BER Comparative Analysis in BPSK, M-PSK and M-QAM Modulation of OFDM System in a Multipath fading channel using Simulink.

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Abstract: Orthogonal Frequency Division Multiplexing OFDM is a system in a communication used to transmit message signal (data) on multiple carrier over single communication channel. In this paper, the multipath fading channel otherwise known as the Rayleigh Fading channel is used in the modelling. The Rayleigh fading channel is characterized by the present of non-line-of-sight component. The BER of different digital modulation technique such as the BPAK, QPAK and QAM is used in an OFDM system in this paper. The BER output was compared to ascertain which is the best. The model used is the OFDM system model with IFFT/FFT application. The application used is the SIMULINK BLOCKs. The Result is then compared and conclusion drowned.

Keywords; OFDM, BPSK,QPSK, QAM, BER, SNR, Multipath Fading, IFFT/FFT.

1. ———————————◆———————————

2. Introduction

A binary digital link is one that the system requirement of transmittingmessage signals by two disjoint electrical step i.e. voltage and frequencies. The Bit error probability also known as Bit error rate (BER) is used to adjudge the suitability of digital link through its Bit error performance. A useful digital link should have BER of 10^{-5} meaning 1 bit out of 100,000 bits will likely to be in error [1]. For short, it is the number of error per total number of bit received. It is also termed as the number of bit errors that occur for a given number of bit transmitted. The BER is related to error probability (P_e) as it is the ratio of bit errors to bit transmitted in a communication system (digital). Error probability in a communication system ranges from 10^{-5} to 10^{-12}in a more demanding application.

2.0 OFDM SYSTEM REVIEW.

The transmit-ability of a digital message signal including data, voice and image in a single channel has come a long way. As a result, different multiplexing techniques like the Time Division Multiplexing (TDM), Code Division Multiplexing (CDM), Space Division Multiplexing (SDM) and Frequency Division Multiplexing (FDM)has undergone various technological advancement in digital communication systems. The power efficiency and bandwidth is one of the major criteria for any of the multiplexing techniques. This paper focuses on the Orthogonal Frequency Division Multiplexing (OFDM) which is an aspect of the FDM Technique. An example of the OFDM signal structure is shown in Fig 1.

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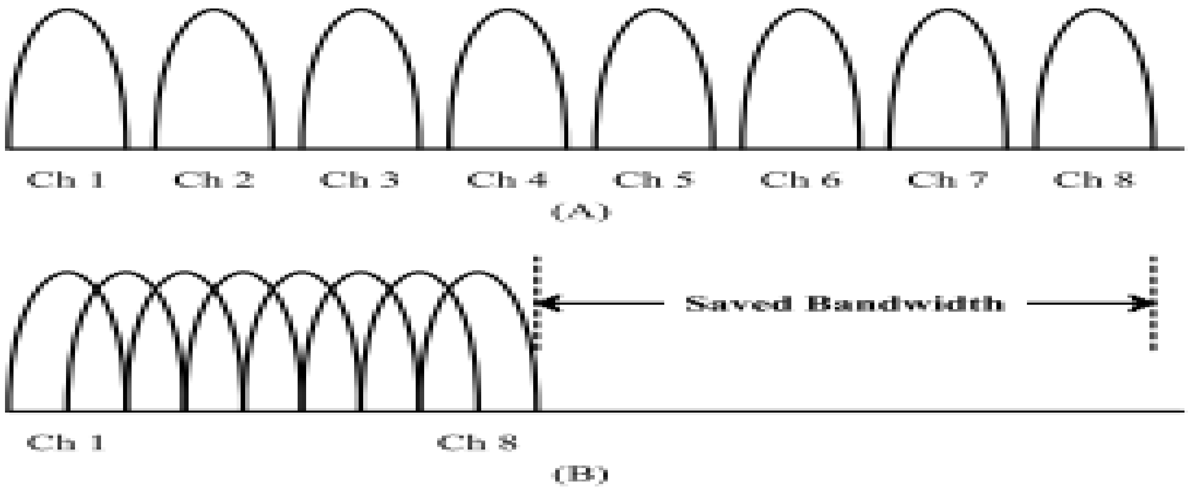

Fig 1. (A) FDM multicarrier showing Guard Band (B) OFDM Technique showing Overlapping Subcarriers.

