International Journal of Engineering Innovation & Research
Volume 10, Issue 5, ISSN: 2277 – 5668

Using OFDM System in Wireless Transmission for Resistance to ISI

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Date of publication (dd/mm/yyyy): 13/09/2021

Abstract **– The main objectives of this paper is investigate the effectiveness of OFDM system as a modulation technique, over single carrier systems for wireless radio applications. An OFDM system is modeled using MATLAB to allow various parameters of the system to be varied and tested. The aim of doing the simulations is to measure the performance of OFDM system under different channel conditions, and to allow for different OFDM configurations to be tested. Two main criteria are used to assess the performance of the OFDM system, which are its tolerance to ISI because of multipath delay spread and channel noise. The simulation software will include generation of 16-QAM complex data symbols, implementation of OFDM modulator, implementation of OFDM demodulator, OFDM signal with the cyclic extension and Symbol Error Rate effected by noise (AWGN) and Doppler frequency. When this technique is used with cyclic extension, the effects of noise channel and Doppler frequency can be reduced significantly. In addition, the symbol error rate gets rapidly worse as the SNR drops below 5dB and the general behavior of the 16-QAM is that SER increases as the Doppler spread increase. The reason is because of the existence of severe ISI caused by Doppler shifts.**

Keywords **– OFDM, 16QAM, IFFT, DFT, ISI, AWGN Channel.**

I. Introduction

In the not -to-distance future, people will be not only accessing high-speed Internet with wireless equipment, but also exchanging media, such as photo, music and video, among various consumer electronic without use of any wires. Among various transmission techniques to fulfill this goal, orthogonal frequency division multiplexing (OFDM) is a promising candidate because of its resistance to inter-symbol interference (ISI) [3], which is a common problem in high-speed wireless data transmission.

Although the popularity of OFDM has been growing rapidly just in recent years, the concept of using parallel data transmission and frequency division multiplexing can be traced back to the 1950's, it was not widely utilize because of its implementation requiring a large number of analogue devices, such as sinusoidal generator, band pass filters and coherent demodulators. A major contribution to OFDM was present in 1971[14], in which the idea of using the Discrete Fourier Transform (DFT) for implementation of the modulation and demodulation of OFDM signal was introduced, which can greatly reduce complexity of the original OFDM scheme by eliminating banks of subcarriers oscillators and coherent demodulators usually required in FDM systems. Another important contribution was made in 1980 [10], in which the cyclic prefix was used to solve the orthogonality problem of OFDM signal over time dispersive channels.

In Section II, Related works are discussed. In Section III, Proposed system is presented. In Section IV, the simulation environment and results are described. In Section V, Comparison with other works is discussed.

II. Related Works

Many methods have been implemented based on different technologies have been proposed in literatures. In this paper is discussed some of these works similar for our study.

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Masoud Olfat [7]. Proposed a paper on Orthogonal Frequency Division Multiplexing (OFDM) is mainly designed to combat the effect of multipath reception, by dividing the wideband frequency selective fading channel into many narrow flat sub channels. OFDM offers flexibility in adaptation to time varying channel condition by adopting the parameters at each subcarriers accurately. To avoid ISI due to multipath, successive OFDM path, successive OFDM symbols are separated by guard band. This makes the OFDM system resistant to multi-path effect.

Mrutyyunjaya Panda, Sarat Kumar Patra [8]. In this paper, the BER curve of OFDM is compared with the single carrier 16-QAM system. The BER curve for COFDM using differential encoding method is also discussed. OFDM may be combined with multiple antennas and both Transmitter and Receiver, resulting a MIMO-OFDM system. Also in this paper, various channel estimation method of MIMO-OFDM system using MMSE and LS are discussed. The effect of various Doppler frequencies on the normalized channel estimation is discussed. Finally, the normalized channel estimation versus no. of iteration by using multiple antennas at both the access point is discussed.

Alan C Brooks, Stephen J. Hoelzer, Thomas L Stewart, In Soo Ahn [1]. In this paper a AMATLAB program has been written to investigate OFDM communication systems. Single-carrier QAM and multicarrier OFDM are compared to demonstrate the strength of OFDM in multipath channels. Two graphical user interface demonstrations show some of the basic concepts of OFDM.

Deepak Sharma, Praveen Srivstava [4]. In this paper, a user interface is designed using GUI tool of MATALAB to analyze the performance of OFDM system in terms of SNR vs. BER variation. BPSK, QPSK, QAM techniques are analyzed in reference to OFDM processing. Rayleigh fading channel and Multipath fading channels are used as a communication channel.

III. PROPOSED SYSTEM

In proposed system we are building a system (OFDM) using Mat lab to allow variety and testing of different system parameters to get a perfect result. Figure 1 shows a block diagram of a generic OFDM system.

