Performance Analysis of OFDM System for Middleton Class A Noise

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ABSTRACT

Power Line Communication (PLC) becomes the preferred technique for providing broadband to homes and offices with the advantage of eliminating the need for new wiring infrastructure and reducing the cost. An effect of an impulsive noise is identified as one of the major impairment in PLC. Orthogonal Frequency Division Multiplexing (OFDM) is one of the modulation techniques for PLC by most researchers and is used in this research. The performance of OFDM is analysed by adding Middleton Class A noise and applying it to the channel in an attempt to corrupt the signal. The results will show that the different modulation orders of Phase Shift Keying (PSK) are applied to test the input image which may be any size of a gray-scale image or a colour image by comparing the values of Bit Error Rate (BER), the average phase error and the percentage of pixel errors in the operation of OFDM system. In doing so, GUI from MATLAB software is used to simulate the operation of virtual transmitter and receiver.

Keywords: Power Line Communication; OFDM; PSK; Middleton Class A noise

I. INTRODUCTION

The Power Line Communication (PLC) refers to a technology for transmitting data using power lines in the frequency range of 50-60 Hz. It exploits the power line infrastructure to provide high-speed broadband to customers and does not require new wiring installation in the building which is a great cost saving.

There are three different network levels are in the PLC. They are high voltage (HV) which has the range of 69-380kV, medium voltage (MV) which is from 2.4kV to 35kV and low voltage (LV) which has the voltages up to 600V [1]. Moreover, there are two transmissions in PLC such as broadband power line communication (BPL) which operates with a carrier frequency range of 2-30 MHz to achieve data rates up to 200 Mbps and narrowband power line communication (NPL) which operates in the frequency bands between 3 kHz and 500 kHz to achieve data rates from 10kbps to 500kbps [2] shown in Fig.1.
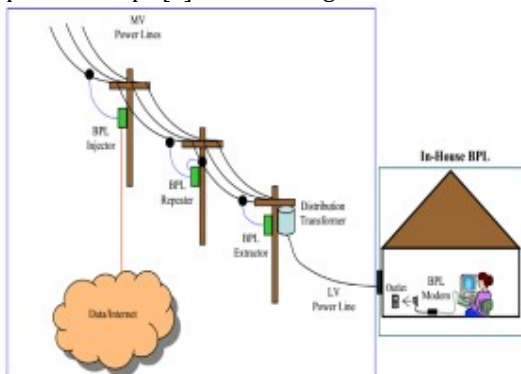

Figure1: Configuration of power line networks [2]

The multipath affects, attenuations and noises are the most significant factors affecting communications over power lines. Power line cables suffer from frequency dependent attenuation which increases with high frequencies and can be severe for long distance communications. Signal reflection is caused by impedance mismatching which increases the multipath fading. The noise is produced by various appliances that are connected or linked to PLC transmission channel.

Therefore, it is important to choose a better modulation technique for the PLC system. There are various available modulation techniques such as a multicarrier modulation, single carrier and spread spectrum modulation. A multicarrier modulation technique such as an OFDM is a modulation technique of choice for PLC systems because of having better performance in comparison with a single carrier modulation and its performance in impulsive noise environments [3] shown in Fig.2.
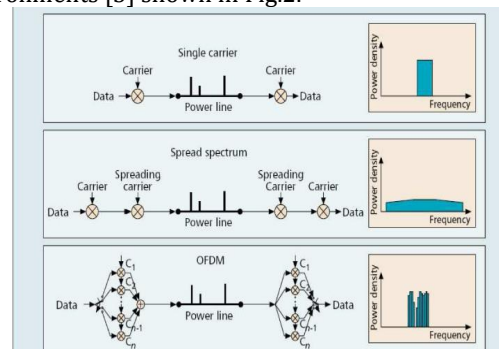

Figure 2: Available modulation approaches [3]

II. OFDM MODEL FOR POWER LINE COMMUNICATION

Orthogonal Frequency Division Multiplexing (OFDM) has been referred to as one of the most advantageous technique. OFDM systems have been widely recognised as a bandwidth efficient transmission technique for wireless communications. This multicarrier transmission technique has been gaining more and more interest from communications and signal processing communities [4]. OFDM is also considered as one of the most promising modulation methods for power line communications [5].

