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Ravi Kant Gupta
M.Tech. Scholar,
Department of Electronics & Communication, Bhagwant University,Ajmer, Rajasthan, India

Anuj Jain
Assistant Professor,
Department of Electronics & Communication, Bhagwant University, Ajmer, Rajasthan, India

Prashant Singodiya
Assistant Professor,
Department of Electronics & Communication, Bhagwant University, Ajmer, Rajasthan, India

Correspondence:
S. Radhika
M.Phil Research Scholar
Department of Computer Science Vivekanandha College for Women
Tiruchengode, Tamilnadu

Bit error rate simulation using 16 qam technique in matlab

Ravi Kant Gupta, Anuj Jain, Prashant Singodiya

Abstract
This paper introduce the Bit error rate (BER) simulation using 16QAM (Quadrature Amplitude Modulation) in Matlab. Bit error rate is used to assess systems which can transmit digital data from one address to other address. BER is a unitless performance measure, often expressed as a percentage.
There are few Systems where bit error rate applications are useful like fiber optic data systems, radio data link systems, Ethernet, or the systems which transmit data in a network where interference, noise may lower the performance of the digital signal.
Orthogonal Frequency Division Multiplexing (OFDM) is an efficient modulation scheme proposed as a solution to this problem. OFDM splits up the data stream into a high number of subcarriers. Each of them has a low data rate and long symbol duration Ts. The various techniques such as Convolution codes and Viterbi decoding to reduce the effect of synchronization by compare OFDM and proposed method through MATLAB Simulation in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) using different parameters like number of subcarriers and modulation techniques. The proposed technique provides overall good results for different value of SNR.

Keywords: OFDM, BER, SNR, MATLAB, EbNo.

1. Introduction

1.1 Bit error rate (BER) definition

A bit error rate (BER) is the rate at which errors occurring in the transmission system. We can also say that it is the ratio of No. of Errors to the stated number of bits.
It is defined as:
BER =(No Of Errors)/(Total No.Of Bits Sent)
The signal to noise ratio (SNR) is high, if the medium between the transmitter and receiver is good, So bit error rate (BER) will become very small. The principal reasons for the reduction of a data channel and the corresponding (BER) bit error rate is noise and changes to the propagation path .

1.2 Bit error rate (BER) and Energy per bit noise spectral density(Eb/No)

Signal to noise ratios and Eb/No diagrams are parameters which are more related with radio communications systems and radio links. Hence the bit error rate (BER), can also be defined in terms of the (POE) Probability of error. To determine this relation, three more variables are used. They are the named as : Error function (Erfc), Energy in one bit (Eb) and Noise power spectral density(No) ,which is the noise power in bandwidth of 1 Hz.
So It should be well-known that for each different kind of modulation, there will be own value for the Erfc (Error function). It is happed due to the presence of noise. Hence for the each type of noise, modulation performs differently.

1.3 Factors affecting Bit error rate, BER

We have seen by using Eb/No, that the BER (bit error rate) may be affected by a no. of factors. We can see that by changing the controllable variable, it is possible to achieve the performance which is required for our system.
Interference: The interference levels are set by external factors which are present in a system and these levels cannot be changed by the main system design. Whether it may be possible to set the system-bandwidth. If we reduce the bandwidth, then the level of interference will be reduced by good amount.
Reduce bandwidth: We may also use another way that can be adopted to diminish the BER (bit error rate) is to reduce the bandwidth.
Increase transmitter power: We may also boost the power level of the system, hence the

power per bit is improved. It should be balanced against interference levels factors.

BER(Bit error rate) is a parameter which provides us an exceptional clue for the performance of a data link. Number of errors is one of the main parameters in any data link, But the BER(bit error rate) is a key parameter. One should have knowledge of the BER so that it gives information on other features like bandwidth and power.

1.4 Multicarrier Modulation

The Multicarrier Modulation is considered as an efficient way to achieve high data rate transmission because the total channel bandwidth is divided into sub-channels with subcarriers and each subcarrier is modulated with a lower data rate. OFDM is a special case of multicarrier transmission. In an OFDM system, the original data stream is split into several parallel data streams at lower data rates, and each of them is modulated separately. Conventional modulation schemes are Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK). After modulation these lower data rate streams are transmitted simultaneously through the subcarriers, resulting in achieving high-speed data transmission.

