Transmission of Digital Information using OFDM

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Abstract-**Orthogonal Frequency Division Multiplexing (OFDM) as needed for the wireless communication system is proven. OFDM has already been applied in the wireless LAN and it is also used with the Multiple Input Multiple Output (MIMO) technique to improve the transmission performance in the multi-fading channel. There is now an increasing demand to transmit digital video, internet data in an indoor environment. A solution to avoid the prohibitive cost of installing dedicated wires for this application is to transmit Data over the Power Line (DoPL). However, LV power lines present a very harsh environment for high frequency communication signals. The high frequency signal undergoes attenuation due to line loss and impedance mismatch because of branches and loads. Also, the dynamics of system changes the topology of the network very frequently. In order to understand more about OFDM technique, in this paper we have studied and simulated about the process of sending the digital data/information with 16-Quadrature Amplitude Modulation (QAM) OFDM.**

Keywords – QAM, OFDM, SER, ICI, ISI

I. Introduction

There is now an increasing demand to transmit digital video, internet data in an indoor environment. A solution to avoid the prohibitive cost of installing dedicated wires for this application is to transmit data on the same power lines which supply electric currents in the home/office environments. However this typical environment is unfavorable to ensure a good communication and this is essentially due to a frequency selective transmission channel in the presence of both an impulsive noise and a background noise. Indeed, the branching structures of the network, the presence of many plugs connected or not to appliances, whose load impedances may vary in a large proportion, give rise to a multipath propagation. Results of both theoretical and experimental approaches on the feasibility of this kind of transmission have been published in the technical literature and are based on usual modulation schemes [1]. These results show that the orthogonal frequency division multiplexing (OFDM) is a robust technique in such environment. OFDM is a subset of frequency division multiplexing technique in which each single channel utilizes multiple sub-carriers on adjacent frequencies. In addition the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency. Ordinarily, overlapping adjacent channels can interfere with one another. However, sub-carriers in an OFDM system are precisely orthogonal to one another. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency without causing adjacent channel interference [2]. OFDM scheme has a large number of sub channels or subcarriers used to transmit digital data. Each sub-channel is orthogonal to every other sub-channel. They are closely spaced and narrow band. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability to handle with multipath interference at the receiver. These two are the main effects of multipropagation; Frequency selective fading and Inter Symbolic Interference (ISI). In OFDM, the large number of narrow band sub-carriers provides sufficiently “flat” channels. Therefore the fading can be handled by simple equalizing techniques for each channel. Furthermore the large amount of carriers can provide same data rates of a single carrier modulation at a lower symbol rate. The symbol rate of each channel can be dropped to a point that makes each symbol longer than the channel’s impulse response. This eliminates ISI.