The aim of this paper is to analyze the performance of OFDM system for power line communication noise, using GUI from MATLAB to simulate the operation of virtual transmitter and receiver. Especially, the overall aim of this paper is to test an OFDM system for a power line communication in order to propose and examine a novel approach in comparing the different modulation orders of PSK such as BPSK, QPSK, 16-PSK and 256-PSK and also the application of Middleton Class A noise and applying it to the channel in an attempt to understand and recognize the most suitable technique for the transmission of an image within a communication system.

The first step is to design a basic OFDM system by using BPSK and the second is to design a more comprehensive OFDM for the purpose of simulation by using Cyclic Prefix (CP), with the aim of counteracting the effects of delay such as Inter-Symbol Interference (ISI) and Inter-Channel Interference (ICI). An additional comparative performance studies will be conducted by tabling the values of BER, average phase error and the percentage of pixel errors for the different modulation orders of PSK. Moreover, additional analysis will be carried out in order to examine the overall performance of the OFDM system by using Middleton Class A noise which is a type of the impulsive noise in power line communications. Finally, the full functioning OFDM system is examined through the transmission of an image. Fig. 3 describes the block diagram of OFDM system with power line communication noise which is designed in this research paper.
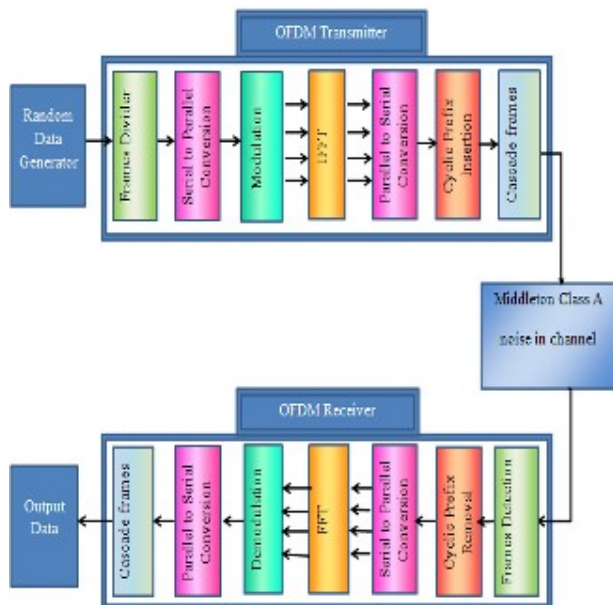

Figure3: Block diagram of OFDM system with Middleton Class A noise

III. NOISES IN POWER LINE COMMUNICATION

The data transmission over power lines provides many attractive properties. However, PLC systems are at risk of internal or external noise and disturbances like all other communication systems. PLC noises can be classified into three categories as follows [6]:

➢ Colored background noise which is caused by summation of numerous noise sources of low power. (Up to 30 MHz)
➢ Narrow band noise, mostly amplitude modulated sinusoidal signals caused by ingress of radio broadcasting stations. (1 - 22) MHz
➢ Impulsive noise

Periodic impulsive noise

➢ Periodic impulsive noise asynchronous to the mains frequency, which is mostly caused by switching the power supplies. (50 – 100) Hz
➢ Periodic impulsive noise synchronous to the mains frequency, which is mainly caused by switching actions of rectifier diodes found in many electrical appliances. (50 – 200) Hz
➢ Asynchronous impulsive noise, which is by switching transients in the power network.

Middleton Noise Models

➢ Middleton Class A noise has been originally defined in order to compare the bandwidth of noise or keep it less than the bandwidth of the receiving system.
➢ Middleton Class B noise is that the noise pulses are able to produce transients within the receiver as the noise bandwidth is greater than the receiving system bandwidth.
➢ Middleton Class C noise is a linear sum of Class A and B. The derivation models concise exposition has been presented by Skomal [7].

This paper offers an insight into the influence of power line communication noise as Middleton Class A noise.