The OFDM is a technique used in digital communication system to transmit the data on multiple carrier over single communication channel. It is also referred to as Multitone modulation. In this OFDM technique, the data is divided into multiple data streams and transmitted using multiple subcarriers at fixed frequencies over the same channel. This aforementioned data streams over the subcarriers can be of any digital modulation method.This technique enable the receiver's demodulators to see only one carrier. It has a good and improved immunity to RF interference and a low multipath distortion [2]. The OFDM technique increases the symbol length, which provides separation in the bits contained in the streams, as a result, the possibility of inter-symbol interference (ISI) is minimized. The demodulator of each channel does not see an interfering signal from the adjacent channel. Two signals are orthogonal when the signals can be sent the medium without interference.The OFDM is a widely-applied technique for both wired or wireless communication channel. It is responsible of a single one-tap equalization by cyclic prefix insertion [1]. That goes a long wayto create a highsensitivity links to receiver than those of a single carrier systems as it has to do with several subcarrier systems. It has also gained enough interest in high capacity optical fiber communication, however it is constrained by the limited reduction of ultra-high-speed DAC and ADC, mostly in the evaluation of optimum clipping ratio of optical OFDM [2]. In the MC-DS-CDMA system, OFDM is used in fading and delay spread and particularly in the Rake receiver result it is used to combat the effect of channel fading and delay spread [3]. The OFDM has the advantage of less complexity, robustness to multipath and high spectral efficiency in uplink OFDMA, mostly in the presence of carrier frequency and timing offset in Rician fading channel [4]. Also, the PAPR reduction is one the problem in the design of OFDM system. As such, PAPR schemes like clipping and filtering, peak reduction carrier scheme, coding schemes, PTS and SLM schemes, interleaving scheme, Tone reservation and Tone injection and Active Constellation Extension schemes are employed. The criteria for the selection of PAPR reduction schemes in OFDM systems includes Power increase in transit signal, PAPR reduction capability, BER

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increase at the receiver, computationalcomplexity, loss in data rate, without additional power needed, no bandwidth expansion and no spectral spillage etc [5]. The OFDM model uses the IFFT/FFT, cyclic prefix (cp) and interleaving application [6]. the FFT is a technique for converting time-varying information into its frequency component the IFFT does the reverse.