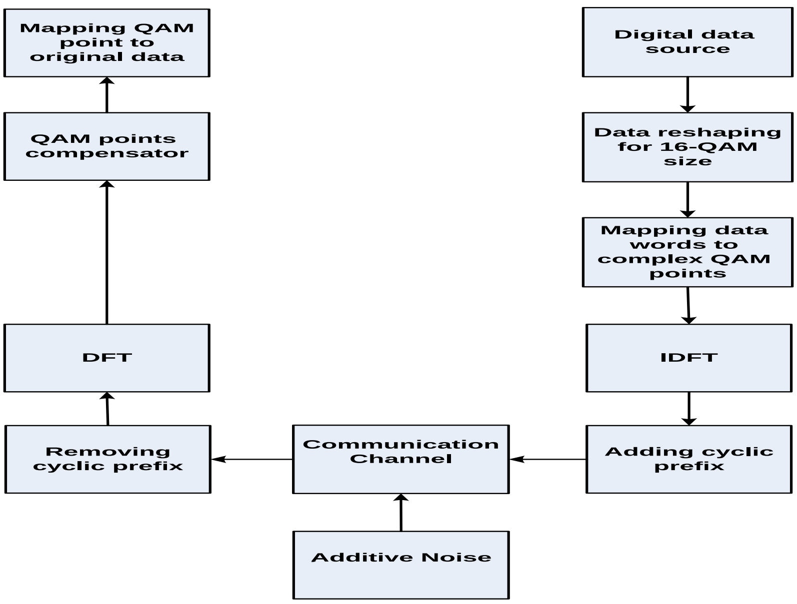

Fig. 1. Block diagram of a generic OFDM system.

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The techniques of OFDM System:-

A. *Mathematical Model*

The design procedure followed a mathematical equations staring from loading raw binary data to the system tell getting these data back. In the first step QAM complex data symbol are generated from raw data. For 16-QAM, each complex data symbol carries n = 4 bits.

$$n = \log_2 16 \tag{1}$$

Each 4 bits $\{n_{k1}, n_{k2}, n_{k3}, n_{k4}\}$ are mapped to a corresponding QAM symbol by equation (2), before this equation, 0's and 1's of data bits are changed to 1's and -1's [12]:

$$s_k = |s_k|e^{j\theta k} = 2n_{k1} + n_{k2} + j(2n_{k3} + n_{k4}) \tag{2}$$

IDFT is used to generate discrete samples $\{x_n\}$ of the signal to be transmitted. For real-valued signal, complex Fourier harmonics (QAM symbol) should satisfy the symmetry property. To comply with this property the complex data symbols $\{S_k\}$ are changed to symmetrical set $\{S_N^{'}\}$:

$$\{S_k'\} = \{0\{S_k\}0\{S_k^*\}\} \tag{3}$$

$$x_n = \frac{1}{\sqrt{N}}\sum_{K=0}^{N-1} S_K' e^{j2\pi n\frac{k}{N}}, n = 0,1,2,\ldots\ldots N-1 \tag{4}$$

Where $N=2K+2$

The discrete time signal $\{x_n\}$ is samples of continues time real signal $x(t)$ given by the equation:

$$x(t) = \frac{2}{\sqrt{N}}\sum_{K=1}^{K-1} | S_k | \cos(\frac{2\pi kt}{T} + \theta_k) \tag{5}$$

To deal with delay spread of wireless channels, a cyclic extension is usually used in OFDM systems. There are three different types of cyclic extensions cyclic prefix, cyclic suffix and cyclic prefix and suffix [11]. In this dissertation we consider cyclic prefix and cyclic suffix. Denote T_g the length of a cyclic extension that is inserted between OFDM blocks. OFDM signal, x (t), can be extended into $\tilde{x(t)}$ by :-

$$\tilde{x}(t) = \begin{cases} x(t) & T \le \text{if} \quad 0 \le t \\ x(t-T) & T_g + T \quad \le \text{if} \quad \text{T} \le t \end{cases} \tag{6}$$

With the cyclic extension, the actual OFDM symbol duration is increased from T to $T_s = T + T_g$.

OFDM symbol is given as follows:

$$x_f(n) = \begin{cases} x(N+n), & n = -GI, -GI+1, \ldots, -1 \\ x(n), & n = 0,1,\ldots, N-1 \end{cases} \tag{7}$$

Where: $GI = (T_g / T)*N$

At receiver side, received signal is sample at the same sampling intervals of $\{x_n\}$ which equal to:

$$T_S = \frac{T}{N} \tag{8}$$

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B. *Effects of Noise and Multipath Channel Compensation*

Additive white Gaussian noise (AWGN) is used as mathematical model for communication channel. The OFDM pulse signal x_t will be corrupted by AWGN at different levels of signal to noise ratio SNR, consequently the discrete sample and recovered QAM symbols at the receiver will deviate from its original value. At this point the channel compensation is essential. 16QAM modulation scheme is used for a64-subcarrier OFDM system with three-path Rayleigh fading channel. The compensation is performed by correcting the distorted data symbols to the nearest neighbor in the 16-QAM constellation. The transmitted signal $x_f(n)$ will pass through the frequency selective time varying fading channel with additive noise. The received signal is given by [13] :-

$$y_f = x_f(n) \otimes h(n) + w(n) \tag{9}$$

Where *w*(*n*) is Additive White Gaussian Noise (AWGN) and *h(n)* is the channel impulse response. At the receiver, cyclic prefix is removed:-

$$y_f = x_f(n) \otimes h(n) + w(n) \tag{10}$$

Then *y (n)* is sent to FFT block for the following operation :-

$$Y(k) = DFT\{y(n)\} \quad k = 0,1,2,...,N-1 \quad = \frac{1}{N}\sum_{n=0}^{N-1} y(n) e^{\frac{-j2\pi nk}{N}} \tag{11}$$