A. Middleton Class A Noise

Middleton classifies the noise in three general classes of Middleton Class A, B and C according to the bandwidth of the noise emitted by each of the interferers, [8]. This paper considers focusing on the Middleton Class A noise model. Its bandwidth is assumed to be comparable or less than the bandwidth of the disturbed communication system and so transient effects in the analogue receiver stages can be neglected. As this paper is partly concentrated on the influence of impulsive noise on OFDM transmission, the channel model for the additive impulsive noise channel will be kept simple as the following equations;

$$r(t) = s(t) + n(t) \qquad (1)$$

Where,
s(t) = The transmitted signal
n(t) = Class A distributed random variable
r(t) = The received signal

Additionally, a Gaussian noise component is added to model that always present thermal receiver noise. The Middleton Class A noise PDF is given by equation (2) which is substituted by equations (3-5) [9].

$$p_z(z) = \sum_{m=0}^{\infty} \frac{\alpha_m}{2\pi\sigma_m^2} \exp\left(-\frac{z^2}{2\sigma_m^2}\right) \qquad (2)$$

$$\alpha_m = e^{-A}\frac{A^m}{m!} \tag{3}$$

$$\sigma_m^2 = \sigma_g^2\frac{(\frac{m}{A})+\Gamma}{\Gamma} \tag{4}$$

$$\Gamma = \frac{\sigma_g^2}{\sigma_i^2} \tag{5}$$

Where,

m = The number of impulsive noise sources
A = Impulsive index
Γ = The Gaussian to impulsive noise ratio (GIR)
σ_m^2 = The impulsive noise power
σ_g^2 = The variance of Gaussian noise components

IV. DIGITAL MODULATION TECHNIQUES

The nature of OFDM only allows the signals to be modulated in amplitude and phase only [12]. This work focuses on PSK technique only. The performance of this modulation technique in a PLC system is evaluated in terms of bit error probability.

Phase-shift keying (PSK) may be a digital modulation theme that conveys information by dynamical, or modulating, the section of a reference signal (the carrier wave).

A. Binary Phase Shift Keying (BPSK)

A binary phase shift keying (BPSK) signal is outlined by

$$s(t) = A\,m(t)\cos 2\pi f_c t, \quad (0 < t < T) \tag{9}$$

Where A is a constant, m (t) = +1 or -1, f_c is the carrier frequency, and T is the bit duration. The signal has a power P = $A^2/2$, so that $A = \sqrt{2P}$.

B. M-ary Phase Shift Keying (M-PSK)

An M-ary phase-shift keying (M-PSK) signal can be defined by

$$s(t) = A\cos(2\pi f_c t + \theta_i + \theta'), \quad (0 < t < T) \tag{10}$$

for i = 0, 1, ..., M - 1. Here, A is a constant, f_c is the carrier frequency, θ' is the initial phase angle, and T is the symbol duration [13].

V. SOFTWARE IMPLEMENTATION

Initially an input image which may be any size of a gray-scale image or a colour image is resized into 256-gray image and compared the received image values of Bit Error Rate (BER), the average phase error and the percentage of pixel errors in the operation of OFDM system by using GUI from MATLAB software. The user input variables include:

➤ Input file – an 8-bit gray-scale (256 gray levels);
➤ IFFT size – an integer of a power of two;
➤ Number of carriers – not greater than [(IFFT size)/2 – 2];
➤ Digital modulation method – BPSK, QPSK, 16-PSK, or 256-PSK.