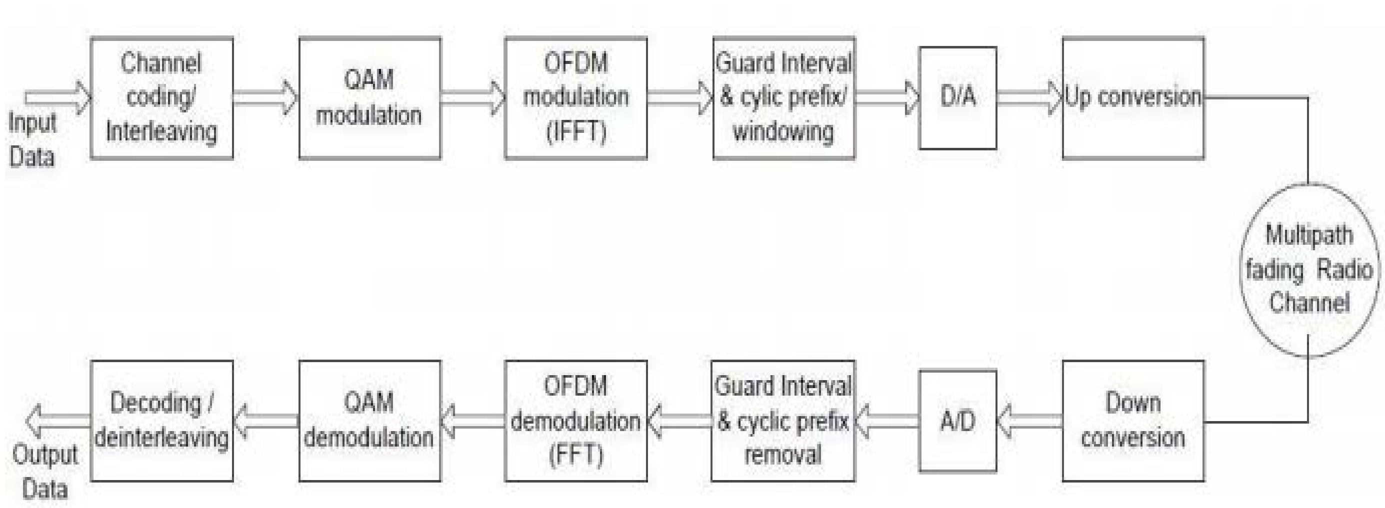

Fig 2. System Model of OFDM showing FFT and IFFT.

2.1 BINARY PHSE-SHIFT-KEYING (BPSK).

The BPSK is a Binary Modulation Scheme of a Digital Modulation Technique whose signal to be transmitted is either 1 or 0. For instance, a BPSK signal where M=2 and n=1, it requires that the $+\sin(w_c t)$ which happens to be a vector will provide the Logical "1" while the $-\sin(w_c t)$ vector will provide the logical "0". The requirement where the frequency of the carrier be shifted is neither here nor there as in the case of FSK system but rather the carrier is phased modulated either the carrier is shifted by incoming binary data. Practically, the carrier frequency is $+\sin(w_c t)$ is phase-shifted by 180^0.this is shown in Fig 3.

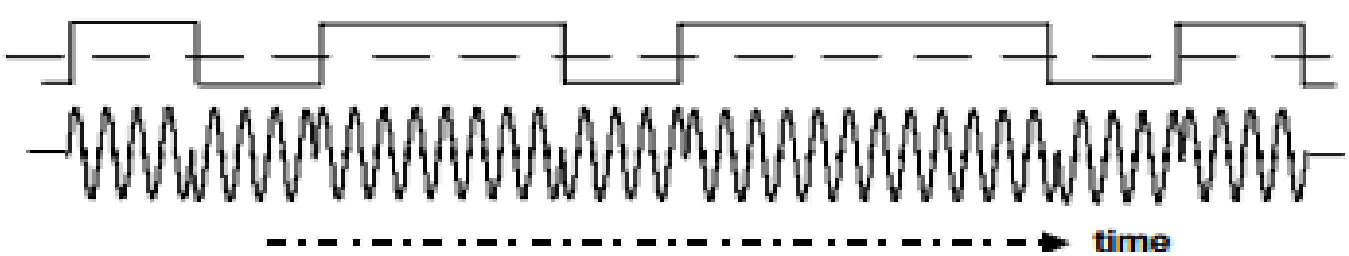

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Fig 3. BPSK modulation output 1011011101 inputs.

At the receiver, the BPSK receiver detects the phase shift in the received signal by a phenomena called the "coherent carrier recovery". The coherent carrier frequency is the mixed with the BPSK input signal to reproduce the demodulated binary output.

i.e.

$$"1" output = [\sin(w_c t)]\,[sin(w_c\, t) = sin^2(w_c t)$$

$$but, \quad sin^2(w_c t) = \frac{1}{2}[1 - \cos(2w_c t)]$$

$$"1"\ output = \frac{1}{2} - \frac{1}{2}[\cos(2w_c t)$$

The output $\frac{1}{2}[\cos(2w_c t)$ is filtered out by a low-pass-filter.

i.e.

$$"1"\ output = \frac{1}{2}$$

Similarly,

$$"0" output = [-\sin(w_c t)]\,[sin(w_c\, t)] = sin^2(w_c t)$$

$$"0"\ output = sin^2(w_c t) = -\frac{1}{2}$$

In any case, the $\pm\frac{1}{2}$ represent the dc values the corresponds to the binary numbers 1 and 0 hence it can also be conditioned for the corresponding input level for the system.

