PERIODIC IMPULSIVE NOISE REDUCTION IN OFDM BASED POWER LINE COMMUNICATION

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Abstract

Different communication technologies are used for the transmission of information such as wireless communication, satellite communication etc. Power Line Communication (PLC) is one of the technologies using existing power cables for the transmission of information. Power cables are not designed for data transmission. So the PLC environment contains different types of noise. This paper presents a novel approach for removing periodic impulsive noise from OFDM based power line communication system. The noise is detected using periodic impulsive noise detection algorithm and the noise is filtered by using adaptive notch filter. An adaptive filter using LMS algorithm is also designed to suppress periodic impulsive noise. Then compare the Bit Error Rate (BER) of PLC system without noise filtering, with noise filtering using notch filter and with noise filtering using adaptive filtering based on LMS algorithm. Results show that the received data is same as that of input data which is transmitted. Simulation results shows that PLC system after noise filtering gives better results than PLC system without noise filtering.

Key Words: *CP (Cyclic Prefix), OFDM, PLC, Periodic Impulsive Noise*

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1. INTRODUCTION

Power Line Communication (PLC) is like any other communication technologies, i.e, the transmitter modulates the data before transmission, injects into the channel (power line channel), and the receiver demodulates the data. PLC does not require additional cables. It re-uses existing power cables. Recently the power line communications has been receiving widespread attention due to its applications in smart grid (such as automatic meter reading, vehicle to grid communications), micro inverters, traffic light control, building automation etc. Power line communication is a leading technology which uses existing cables for transmission of signals. So installation cost is less than other communication approaches. But power cables are originally designed for supplying power to the electrical appliances. These electrical appliances also produce noise. The noises in the low voltage power line has been categorized into five general classes [1] such as:- coloured background noise; narrowband noise; periodic impulsive noise asynchronous to main frequency; periodic impulsive noise synchronous to main frequency; asynchronous impulsive noise. Coloured background noise and narrowband noise can be summarized as background noise. The other noises are impulsive noises produced by the electrical appliances. i.e, the power line noises are the summation of background noise and impulsive noises. The periodic impulsive noises remain stationary over periods of seconds, minutes or even hours. This periodic impulsive noise interfered with the transmitted OFDM signals affect the system performance. So these impulsive noises must be removed to improve the performance of the PLC system [2]. OFDM is a multi carrier modulation technique which is adaptable for several channel conditions. So the PLC system uses OFDM modulation for reliable power line communication.

2. OFDM SYSTEM FOR PLC

The OFDM system consist of transmitter section, channel and receiver section.

OFDM is a multi carrier modulation technique in which the available spectrum is divided into several sub carriers. It is based on orthogonality property which allows the subcarriers are orthogonal to each other. Therefore the cross talk between co channels can be eliminated. The main advantage of OFDM over single carrier modulation is its robustness to narrowband interference and its adaptability to several channel conditions [3]. Figure 1 shows the OFDM system for PLC.

2.1 Transmitter

The input bit stream is randomly generated and transmitted through the OFDM transmitter. Some redundant bits are added with the generated bit stream for coding purposes. It is used for error detection and correction. In OFDM system several coding techniques are used such as block codes, convolution codes, turbo codes etc. In this system convolutional coding is used for coding the input data. The known symbols (also known as pilot symbols) are added with the OFDM transmitted signals. By using Inverse Fast Fourier Transform (IFFT) the transmitted data is converted into orthogonal streams. Cyclic Prefix is inserted to prevent interference between two overlapping channels. It also reduces inter symbol interference. This OFDM symbol is transmitted through the power line channel which contains noise.

