Simulation and Analysis of QAM-OFDM System Based On Simulink

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Abstract*-Orthogonal frequency-division multiplexing (OFDM) is a method of digital modulation which a signal is split into several narrowband channels. OFDM uses a large number of closely-space orthogonal subcarriers to carry data. The data divided into several parallel data streams or channel, one for each subcarrier. Each subcarrier then has been modulated using conventional modulation scheme such as quadrature amplitude modulation (QAM) or phase shift keying (PSK). OFDM is a method that allows transmitting high data rates over extremely hostile channels at a comparable low complexity. One of the main reasons to use OFDM is to increase robustness against frequency selective fading or narrowband interference. The objective of this paper is to obtain the performance of the OFDM and get the measurements of bit error rate (BER) under different communication channels using a conventional modulation scheme (64-QAM). Orthogonal Frequency Division Multiplexing (OFDM) is modeled and simulated under different communication channels such as AWGN and Rayleigh fading. The functionality of the block diagram of OFDM will be obtained from the simulation using the MATLAB/SIMULINK software. The measurement of BER under the different channels conditions will be shown in graph format.

***Index Terms*— AWGN, BER, OFDM, QAM**

I. Introduction

With the rapid growth of digital communication in recent years, the need for high- speed data transmission has increased. Often, these services require very reliable data transmission over very harsh environments and must meet much constraints such as finite transmit power and efficient Bandwidth. A common problem found in high speed communication is inter-symbol interference (ISI). In a wireless communication system the signal reflects from large objects such as mountains or buildings, the receiver sees more than one copy of the signal. In communication terminology, this is called multipath. Many methods are proposed to combat the multipath effects in wireless communication. One of the solutions to combat Inter Symbol Interference (ISI) is multicarrier modulation for data transmission [1], [2], [3], that is Orthogonal Frequency Division Multiplexing (OFDM).

The main idea behind OFDM is that since low-rate modulations (i.e. modulations with relatively long symbols compared to the channel time characteristics) are less sensitive to multipath, it is better to send a number of low rate streams in parallel than sending one high rate waveform[4]. Orthogonal frequency division multiplexing is a telecommunication technology that is foundation of most next-generation, or 4G wireless Internet services. Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission technique and it's history dates back to the mid-1960s. Although the concept of OFDM has been around for a long time, it has only recently been recognized and adopted as an effective technique for high-speed bidirectional wireless data transfer 802.11a. DAB (Digital Audio Broadcasting), DVB-T (Digital Video Broadcasting) are some of the new emerging standards that uses OFDM. This is because of the two main reasons i.e. OFDM is very immune to channel imperfections and OFDM uses bandwidth very efficiently.

Section II discusses the basic block diagram of the OFDM system and it shows how the signal is processed at transmitter and at receiver side. Section III shows the simulation model for the system and implementation of the system for particular modeling parameters. Section IV describes the simulation result of the system.

II. OFDM Communication SYSTEM MODEL

A. Review Stage

Figure.1 shows the basic block diagram of an OFDM system. In the figure 1, first of all, entire data stream is converted from serial to parallel form which means it is subdivided into a number of sub streams. These sub streams are modulated over carrier signal which is known as sub carriers and because of the modulation each data bits are converted in to complex numbers shown by using 64-QAM signal constellation diagram in figure 2.

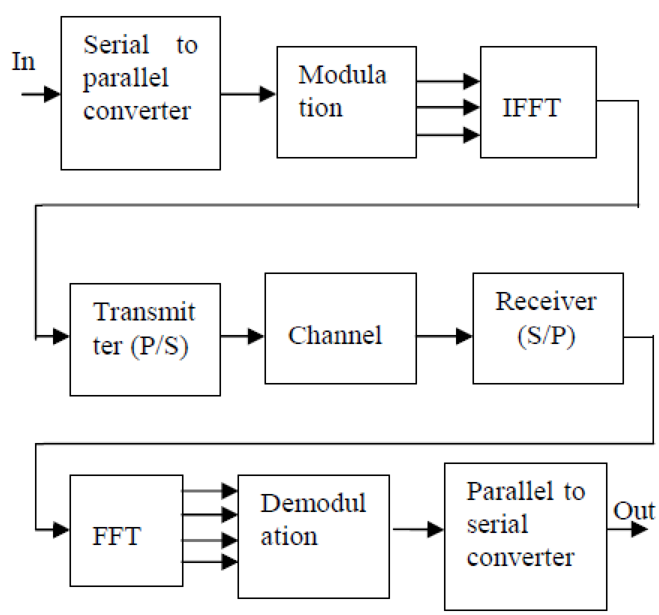

Fig. 1. OFDM Model [5].