The orthogonality also greatly simplifies the design of both transmitter and receiver. A receiver can detect every subcarrier data, which commonly is done via Fast Fourier Transform (FFT). Hence we'll not require a separate filter for each sub channel . OFDM transmission has efficiency to deal with the delay spread of the multipath channel.

1.5 Multipath Channel

A phenomenon inherent to wireless system is the multipath channel. To simplify the modeling of the complex and varying channel, the channel is assuming to be wide sense stationary uncorrelated scattering. Several parameters of the channel are present to briefly explain channel effects, i.e. delay spread, coherence bandwidth, Doppler spread and coherence time. The delay spread and coherence bandwidths are used to describe flatness and frequency selectivity of the channel. When the coherence time, which describes the time variation of the channel impulse response and is the inverse of the Doppler spread, is shorter than symbol duration, time variations of the channel during one symbol cannot be neglected. Therefore, time variations can cause ICI since the Doppler spread is longer than the carrier spacing, resulting in spectral spreading from one subcarrier to another. ISI and ICI are considered as major problems of OFDM transmission.

1.6 Cyclic Prefix

For the purpose of eliminating effects of the ISI, a Guard Interval (GI) is inserted between each OFDM symbol. The guard time is chosen to be longer than the expected delay spread. To eliminate the ICI, cyclic extension which usually is called Cyclic Prefix (CP) extends the OFDM signal into the GI. Normally, this can be done by copying a part of the signal and putting it at the beginning of the signal.

1.7 Implementation of an OFDM System

An OFDM transceiver is described in Figure 1. , it can be seen how the OFDM transceiver works. First, the input data is coded by a certain coding scheme. For example, if the Forward Error Correction (FEC) coding is used, the input bits are binary data that is fed into the coder. Typical FEC codes, such as a block code, convolution code and Turbo code are used to improve the performance of the OFDM system. The signal mapping in the block diagram is used to map the bits to complex symbols. Most common signal mapping methods are PSK and QAM.