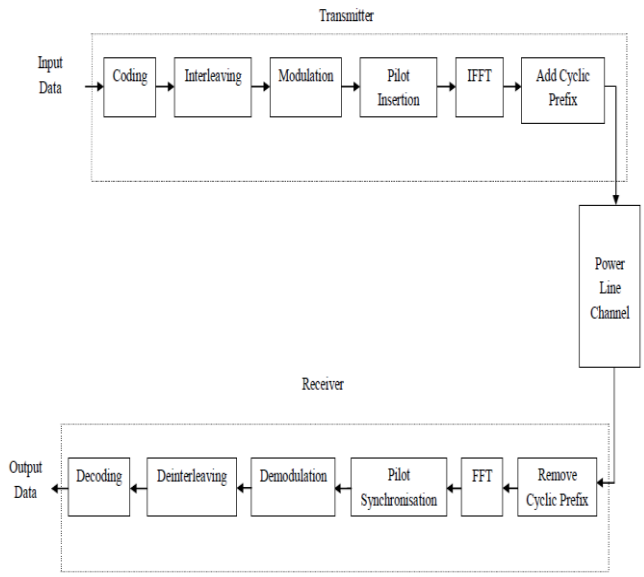

Fig-1: OFDM System for PLC

2.2 Power Line Channel

The data is transmitted through power line channel. Like any other communication systems, PLC channel also contains internal and external noise or disturbances. Channel noise varies with load, frequency, geographic locations etc. These noise removal technique will be explained later.

Power lines noises are classified into five categories [4].

- Coloured background noise-It is caused by summation of multiple sources of noises with low power. Its power spectral density decreases with increasing frequencies.
- Narrow band noise-consists of amplitude modulated sinusoidal signals which is caused by broadcasters, radio stations etc.
- Periodic impulsive noise asynchronous to mains frequency-It is a kind of impulsive noise which is caused by switched-mode power supplies.
- Periodic impulsive noise synchronous to mains frequency-which is mainly caused by switching actions of rectifier diodes found in many electrical appliances.
- Asynchronous impulsive noise-which caused by switching transients in the power network. First two types summarized as background noise and last three types summarized as impulsive noises.

2.3 Receiver

At the receiver the inverse process is performed. The cyclic prefix is removed and signal is transformed into frequency domain using Fast Fourier Transform (FFT). Then pilot symbols are removed and demodulated. After that the data is decoded to produce the output data. Then the signals are demodulated to produce the output data. The received data must be same as that of the transmitted data without any bit error.

3. PERIODIC IMPULSIVE NOISE DETECTION ALGORITHM

The received signal consists of signal, background noise and impulsive noise. Signal is transmitted data from the transmitter, background noise can be modelled as white Gaussian noise (WGN), and the periodic impulsive noise is the dominant impulsive noise. The periodic impulsive noise is interfered with the transmitted signal and causes the performance of the PLC system [5]. This system is a simple and effective method to remove this periodic impulsive noise in the frequency domain. By mitigating the impulsive noise, the system performance improves.

First step is to detect the presence of noise. The periodic impulsive noise interfered in N symbols are almost the same, because the periodic impulsive noises remain stationary over periods of seconds, minutes or even hours. The OFDM signals are sent to the detection algorithm to detect the presence of noise. The OFDM signals are converted into frequency domain using FFT. These signals are given to the noise detection algorithm. A threshold value [6] is set and maximum values of the signals are calculated. If the maximum value is greater than threshold value, then the presence of periodic impulsive noise is confirmed. Otherwise we can confirm that the noise is not interfered with the signal. After detecting the presence of noise, the next step is to design an adaptive notch filter. Notch filter is also called as narrow band reject filter. It is commonly used for the rejection of single frequency such as 60 Hz power line hum. Notch filter plays an important role in communications for eliminating undesired frequencies. An adaptive notch filter is designed to suppress the periodic impulsive noise. If the periodic impulsive noise is detected, the notch filter, filtered the frequencies above a particular threshold value, otherwise it is bypassed. It is an effective method to filter the periodic impulsive noise from the power line communication.