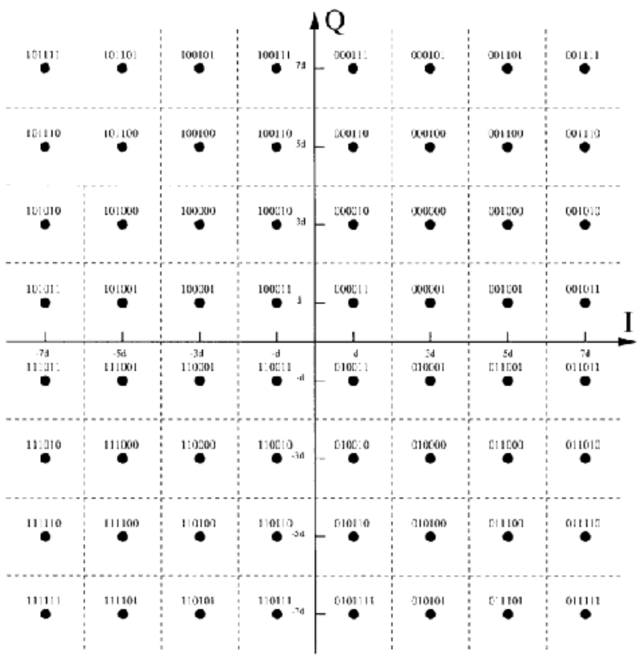

Fig. 2. Constellation diagram of 64-QAM [6]

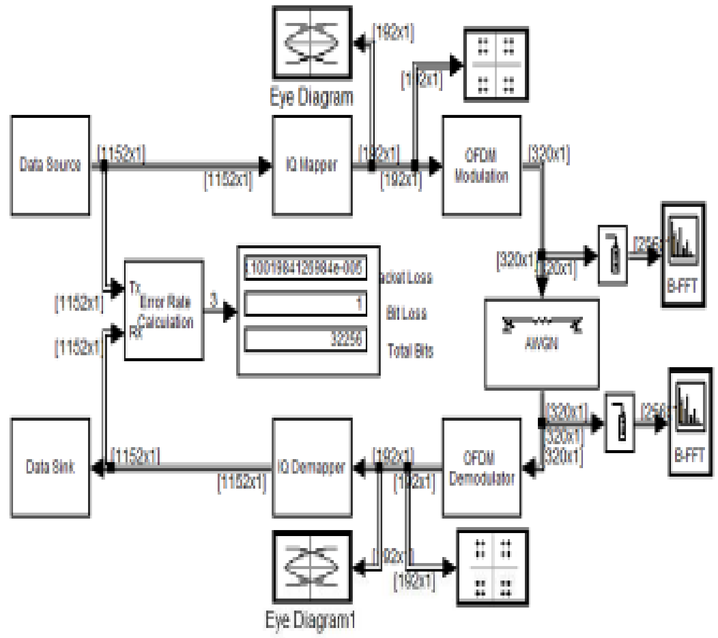

Fig. 3. Simulink Block diagram of OFDM

The output of Modulation is given to the Inverse Fast Fourier Transform (IFFT) block which converts the signal from frequency domain to time domain. After conversion the multiplexed signal is passed through AWGN channel. At the receiver side, OFDM signal is received and converted form serial to parallel form and the FFT operation is performed. After performing the FFT and de-mapping of binary data, it is again converted back to the serial form.

III. IMPLIMENTATION

A. Methodology

In this paper, QAM-OFDM system is implemented. The following OFDM system parameters are considered for the simulation.

Subcarriers: 192
Data mapping: M-QAM
IFFT, FFT size: 256-point
Channel used: AWGN, Rayleigh channel
Guard Interval size: IFFT size/4 : 64 samples
OFDM transmitted frame size: 256+64 = 320

B. Simulation Model

The system modeled for OFDM with QAM mapping is shown in the figure 3.