2.2 QUADRATURE PHASE-SHIFTY KEYING (QPSK)

QPSK is a digital modulation technique where only the frequency of each of the original bits divided by 2 fb/2 in the original bits in the data is required. With the QPSK technique transmission, a data bandwidth compression is realized, i.e. the more data are compressed into same available bandwidth [2]. QPSK allow two bits to be modulated at the same time, i.e. one of four possible carrier phase (0, 90, 180, and 270) degree is selecting. QPSK is also known as 4-PSK, that is a PSK that utilizes a phase shift of 90° = π/2 rad ⇒4 different signals generated, each representing 2 bits.

$$S(t) = \begin{cases} A\,cos(2\pi fct) & \text{binary 00} \\ A\,cos\,(2\pi fct + \pi/2) & \text{binary 01} \\ A\,cos(2\pi fct + \pi) & \text{binary 10} \\ A\,cos(2\pi fct + 3\pi/2) & \text{binary 11} \end{cases}$$

QPSK also allow signal to carry twice as much signal or information as ordinary PSK utilizing the same bandwidth. I.e.it has a higher data rate than the PSK scheme (2 bits per bit interval), while the bandwidth occupancyis the same, it is also a flexible scheme as it can be in for the four 4-PSK to 8-PSK i.e. n-PSK where n can be any number. The 00, 01, 10, and 11 is called the Di-bit representing 0, 90, 180 and 270 phases.

2.3 QUADRATURE AMPLITUDE MODULATION (QAM)

The QAM is a modulation scheme used in achieving high data rates in a limited bandwidth channels. It is mainly characterized by two data signals that is usually out of phase by 90º with each other. i.e. it uses a two-dimensional signaling system. That also means that original information stream is divided into two sequences that normally will consist of odd and even symbols. The QAM is both an analog modulation scheme and digital modulation scheme, as it contains a sequence known as the in-phase component being modulated by $Cos(2\pi fct)$ and another sequence called the quadrature – phase component being modulated by $Sin(2\pi fct)$ where fc is the carrier frequency and t is the time (t) in seconds. The in-phase and quadrature phase components is combined to form a composite signal.

$$A\,Cos(2\pi fct) + B\,Sin(2\pi fct)$$

where A and B is the amplitude of the signal. This composite signal is then sent through the channel.

$Y_1(t)$ and $Y_q(t)$ are the two-analog signal that is added and sent to through the channel. It has the advantage of a data rate of 2 bits per bit interval. It can also convey two digital bit streams by modulating the amplitudes of the two carrier waves using Amplitude Shift Keying (ASK) digital modulation scheme or two analog signal by using the Amplitude Modulation (AM) analog modulation scheme. This two carrier waves are out of phase by 90º as earlier mentioned. The composite signals are phase shift keying (PSK) and Amplitude Shift Keying (ASK) respectively.

That is,

$$A\,Cos(2\pi fct) + B\,Sin(2\pi fct) = (A2 + B2)1/2\,Cos(2\pi fct + tan - 1\tfrac{B}{A})$$

QAM Demodulation is achieved by multiplying the composite signal by 2. $Cos(2\pi fct)$ and subsequently low pass filtering the resultant signal to obtain A and also multiplying the composite signal again by 2. $Sin(2\pi fct)$ and low pass filtering the resultant signal to obtain B. i.e.

$$(A\,Cos2\,(2\pi fct) + B\,Sin(2\pi fct))\,x\,2\,Cos(2\pi fct)$$

$$= 2\,A\,Cos2(2\pi fct) + 2\,B\,Cos(2\pi fct)\,Sin(2\pi fct)$$

$$= A(1 + Cos2(4\pi fct)) + 2\,B(0 + Sin(4fct))$$

Where $B(0 + Sin(4\pi fct))$ is smoothed to zero during the filtering stage.

