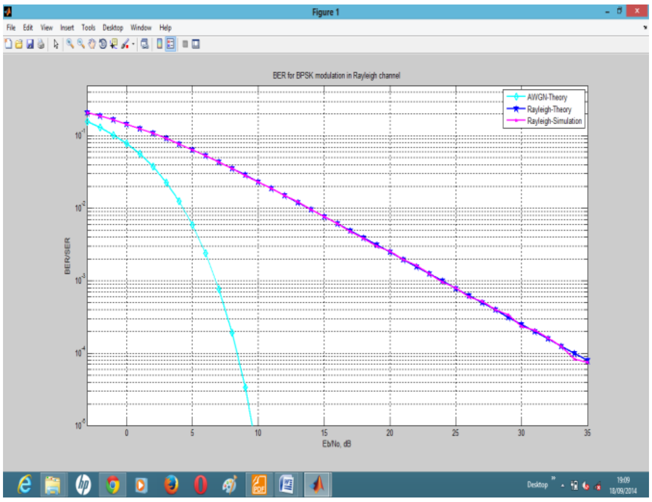



**Figure 4.3** Ber/Ser curve for BPSK modulation in Rayleigh channel

When compared to the AWGN case, around 25dB degradation due to the multipath channel (at the $10^{-4}$point). This is both good and bad: bad because we need to spend so much energy to get a reliable wireless link up (in this era of global warming), and good because we signal processing engineers are trying to figure out ways for improving the performance.

Here, in the figure 4.4 which is the Ber curve of QPSK in Rayleigh channel, it is clear that the simulation result of QPSK over Rayleigh channel is much differ as compared to theoretical results of QPSK in AWGN and Rayleigh channel. There is a large ber difference between the simulation and theoretical results of QPSK.

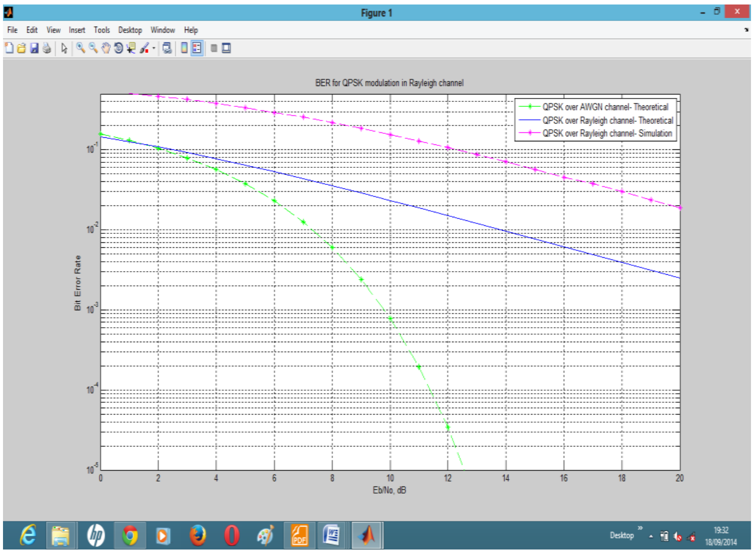



Figure 4.4 Ber curve for QPSK modulation in Rayleigh channel

The BER performance of an OFDM system with BPSK modulation over AWGN channel and N = 64 is shown in Figure 6.3. From the simulation result we can observe that the theoretical and simulated results of BPSK modulation over AWGN channel are the same.

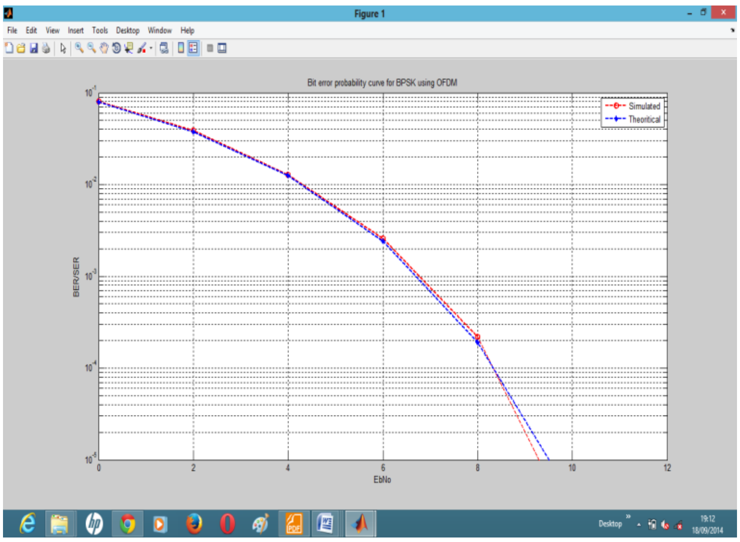



**Figure 4.5** Ber/ser curve for OFDM-BPSK modulation in AWGN

The Ber performance of an OFDM system with QPSK modulation over AWGN channel and N=64 is shown. From the result it is observed that the simulation result of QPSK is differ from the theoretical result of QPSK. But the theoretical result of OFDM and QPSK modulation over AWGN are the same.