The Data source, using this random binary generator generates binary data that is frame based. The output of the data source is 192 samples per frame. Before the digital modulation scheme is applied (i.e. modulation is done.), using the mapper block, the data stream is converted into parallel form and the sub carriers are allocated to the symbols. Modulated data is in complex form because it has in-phase and quadrature-phase component. The constellation diagram of M-QAM mapping is shown in Figure 2.

The subbolcks of the OFDM Modulation like inport, outport, Multiport Selector, Matrix Concatenation, IFFT and Cyclic Prefix are shown in the figure 4. Multiport selector distributes arbitrary subsets of input rows or columns to multiple output port. Matrix Concatenation concatenates inputs horizontally or vertically. The IFFT block computes the inverse fast Fourier transform (IFFT) of the input signal(streams). Selector block is used to add cyclic prefix as a guard interval, which eliminates the ISI from the previous symbol.

The IFFT converts frequency domain data into time domain signal and at the same time maintains the orthogonality of subcarriers. IFFT size is 256. Cyclic Prefix is the copy of the data stream's last 64 bits. The disadvantage of the cyclic prefix is that it adds the timing overhead and decreases the overall spectral efficiency of the system. Cyclic prefix duration should be more than the channel delay spread.

Using the channel model block, OFDM Signal is transmitted on AWGN channel or Rayleigh channel. This block allows the user to change the different values of signal to noise ratio. The receiver performs the reverse operation of the transmitter i.e. removal of cyclic prefix, FFT, removal of zero padding and de-mapping of data.

The error rate calculation block compares input data from a transmitter with output data from the receiver [7]. It calculates the error rate as a running statistic by dividing the total number of unequal pairs of data elements by the total number of input data elements from one source. As in our case the input are bits, then the block computes the bit error rate. In figure 3, it can be seen that the first box of the display indicates the error rate, the second indicates the total number of error bits, and the third one indicates total number of bits that has been sent.

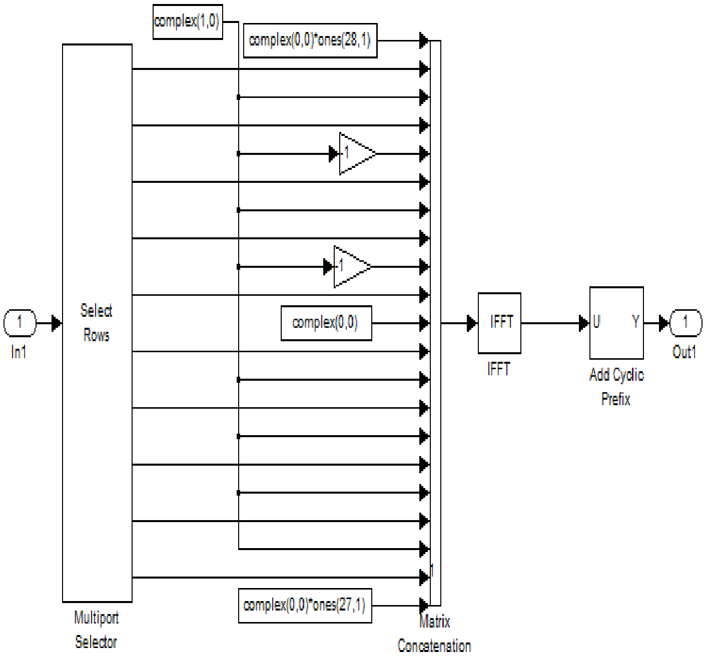

Fig. 4. OFDM modulator block

IV. SIMULATION RESULT

A. OFDM under AWGN channel

The OFDM under AWGN channel is simulated in Matlab/Simulink. The performance of the OFDM under this channel has been evaluated in the figure below.

