PERFORMANCE ANALYSIS OF OFDM WITH QPSK USING AWGN AND RAYLEIGH FADING CHANNEL

Swati Sharma[1] & Jyoti Gupta[2]
[1]M.Tech Scholar & [2]Lecturer,
Department of Electronics and Communication, MMU Mulana, Ambala, Punjab, India

ABSTRACT

Wireless technologies have gradually become more and more involved into everyday life. Among multicarrier transmission techniques, Orthogonal Frequency Division Multiplexing (OFDM) is the most popular one that uses parallel data streams. Compared with single carrier modulation, OFDM has many advantages as immunity to impulse interference, high spectral density, robustness to channel fading, resistance to multipath, much lower computational complexity. However, OFDM has some major drawbacks to implement it in practical telecommunication systems. Some of them are that OFDM signal suffers Packet loss, Bit loss, Bi t Error Rate (BER), Signal to Noise Ratio (SNR). In this paper all these terms are discussed and all the four parameters are compared using AWGN and Rayleigh fading channel by changing the phase of some of the subcarriers using QPSK in OFDM modulation. Results shows that in case of Rayleigh fading the Packet loss is .4574, Bit loss is 1.77e+004, Bit Error Rate is .520444651and Signal To Noise Ratio is 2.6dB.Where as in case of AWGN channel Packet loss is .36355,Bit loss is 28061,Bit Error Rate is .36355980514096 and Signal to Noise Ratio is 3.2 dB. Which shows that Rayleigh fading channel is better than the AWGN channel. The simulation is done on MATLAB software

KEYWORDS: *Orthogonal Frequency Division Multiplexing (OFDM), Bit Error Ratio (BER), Signal To Noise Ratio (SNR), Quadrature Phase Shift Keying (QPSK), Additive White Gaussian Noise (AWGN).*

I. INTRODUCTION

The nature of WLAN applications demands high data rates. Naturally dealing with ever unpredictable wireless channel at high data rate communications is not an easy task. The idea of multi-carrier transmission has surfaced recently to be used for combating the hostility of wireless channel as high data rate communications. OFDM is a special form of multi-carrier transmission where all the subcarriers are orthogonal to each other. OFDM promises a higher user data rate transmission capability at a reasonable complexity and precision. At high data rates, the channel distortion to the data is very significant, and it is somewhat impossible to recover the transmitted data with a simple receiver. A very complex receiver structure is needed which makes use of computationally extensive equalization and channel estimation algorithms to correctly estimate the channel, so that the estimations can be used with the received data to recover the originally transmitted data. OFDM uses the available spectrum very efficiently which is very useful for multimedia communications. The name ‘OFDM’ is derived from the fact that the digital data is sent using many carriers, each of a different frequency (Frequency Division Multiplexing) and these carriers are orthogonal to each other, hence Orthogonal Frequency Division Multiplexing. It can be seen from the fig. 1 that using the overlapping multicarrier technique, almost 50% of the bandwidth can be saved. The transmission channel plays very important role in the communication. Here OFDM is studied by using AWGN and Rayleigh Fading channel. [1]

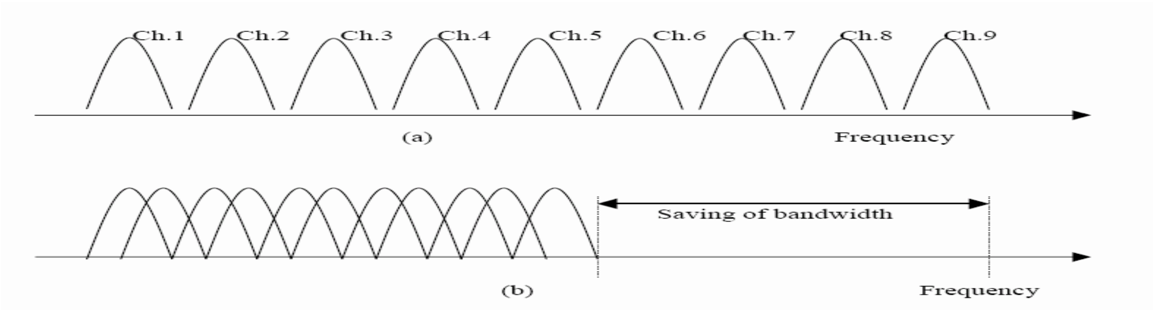

Figure 1 Overlapping Multicarrier Technique

1.1 Basic Principles of OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is very similar to the well-known and used technique of Frequency Division Multiplexing (FDM). OFDM uses the principles of FDM to allow multiple messages to be sent over a single radio channel. It is however in a much more controlled manner, allowing an improved spectral efficiency. A simple example of FDM is the use of different frequencies for each FM (Frequency Modulation) radio stations [2]. All stations transmit at the same time but do not interfere with each other because they transmit using different carrier frequencies. Additionally they are bandwidth limited and are spaced sufficiently far apart in frequency so that their transmitted signals do not overlap in the frequency domain. At the receiver, each signal is individually received by using a frequency tunable band pass filter to selectively remove all the signals except for the station of interest. This filtered signal can then be demodulated to recover the original transmitted information.