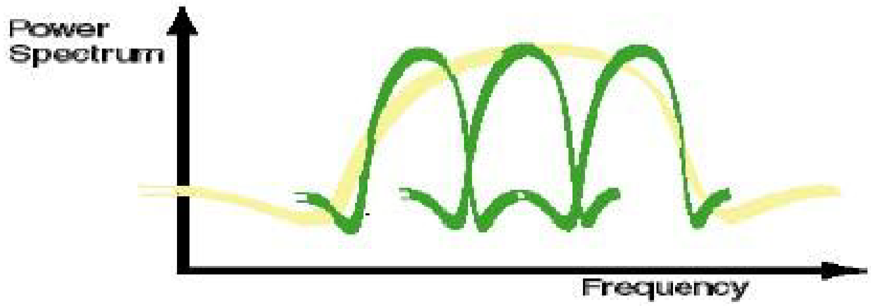

Figure 1. OFDM Power Spectrum

Fig.1 shows the OFDM Power Spectrum in which spectra overlap but signals are orthogonal. Different symbols are transmitted over different sub carriers. However, there are two main drawbacks of OFDM; large dynamic range of the signals being transmitted and the sensitivity to frequency errors Time synchronization errors originating from misalignment of symbols at demodulator is a serious OFDM design consideration. This is because they cause Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) which severely degrade the OFDM performance. Many research efforts have emerged to address this problem as presented in [3]. Quadrature Amplitude Modulation (QAM) is an attractive technique to achieve high transmission rate without increasing bandwidth. It has been implemented in xDSL systems as well as next generation wireless access and wireless LAN (WLAN). The BER and symbol error rate (SER) expressions for M-ary QAM for several applications and scenarios were derived by various authors. It is well known for M-QAM that the BER performance degrades for higher modulation levels i.e. for higher values of M, thus, 16-QAM has better BER performance than 64-QAM [4]. It has also been observed that orthogonal systems have the property that as you increase the number of orthogonal signals (channels), the performance graph shifts to the left (better performance). If you thus combine the effect of multilevel modulation (M-QAM) and orthogonal channels (OFDM), there should be a performance increase visible overall. Quadrature Amplitude Modulation (QAM) modulation scheme has been very popular in OFDM system since it offers wider range of envelope fluctuations as explained in [1, 4]. Besides, it provides higher spectral efficiency due to the usage of amplitude and phase modulation which effectively increase the channel capacity. OFDM has attracted many researchers due to higher demands for high-speed mobile communications. When using a guard interval and a frequency domain equalizer (FDE), OFDM is robust to the frequency selective fading channel, and has high frequency efficiency. Low complexity OFDM receivers can be implemented using Fast Fourier Transform (FFT). Time synchronization errors originating from misalignment of symbols at demodulator is a serious OFDM design consideration. This is because they cause Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) which severely degrade the OFDM performance. Many research efforts have emerged to address this problem. In this paper, a study about the process of sending the data information with M-Quadrature Amplitude Modulation (QAM) OFDM has been done by sending the data information with M-Quadrature Amplitude Modulation (QAM) OFDM. Through the results of the simulation, we can see that QAM symbol constellation is fully recovered. The focus is that using Matlab Simulation we can implement an OFDM transmission of 16-QAM. Using the simulation we can easily change the values of SER by suppressing the worst sub carriers and thus improve (reduce) the overall SER. The paper is organized as follows. Section II describes the OFDM system used in the simulation of the 16-QAM OFDM system. In Section III, we discuss some System Models of OFDM systems. Section IV shows the simulated results obtained. Lastly, in Section V some conclusions are drawn based on the work carried out and the simulated results.

II. OFDM SYSTEM

OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers on adjacent frequencies. In addition the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency. Ordinarily, overlapping adjacent channels can interfere with one another. However, sub-carriers in an OFDM system are precisely orthogonal to one another. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency without causing adjacent channel interference. The frequency domain of an OFDM system is represented in the fig.2 below.

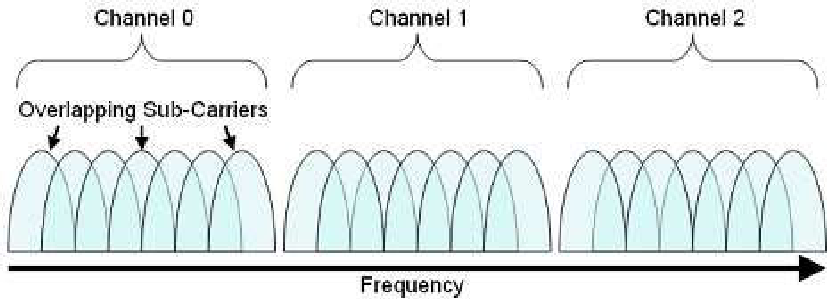

Figure 2 Frequency Domain of an OFDM system

As can be observed, there are seven sub-carriers for each individual channel. Because the symbol rate increases as the channel bandwidth increases, this implementation allows for a greater data throughput than with an FDM system [5]. The basic idea of OFDM is to divide the available spectrum into several sub channels (sub carriers). By making all sub channels narrowband; they experience almost flat fading, which makes equalization very simple. To obtain a high spectral efficiency, the frequency response of the sub channels are overlapping and orthogonal, hence the name OFDM. This orthogonality can be completely maintained, even though the signal passes through a time dispersive channel, by introducing a cyclic prefix (CP).

