Bit Error Rate performance in Power Line Communication Channels with Impulsive Noise

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***Abstract*— The performance of Power Line Communication (PLC) degrades due to the presence of different types of noise interferences generated by electrical appliances. This paper investigates the bit-error rate (BER) performance of a higher-order 64-QAM constellation with orthogonal frequency multiplexing modulation (OFDM) in presence of impulsive noise modelled as Middleton Class A over a multipath PLC. It is observed that BER for the impulsive noise is higher than the background noise. The BER further deteriorates on increasing the level of the impulsive noise, even while being injected into the PLC channel at a lower rate. Investigations would assist applying methods to mitigate and reduce the effect of impulsive noise over PLC systems for higher constellations with a view to increase the data rates.**

Keywords—AWGN, BER, Impulsive Noise, Middleton Class A, PLC,Power Line Communication, OFDM, QAM

I. INTRODUCTION

The Power Line Communication (PLC) technology is emerging as an alternative to the broadband access network with the advantage of using the existing infrastructure of power line networks which results a great cost reduction. However the PLC channel is not conducive to high speed data transmission due to attenuation and interferences from various sources [1]. In [2] different types of PLC noise sources are modelled in Matlab/Simulink, among these the background and impulsive noises are the main source of interference resulting in signal distortion. The background noise can be modelled as an Additive White Gaussian Noise (AWGN) and the impulsive noise is based on the Middleton Class A noise model [3]. The Bit Error rate (BER) performance of a Wireless Local Area Network (WLAN) channel in presence of Middleton Class A noise is investigated in [4]. In [5] the performance of using Orthogonal Frequency Division Multiplexing (OFDM) modulation for a PLC channel is analysed and compared with a single carrier modulation system and is found that the former enhances the BER performance over the later. In [6] the BER performance using OFDM modulation in presence of impulsive noise is given and is shown that convolution coding with a Viterbi decoder improves the transmission performance. In [7] the space diversity in MIMO power line channels with independent impulsive noise is analysed.

This paper quantifies the BER performance of PLC channel for higher signal constellations such as 64-Quadrarture Amplitude Modulation (QAM) with OFDM with Hamming Code in presence of impulsive noise modelled as the Middleton Class A noise source. Simulations are under taken in Matlab 2012a. Section II gives a brief overview of the basic concept of data transmission over PLC. Noise in the PLC channel with the Middleton Class A impulsive noise is discussed in section III. In section IV simulations for the OFDM PLC are given in Matlab 2012a followed by the results. Conclusions are given in section V.

II. PLC DATA TRANSMISSION

A PLC can be modelled as in Fig. 1. The model consists of a PLC transmitter, the PLC channel with noise and the receiver block. According to the model, the received signal $r(t)$ is given by [8]:

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

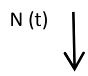
where:
$s(t)$ is the signal injected into the channel by the transmitter, $h(t)$ is the impulse response of the channel and $n(t)$ is the noise in the channel.

According to [9][10] there are various models available for PLC channel such as the Zimmermann and Dosteret model, Philipps model and the Anatory et al. model. The multipath model proposed by Philpps and Zimmermann is a widely used model for investigating the data transmission over power lines and is given by [9]:

$$H(f) = \sum_{i=1}^{N} g_i . e^{-(a0+a1 f^k)di} . e^{-j2\pi f d_{i}/V_p} \qquad (2)$$

where:
$H(f)$ is the frequency response of the channel, g_i is the weighting factor , d_i the length of the data transmission path, k is the exponent of the attenuation factor; a_0 and a_1 are attenuation parameters.

As in PLC frequency shift keying (FSK), amplitude shift keying (ASK) and phase shift keying (PSK) are used for low data rate (300Kbps), for higher data rate transmission of more than 1Mbps modulations such as M-ary PSK, M-ary QAM and OFDM are used [11]. In OFDM as the symbol duration increases for the lower rate subcarriers, the amount of dispersion in time caused by multipath delay reduces, thereby reducing the inter-symbol interference (ISI) leading to higher data rates.