4. ADAPTIVE LMS FILTERING

Adaptive filters are filters whose tap weight vectors vary with time. The principles of adaptive filter are also known as adaptive noise canceller (ANC).In this filter reference signal is adaptively filtered and it is subtracted with input signal produces the estimated signal. The OFDM transmitted signals are interfered with periodic impulsive noise when signals are transmitted through the power line cables. These corrupted signals can be recovered by using the adaptive filtering using Least Mean Square (LMS) algorithm[7]. Figure 2 shows the adaptive noise cancellation system. By using adaptive filtering the BER of PLC system reduces and thus system performance improves.

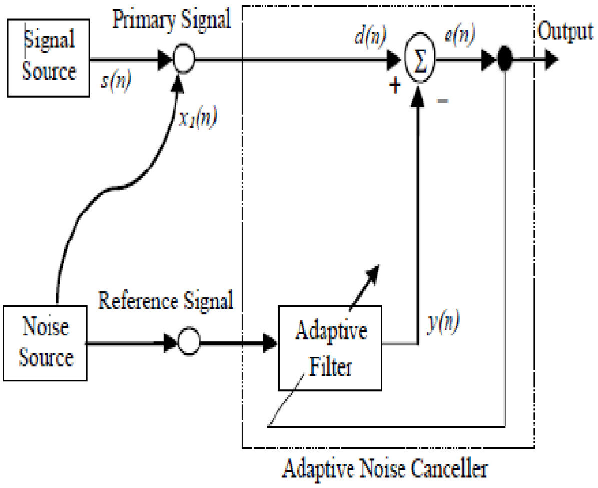

Fig-2: Adaptive Noise Cancellation System

Adaptive filters are self learning filters which do not require any prior knowledge about the input signal. Adaptive noise cancellation system consists of two inputs such as primary input signal d(n) and reference input signal x(n). The desired transmitted signal d(n) corrupted with periodic impulsive noise and x(n) is the reference signal which is the undesired noise must be filtered out of the system. The adaptive filter using LMS algorithm filtered the undesired noise and produce the uncorrupted signal.

$$e(n) = s(n) + x1(n) - y(n) \text{------}(1)$$

Then the output y(n) is subtracted from the primary input to produce the system output *e(n).*

4.1 LMS Algorithm

Adaptive filter using LMS algorithm is used for cancelling the noise which is interfered with transmitted OFDM signal. The algorithm is as follows:-

1) Initialize the algorithm by setting all filter coefficients to zero.
2) Estimation error is calculated by subtracting the desired signal d(n) with filtered signal y(n)

$$e(n) = d(n) - y(n) \text{-------------------------}(2)$$

3) Updated estimate is the summation of old estimate and product of adaptation costant ,estimation error and tap input.

$$wi(n+1) = wi(n) + mu*e(n)*u(n-i) \text{-----}(3)$$

4) *(4)* constitutes the filteration process.

$$y(n)= wi(n)*u(n-i) \text{----------------------}(4)$$

5) Increment the iteration number N by one, go to back to step 2, and repeat the computation. Figure 3 shows the flow chart of adaptive filter using LMS algorithm.