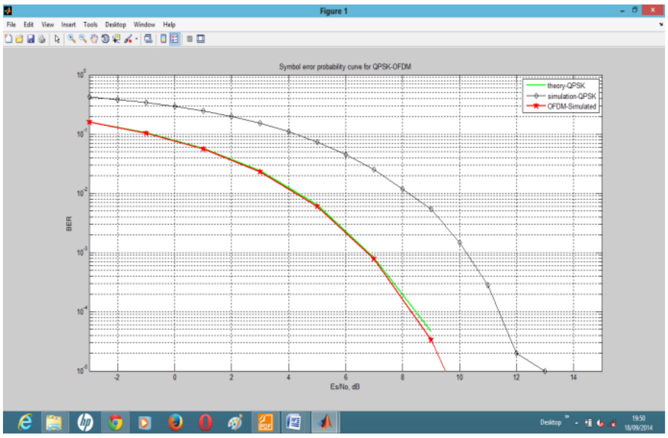



**Figure 4.6** Ber curve for OFDM-QPSK modulation in AWGN

The BER/SER performance of an OFDM system with BPSK modulation over Rayleigh channel. Figure 6.4 shows the BER/SER performance of an OFDM system having N=64 and BPSK modulation scheme over frequency flat Rayleigh multipath fading channel, where the number of taps are used 10 in calculating the theoretical BER/SER value. In OFDM system the size of FFT is 64 and no. Of subcarriers are 52 with sampling frequency of 20MHz. The numbers of taps do not introduce much deviation to the real performance given by simulation results. Comparing the theoretical BER/SER for Rayleigh equation, it is identical with the simulation result. we observe that the OFDM-BPSK modulation in AWGN channel has a specific advantage over a BPSK-OFDM in RAYLEIGH channel.

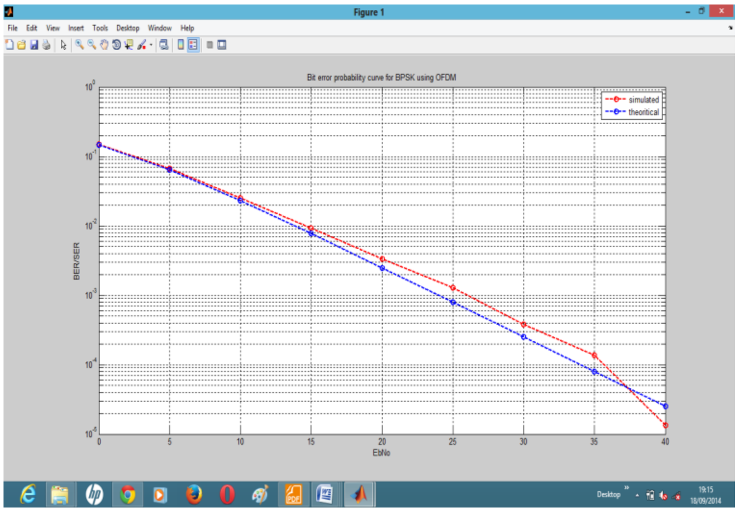



**Figure 4.7** Ber/ser curve for BPSK-OFDM in Rayleigh channel

In figure 4.8 OFDM system the size of FFT is 64 and the subcarriers are 52 with sampling frequency of 20MHz. The numbers of taps do not introduce much derivation to the real performance given by simulation results. Comparing the theoretical BER for Rayleigh equation, it is identical with the simulation result. It is observed that OFDM-QPSK modulation in AWGN channel has a advantage over QPSK-OFDM in Rayleigh channel.

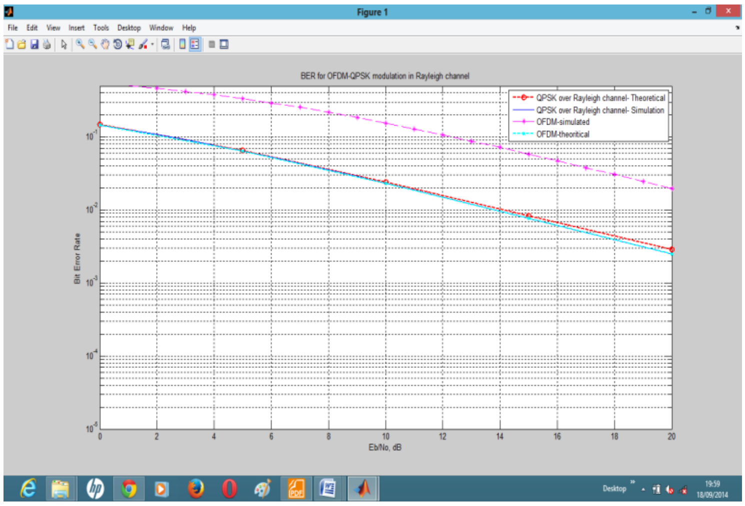



**Figure 4.8** Ber curve for OFDM-QPSK in Rayleigh channel

SER curves in QPSK

In this figure, the symbol error rate of QPSK in Rayleigh channel. In this the theory and simulation of the QPSK in AWGN channel is almost same. And the QPSK theoretical and simulation results in Rayleigh channel is same. The SNR or S/N is equal to Eb/No means that- if we multiply the Eb/No to fb/B than it is equal to the SNR.