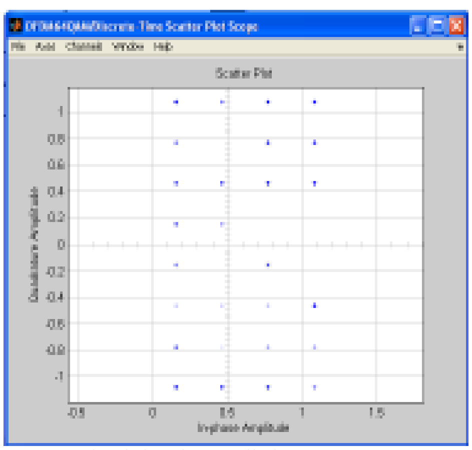

Fig. 5(a). OFDM transmitted signal constellation

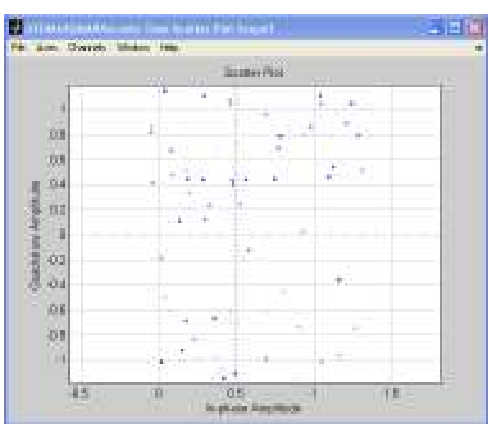

Fig. 5(b). OFDM received signal constellation

The time is set to 500 second with varying M-ary number 64 and SNR = 20db. The measurement of BER under AWGN channel with SNR 20db is 0.31.

In figure 5, the scatter plot shows for the transmitted signal without presence of noise[(fig 5.(a)] and the received signal plotted with presence of noise [(fig 5.(b)],after the signal passed through the AWGN channel. As per theory, an AWGN channel adds white Gaussian noise to the signal that passes through it. The AWGN channel corrupts the transmitted signal which results in a different received 64-QAM constellation and eye diagram pattern.

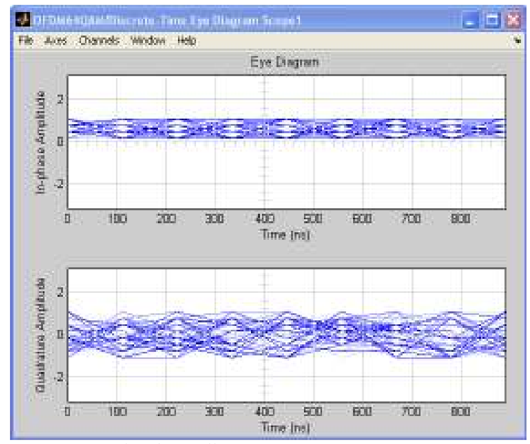

Fig. 6(a). OFDM transmitted eye diagram

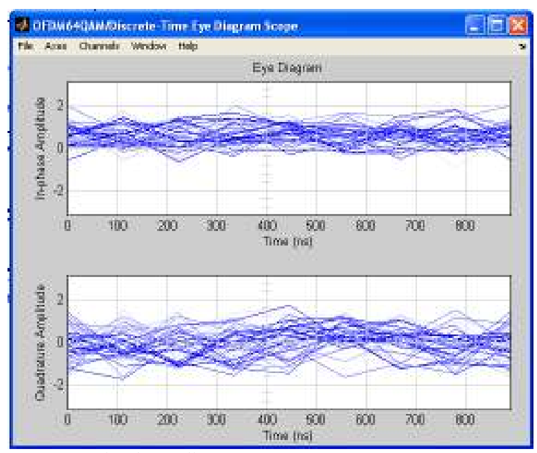

Fig. 6(b). OFDM received eye diagram

An eye diagram is used to evaluate the received signal quality. The figure 6(b) shows the amount of distortion signal at transmitter and receiver side which is set by signal-to-noise ratio (SNR). The most open part of the eye indicates the best performance of the system.

From the figure 7, it can be seen that for a small value of SNR, the calculated error rate is quite large. It may cause the Inter-symbol Interference (ISI) which is introduced by the noise at the receiver side for the relative high power noise. As SNR increases, the bit error rate was decreases as expected. Moreover, for a value for SNR greater than 45, the error is zero. To measure the performance of OFDM under AWGN channel, the variable number of SNR value has been set in the block channel parameter where bit error rate (BER) is caused by symbol errors, Which related with the probabilities that the mapper maps input bits into symbols.