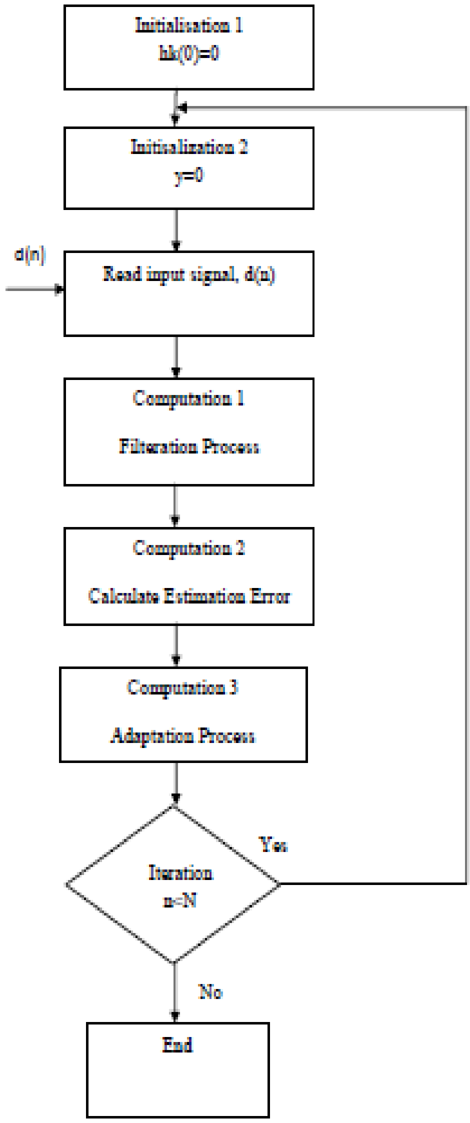

Fig-3: Flowchart of Adaptive LMS Algorithm

5. SIMULATION RESULTS

Simulation is done in MATLAB. The input bit stream is randomly generated at the transmitted end. Error detection and correction techniques are essential for reliable communication over noisy channel [8]. Convolution coding is used for coding the input bit stream. Convolution codes are one of the powerful and efficient error correcting codes for detecting and correcting burst errors. Figure 4 shows the randomly generated input data.

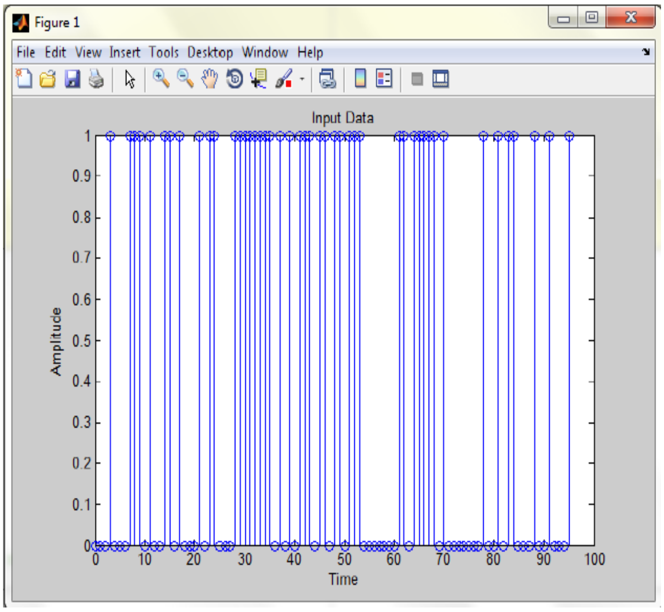

Fig-4: Input Data

OFDM modulation gives good performance in communication channel with harsh characteristics. So the input coded data is modulated using OFDM modulation technique. The OFDM data is transmitted through the PLC channel which contains periodic impulsive noise. The background noise can be modelled as white gaussian noise. Thus the OFDM data is corrupted with periodic impulsive noise and background noise. Figure 5 shows the corrupted OFDM data.

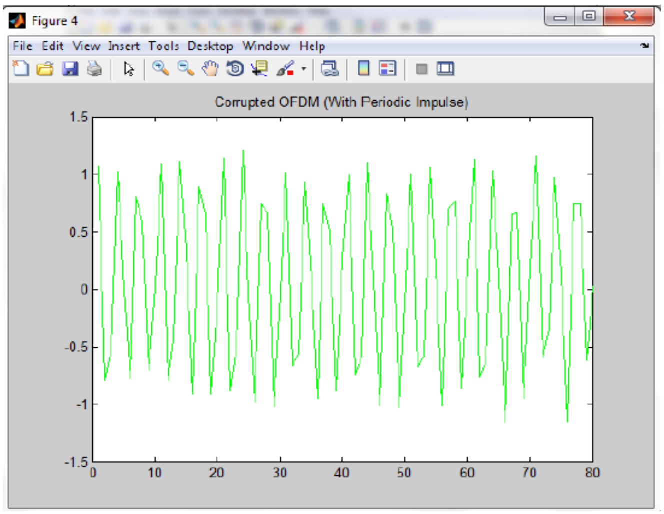

Fig-5: Corrupted OFDM Data

When the OFDM data is not interfered with periodic impulsive noise, the PLC system works normally. It is difficult to identify the frequency components by looking the signal. So By taking the frequency spectrum of the data, we can easily understand the noise. Figure 6 shows the frequency spectrum of the OFDM data corrupted with periodic impulsive noise.