If the number of carriers is greater than [(IFFT size)/2-2], the program will stop definitely. The overall flow chart for this research is shown in Fig.4.
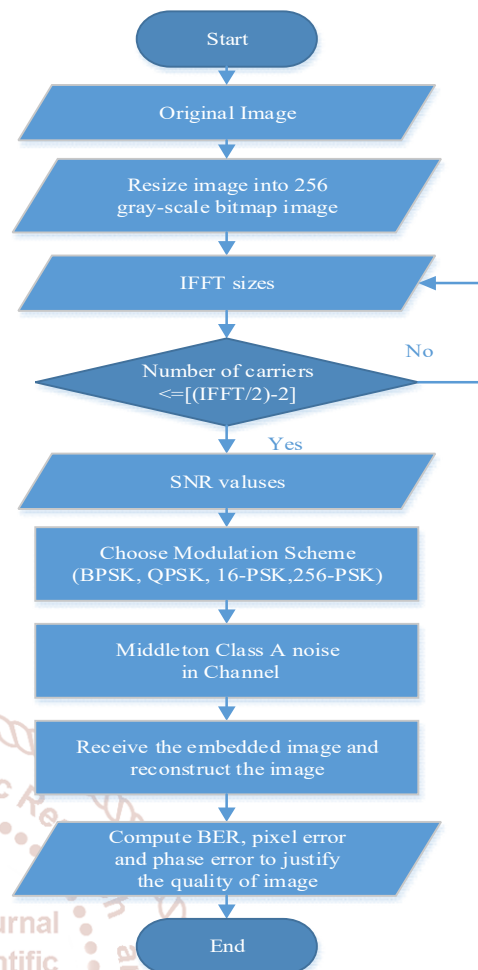

Figure 4: Flow chart of testing an input image through OFDM system with Middleton Class A noise

VI. SIMULATION RESULTS AND ANALYSIS

This section concentrates on presenting the simulation response for different simulation results, considering the comparison for different modulation orders of PSK, total number of errors, BER, average phase errors and percentage of pixel errors for the channel which is added by adding Middleton Class A noise.
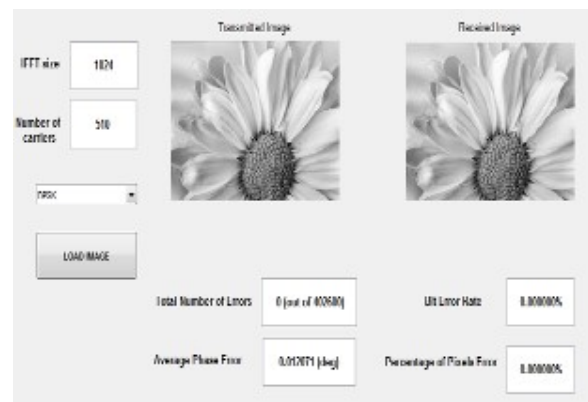
A. Testing an image through BPSK in GUI

Figure 5: Transmission an image through BPSK in OFDM

The values of IFFT size, number of carriers and SNR are 1024, 510 and 25 that are used to apply an image in OFDM with BPSK modulation to get these values of total number of

errors, BER in percentage, average phase errors in degree, pixel errors in percentage and transmitted channels with noises are shown in Fig.5 and 6.
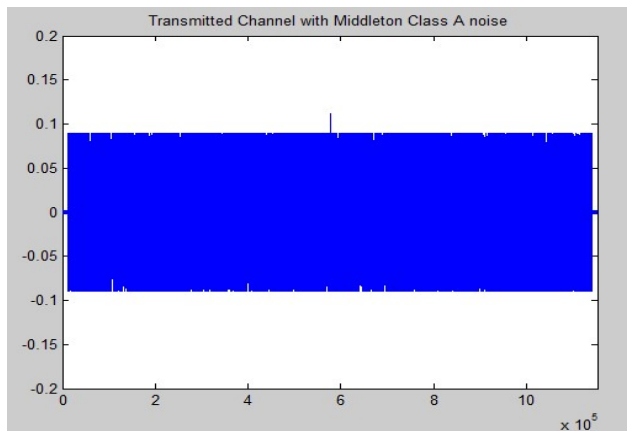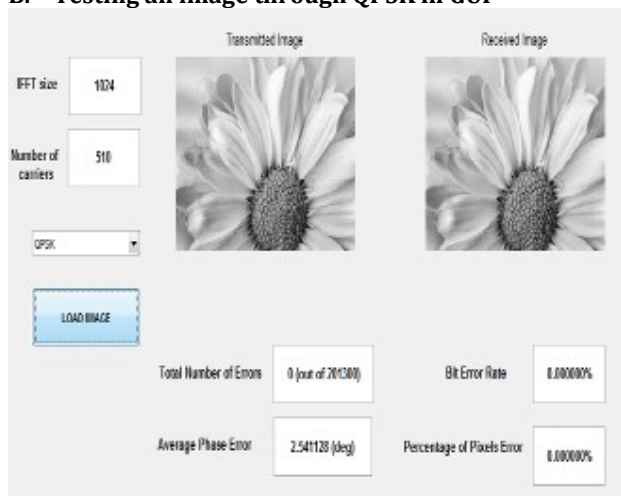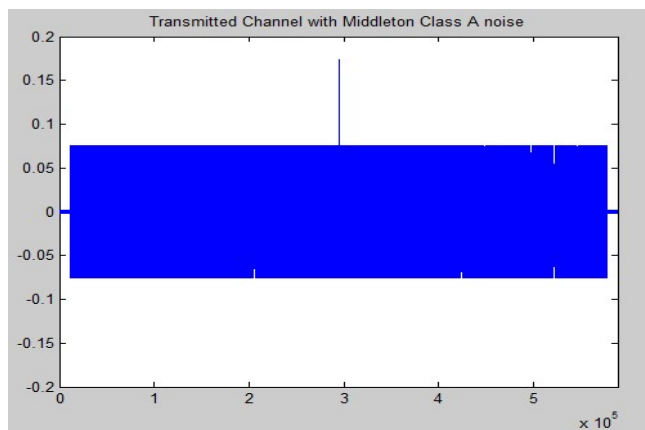

