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Performance Analysis of 16-QAM using OFDM for Transmission of Data over Power Lines

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Abstract

The robustness of multiple access schemes such as Orthogonal Frequency Division Multiplexing (OFDM) as needed for the wireless communication system is well proven. There is now an increasing demand to transmit digital video signals and other digital information 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. As the medium voltage and low voltage power lines transmit such high frequency communication signals, these signals undergo attenuation due to line loss and impedance mismatch because of branches and loads. Thus a signal which is received at the receiver end is not a replica of transmitter end signal, signifying of symbol error. In order to understand more about OFDM technique of transmission of data, in this paper we have carried out the performance analysis of transmission of digital data over indoor power lines using OFDM. The simulation results of the performance analysis show that 16-QAM symbol constellation is fully recovered and symbol error can be reduced significantly by suppressing some weak carriers.

Keywords: BPL; OFDM ; Quadrature Amplitude Modulation ; SER

1. Introduction

Broadband over power lines (BPL) promises to offer high speed data transmission over the same lines that deliver electricity. BPL is essentially a “last mile” radiofrequency data-delivery technology in which data packets travel in a particular range of frequency, simultaneously, with electrical currents traveling in a separate one [1]. Broadband-over-power-line service promises the convenience of letting users plug low cost BPL modems into any standard electrical outlet [2]. The key reason for the use of BPL technology is the fact that every home and office is connected to the power grid and contains electric wiring and the data through the same wiring can easily be transmitted to the consumer without additional installations thus reducing the cost considerably and has the potential to provide a truly ubiquitous method to access

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the Information/digital data for the data and control signals, IP telephony transfer, and remote data acquisition, etc [3].

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 [4]. Due to a number of distributed branches of various lengths and varying connected load impedances, power line channel is characterized by a multi-path fading environment. The delayed waves due to loads and branches interfere with the direct waves causing inter symbol interference (ISI) degrading the overall network performance. The effect of multi path is reduced by OFDM as it is based on parallel broadband data transmission [3] and [5].

2. Problem Formulation

In this paper, Performance Analysis of 16-QAM using OFDM for Transmission of Data over Power Lines has been carried out using MATLAB. 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 Symbol Error Rate (SER) by suppressing the worst sub carriers and thus improve (reduce) the overall SER.

With 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 [3], [4], [6] and [7].

3. PLC Transmission Model

Power line communications use the RF signal sent over either MVPL/LVPL to permit the end users to connect to the Internet or retrieve data sent over Power Lines. The RF signal is modulated with digital information that is converted by an interface in the home like power grid [8]. As power lines are used as a medium to send and receive discrete frequency-based control, monitoring and communication messages to run home devices, exchange data and share high speed Internet access among multiple PCs and other devices. A radio signal is modulated with the data that has to be sent and then transferred down the copper medium in a band of frequencies not used for the purpose of supplying electricity and managing electricity. The frequencies and encoding schemes used greatly affect on reliability, efficiency and the speed of the PLC service. Most PLC radio traffic generally occurs in the same bandwidth roughly 1.6 MHz to 80 MHz.

3.1. Principle of PLC

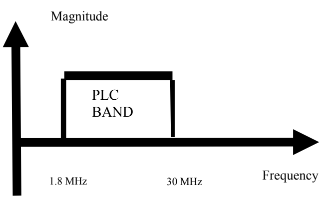
Fig.1. shows the principle of PLC system which consists in superposing , using a broadband coupling circuit, a wide frequency signal in the range of 1 to 30 MHz on the low frequency electric power voltage

of 50 Hz. This technology is widely used for transmitting digital streams carrying voice, data, and video contents at high speed rates within the house or within home/office environments. The PLC signal is emitted and received by a PLC modem as shown in Fig. 2 and Fig.3. The wideband PLC signal propagates and reflects on all electric lines and terminations of the housing environment in differential mode, using the phase and the neutral wires [8].PLC modems and their chipsets use most often some OFDM or spread spectrum modulation techniques like DSSS, which offer adaptability in presence of frequency selective channels, resiliency to narrow band interference, and robustness to impulsive noise. Each carrier of OFDM symbol may be modulated using different modulation alphabets such as BPSK modulation or even higher states modulation such as 4- QAM, 8-QAM, 16-QAM……1024-QAM with each symbol carrying multiple bits of information and therefore enabling high data rates [9] and [10].As the power-line cables are not shielded and they behave like long antennas when high-frequency PLC signals are transmitted which can cause EMI for services operating in the same frequency range. The high levels of emitted radiation are a cause of concern for the regulatory bodies.

Further, the frequency bands of 1–30 MHz are the same as those used for applications such as broadcasting, military communications, aeronautical services, maritime safety services, radio amateurs, and others. As long as the EMI issue is not resolved, there would be a major concern for the widespread deployment of broadband PLC technology [8].