OFDM is different from FDM in several ways. In conventional broadcasting each radio station transmits on a different frequency, effectively using FDM to maintain a separation between the stations. There is however no coordination or synchronization between each of these stations. With an OFDM transmission such as DAB, the information signals from multiple stations are combined into a single multiplexed stream of data. This data is then transmitted using an OFDM ensemble that is made up from a dense packing of many subcarriers. All the subcarriers within the OFDM signal are time and frequency synchronized to each other, allowing the interference between sub carriers to be carefully controlled [3]. These multiple subcarriers overlap in the frequency domain, but do not cause Inter-Carrier Interference (ICI) due to the orthogonal nature of the modulation. Typically with FDM the transmission signals need to have a large frequency guard-band between channels to prevent interference. This lowers the overall spectral efficiency. However with OFDM the orthogonal packing of the subcarriers greatly reduces this guard band, improving the spectral efficiency [4].

1.2 OFDM Transceiver Systems

A complete OFDM transceiver system is described in Figure 2 In this model, Forward Error Control/Correction (FEC) coding and interleaving are added in the system to obtain the robustness needed to protect against burst errors. An OFDM system with addition of channel coding and interleaving is referred to as Coded OFDM (COFDM). In a digital domain, binary input data is collected and FEC coded with schemes such as convolutional codes. The coded bit stream is interleaved to obtain diversity gain. Afterwards, a group of channel coded bits are gathered together (1 for BPSK, 2 for QPSK, 4 for QPSK, etc.) and mapped to corresponding constellation points. At this point, the data is represented in complex numbers and they are in serial. Known pilot symbols mapped with known mapping schemes can be inserted at this moment. A serial to parallel converter is applied and the IFFT operation is performed on the parallel complex data. The transformed data is grouped together again, as per the number of required transmission subcarriers. Cyclic prefix is inserted in every block of data according to the system specification and the data is multiplexed to a serial fashion.

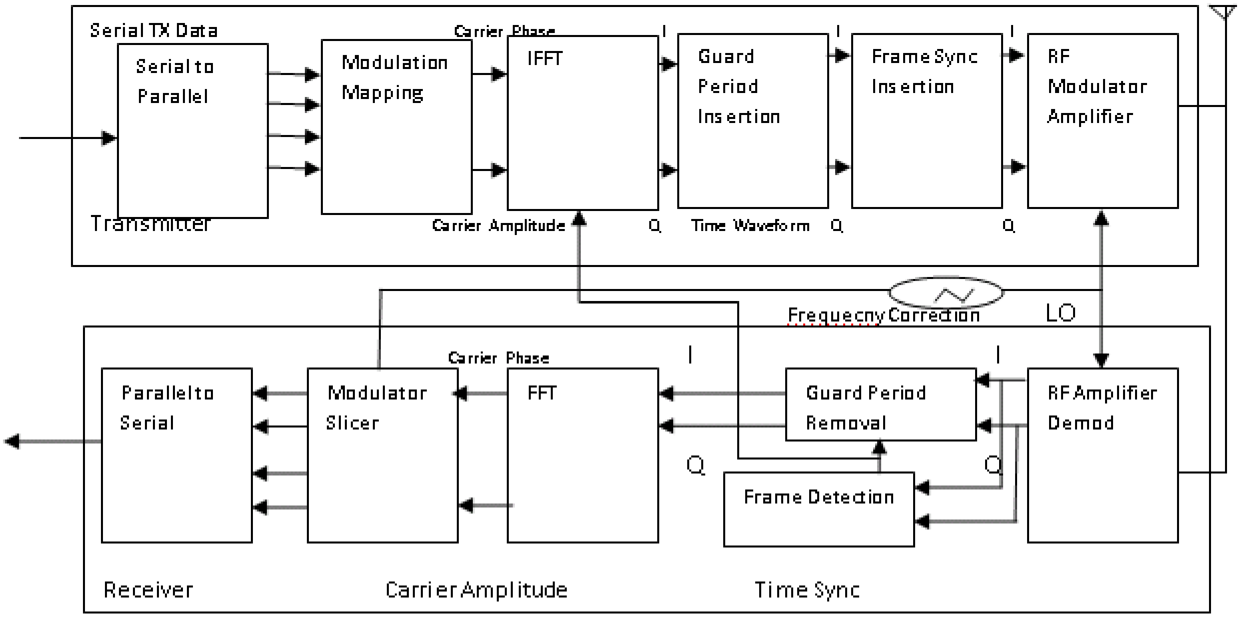

Figure 2 OFDM Transceiver

At this point of time, the data is OFDM modulated and ready to be transmitted[11]. A Digital to-Analog Converter (DAC) is used to transform the time domain digital data to time domain analog data. RF modulation is performed and the signal is up-converted to transmission frequency. After the transmission of OFDM signal from the transmitter antenna, the signals go through all the anomaly and hostility of wireless channel. After the receiving the signal, the receiver down converts the signal; and converts to digital domain using Analog-to-Digital Converter (ADC). At the time of down-conversion of received signal, carrier frequency synchronization is performed. After ADC conversion, symbol timing synchronization is achieved[7]. An FFT block is used to demodulate the OFDM signal. After that, channel estimation is performed using the demodulated pilots. Using the estimations, the complex received data is obtained which are demapped according to the transmission constellation diagram. At this moment, FEC decoding and deinterleaving are used to recover the originally transmitted bit stream.