Figure 6: Transmitted channel with Middleton Class A noise

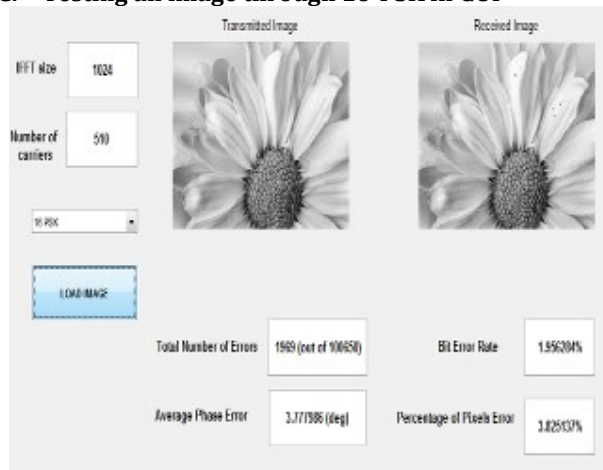**B. Testing an image through QPSK in GUI**

Figure 7: Transmission an image through QPSK in OFDM

The values of IFFT size, number of carriers and SNR are 1024, 510 and 25 that are used to apply an image in OFDM with QPSK modulation to get these values of total number of errors, BER in percentage, average phase error in degree, pixel errors in percentage and transmitted channel with noises are shown in Fig.7 and 8.

Figure 8: Transmitted channel with Middleton Class A noise

C. Testing an image through 16-PSK in GUI

Figure 9: Transmission an image through 16-PSK in OFDM

The values of IFFT size, number of carriers and SNR are 1024, 510 and 25 that are used to apply an image in OFDM with 16-PSK modulation to get these values of total number of errors, BER in percentage, average phase error in degree pixel errors in percentage and transmitted channel with noises are shown in Fig.9 and 10.
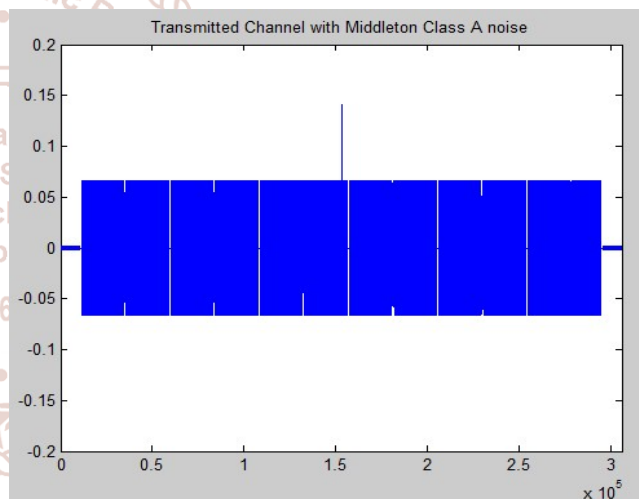