Assuming there is no ISI, then the relation of the resulting Y (k) to $H_e(k)$ = DFT {$h(n)$}, I(k) (ICI because of Doppler frequency) and $W(k)$ = DFT {$w(n)$}, with the following equation :-

$$X_e(k) = \frac{Y(k)}{H_e(k)} \quad k = 0,1,...,N-1 \tag{12}$$

IV. SIMULATION

The simulation software will include Generation of 16-QAM complex data symbols, Implementation of OFDM modulator, and Implementation of OFDM demodulator, OFDM signal with the cyclic extension to eliminate ISI, Effect of Noise and Multipath Channels compensation on OFDM symbol.

A. *OFDM Model Parameters*

The parameters of an OFDM system can be determined as follows [11] :

- As a rule of thumb, the guard time T_g should be at least twice the delay spread, i.e. $T_g \geq 2\tau$
- To minimize the signal-to-noise ratio (SNR) loss due to the guard time, the symbol duration should be much larger than the guard time. However, symbols with long duration are susceptible to Doppler spread, phase noise, and frequency offset. As a rule of thumb, the OFDM symbol duration T should be at least five times the guard time, i.e. $T \geq 5T_g$
- The frequency spacing between two adjacent subcarriers Δf is:- $\Delta f = \frac{1}{T_s}$
- For a given data rate *R*, the number of information bits per OFDM symbol B_{info} is:- $B_{info} = RT_s$

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- For a given B_{info} and the number of bits per symbol per subcarrier R_{sub}, the number of subcarriers N is: $N = \frac{B_{info}}{R_{sub}}$
- The OFDM signal bandwidth is defined as:- $BW = N\Delta f$

For the results to be clearly demonstrated and viewed, the designed example in this paper chosen to have the simple parameters presented in table (I) and an OFDM system loosely based on IEEE 802.11a specifications presented in table (II) will be used to investigate the BER for BPSK with OFDM in a Rayleigh fading channel.

Table I. Key Parameters of the designed OFDM model parameters.

Parameter	Description
OFDM pulse duration (T)	100 µsec
Pulse shaping	Rectangular
Number of sub channels (K)	9
Size of FFT/IFFT (N)	20
Length of cyclic prefix (Tg)	(Ts /4) = 25 µsec
Bandwidth of OFDM signal	9*0.01 HZ

Where N = 2K + 2.

Table II. Key parameters of the IEEE 802.11a OFDM standard.

Parameter	Value
FFT size. Nfft	64
Number of used subcarriers. Ndsc	52
FFT Sampling frequency	20MHz
Subcarrier spacing	312.5kHz
Used subcarrier index	{-26 to -1, +1 to +26}
Cylcic prefix duration, Tcp	0.8µs
Data symbol duration, Td	3.2µs
Total Symbol duration, Ts	4µs

B. *Simulation Results and Discussion*

The simulation program returns result at different stages of OFDM system.

Figurer 2 Shows Discrete Sample generated from symmetrical complex data point. Figurer 3 Shows both discrete sample and continuous OFDM signal. It is clear that sampling time is equal to 5 second T/N = 100/5 = 5 Seconds. The power density spectrum of an OFDM is shown in figurer 4.

Signal and discrete sample with cyclic prefix are shown in Figure 5 and figure 6. It is clear that cyclic prefix is simply a repetition of the last T/4 samples. OFDM Signal and discrete sample with Cyclic Suffix are shown in figure 7 and figure 8.

Figure 9 shows that the complex data symbol are recovered by DFT exactly as they generated at the QAM m-

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-odulator, blue circle represent the original position of QAM point and the red cross represent the received QAM point, it is clear that they are coincident, so there is no error in reception since the channel is noise free.

For transmission through noisy channel. Gaussian noise adds to a continuous OFDM signal made the QAM point generated by DFT to deviate from its correct position. Figure 10 shows Received QAM symbol through noisy channel. The deviated distance depend on channel noise and signal to noise ratio SNR.

It's clear that for low SNR there are still points estimated wrongly. As SNR becomes higher the estimation algorithm works better and data points correctly estimated. Figures 11, 12, 13, 14 shows the estimated data points for different levels of SNR. As shown in figure 15 the symbol error rate gets rapidly worse as the SNR drops below 5dB.

Simulation result in figure 16 shows the performance of 16-QAM OFDM system in Rayleigh fading channel for different Doppler frequency. The general behavior of the 16-QAM is that SER increases as the Doppler spread increase. The reason is because of the existence of severe ISI caused by Doppler shifts.