Like wise

$$A\,Cos(2\pi fct) + B\,Sin(2\pi fct)$$

$$= 2\,B\,Sin2\,2\pi fct + 2\,A\,Cos(2\pi fct)\,Sin(2\pi fct)$$

$$= B\,(1 - Cos(4\pi fct)) + A\,(0 + Sin(4\pi fct))$$

Where $A(0 + Sin(4\pi fct))$ is smoothed to zero at the fullering stage.

QAM has its application mostly in the digital communication systems as it has some arbitrarily high spectral efficiencies by setting a suitable constellation size limited only by the noise level and linearity of the communications channel. QAM is also applicable in fiber optical system as bit rates increase; QAM 16 and QAM 64 can be optically emulated with a 3 – path inter ferro meter.

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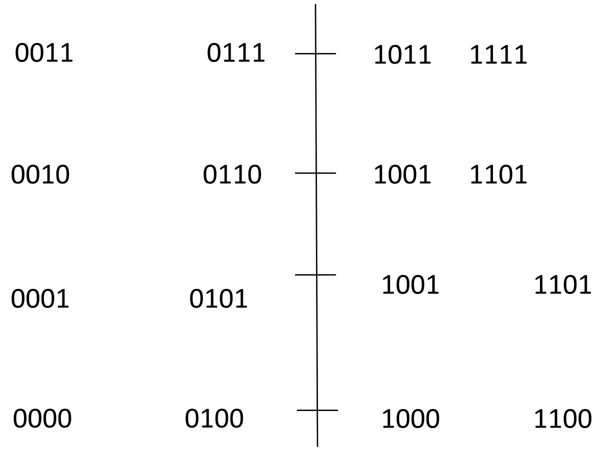

Fig 4 QAM16 (4 × 4)constellation pattern

Fig4 is used to represent possible symbols that may be selection by a given modulation scheme and in thin case it's 0a 4 by 4 symbol as points in a 2-D plane. The Q represent the quadrature carrier! $\sin(2\pi fct)$ while the I is the in-plane carrier! $\cos(2\pi fct)$ in a 4×4 bits per symbol.

The A and B can individually assume 4 different levels i.e. -1, -1/3,1/3,1 and the data rates in 4bits/pulse equivalent to 4 w bit/seconds QAM in easily affected by noise due to Amplitude changes as the number of phase shifts used by QAM system in greater than the number of amplitude shifts.

M	4	16	54	258	1024
E_b/N_o for BER of 10^{-5}	10.5	15	18.5	24	28

Table 1.Shows the bandwidth and power efficiency of a typical QAM at different M.

Bit Error Rate (BER)

The quality of a digital communication system is mostly referredto as the Bit error rate (BER) it in referred to as the number of hit error that may mostly occur for a given number of bit transmitted. Several factors is responsible for this error including noise, inter symbol interference is amongst others. It may arise from the source through the channel to the destination. BER is related to the error to the probability(P_e) as it is the ratio of bit error to the, bits transmitted.

QPSK as a quaternary modulation scheme, is easily seen as a two independently modulated quadrature in equavadent to 4 different signal generated, and each representing of bits.