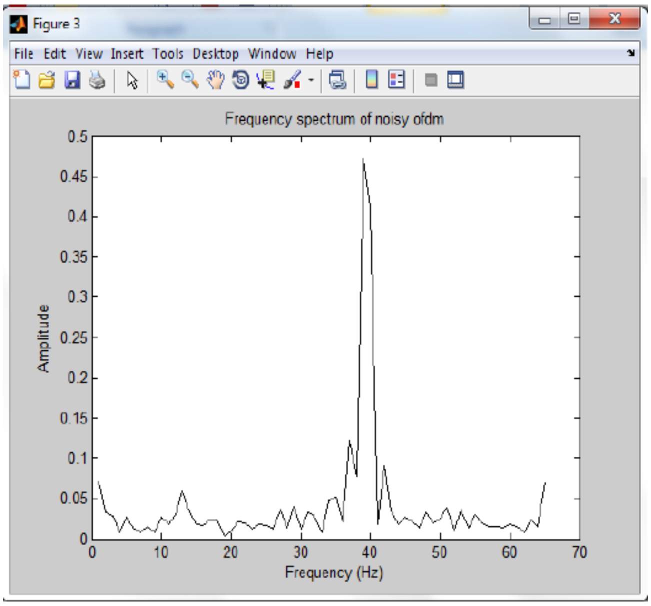

Fig-6: Frequency Spectrum of Noisy OFDM

The PLC system will work normally upto certain threshold. The maximum value of the OFDM data is calculated. If it is greater than the threshold, it will adversely affect the PLC system performance. After detecting the noise, it is filtered using notch filter. Figure 7 shows the frequency spectrum of filtered OFDM using notch filter.

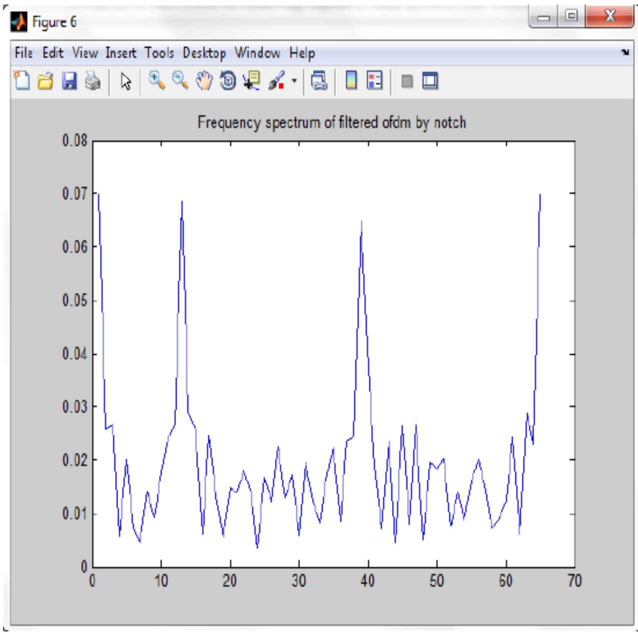

Fig-7: Frequency Spectrum of Filtered OFDM using Notch Filter

An adaptive filter using LMS algorithm is also designed to reduce the periodic impulsive noise. Figure 8 shows the frequency spectrum of the filtered OFDM using adaptive LMS filtering.