II. PARAMETERS USED

2.1 Bit Error Rate (BER)

As the name implies, a bit error rate is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be translated into a simple formula:

BER = number of errors / total number of bits sent

As an example, assume this transmitted bit sequence:

0 1 1 0 0 0 1 0 1 1, and the following received bit sequence: 0 $\underline{0}$ 1 0 $\underline{1}$ 0 1 0 $\underline{0}$ 1

The number of bit errors (the underlined bits) is in this case 3. The BER is 3 incorrect bits divided by 10 transferred bits, resulting in a BER of 0.3 or 30%

2.2 Signal to Noise Ratio (SNR)

Signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal):

$$SNR = P_{signal}/P_{noise} \quad \text{(i)}$$

Where *P* is average power. Both signal and noise power must be measured at the same and equivalent points in a system, and within the same system bandwidth. If the signal and the noise are measured across the same impedance, then the SNR can be obtained by calculating the square of the amplitude ratio.

$SNR= P_{signal}/P_{noise} = (A_{signal}/A_{noise})^2$ (ii)

Where *A* is root mean square (RMS) amplitude (for example, RMS voltage). Because many signals have a very wide dynamic range, SNRs are often expressed using the logarithmic decibel scale. In decibels, the SNR is defined as[10]

$SNR_{dB} = 10\log_{10}(P_{signal}/P_{noise}) = P_{signal,dB} - P_{noise,dB},$ (iii)

Which may equivalently be written using amplitude ratios as

$SNR_{dB} = 10\log_{10}(A_{signal}/A_{noise})^2 = 20\log_{10}(A_{signal}/A_{noise}).$ (iv)

III. ADDITIVE WHITE GAUSSIAN NOISE (AWGN)

Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered [8].

Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun.

The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self-interference that modern radio systems encounter in terrestrial operation. [7]

IV. RAYLEIGH FADING CHANNEL

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution - the radial component of the sum of two uncorrelated Gaussian random variables[9].

Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals.[5][6] Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

In the present time, the rapid expansion of wireless technology requires new demand of communication channels with low data loss. For a good communication to occur following conditions should be satisfied.

Small size, No fading, Less PAPR, Less BER, Less SNR, Good efficiency, No complex instruments

The problem which encouraged this work is the choice of communication channel, here the Problem was that whether the AWGN channel should be used or the Rayleigh fading channel?

V. PROPOSED DESIGN

In this work the OFDM transreceiver system is designed with both AWGN and Rayleigh fading channel using QPSK modulation in MATLAB Simulink. The terms which are used in constructing the AWGN and Rayleigh fading channel are explained below

5.1 Data source

Data source consists of Random Integer Generator and Integer to bit converter.

5.1.1 Random Integer Generator: The first block of the OFDM system is the random bit generator, this block generates the serial binary data that will arrive to the serial to parallel converter.

5.1.2 Integer to bit converter: Integer to bit converter converts the integer number to digital bits. The Integer to Bit Converter block maps each integer or fixed-point value in the input vector to a group of bits in the output vector. The block maps each integer value (or stored integer when a fixed point input is used) to a group of *M* bits, using the selection for the Output bit order to determine the most significant bit. The resulting output vector length is *M* times the input vector length.

5.2. IQ Mapper

It gets the input from the data source and consists of Bit to integer converter converts digital bits to integer numbers and General QAM modulator baseband in which the process of QAM occurs. Then the conjugation of out coming signal is taken.

5.3. OFDM modulation

The output of the IQ Mapper is given to multiport selector which selects the rows then the matrix concatenation occurs and the output is given to IFFT, then a cyclic prefix is added.

5.4 OFDM Demodulation

In this process the receiver, receives the signal and then cyclic prefix is removed after that FFT occurs. Then the process of frame status conversion, removing zero padding occurs and at last pilots are removed.

5.5. IQ Demapper

Output from the above process is given to IQ Demapper where the conjugation of the signal is taken, then general QAM demodulator is used and then Integer to bit converter is used.

5.6 Data sink

The output of above process is given to input of data sink i.e. to bit to integer converter , from where we can get the desired output .The output from the IQ Demapper can be used for SNR estimation as shown in the model above.