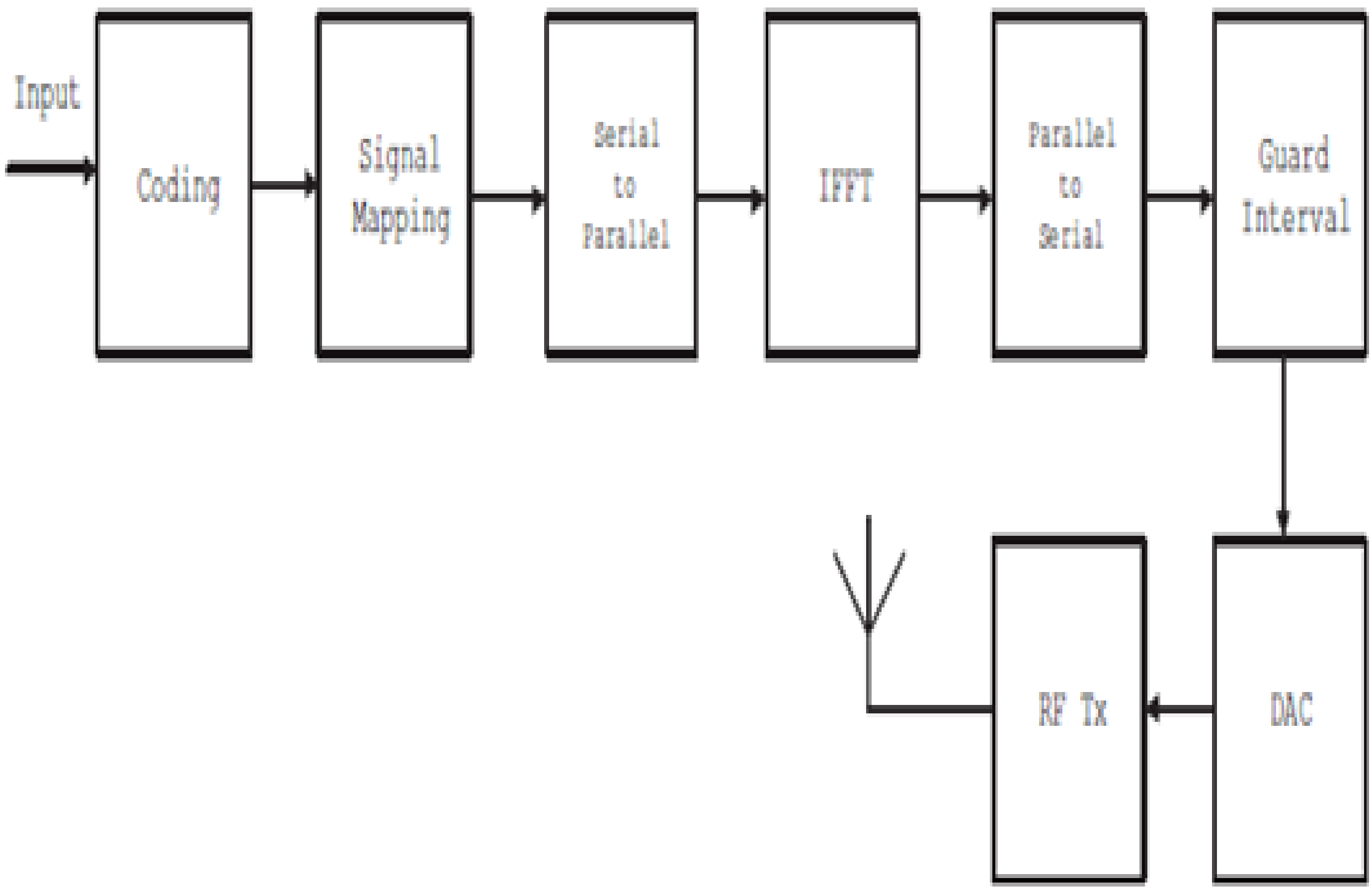

Fig 1(A): Transmitter

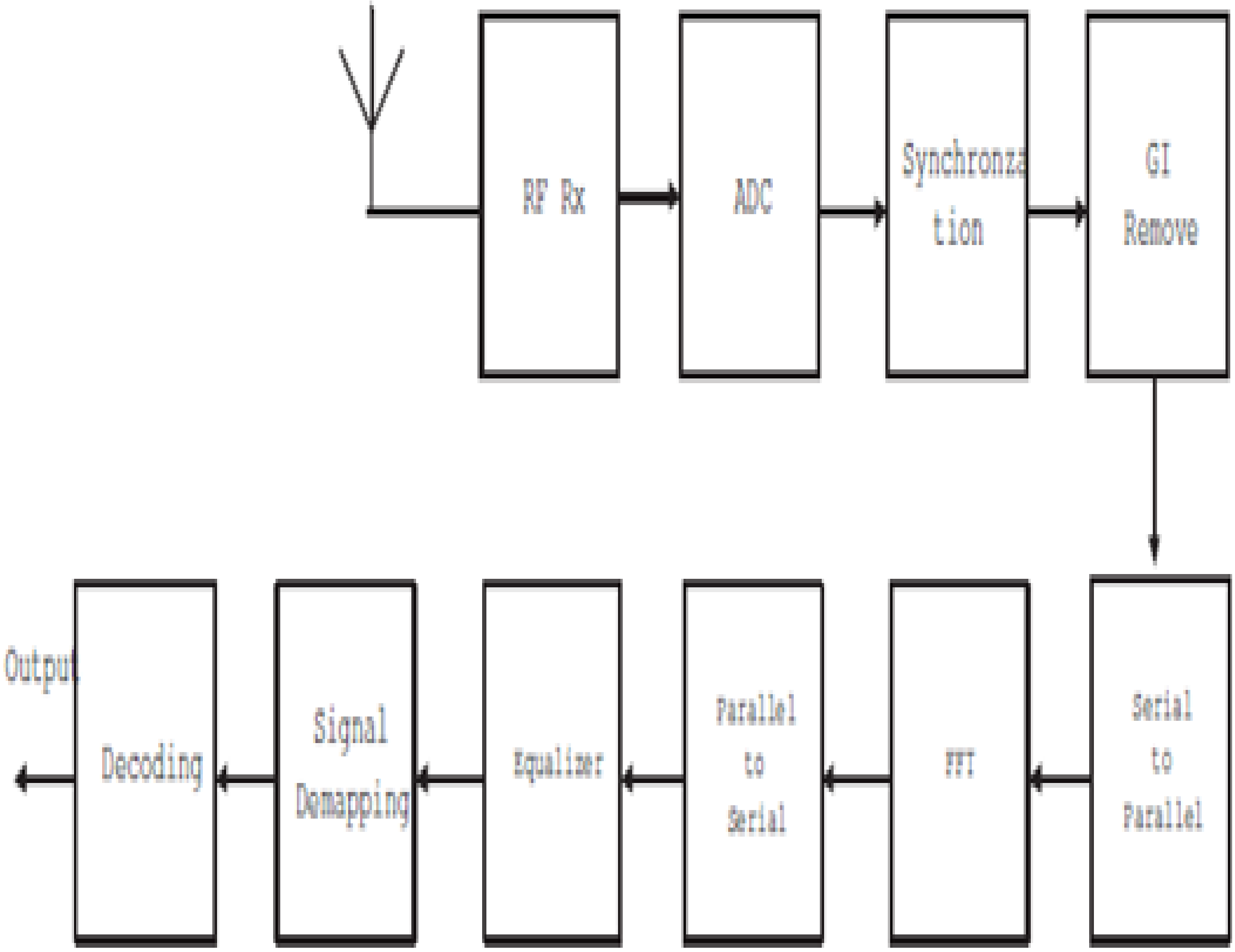

Fig 1(B): Receiver

Fig1: Block diagram of OFDM Transceiver

2. Simulation Tool

MATLAB (matrix laboratory) is a calculating environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java.

Matlab is an ideal tool for simulating digital communications systems, it is possible due to its easy language and excellent information revelation properties. Bit-error- rate testing of modems is most frequently simulation tasks in the field of digital communications. The BER (Bit-error-rate) performance of a receiver is a figure of merit which allows comparison of different designs in a blond style.

Before we can performance bit-error-rate test, we must precisely understand the meaning of these samples. We must know the purpose of representation the signal values of these samples. We must also know the time interval between successive samples. For communications simulations, the numeric value of the sample represents the amplitude of the continuous-time signal at a specific instant in time. *Ts* is the time between successive samples. It shows us how often the sampling of continuous time signal has been performed. In place of *Ts* , we usually specify the sampling frequency *fs* , which is the inverse of *Ts.*

3. Working Methodology

Orthogonal Frequency Division Multiplexing (OFDM) system has been considered as one of the strong standard candidates for the next generation mobile radio communication systems. Multiplexing a serial data symbol stream into a large number of orthogonal sub-channels makes the OFDM signals spectral bandwidth efficient. It has been shown that the performance of OFDM system over frequency selective fading channels is better than that of the single carrier modulation system. One of the major drawbacks of OFDM system is not well synchronized which brings on the OFDM signal distortion.

Recently many works [1], [2], [3], [4], [5], [6], have been done in developing a method to reduce the effect of un-synchronization. The simple and widely used method is frequency synchronization. Block coding [3], the encoding of an input data into a codeword with low PAPR is another well known technique to reduce the effect of un-synchronization problem, but it incurs the rate decrease. Convolutional coding may be used with Viterbi decoding for synchronization.

3.1 Proposed method

This proposed method use convolution decoding and pilot for synchronization in OFDM. Following diagram of proposed algorithm given below:

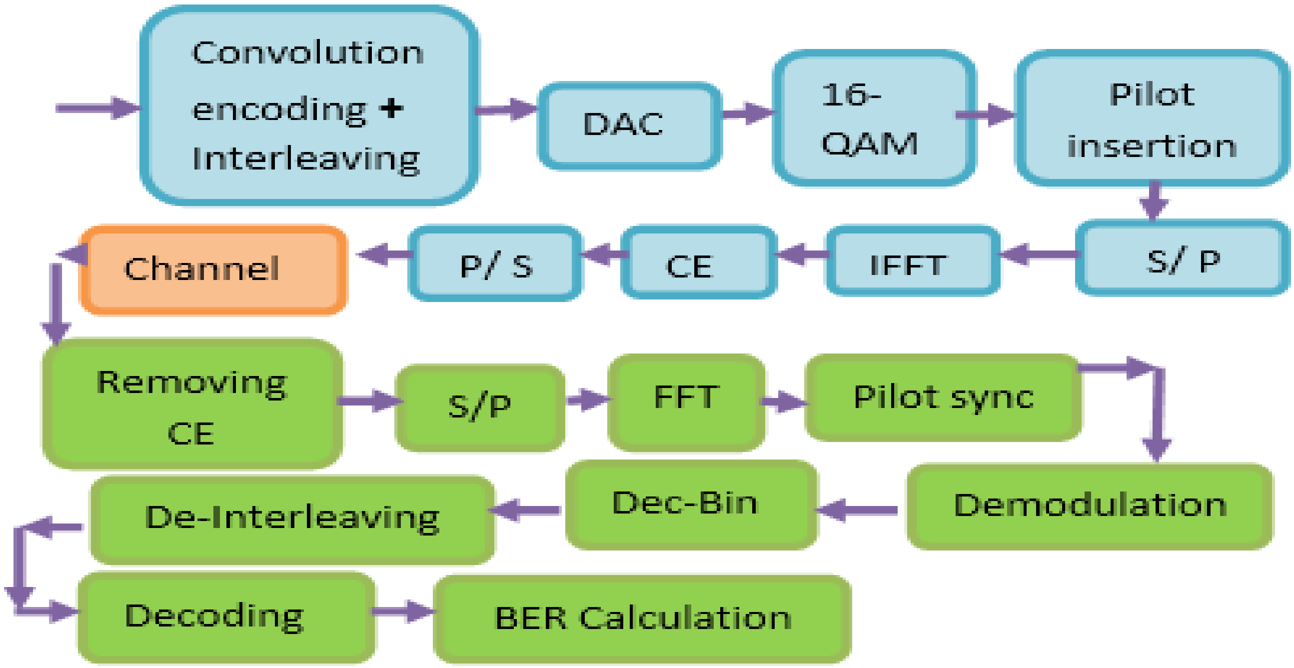

Fig 2: Proposed OFDM block diagram for Synchronization

3.2 The Viterbi Algorithm

The Viterbi algorithm is a dynamic programming algorithm for finding the most likely sequence of hidden states called the Viterbi path. We can find the most probable sequence of hidden states by listing all possible sequences of hidden states and finding the probability of the observed sequence for each of the combinations. The Viterbi algorithm is commonly expressed as the trellis diagram. It is made by using state diagram and then it is indexed in time. Maximum detection of a digital stream with ISI (Inter-symbol interference) can be described as finding the most-probable path through state transitions of trellis diagram. Each state shows the possible pattern of recently received data bits and each trellis diagram branch shows the reception of the next noisy input.

The Viterbi algorithm has 3 main parts:

1. **Branch metric calculation** – It provides the distance between the input pair of bits and the 4 probable "perfect" pairs

I) 00,
II) 01,
III) 10,
IV) 11.

For hard decision and soft decision decoders , methods of branch metric calculation are different

2. **Path metric calculation** – For each encoder state, we calculate a metric for the minimum metric path ending in this state. Path metrics are calculated by using a process named as ACS (Add-Compare-Select). It is recurring for each encoder state.

3. **Trace back** – It is necessary step for hardware implementations, which don't store complete information about the minimum metric paths, but store only one bit decision each time when one minimum metric path is selected from the two.

4. Simulation Procedure

Bit-error-rate testing requires a transmitter, a channel, and a receiver. We'll start by generating a long sequence of random bits, which is input to the transmitter. The transmitter modulates these bits onto some form of digital signaling, which we'll transmit though a simulated channel. BER (Bit-error-rate) performance is typically showed on a 2D (two dimensional) graph like X-Y axis. The X- axis is $Eb/N0$ (known as the energy-per-bit divided by the noise power spectral density), expressed in dB (decibels). The Y- axis is the BER (bit-error-rate), which is dimensionless quantity, usually expressed in powers of 10. To generate a graph of BER versus SNR, we plot a series of points.

To obtain the BER at a particular SNR, we follow the procedure given below :

4.1 Calculation of energy per symbol noise spectral density

EsN0dB = EbN0dB + 10*log10(nDSC/nIFFT) + 10*log10(nIFFT/(nIFFT+CP))

4.2 Signal to noise ratio calculation

Snr = EsNo - 10*log10((nIFFT+CP / nIFFT))

4.3 Run Transmitter

It is use to create a digitally modulated signal from a sequence of pseudo-random bits. It includes Data Generation, Data Modulation, FFT, Addition of cyclic prefix. Then OFDM signal is generated.