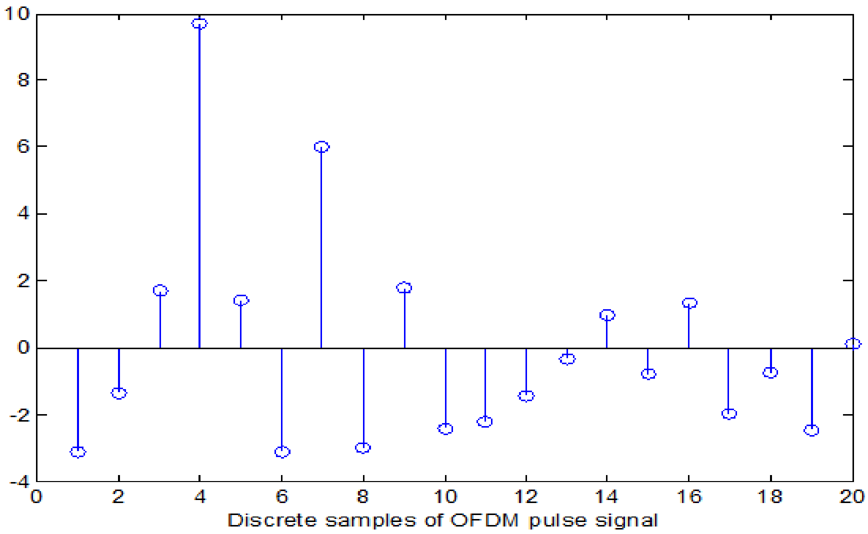

Fig. 2. Discrete sample generated from symmetrical complex data point.

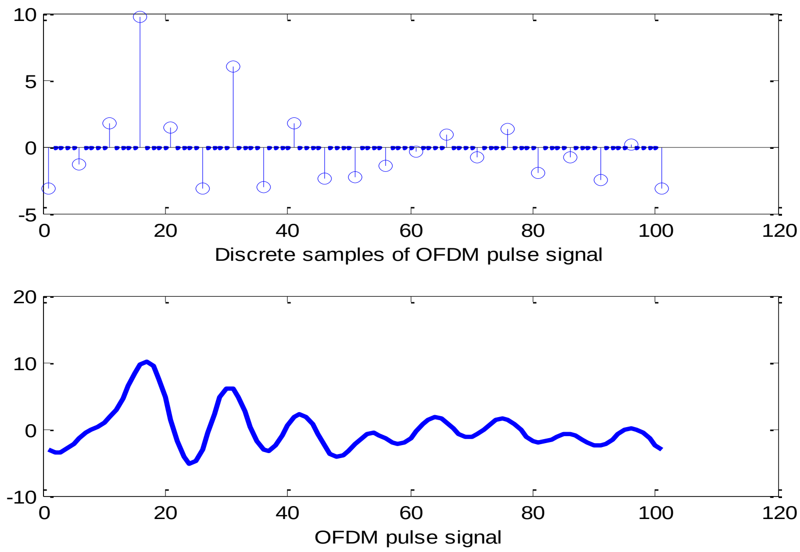

Fig. 3. Discrete Sample and its corresponding OFDM signal.

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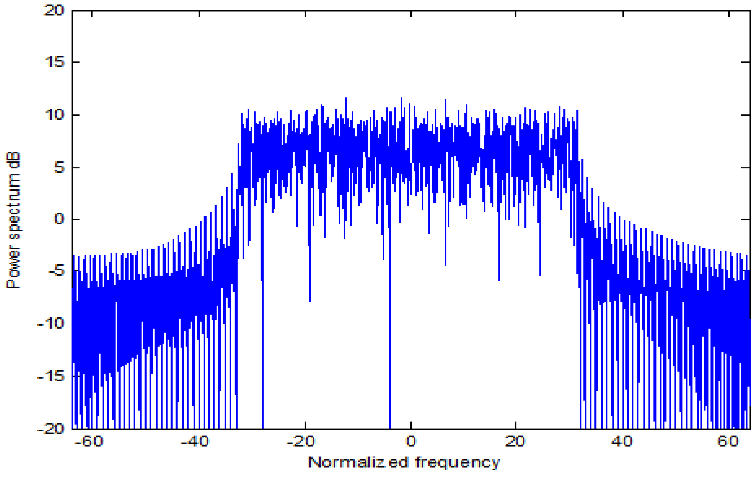

Fig. 4. The power density spectrum of an OFDM signal.