3 Multipath Fading Channels.

Antenna is one of the important structure in a wireless communication systems. This structure converts the already modulated high frequency current into

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electromagnetic waves (Radio waves) and send it into free space via transmitting antenna, be it in analog or digital communication systems. The point is that, sometimes the radio waves do not get to the receiving antenna due to obstacles along the path in the direction of the waves during propagation. This phenomenon is described as non-line-of-sight (Non-LOS) and it is referred to as a Rayleigh Fading Channel. This Non-LOS is as a result of reflection, refraction and or scattering which might be caused by high rise buildings in the along the path, trees and or other obstacles in the direction of propagation. Hence the name multipath propagation. This signals on reaching the receiver antenna may be attenuated, delayed and or phase shifted there making the receiver antenna not to receive the original signal or none at all. The channel is best described by scholars/researchers as a multipath fading channel. Another scenario where the transmitted signal gets to the receiver antenna without any form of obstruction is known as the Line-of-sight (LOS) otherwise termed Rician fading channels [9].

The Rayleigh fading channel which is the main focus of this paper is a modeled to have a Rayleigh distribution model as follows:

The form of the circularly symmetric complex Gaussian random variable is

$$Z = X + jY$$

Where X is real and Y is imaginary parts and zero mean independent and identically distributed Gaussian random variables.

For a circularly symmetric complex random variable

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

And the statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance.

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

The magnitude [z] which has a probability Density function (PDF), [7] [8].

$$P(z) = \frac{z}{\delta^2} e^{\frac{-z^2}{2\delta^2}}, z > o$$

That is called Rayleigh random variable.

The Rayleigh fading channel model also known as Non-line of sight (Non-LOS) is good in a complex environment where there is no Line of Sigh (LOS) between the transmitter and the receiver. Possibly, reflection, diffraction and scattering is bound to happen. They are the possible mechanism responsible for electromagnetic wave propagation in wireless communication.

Also, the impulse is

$$h(t) = \frac{1}{\sqrt{n}}[h_1(t - t_1) + \cdots . + hn(t - t_n)]$$

$h_1(t\text{-}t_1)$ is the channel coefficient of the first tap

$h_2(t\text{-}t_2)$ is the channel coefficient of the second tap

$h_3(t\text{-}t_3)$ is the channel coefficient of the third tap and so on. However, the real and imaginary part of each tap is an independent Gaussian random variable with mean 0 and variance ½. The term $^1/_{\sqrt{n}}$ is for normalizing the average channel power over multiple channel realization to 1.

3 SimulationModel.

S/no	Digital Modulation of OFDM System Rayleigh Channel	Bits	Bit Error	BER Values
1	BPSK Modulation of OFDM System	11	5	0.4545
2	QPSK Modulation of OFDM System	11	6	0.5455
3	QAM Modulation of OFDM System	11	7	0.6364

Table 2. BER results of Simulink Model.

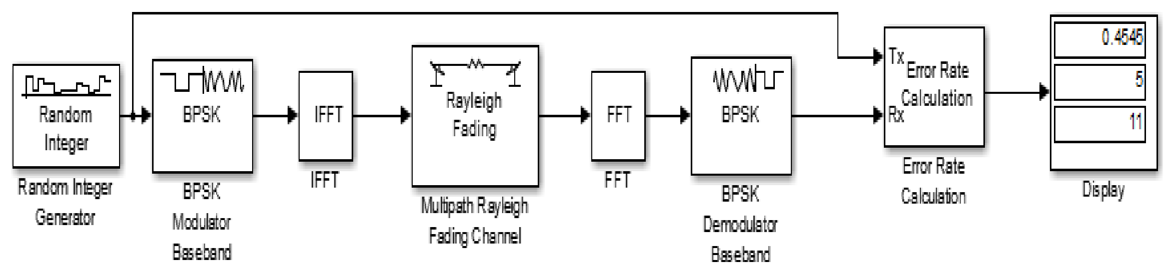

Fig .1. BER output of BPSK Modulation of OFDM system in a Rayleigh Channel.