III. SYSTEM MODELS

The diagram in Fig.3 presents the main steps of the OFDM transmission scheme in base band. The high speed data being transmitted is first coded. The coded data is modulated using M-QAM technique. The modulated data is fed into the IFFT circuit generating an OFDM signal. The signal is then fed into a guard time insertion circuit in order to reduce ISI. At the receiver, all the steps carried out at the transmitter are reversed. The guard time is first removed. The signal is then passed through the fast Fourier transform circuit in order to change the signal back to frequency domain. Finally the demodulation and decoding steps are carried out and the high speed data bits are recovered [2, 6].

A. Serial to Parallel Conversion

In an OFDM system, each channel can be broken into various sub-carriers. The use of sub-carriers makes optimal use out of the frequency spectrum but also requires additional processing by the transmitter and receiver. This additional processing is necessary to convert a serial bit stream into several parallel bit streams to be divided among the individual carriers. Once the bit stream has been divided among the individual subcarriers, each sub-carrier is modulated as if it was an individual channel before all channels are combined back together and transmitted as a whole. The receiver performs the reverse process to divide the incoming signal into appropriate sub-carriers and then demodulating these individually before reconstructing the original bit stream.

B. Modulation with the Inverse FFT

The modulation of data into a complex waveform occurs at the Inverse Fast Fourier Transform (IFFT) stage of the transmitter. Here, the modulation scheme can be chosen completely independently of the specific channel being used and can be chosen based on the channel requirements. In fact, it is possible for each individual sub-carrier to use a different modulation scheme. The role of the IFFT is to modulate each sub-channel onto the appropriate carrier.

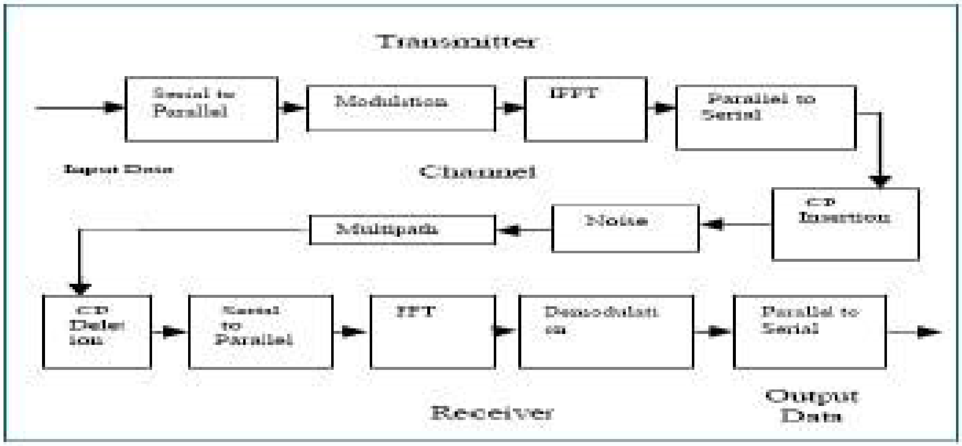

Figure 3. Block Diagram Representation of Implemented OFDM Model

C. Cyclic Prefix Insertion

Because wireless communications systems are susceptible to multi-path channel reflections, a cyclic prefix is added to reduce ISI. A cyclic prefix is a repetition of the first section of a symbol that is appended to the end of the symbol. In addition, it is important because it enables multi-path representations of the original signal to fade so that they do not interfere with the subsequent symbol. A cyclic prefix is a copy of the last part of the OFDM symbol which is prepended to the transmitted symbol [fig.4]. This makes the transmitted signal periodic, which helps in reducing Intersymbol Interference (ISI) and Intercarrier Interference (ICI).

Tcp denotes the length of the cyclic prefix and T=Tcp +Ts is the length of the transmitted symbol. The length of the cyclic prefix should be made longer than the experienced impulse response of the channel to avoid ISI and ICI. However, the transmitted energy increases with the length of the cyclic prefix. The SNR loss due to the insertion of the CP is given by

$$\text{SNR loss} = -10 \log10 (1-Tcp/T) \quad (1)$$

Even though CP introduces a loss in signal to noise ratio (SNR), it outweighs the price to be paid to mitigate interference.