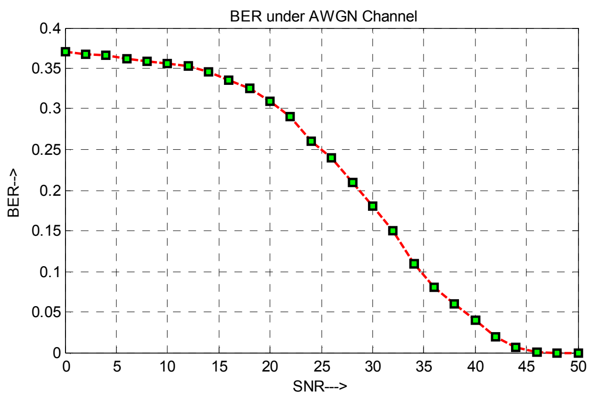

Fig. 7. BER under AWGN channel

Figure 8 shows the spectrum of the OFDM receiver and OFDM transmitter.

B. OFDM under Rayleigh channel

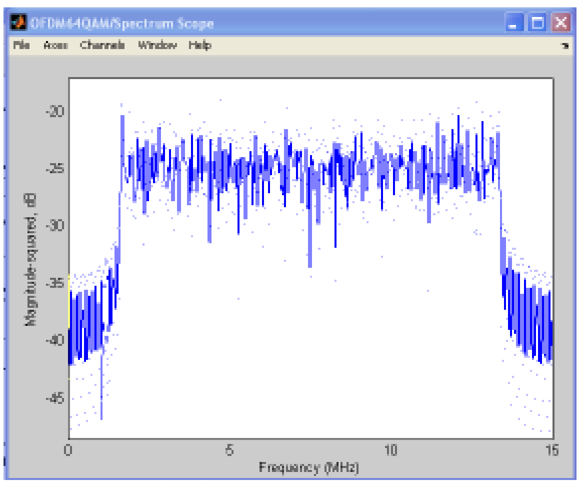

Fig. 8(a). OFDM transmitted spectrum

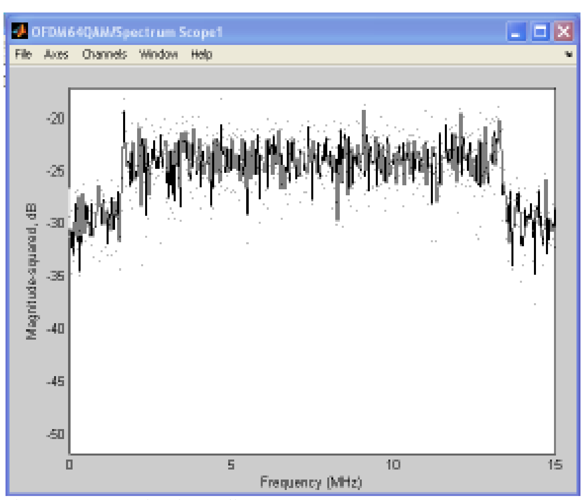

Fig. 8(b). OFDM received eye diagram

The OFDM under Rayleigh channel is simulated in Matlab/Simulink. The performance of the OFDM under this channel has been evaluated in the figure below. The time is set to 500s with varying M-ary number 64. Maximum Doppler shift frequency is set to 10 Hertz. The measurement of BER under this channel with maximum Doppler frequency 10 Hertz is 0.3746. For this channel, the maximum Doppler shift value must be less than 1/ (10*Ts) where Ts is the input sample period. Input sample period, Ts = 1/192.

OFDM has been simulated under Rayleigh channel and the performance of OFDM is shown in figures above.