Figure 10: Transmitted channel with Middleton Class A noise

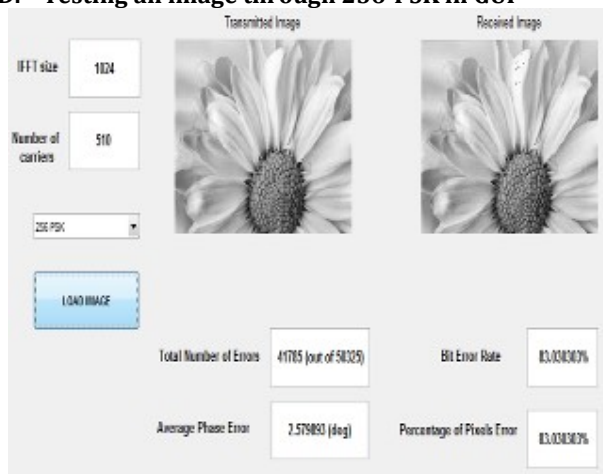**D. Testing an image through 256-PSK in GUI**

Figure 11: Transmission an image through 256-PSK in OFDM

The values of IFFT size, number of carriers and SNR are 1024, 510 and 25 that are used to apply an image in OFDM with 256-PSK modulation to get these values of total number of errors, BER in percentage, average phase error in degree, pixel errors in percentage and transmitted channel with noises are shown in Fig. 11 and 12.
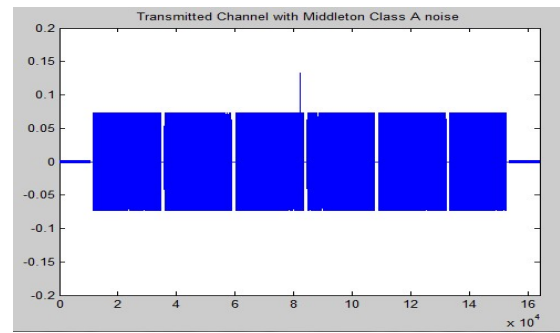

Figure 12: Transmitted channel with Middleton Class A noise

After adding Middleton Class A noise, especially 256-PSK modulated received image has most of the information is still observable even high BER. For example, at 25 dB of SNR, even though the 256-PSK received image has a BER of 83.030303 %, the image is still observable. For gray-scale digital images, if the decoded value of a pixel is off by a small number of gray levels, it's not easily observed by human eye, but will be counted as a bit error. It's obvious that the gray level on most of the pixels changed when toggling between the original and received image, but the relatively contents are still somewhat intact. The overall error results of BPSK, QPSK, 16-PSK and 256-PSK in OFDM system are shown in Table.1. BPSK is better than other modulation orders of PSK by analyzing all results.

TABLE I. Error calculation results of Ofdm system with Middleton Class A noise

Error Calcula-tions	BPSK	QPSK	16-PSK	256-PSK
Total numb -er of errors	0 out of 402600	0 out of 201300	1969 out of 100650	41785 out of 50325
BER (%)	0.000000%	0.000000%	1.956284%	83.030303%
Phase errors (deg)	0.012071 (degree)	2.541128 (degree)	3.777986 (degree)	1.337460 (degree)
Pixel errors (%)	0.000000%	0.000000%	3.825137%	83.030303%

VII. CONCLUSION

In this paper, performance analysis of OFDM system for power line communication was presented. In doing so, GUI from MATLAB software was used to simulate the operation of virtual transmitter and receiver. The performance of the system design was then analyzed by adding Middleton Class A noise and in an attempt to corrupt the signal. The simulation results presented in this project suggest that BPSK is the most preferred modulation technique than other high orders of PSK by comparing their considerable performances. So BPSK modulation is more suitable to design in OFDM system for power line communication. Indeed, applying Middleton Class A noise to the channel has proven very successful and will be accounted as a novel approach for the transmission of an image within OFDM system.

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