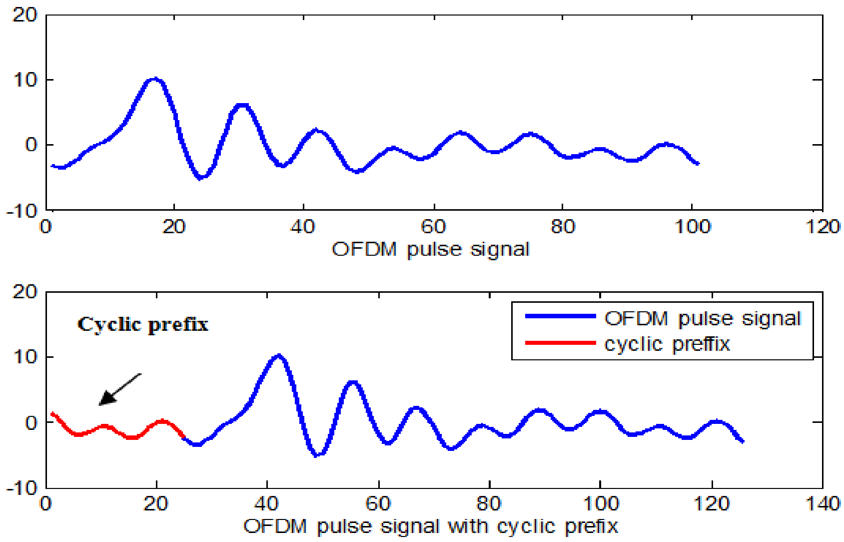

Fig. 5. OFDM signal with and without cyclic prefix.

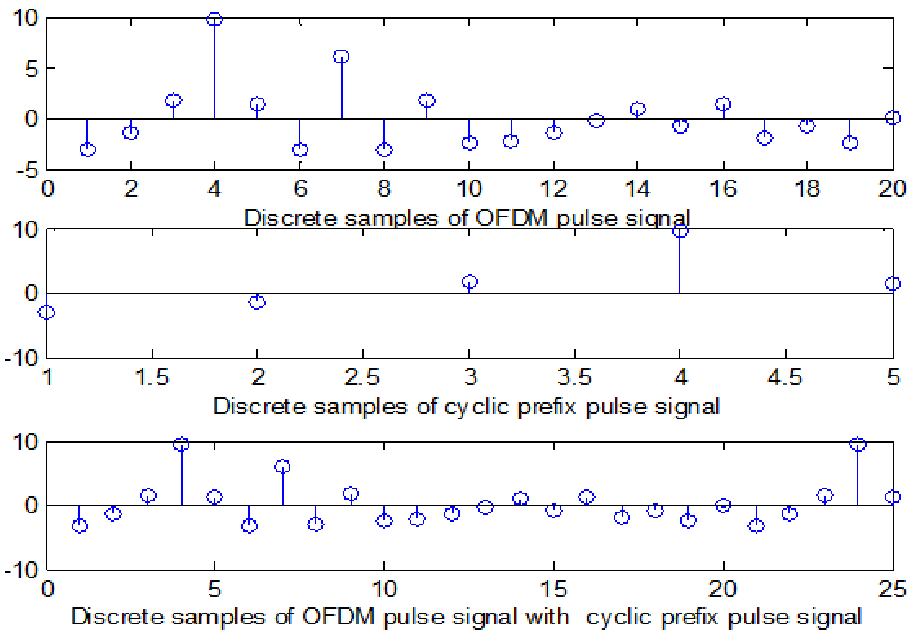

Fig. 6. Discrete sample of OFDM signal with cyclic suffix.

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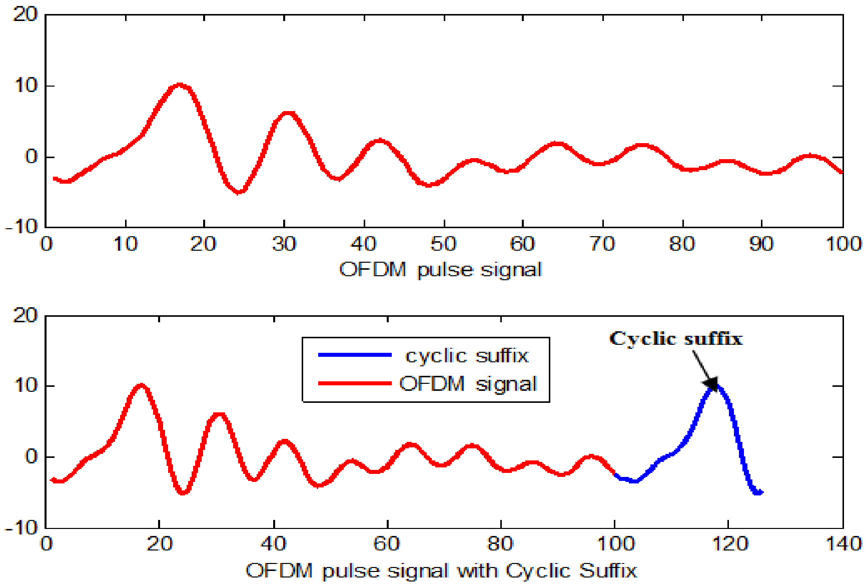

Fig. 7. OFDM signal with and without cyclic suffix.