5.7 AWGN Channel

AWGN channel is used for the communication to occur. An AWGN channel adds white Gaussian noise to the signal that passes through it.
The Noise Level of an AWGN Channel: The relative power of noise in an AWGN channel is typically described by quantities such as

- Signal-to-noise ratio (SNR) per sample. This is the actual input parameter to the awgn function.
- Ratio of bit energy to noise power spectral density (E_b/N_0). This quantity is used by BERTool and performance evaluation functions in this toolbox.
- Ratio of symbol energy to noise power spectral density (E_s/N_0)

5.7.1 Relationship between Es/N0 and Eb/N0: The relationship between E_s/N_0 and E_b/N_0, both expressed in dB, is as follows:

$$Es/No(dB)=Eb/No(dB)+10\log_{10}(k) \quad \text{(v)}$$

Where k is the number of information bits per symbol. In a communication system, k might be influenced by the size of the modulation alphabet or the code rate of an error-control code. For example, if a system uses a rate-1/2 code and 8-PSK modulation, then the number of information bits per symbol (k) is the product of the code rate and the number of coded bits per modulated symbol: $(1/2)\log_2(8) = 3/2$. In such a system, three information bits correspond to six coded bits, which in turn correspond to two 8-PSK symbols.

5.7.2 Relationship between E_s/N_0 and SNR: The relationship between E_s/N_0 and SNR, both expressed in dB, is as follows:

$$Es/No\ (dB) = 10\log_{10}(T_{sym}/T_{samp}) + SNR\ (dB) \text{ for complex input signal.} \quad \text{(vi)}$$

$$Es/No\ (dB) = 10\log_{10}(.5T_{sym}/T_{samp}) + SNR\ (dB) \text{ for real input signal.} \quad \text{(vii)}$$

Where T_{sym} is the signal's symbol period and T_{samp} is the signal's sampling period.

For example, if a complex baseband signal is over sampled by a factor of 4, then E_s/N_0 exceeds the corresponding SNR by 10 $\log_{10}(4)$.

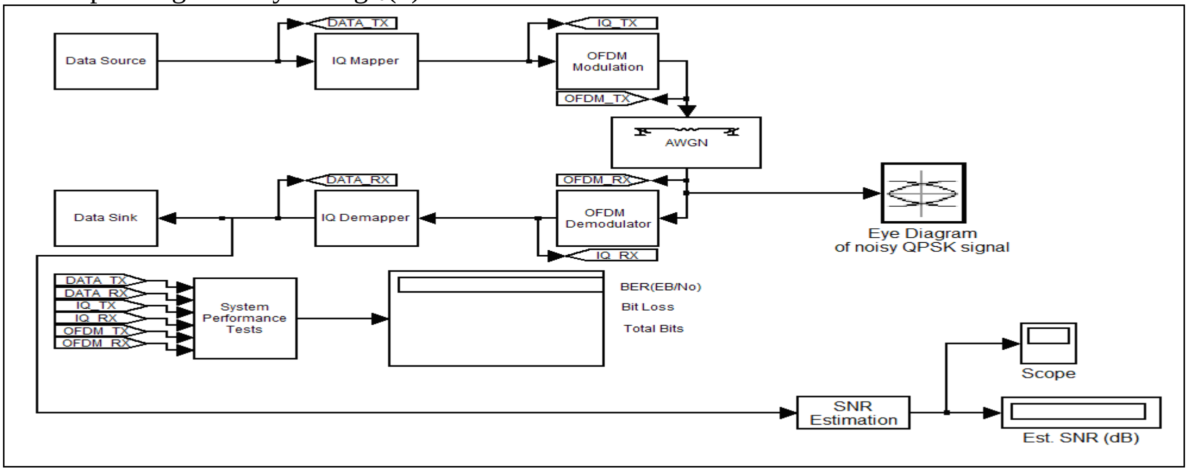

Figure 3 OFDM Modulation using AWGN channel

5.8. Rayleigh fading channel

Rayleigh fading channel is used for the communication to occur. The Multipath Rayleigh Fading Channel block implements a baseband simulation of a multipath Rayleigh fading propagation channel. This block accepts only frame-based complex signals at its input. The block inherits sample time from the input signal. The input signal must have a discrete sample time greater than 0.