4.4 Add Noise

In this section we add Additive white Gaussian noise. By using this code

chan_awgn = awgn(ser_data,snr(ii),'measured');

4.5 Run Receiver

Once we have created a noisy signal, we start demodulating this signal with the help of the receiver. The receiver will produce a sequence of demodulated bits, that are compared with the transmitted bits, in order to determine how many demodulated bits are in error. In this section we use Serial to

Parallel conversion, Cyclic Prefix Removal, IFFT, Pilot removal.

4.6 Plotting the Result in terms of EbNo and BER
Here we first find SNR by using the following formula
ber=no_of_error/(nbitpersym*nsym);
After calculating it, we move on to plot the result in terms of EbNo(energy per bit noise spectral density)and BER.

4.7 Trellis code generation at transmitter
Here we generate the trellis code by using this code :
trellis = poly2trellis(constlen, codegen);
After generation we do interleaving and binary to decimal conversion.

4.8 16-QAM Modulation at transmitter
We use the following code for 16-QAM
y = qammod(dec,M);
After QAM modulation we do pilot insertion, IFFT, Add cyclic extension at transmitter.

4.9 Starting of SNR loop and Addition of Additive White Gaussian Noise
ofdm_sig=awgn(cext_data,snr,'measured');

4.10 Run Receiver
For receiving the transmitted data by verious processes we use the code given below
rxed_sig(i)=ofdm_sig(i+16);
After this we code for FFT, Pilot Synchronization, Demodulation, Decimal to binary conversion,De-Interleaving and Decoding.

4.11 BER Calculation and End of SNR loop
BER(si,o)=errors/length(data);

4.12 Plotting of BER vs SNR Curve
semilogy(snr,BER(2,:),'.-');

5. Results
The main aim of this dissertation is to simulate the OFDM systems by using pilot insertion and cyclic prefix for the reduction of BER. The aim of doing the simulation is to measure the performance of OFDM with BER and SNR calculation under Additive White Gaussian Noise channel conditions, under 16 point QAM modulation scheme.
All simulations are performed in MATLAB 7.10.0.499 (R2010a).

6. Simulation Results
Fig 3 represents the randomly generated transmitted data (showing data points and phase representation).

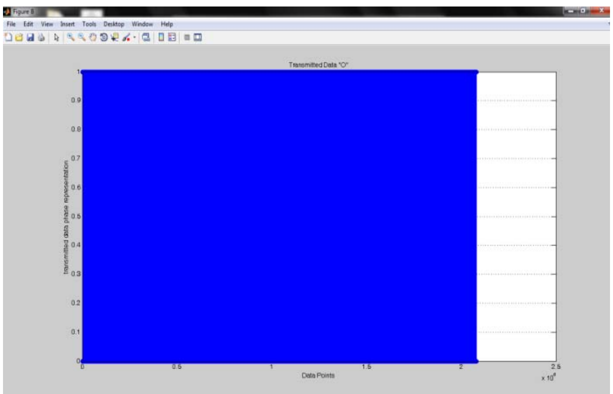

Fig 3: Randomly Generated Transmitted Data

Fig 4 represents OFDM signal input (graphical representation between amplitude and time)

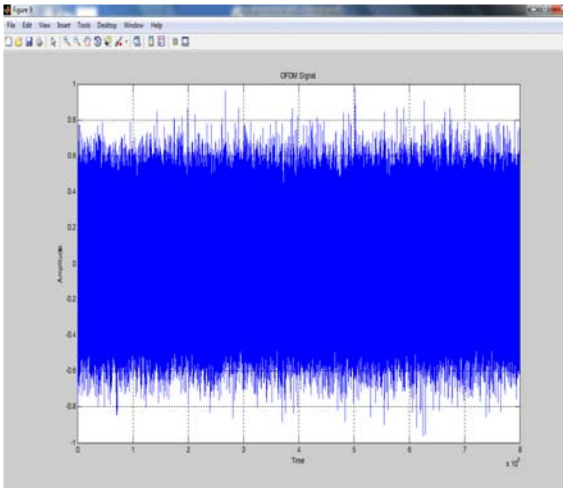

Fig 4: OFDM Signal

Fig 5 displays the scatter plot for QAM 16 point without interference of AWGN.