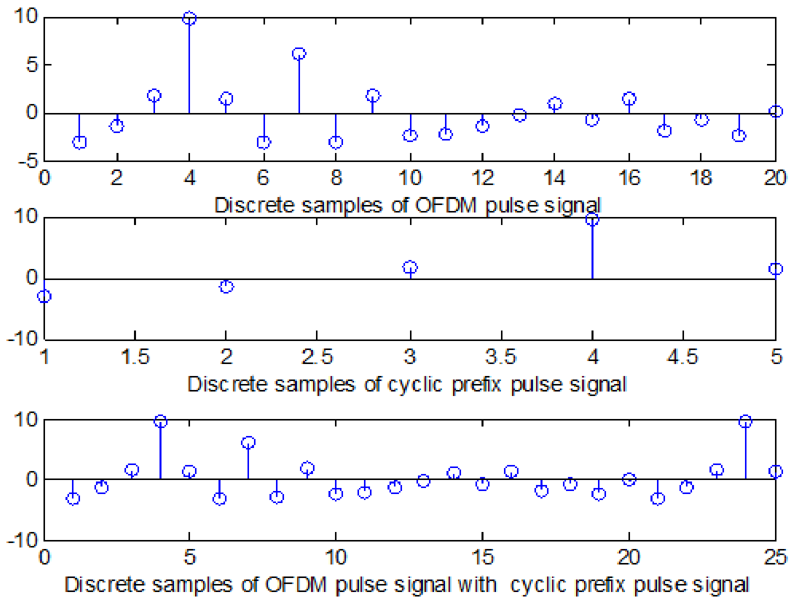

Fig. 8. Discrete sample of OFDM signal with cyclic suffix.

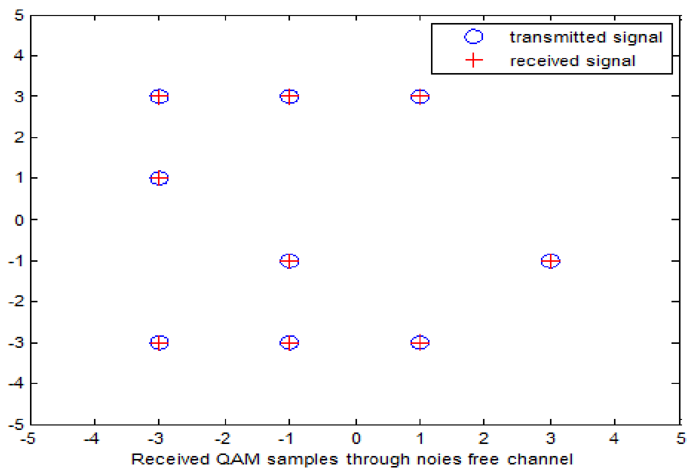

Fig. 9. Received QAM symbol through noise free channel.

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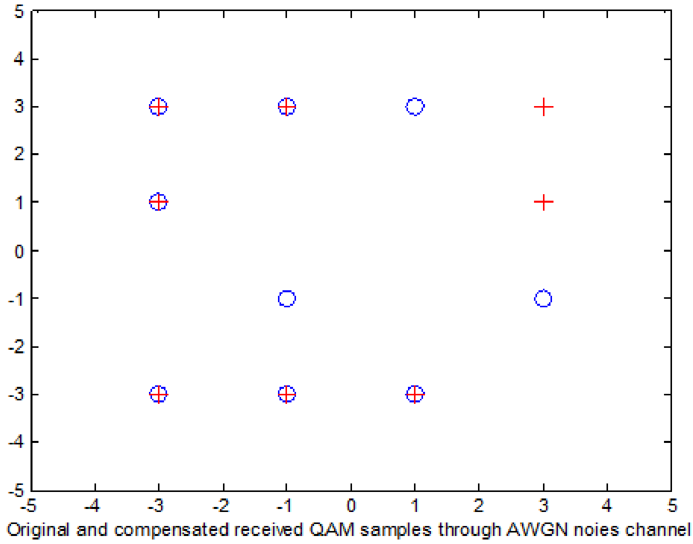

Fig. 10. Received QAM symbol through noise channel.

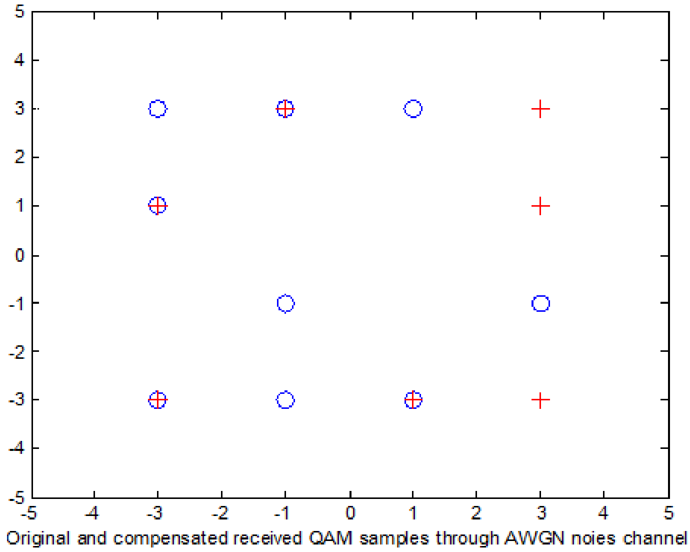

Fig. 11. The nearest neighbor QAM symbol through noisy channel with SNR = 8dB.