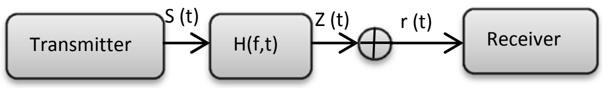


Fig.1. The basic PLC model

III. IMPULSIVE NOISE IN PLC

Noise in PLC can be classified as a background and impulsive noise. Background noise is stationary and can be modelled by the Gaussian distribution [11]. An impulsive noise originates from variation sources such as heating processes, microwave ovens, electric motors and any other electrical sources. There are number of statistical models for characterization of an impulsive noise such as the Bernoulli-Gaussian and Poisson-Gaussian model [12]. An accurate model which is widely used is the Middleton Class A based on the Poisson-Gaussian model. As it reported in [12] the probability of impulsive noise with *m* impulsive noise events in a time interval *T,* for Poisson distribution parameter λ can be modelled as:

$$P = \frac{(\lambda T)^m \, e^{(-\lambda T)}}{m!} \quad (3)$$

If the impulsive index is given by A= λT then the Probability Density Function (pdf) of the Middleton Class A impulsive noise is given by [12]:

$$pA(n) = \sum_{m=0}^{\infty} e^{-A} \, \frac{A^m}{m!\pi N_0} \, \frac{A(1+\Gamma)}{m+A\Gamma} \, exp \left[\frac{-A(1+\Gamma)}{(m+A\Gamma)} \, \frac{|n|^2}{N_0} \right] \quad (4)$$

where:
σ^2 = the total noise power (both Gaussian and impulsive). $\Gamma = \sigma_G^2/\sigma_I^2$, is the mean power ratio of the Gaussian to impulsive noise. $N_0 = 2\sigma^2$, is the one sided Power Spectral Density (psd) of the total white noise.
The main advantage of using Middleton Class A is that an equivalent noise source can be constructed and simulated from real world measured data. This enables the opportunity for quantifying noise characteristics based on real world measurements on various devices.
In Fig.2 the pdf of the Middleton Class A noise is given with an impulsive index *A*=0.01.

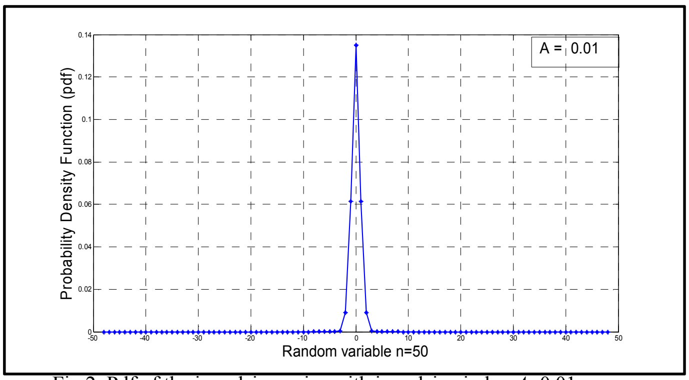


Fig.2. Pdf of the impulsive noise with impulsive index *A*=0.01.

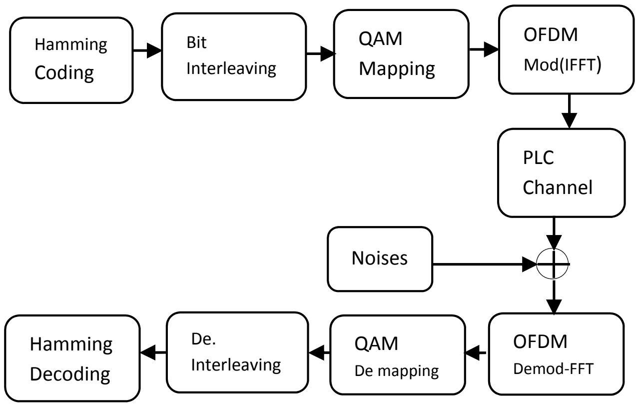
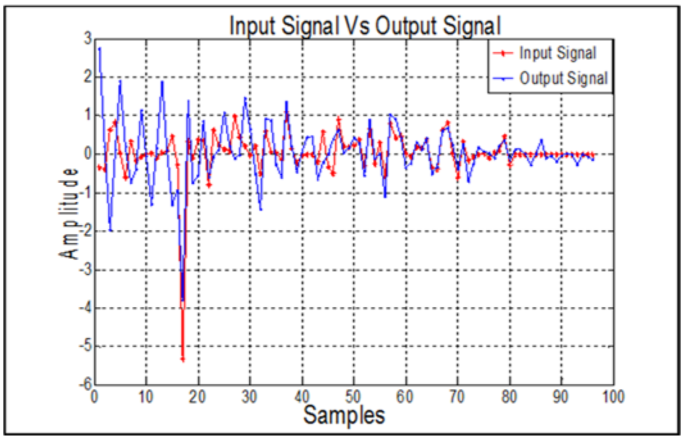


Fig.3. Diagram of an OFDM system consisting of a transmitter, a PLC channel and a receiver

IV. SIMULATION AND RESULTS

Results of simulations undertaken in Matlab to quantify the BER performance of a PLC system using a higher modulation constellation of 64-QAM with Hamming code in presence of impulsive noise are given in this section. Fig.3. illustrates the diagram of the OFDM system used for simulation. A forward error correcting (FEC) code such as the Hamming code is used to enhance the data rate. An interleaving block is used to arrange the coded bits in a way that erroneous bits will be randomly distributed over many code-words rather than only a few code-words, subsequently the data bits are sent to the QAM modulator for mapping. Next is the OFDM stage which uses pilot signals to detect the channel response. The data stream is split into 64 parallel streams (by use of serial to parallel converter) that modulate 64 subcarriers using the Inverse Fast Fourier transform (IFFT). The Cyclic Prefix (CP) is inserted to reduce Inter-symbol interference (ISI). The multipath channel model has been used as given in (2). Background and impulsive noise are injected through the channel.