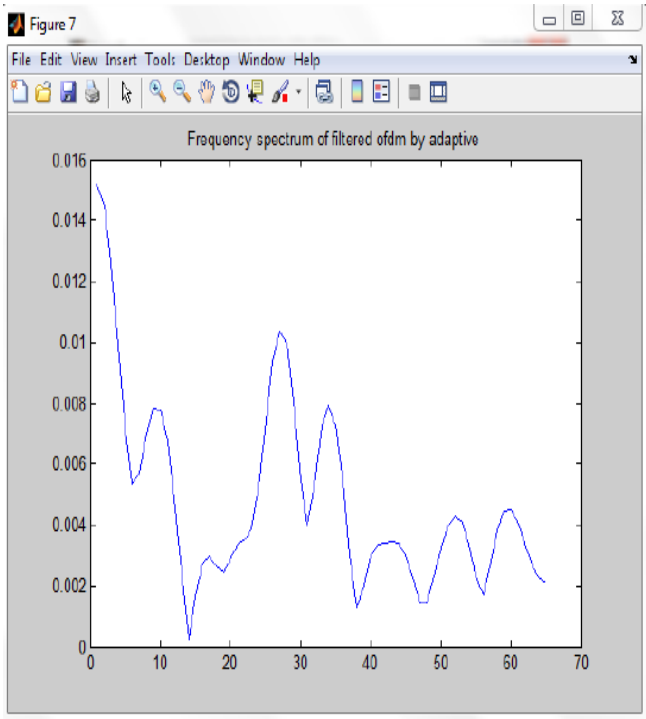

Fig-8: Frequency Spectrum of Filtered OFDM using LMS Filtering

After filtering the periodic impulsive noise, the OFDM data is demodulated to produce the output data. The output bit stream is same as that of input bit stream without any BER. Figure 9 shows the output data after notch filtering. Figure 10 shows the output data after adaptive LMS filtering.

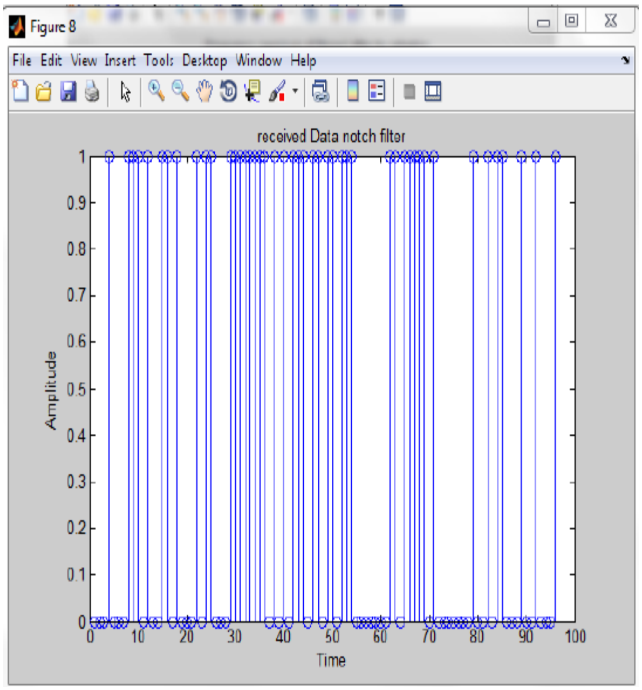

Fig-9: Received Data using Notch Filter.