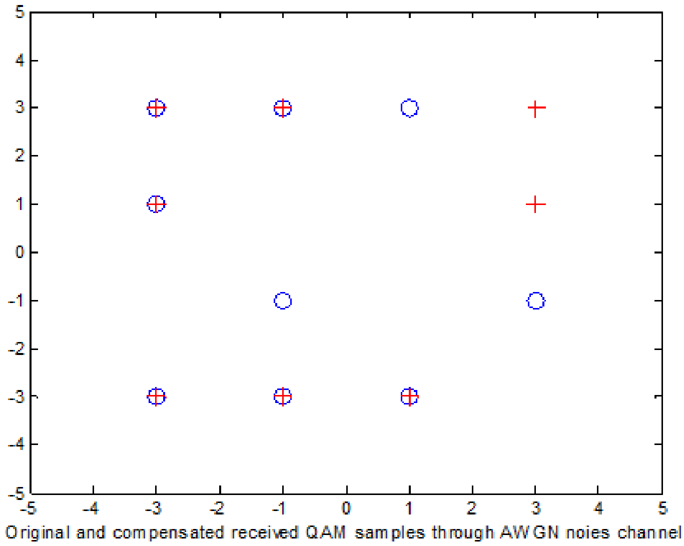

Fig. 12. The nearest neighbor QAM symbol through noisy channel.

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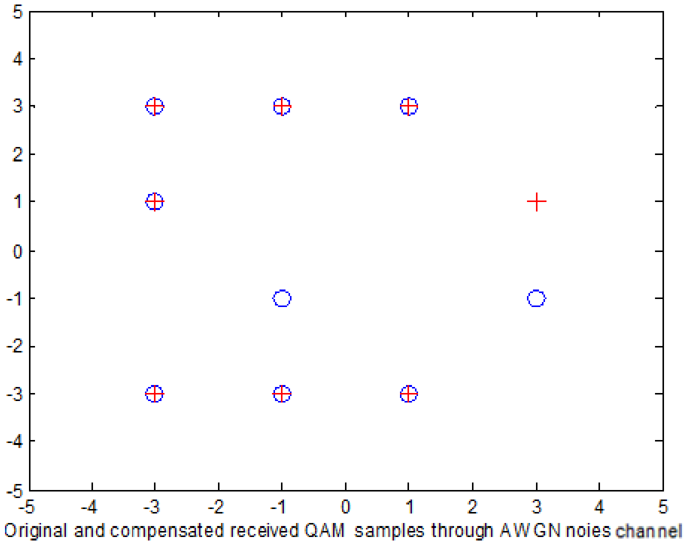

Fig. 13. The nearest neighbor QAM symbol through noisy channel with SNR = 10dB.

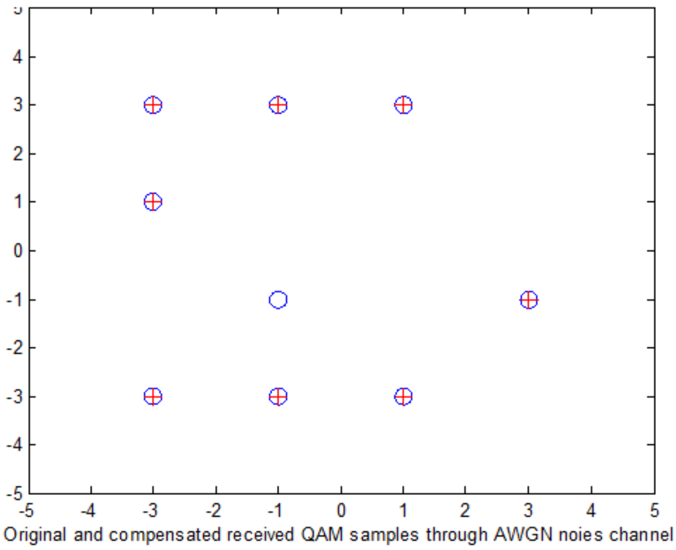

Fig. 14. The nearest neighbor QAM symbol through noisy channel with SNR = 11dB.

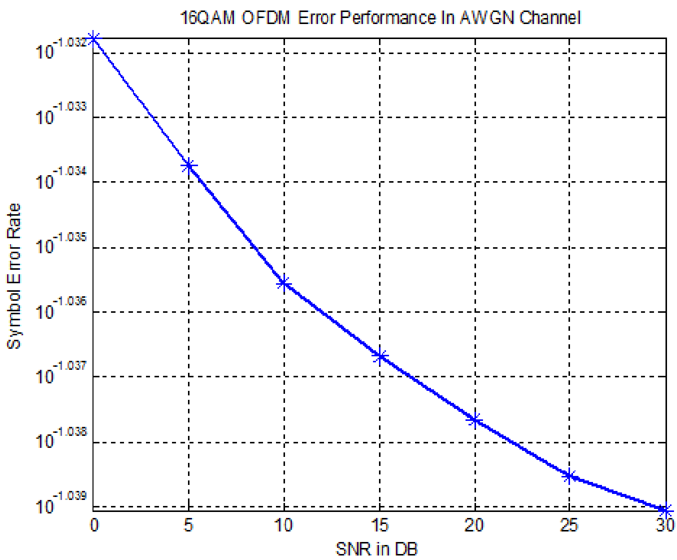

Fig. 15. Symbol error rate effected by noise (AWGN).