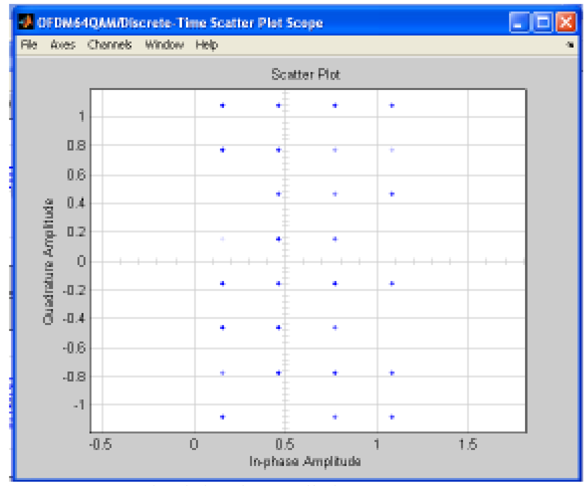

Fig. 9(a). OFDM transmitted signal constellation

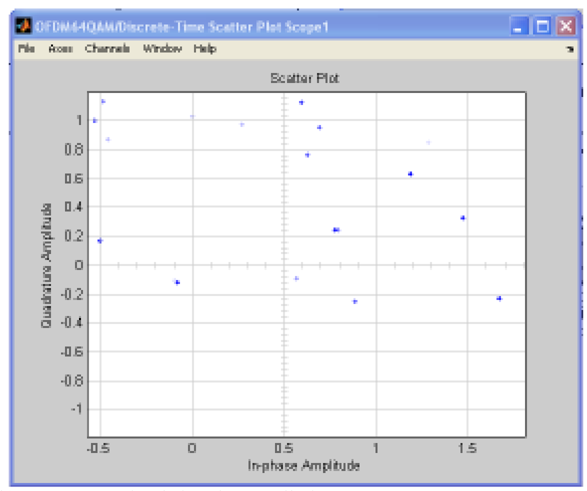

Fig. 9(b). OFDM received signal constellation

As stated before, Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal that is used by wireless devices. In figure 9, the scatter plot shows the transmitted signal plotted without presence of noise and the received signal plotted with presence of noise after the signal passing through the Rayleigh channel. The figure 11 shows the amount of distortion in the signal at transmitter and receiver side which is set by the variable value of maximum Doppler shift frequency in the block set parameter. The problem occurs when zero BER is not achieved even though the Doppler frequency is set to the highest value.

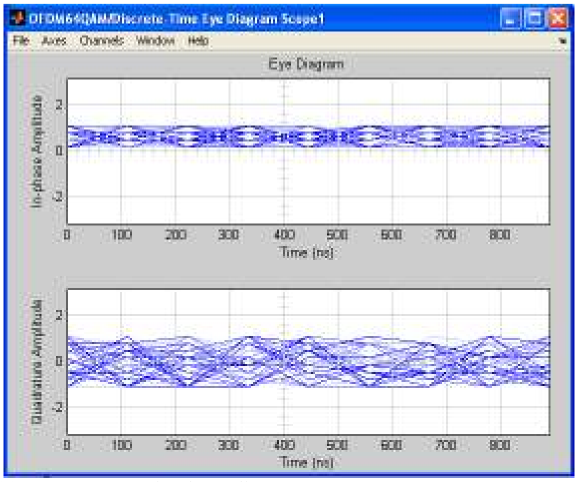

Fig. 10(a). OFDM transmitted eye diagram

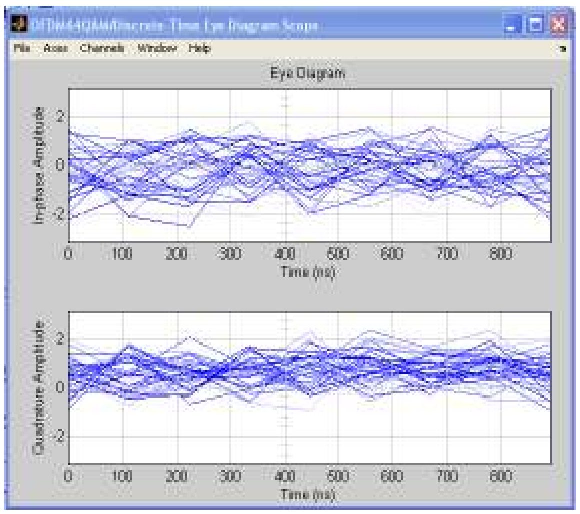

Fig. 10(b). OFDM received eye diagram

Figure 12 shows the spectrum of the OFDM receiver and OFDM transmitter.