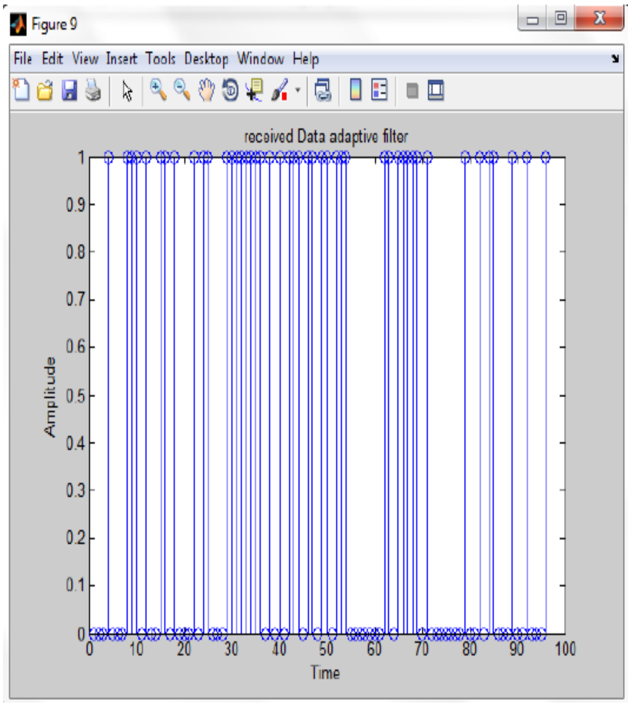

Fig-10: Received Data after Adaptive LMS Filtering

The input data stream is divided into parallel data streams using IFFT and match filtering of subcarriers is done by using FFT. Channel coding and channel estimation is done before IFFT and FFT, which improves BER performance of the PLC system.

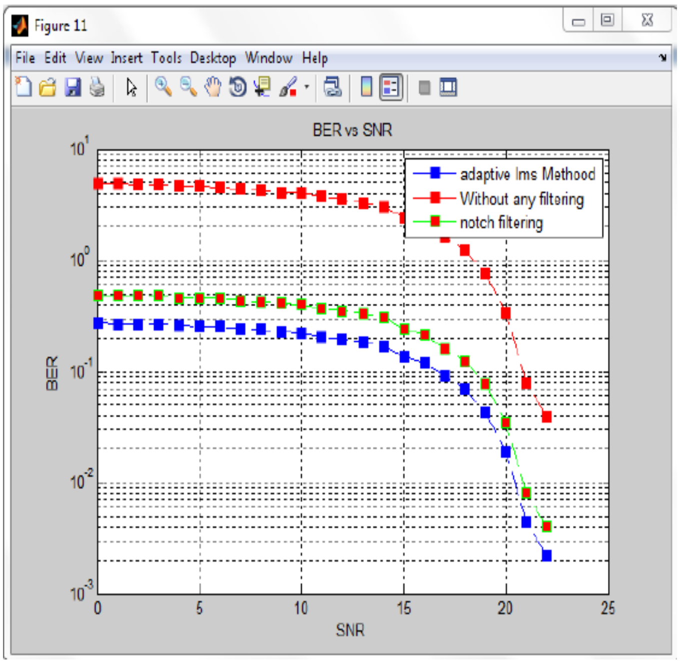

Fig 11 BER of PLC System under Periodic Impulsive Noise

To evaluate the proposed system, we calculated the BER of PLC system with noise mitigation technique and BER of the PLC system without noise mitigation technique for different SNR values. Bit Error Rate (BER) of the PLC system increases with increase in noise interfered with the OFDM data. The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received.

Fig 11 shows the BER of the PLC system under periodic impulsive noise. Red colour represents without any filtering, light green colour represents with filtering using notch filter and blue colour represents with filtering using adaptive LMS filtering . Simulation results shows that BER rate of the PLC system with noise mitigation technique is decreased than BER of the PLC system without noise mitigation algorithm. BER of PLC system using adaptive LMS filtering is decreased than BER of PLC system using notch filter. Thus these filtering techniques can be used to mitigate the periodic impulsive noise from the power line communication system. The proposed algorithm is a simple and effective method for mitigating periodic impulsive noise from the power line communication channel and thus it improves the performance of the PLC system

6. CONCLUSIONS

The main objective of the paper is to reduce the effect of periodic impulsive noise in the Power Line Communication channel. First the presence of periodic impulsive noise is detected and then an adaptive notch filter is designed to mitigate the impulsive noise which is interfered with the OFDM data. Then an adaptive LMS filter is designed and suppress the noise. Simulation results shows that proposed algorithm gives better performance than conventional PLC system. i.e, BER of PLC system with filtering is decreased than BER of PLC system without filtering. Adaptive LMS algorithm can be used for effectively remove the periodic impulsive noise.

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BIOGRAPHIES

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