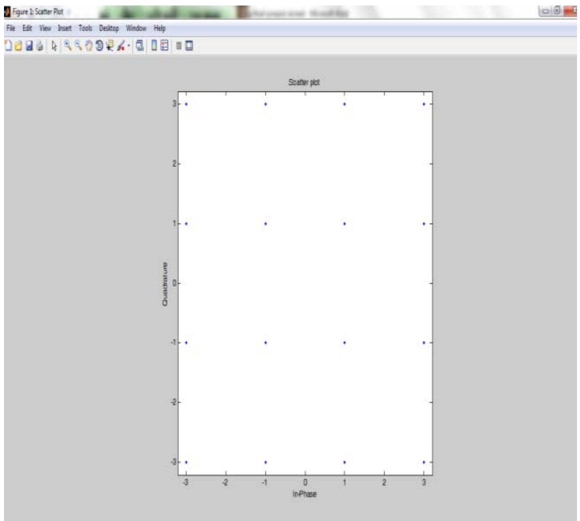

Fig 5: Scatter plot of 16 QAM without Interference

Fig 6 displays a comparison of BER and SNR of proposed method and simple OFDM by 16-QAM modulation scheme with a number of data sub-carriers 58 and FFT size is 256.

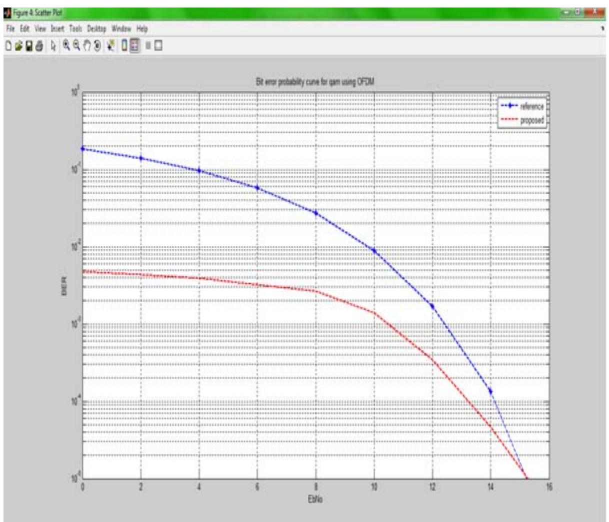

Fig 6: BER vs Ebno. Curve

Fig 7 displays graphical representation shows a comparison between BER and SNR using viterbi algorithm method and convolutional codes.

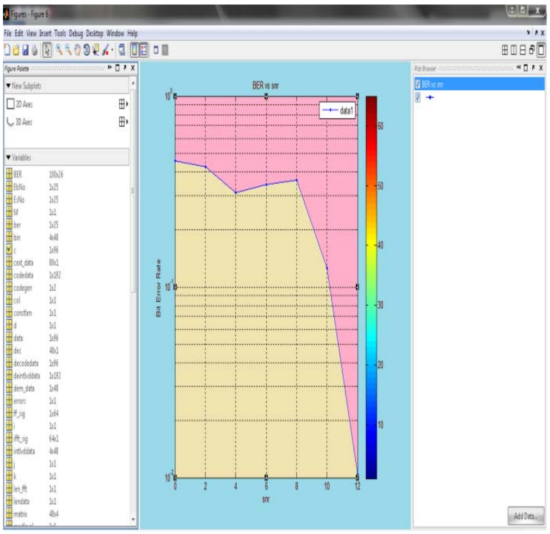

Fig 7: BER vs SNR Curve

7. Conclusion

The performance of OFDM systems depends on the signal quality seen by the receiver. The main advantage of the work done is as follows: The important parameters in viterbi algorithm for synchronization problem reduction have been studied through MATLAB simulation. Here the convolution method has been used to reduce the effect of error in OFDM. Viterbi algorithm is used for decoding purposes. Computer simulations have shown that: Error between simple OFDM method and convolution method in terms of bit error rate, taking different values of signal to noise ratio. Outputs are shown in graphical representation between BER and S/N ratio, which is known as bit error probability curve. Our algorithm improves the accuracy compare to simple OFDM by:

10^{-1} at 0db SNR for simple OFDM and 10^{-3} at 0db SNR for proposed method (Convolution OFDM). This method shows here the better result as compared to simple OFDM.

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