Fig.4. it illustrates the input signal Vs output affected by AWGN and Impulsive noise



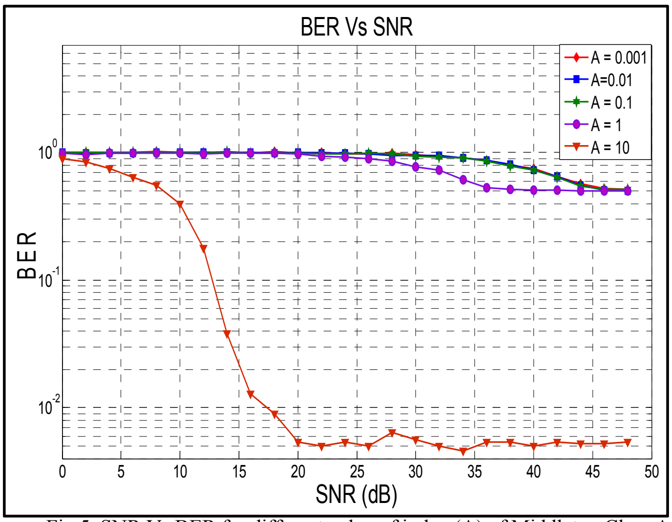


Fig.5. SNR Vs BER for different value of index (A) of Middleton Class A for the PLC channel

The effect of background and impulsive noise on the signal amplitude are given in Fig.4. As observed the impulsive noise distorts the signal amplitude while propagating through the channel. For 64 QAM the effect of variation in the impulsive index *A* from 0.001 to 10 on the BER is shown in Fig.5. A high value of *A* corresponds to low amplitude pulses with frequent occurances, while a low value of *A* corresponds to high amplitude and less frequent pulses. As *A* increases the BER performance improves with increasing SNR. A low value of *A* would correspond to a signifant fault interference in the power line likely as a result of a major fault, while higher values of *A* would be the more regular low power interference caused due to common sources such as heating and electric motors.

Fig.5 shows the BER perforamance of the PLC through a multipath channel with background and impulsive noise.The BER performance is for *A*=10. The BER perfromance of the impulsive noise is worse than the background noise, even though for higher *A* values. The BER peformance can be improved by using suitable filters. However the improvement is likely to occur for high values of *A*, for low *A* values the improvement is not likely to be the same due to a much higher level of interference.

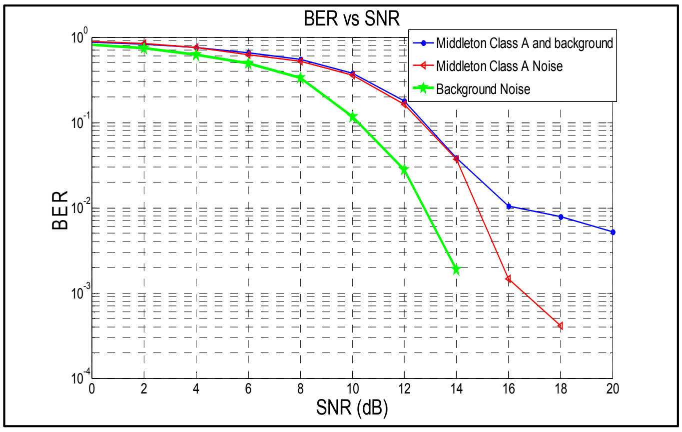


Fig.6. SNR Vs BER for multipath PLC channel

V. Conclusion

Main sources of noise in a power line are caused by the interference due to electric appliances connected to it which affect the data transfer over PLC channels. The main sources being the background and impulsive noise, are modelled and BER performance investigated for a higher signal 64-QAM constellation using OFDM signal. It is observed that BER for the impulsive noise is higher than the background noise. The BER further deteriorates on increasing the level of the impulsive noise, even while being injected into the PLC channel at a lower rate. Applying methods to mitigate and reduce the effect of impulsive noise over PLC systems for higher constellations to increase the data rates could be by means of alternate forward error correction/ convolution codes and suitable filters which are currently being investigated and would be published in a future publication.

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