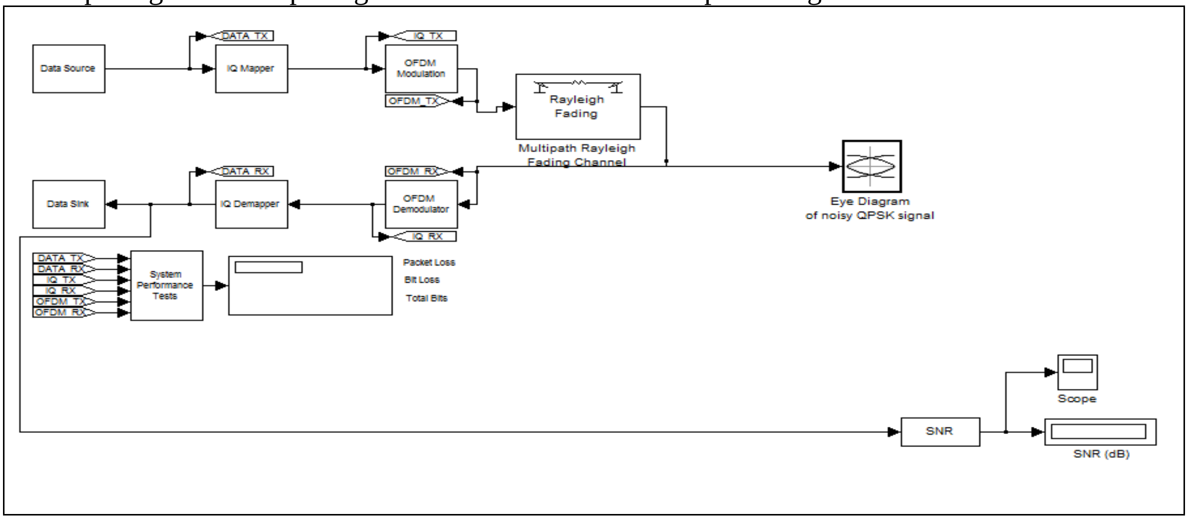

Figure 4 OFDM Modulation using Rayleigh Fading channel

VI. RESULTS AND DISCUSSION

In this section analysis and discussion on simulated results have been done. OFDM with AWGN and Rayleigh fading channels were analyzed. MATLAB software was used for designing.

Graphical Results using AWGN channel

Figure 5 represents the spectrum scope of AWGN channel .Graph is plotted between frequency (Hz) and Magnitude squared (dB).It computes and displays period gram of each input signal.

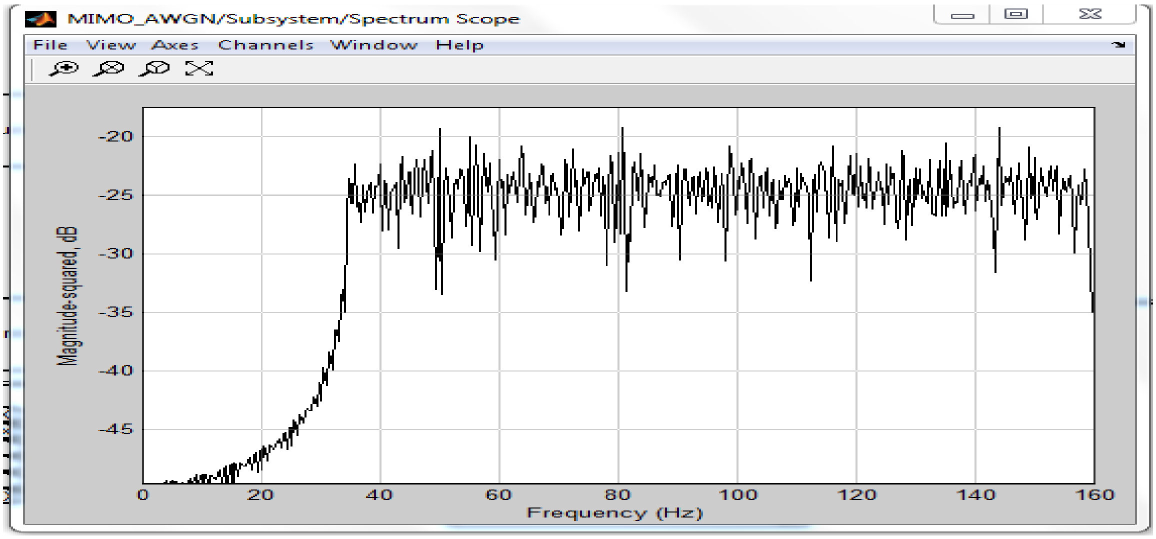

Figure 5 AWGN subsystem spectrum scope

Fig. 6 represents the discrete time scatter plot of AWGN channel. It displays in-phase and quadrature components of modulated signal constellation.