3.2. Model of PLC

For a complete PLC communication system, there is necessity to create model of channels as well as noise model and a transmitter and a receiver model. The complete PLC model will be created from particular models. Then it will be possible to create analysis of a concrete power line based on the simulations of this system with various models of lines. The analysis will enable the possibility to judge in terms of using of various combinations of PLC technologies, security transfer, modulations, coding etc. It is necessary to create the channel models for the PLC simulation. There are more possibilities of power line model creating. First of them is the power line model as environment with Multipath signal propagation. PLC communication modeling involves the issues depicted in Fig.4 [11]. We can classify the PLC channel modeling works of the current literature in three categories for the purpose of modeling; PLC communication model, Models of power lines and Noise (Source of Interference) model.



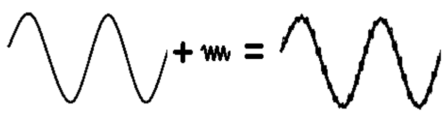


Fig.1. Concept of PLC

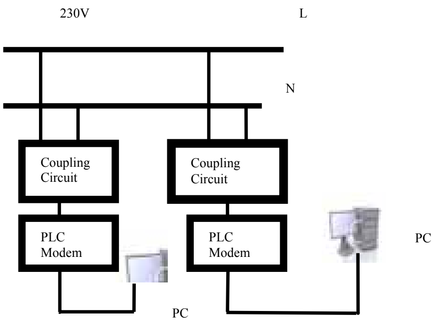


Fig. 2. Power and Data communication over a power-line cable

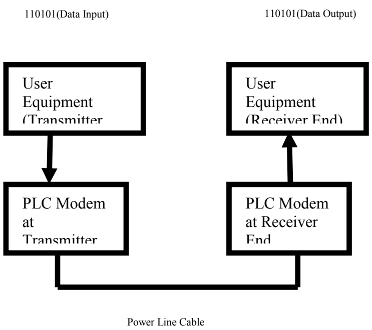
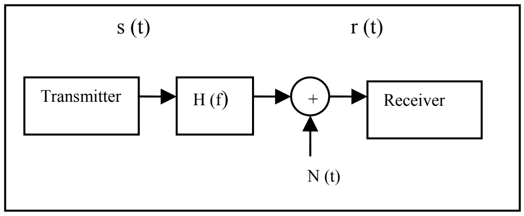


Fig.3. Data Communication between two PLC modems over a Power line

Cable.



N (t) =Noise; H (f)= Transmission Channel Function

Fig.4. Model of PLC Communication Channel along with Noise (t)

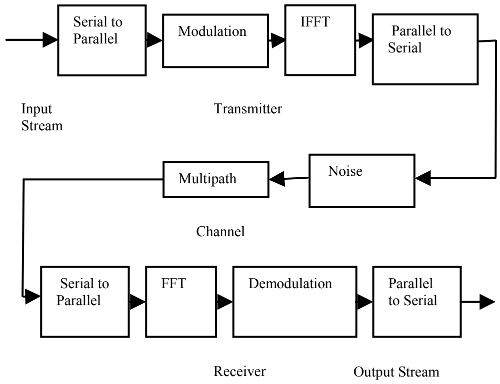


Fig. 5. Block Diagram Representation of Implemented OFDM Model

4. OFDM Model For PLC Communication

OFDM scheme is a subset of frequency division multiplexing which has a large number of sub channels or sub-carriers used to transmit digital data. Each sub-channel is orthogonal to every other sub-channel.. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. Also a single channel utilizes multiple sub-carriers on adjacent frequencies with the sub-carriers in an OFDM system 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. 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). 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. However, there are two main drawbacks of OFDM; large dynamic range of the signals being transmitted and the sensitivity to frequency errors [9]. Time synchronization errors originating from misalignment of symbols at demodulator is a serious OFDM design consideration. This is because they cause ISI and ICI which severely degrade the OFDM performance.

High transmission rates can be achieved by using QAM without increasing bandwidth. With M-QAM, 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 [9]. Since orthogonal systems have the property that as the number of orthogonal signals increases, the performance graph shifts to the left (better performance). If we can combine the effect of multilevel modulation (M- QAM) and orthogonal channels, there should be a performance increase visible overall. Fig. 5 shows the main steps of an OFDM transmission scheme used in our work.

4.1. Serial to Parallel Conversion

The use of sub-carriers, in OFDM although allows 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 sub-carriers, 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.

4.2. Modulation with the Inverse FFT

The modulation of data into a complex waveform occurs at the 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.

4.3. Cyclic Prefix Insertion

As unguided communications systems are susceptible to multi-path channel reflections, a cyclic prefix is added to reduce ISI. 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 perpended to the transmitted symbol, makes the transmitted signal periodic, which helps in reducing ISI and ICI.

5. Simulation and Results

Computer simulation of PLC systems based on OFDM Model will enable a better understanding of the problematic of data transmission over power lines, revealing the potentials of these systems, and the area of PLC applicability will be better defined. Sufficiently precise computer models of PLC systems will thus make the process of selecting and deploying new technologies in an effective way. The model is based on frequency division of spectrum using the OFDM technique, where particular carrier frequency is mapped with 16-state QAM modulation.