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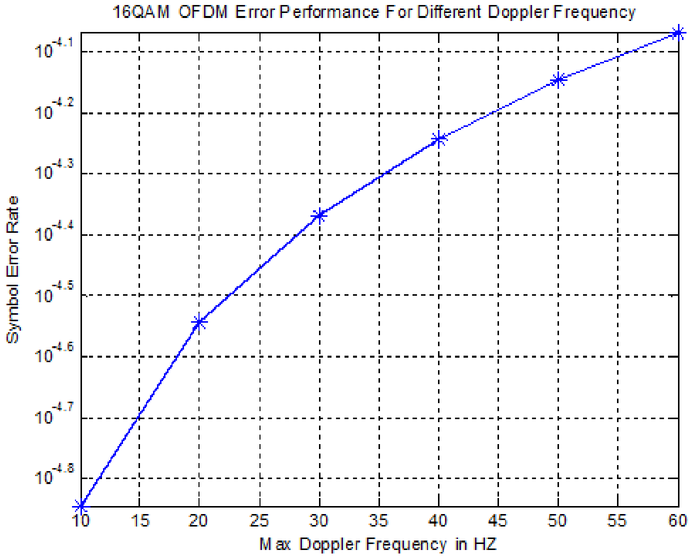

Fig. 16. Symbol error rate effected by Doppler Frequency.

V. Comparison with Other Works

We have compared with some basic OFDM techniques has been conducted by evaluating a paper work with other studies. Table 1 shows some papers that compare them.

Table III. Comparison evaluating of Simulation results with our study.

Author (s)	**The Proposed System**	**Simulation of the Results**
S.S. Ghorpade et al (2013)	The proposed of the project is to implement the core signal processing blocks of OFDM system. These blocks are simulated using MATLAB.	The results in this project OFDM system are simulated using 64 subcarriers. This is very basic implementation and has advantage of less processing time requirement and complexity. The spectral efficiency can be increased by problem of Peak-to average ratio can be reduced by using power amplifier with wide linear range at the front end of transmitter. Some other methods like Clipping, Peak
Orlandos Grigoriadis, H. Srikanth Kamath, Member, IAENG (2008)	The purpose of this paper is to use a Matlab simulation of OFDM to see how the Bit Error Ratio (BER) of a transmission varies when Signal to Noise Ratio (S/N Ratio) and Multi propagation effects are changed on transmission channel.	The results in this paper the BER as a function of the S/N ratio, that when the S/N ratio is very low (0.1) multipropagation does not have any impact on the BER. Furthermore, it has an impact when the S/N ratio has high values, for example 512 carriers have 15% BER when Multipropagation is low and the S/N ratio is 10 but it drops to 8% BER when Multipropagation is high and the S/N ratio is again 10.
Ashok Kamboj Geeta Kaushik (2012)	The purpose of this paper is study and simulation of basic OFDM system. In the study the following features have sbeen taken care of encoding (Linear and Convolution), pilot carriers and multipath in the channel. For each simulation, observed the following things : BER between the transmitted and received signals, constellation diagrams for transmitted and received signals, and Frequency spectrum of the channel.	The results in this paper is most practical systems would use forward error correction to improve the system performance. Thus more work needs to be done on studying forward error correction schemes that would be suitable for telephony applications, and data transmission. MATLABTM simulation proves that OFDM is better suited to a multipath channel than a single carrier and OFDM's tolerance to multipath delay spread, channel noise, peak power clipping and start time error.

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Author (s)	The Proposed System	Simulation of the Results
Our work	The proposed system is building system (OFDM) using Mat lab,the system include generation of 16-QAM complexs data symbols ,implementation of OFDM modulator. ,implementation of OFDM demodulator, OFDM signal with the cyclic extension and Symbol Error Rate effected by noise (AWGN) and Doppler systems for wireless radio applications.	Simulation result in figure 16 shows the performance of 16-QAM OFDM system in Rayleigh fading channel for different Doppler frequency. The general behavior of the 16-QAM is that SER increases as the Doppler spread increase. The reason is because of the existence of severe ISI caused by Doppler shifts.

VI. Conclusion

1. OFDM symbols has a longer duration than a single carrier pulse by factor K which equal to the number orthogonal transmit pulses contained in a OFDM symbol.
2. OFDM system suffered from interference of adjacent channel (Inter Channel Interferences ICI)
3. Due to this longer duration of OFDM pulse, the effect spread (pulse broadening) will be reduced.
4. Using of time Cyclic prefix and cyclic suffix between OFDM symbol the effect of pulse spread will be completely removed and inter symbol interference ISI will no longer be exist.
5. Since the bandwidth of each subcarrier is relatively narrow over channel bandwidth, the frequency distortion on each sub channel will be equal (flat fading) ,this leads to very simple equalizer implementation in OFDM receiver.

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Author’s Profile

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