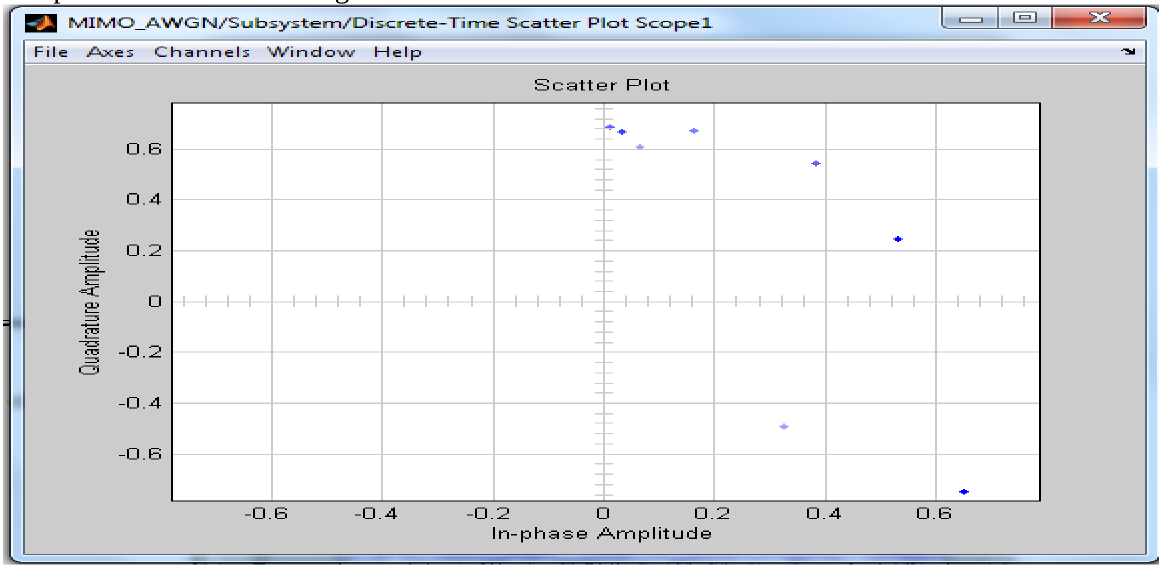

Figure 6 AWGN Discrete –Time Scatter Plot

It displays the scatter plots of a modulated signal, to reveal the modulation characteristics, such as pulse shaping or channel distortions of the signal. The Discrete-Time Scatter Plot Scope block has one input port. The input signal must be complex. The block accepts signal of type double, single, base integer, and fixed-point for input, but will cast it as double

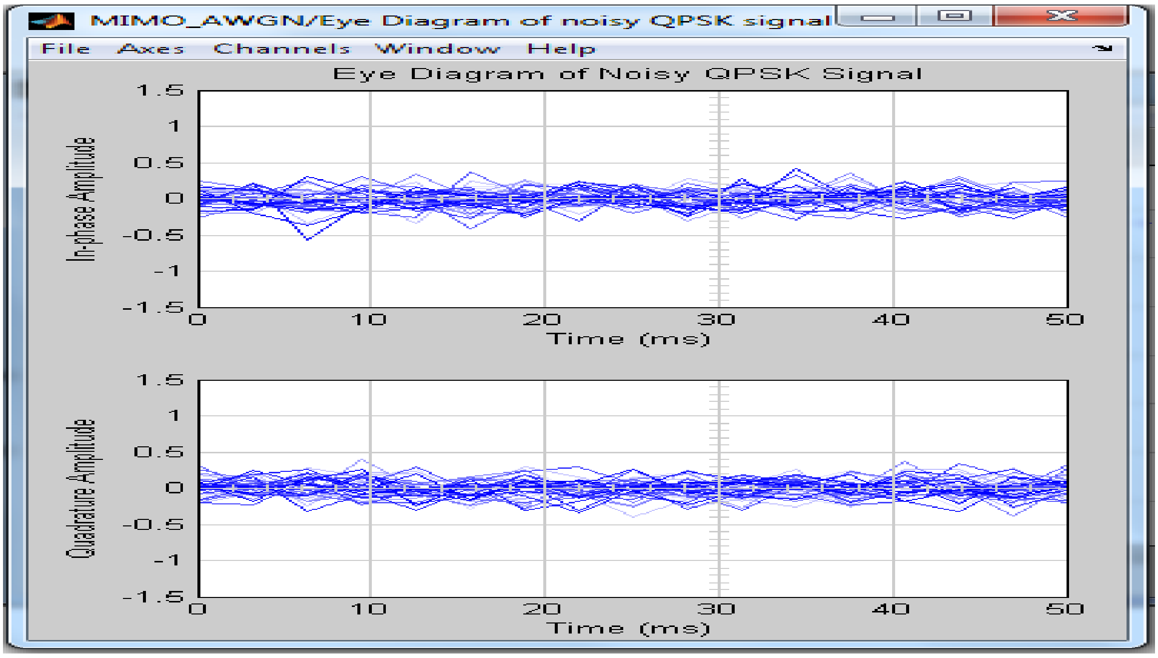

Figure 7 Eye Diagram of noisy QPSK Signal

Fig. 7 represents the eye diagram of noisy QPSK signal. It displays multiple traces of modulated signal. The Discrete-Time Eye Diagram Scope block has one input port. The block accepts signal of type double, single, Boolean, base integer, and fixed-point data types for input, but will cast as double prior to display. In sample-based mode, the input signal must be a scalar value. In frame-based mode, the input signal must be a column vector or a scalar value.