$S/N=\frac{E_b}{N_o}(fb/B)$

Where,

B=channel bandwidth

Fb=channel data rate

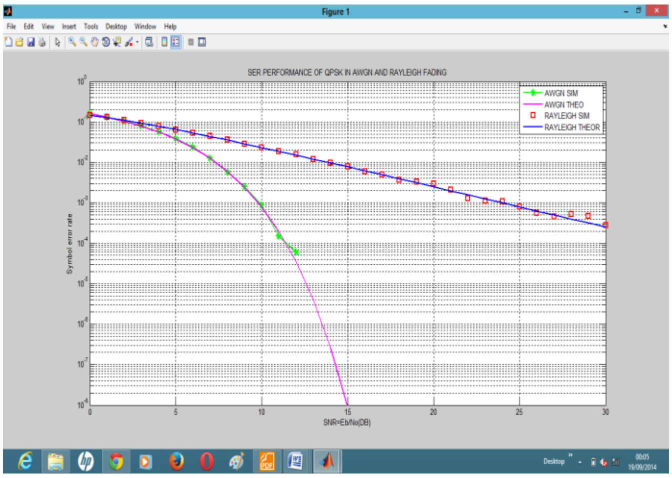



**Figure 4.9** Ser curve for QPSK in Rayleigh channel

Comparison graph between BPSK-QPSK

In this figure, it is observed that the performance of BPSK is gives better performance as compared to QPSK.

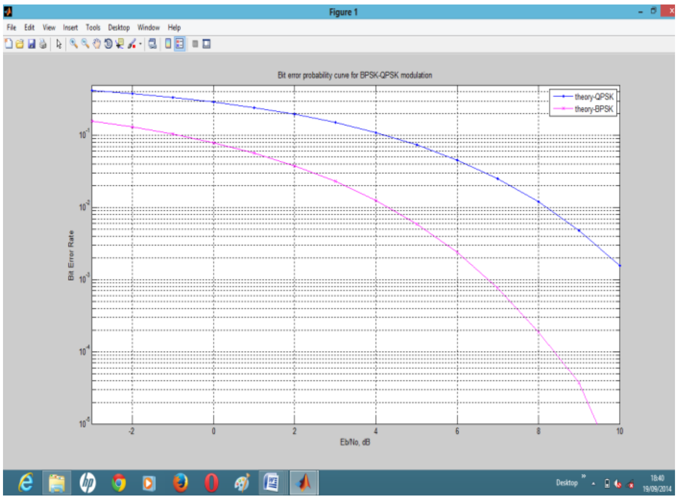



**Figure 10** Ber curve for BPSK-QPSK

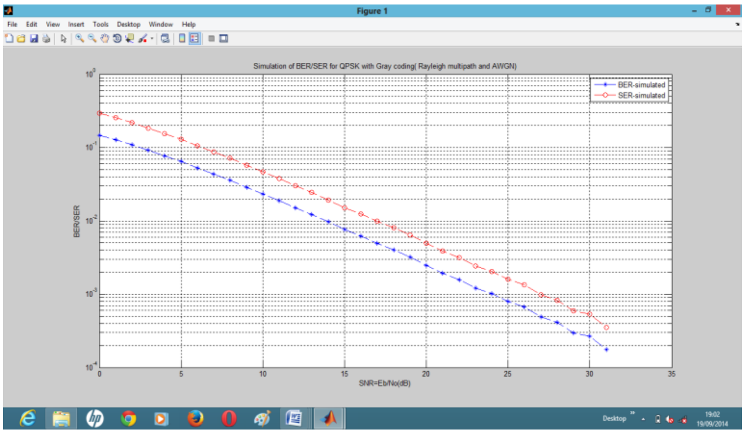



**Figure11** comparison between SER and BER

## 5. CONCLUSION

The performance of Fourier transform based OFDM system in terms of bit error rate probability for different channels scenarios. From the performed simulations in the AWGN channel, it is found that OFDM- BPSK/QPSK modulation has no advantage over a conventional BPSK/QPSK modulation scheme. But it is found that both OFDM-BPSK and conventional BPSK/QPSK having small bit error rate probability than that of the Rayleigh fading based BPSK/QPSK system. The purpose of this paper is to implement and find the efficient modulation combination that performs better in the wireless channels that are mostly multipath. The paper compares the performance of the OFDM system using binary phase shift keying whereas the future work may include the implementation of other modulation schemes and different channel scenarios for performance evaluation of any OFDM based system.

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