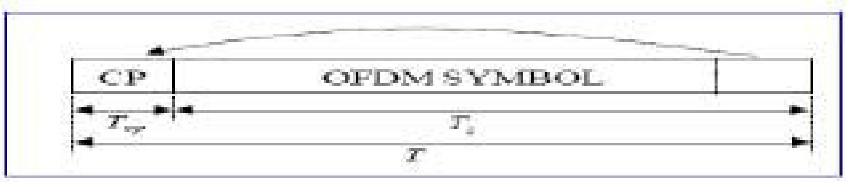

Figure 4. Cyclic Prefix of an OFDM system

IV.SIMULATION AND RESULTS

This paper does not explain in detail the MATLAB simulation code. It uses it to create results and see the behavior of OFDM under different sub carriers suppressed conditions. However, some of the main variables of the code are described, because the choice of them has a critical effect on the results. The simulated results/code is partially depicted in Fig. 5.

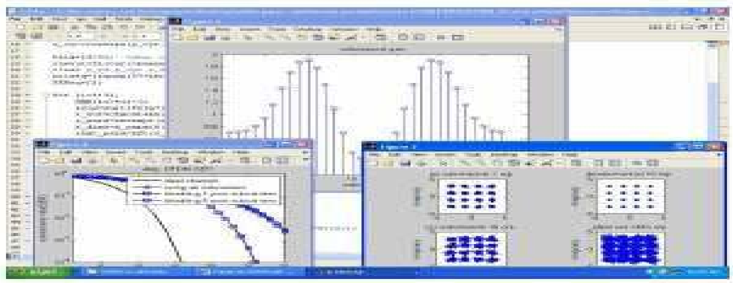

Figure 5. Simulations of OFDM Transmission using 16-QAM

One of the main characteristics of every simulation model of OFDM is the size of the Fast Fourier transformation (FFT) used to generate the signal. In the simulation it is equal to the number of samples for the transmission signal. In the code this variable is named FFT size. The more the size of the FFT is increased the more samples there are for each signal. The more samples there are the smoother and more accurate the signal is. Another very important variable is the number of the carriers (or the sub – channels) being used in every simulation

V. CONCLUSIONS

The first and obvious thing we can notice from all the Plots of the simulation are that we can easily change the values of SER by suppressing the worst sub carriers and thus improve (reduce) the overall SER. The authors have typically obtained the results by suppressing a single worst subcarrier and also suppressed five worst sub carriers. The more is the number of worst sub carriers suppressed, the better is the performance shown by the OFDM transmission.

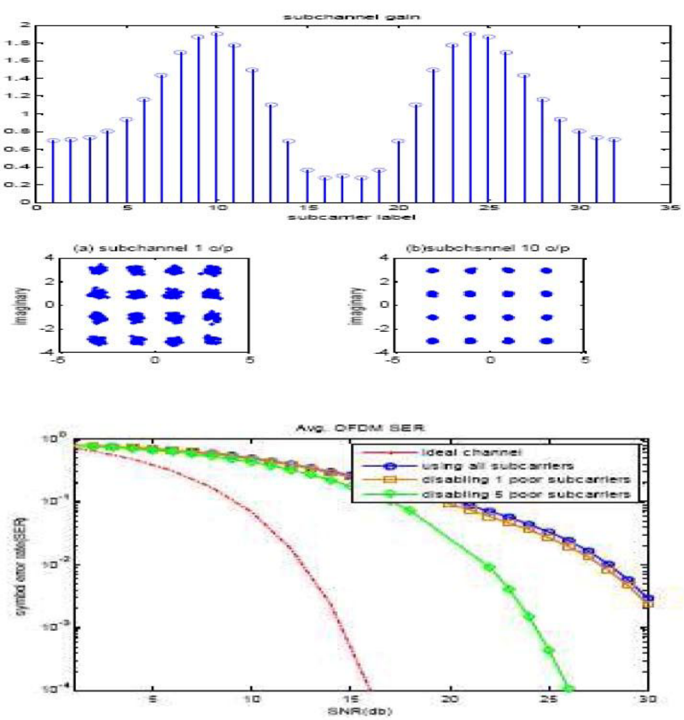

Figure 6. Simulated Results of OFDM Transmission using 16-QAM
a) Subcarrier Gain b) Scatter Plots c) SER versus SNR Plot

VI. REFERENCES

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