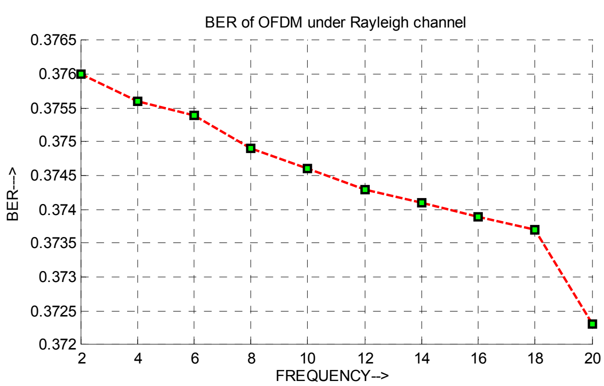

Fig. 11. BER under Rayleigh channel

V. Conclusion

Considering AWGN noise and Rayleigh effect, a good approximation to the real performance can be observed along with the degradation in BER. Also, the channel effect can be observed in the output constellation and eye diagram of transmitted and received signal, using some routines in

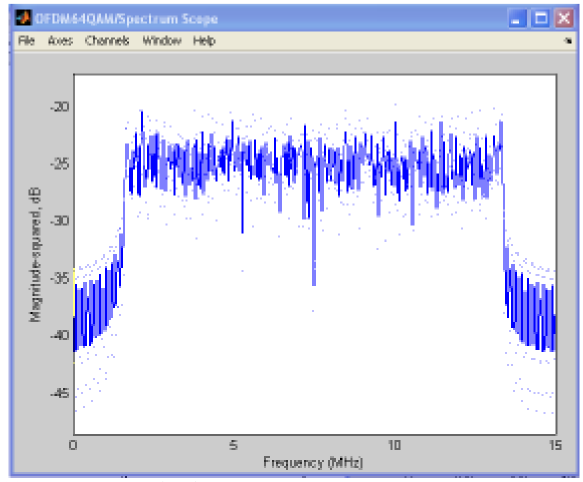

Fig. 12(a). OFDM transmitted spectrum

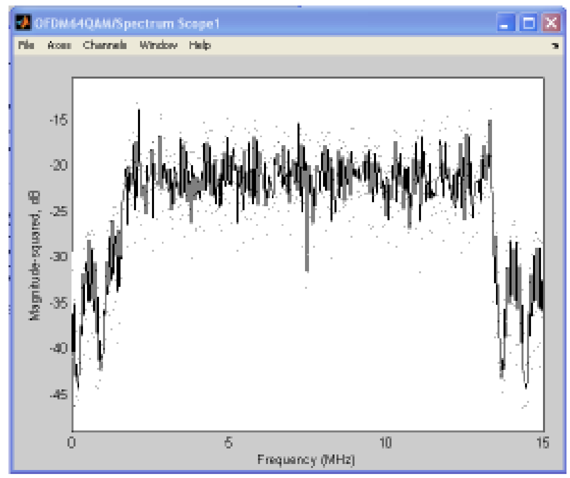

Fig. 12(b). OFDM received spectrum

Matlab. OFDM uses large number of parallel narrowband subcarriers instead of single wideband carrier to transfer the information. Each subcarrier is modulated using a conventional modulation scheme. In this paper, OFDM signal is generated and decoded using 64-QAM as conventional modulation scheme. During the transmission of information signal, the Additive White Gaussian noise (AWGN) corruptes the transmitted signal which results in a different received 64-QAM constellation compared to transmitter side.

The eye diagram is used to evaluate the received signal quality. The result of the simulation shows the amount of distortion in the signal at transmitter and receiver side which is set by different values of signal-to-noise ratio (SNR). The most open part of the eye, the best performance of the system. As bit error rate increases, the absolute time error represents an increasing portion of the cycle, reducing the size of the eye opening which also increases the potential for data or systems error. It can be concluded from the simulation results shown above that the bit error rate for each communication model is quite higher, around 0.4 to 0.5.

For a small signal-to-noise ratio (SNR) values, the measurement of bit error rate (BER) is quite higher due to the high power of noise transmitted during the transmission of signal. SNR is a measure, used to identify how much the signal has been corrupted by noise. The higher the ratio, the less it produces the background noise. The graph of BER shows that OFDM under AWGN channel give the best and ideal performance compared to OFDM under Rayleigh fading channel.

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