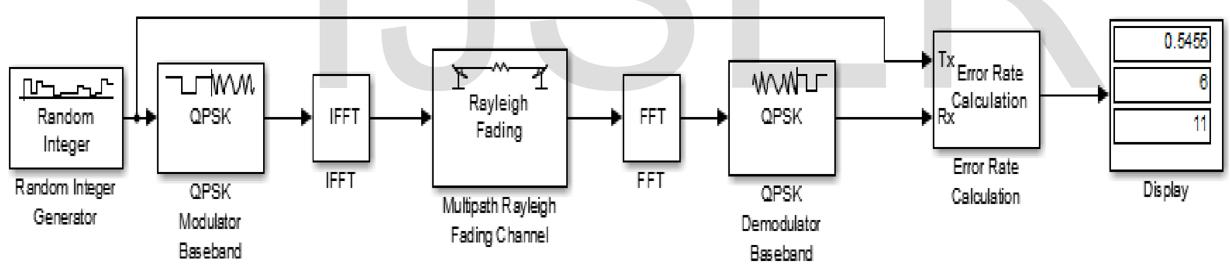

Fig .2. BER output of QPSK Modulation of OFDM system in a Rayleigh Channel.

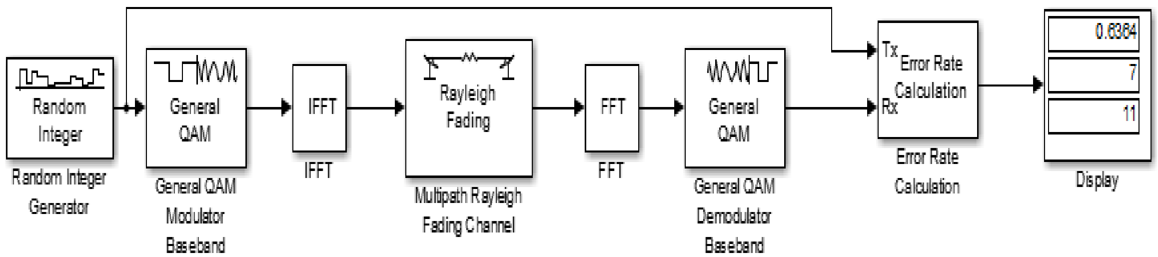

Fig .3. BER output of QAM Modulation of OFDM system in a Rayleigh Channel.

5 Discussion.

From the results shown in Table 2, BER value of BPSK is lower in a Rayleigh Channel using and higher for QAM modulation Technique at the same number of transmitted bits. The signal to noise ratio (SNR) is also higher in BPSK. The SNR is used as a measure of the quality of the transmission channel. It is a very important parameter for analysis of digital modulation technique. Enhancing the performance of an OFDM requires a minimum value of SNRas it can reduce noise drastically in an OFDM system in a Rayleigh channel (Non- Line of Sight).

6 Conclusion.

This paper is based on the BER analysis of three different Digital Modulation Techniques in an OFDM System BPSK, QPSK and QAM. The Rayleigh Channel is used as a medium of Transmission. It is a Non-Line-of-Sight (NON-LOS). The model is design using MATLAB/SUMULINK block and simulation carried. It is discovered from the results of the simulation that the BPSK has a lower BER values of 0.04545 followed by the QPSK with 0.5455 and QAM with 0.6364. So, it is concluded that the binary scheme of BPSK is better of as compared to the M-array scheme of QPSK and QAM. Also, a more better performance can be achieved using a more advanced OFDM system with a particular cyclic prefix and coding and decoding of the required modulating signal.

Further work will be focused on the Clarke's Model where by a Doppler shift can be included into the Rayleigh Channel Model by passing;

$$r(t) = \sqrt{Tc(t)^2 + Ts(t)^2}$$

By passing r(t) through a filter s(t) will give;

$$S(f) = 1.5/(\pi * Fd * \sqrt{1 - ({}^{Fc}/_{Fd})^2}$$

Where Tc(t) and Ts(t) is the Gaussian random processes. At any time, Tc and Ts are uncorrelated zero mean Gaussian random variables.

The channel response envelops, r(t), having a Rayleigh PDF.

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