The results obtained are as follows:

BER = .36355980514096

Bit Loss =28061

Estimated SNR =3.291dB

Total Bits =77184

Graphical Results using Rayleigh fading channel

Following fig. 8 represents the spectrum scope of Rayleigh fading channel .Graph was plotted between frequency (Hz) and Magnitude squared (dB).It computes and displays periodogram of each input signal

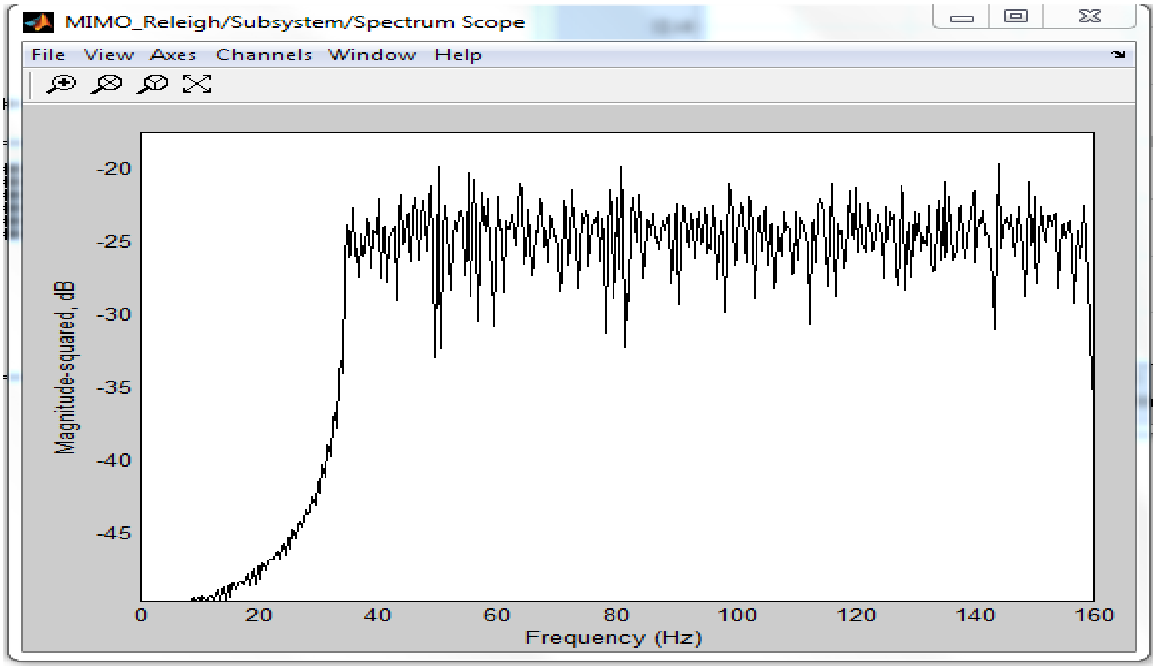

Figure 8 Rayleigh subsystem spectrum scope

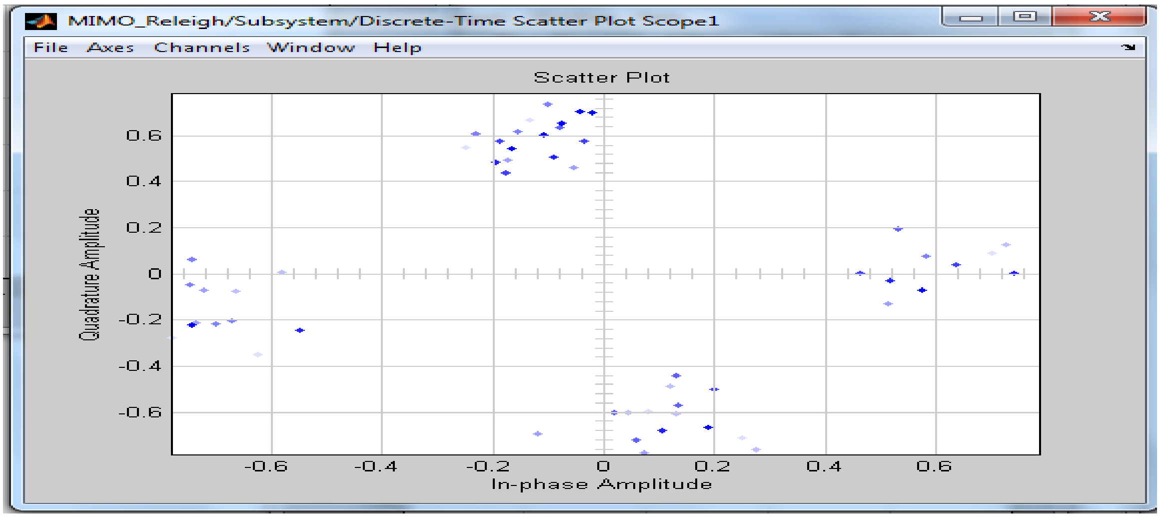

Figure 9 Rayleigh Discrete –Time Scatter Plot Scope

Fig. 9 represents the discrete time scatter plot of AWGN channel. It displays in-phase and quadrature components of modulated signal constellation. It displays the scatter plots of a modulated signal, to reveal the modulation characteristics, such as pulse shaping or channel distortions of the signal.
The Discrete-Time Scatter Plot Scope block has one input port. The block accepts signal of type double, single, base integer, and fixed-point for input, but will cast it as double