5.1. Selected Simulation Parameters

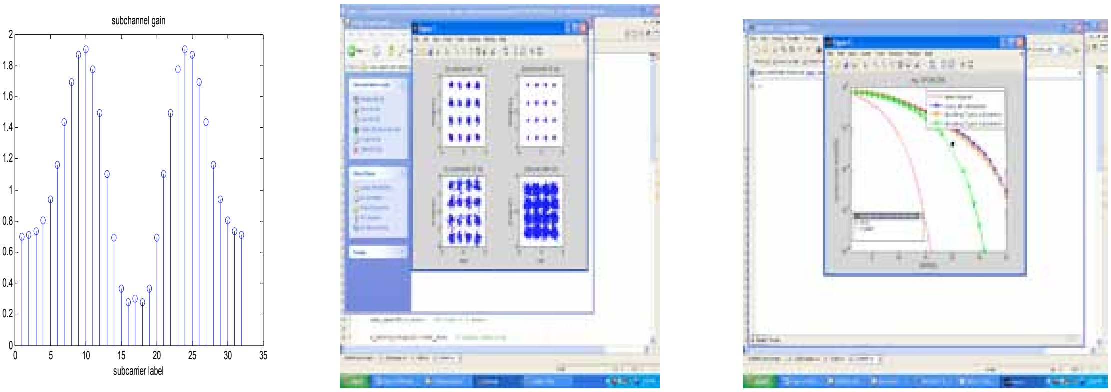
Some of the main variables of the code are described, in Table 1. because the choice of these has a critical effect on the results of simulation.

Table 1. Selected Simulation Parameters

Parameter	Value
Modulation	16-QAM
No. of Sub carriers used	32, 64
Cyclic Prefix	5 in both schemes
No. of worst sub carriers suppressed	1,5 for 32 sub carriers; 5,11 for 64 sub carriers

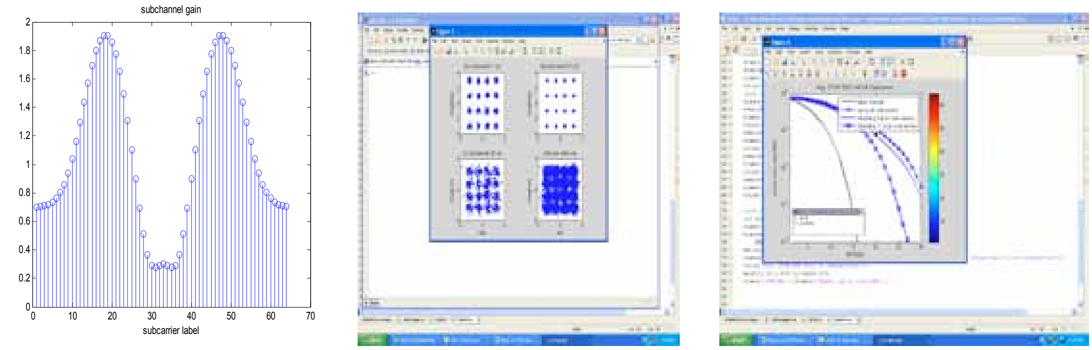
5.2. The MATLAB Source Code

This paper does not explain in detail the simulation code. It uses it to create results and see the behaviour of OFDM under different channel properties. Fig.6 and Fig.7 show the simulated results obtained for 32 sub carriers and 64 sub carriers respectively. Sub channel gain in Fig 7(a) indicates that among the 64 sub channels, 11 sub carriers near the centre have the least gains and also the least SNR, and thus exhibit worst performance. If these are suppressed, we can see SER improves (fig.7c). Fig 7 (b) shows the scatter plots of the output channels and a contrast is signified. Overall OFDM performance is dominated mainly by the poor sub channels. The comparison is drawn on the basis of Fig.6 and Fig.7. As simulation results show, the transmission performance of 32 sub carriers and 64 sub carriers with equal number of sub carriers (5) suppressed gives a symbol error rate (SER) of 0.0676 for SNR of 20.01dB in case of 64 sub carriers as against symbol error rate (SER) of 0.04067 for SNR of 20.02dB in case of 32 sub carriers.



a) Subcarrier Gain b) Scatter Plots c) SER vs. SNR Plot

Fig.6. Simulations of OFDM Transmission using 16-QAM with 32 sub carriers



a) Subcarrier Gain b) Scatter Plots c) SER vs. SNR Plot

Fig7. Simulations of OFDM Transmission using 16-QAM for 64 sub carriers

6. Conclusions

BPL offers a convenient and inexpensive medium for data transmission, however the communication technology needed faces a difficult challenge and that is to develop the most suitable models and standards. There is now an increasing demand to transmit digital data in an indoor environment using the already installed indoor LV power lines. These lines present a very harsh environment for high frequency communication signals which undergo attenuation due to line loss and impedance mismatch because of the branches and loads. The paper has dealt with the PLC communication model based on 16-QAM OFDM technique and the performance analysis has been made on Symbol error rate. The results of the simulation show that 16-QAM symbol constellation is fully recovered.

The plots of the simulation reveal that we can easily change the values of SER by suppressing the worst sub carriers and thus improve (reduce) the overall SER.

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