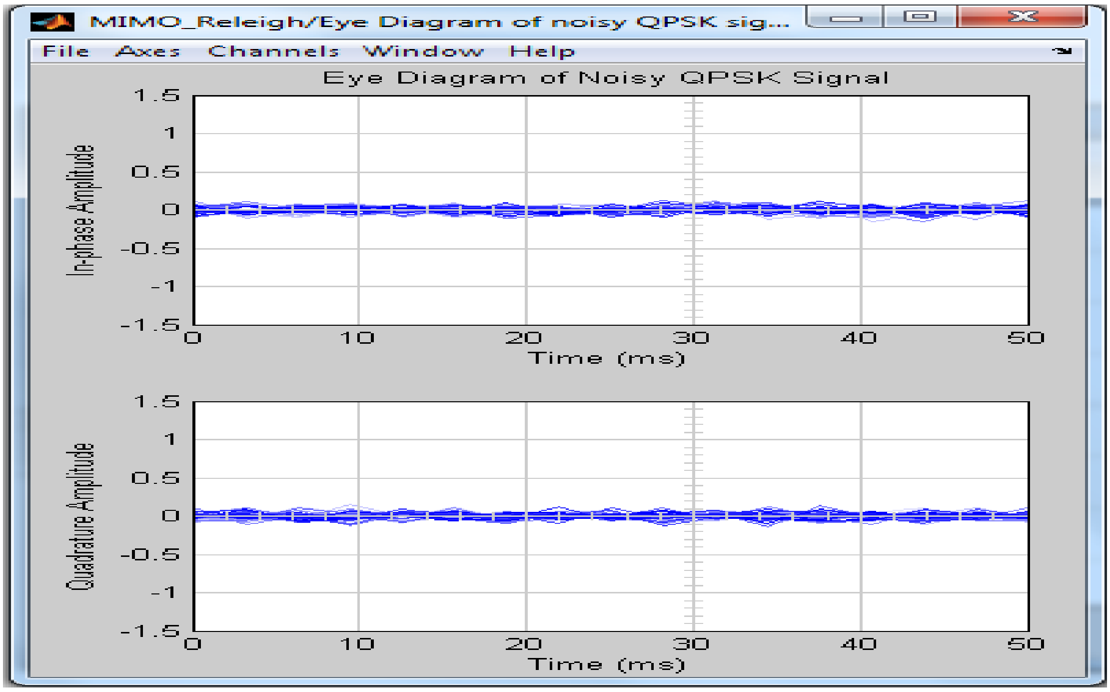

Figure 10 Eye diagram of noisy QPSK signal

Fig. 10 represents the eye diagram of noisy QPSK signal. It displays multiple traces of modulated signal. The Discrete-Time Eye Diagram Scope block has one input port. The block accepts signal of type double, single, Boolean, base integer, and fixed-point data types for input, but will cast as double prior to display. In sample-based mode, the input signal must be a scalar value. In frame-based mode, the input signal must be a column vector or a scalar value.
The results obtained are as follows:
BER = .520444651
Bit Loss =4.017e+004
Estimated SNR =2.6dB
Total Bits =77184

VII. CONCLUSIONS

In this paper we found that as compared with single carrier modulation, OFDM has many advantages as immunity to impulse interference, high spectral density, resilient to RF interference, robustness to channel fading, resistance to multipath, much lower computational complexity.

Table I

Channel	Packet loss	Bit loss	BER	SNR
Rayleigh fading	.4574	1.774e+004	.520444651	2.6dB
AWGN	.36355	28061	.36355980514096	3.29dB

We have studied about OFDM, Bit loss, Packet loss, BER, SNR. We have analyzed OFDM with QPSK using AWGN and Rayleigh fading Channel using MATLAB simulation. From the above shown results we concluded that with Rayleigh fading channel is better than the AWGN channel, because the packet loss, bit loss BER and SNR are less in Rayleigh fading channel as compared to AWGN channel.

VIII. FUTURE SCOPE

OFDM promises to be a suitable modulation technique for high capacity wireless communications and will become increasingly important in the future, as wireless networks are becoming more reliable. The following points can be investigated in the future.

- The use of OFDM in a multi-user environment in which receiver may require a very large dynamic range in order to handle the large signal strength variation between users.
- Forward Error Correction (FEC) Technique can be used as another parameter to evaluate the OFDM System performance.
- Symbol scrambling techniques to reduce the PAP ratio of a transmitted OFDM signal can be seen of great interests for improvement as it gives a small improvement of 0.25 and 0.75 dB in the required back off respectively, compared with the case without scrambling

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BIOGRAPHY

Swati Sharma. M.Tech. From Maharishi Markandeshwer University Mullana (Ambala). My dissertation work is under the guidance of Mrs. Jyoti Gupta on the above discussed topic. The project on which I have worked is -Communication Electronic Project: ('Finger Print Recognition System Using 8051 Microcontroller'). This project is about the fabrication of various Electronic components such as LCD, Memory (ROM RAM), Registers. Results obtained are similar to obtained by practical Sensor. I am Executive Member of the Technocrats Club and successfully organize several technical seminars. I have got knowledge about IJAET from internet and I am very much eager to publish my paper in the conference.