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Periodic Impulsive Noise Suppression in OFDM-Based Power-Line Communications through Filtering Under Different Coding Schemes

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***Abstract*-Power line communication (PLC) approach is in demand owing to its high data rate and low cost. PLC has a number of application areas ranging from home automation to internet access. Since the power grid is designed optimally for power delivery (not the data), the power transmission line generally appears as a harsh environment for the low-power high-frequency communication signals. The electrical appliances in the power-line network produce different types of noises, leading to performance degradation. In this paper, an adaptive infinite impulse response (IIR) notch filter has been used to remove the periodic impulsive noise arising in the orthogonal frequency-division multiplexing (OFDM) based PLC system. Channel coding techniques such as concatenated Reed Solomon – Convolutional coding and Turbo coding have been done to improve the efficiency of the system. Performance comparison of the system under the two coding schemes has also been done. The simulation results show that the periodic impulsive noise mitigation technique is simple and effective for the OFDM- based PLC system and that the performance of the system is better under turbo coding than concatenated encoding.**

Index terms* : *Adaptive IIR Notch Filter, Bit Error Rate (BER), Convolutional Coding, OFDM, Periodic Impulsive Noise, PLC, Reed-Solomon Codes, Turbo Coding.

I. INTRODUCTION

Power Line Communication (PLC) is a technology where power lines or transmission lines are being used for communication purposes along with transmitting electrical energy. Because the power grid is already in place, the PLC has the obvious advantage of reducing communication infrastructure cost. Power line networks, however, present a hostile channel for communication signals, since their fundamental purpose is the transmission of electric power at super-low frequencies (i.e. 50 Hz or 60 Hz) [1].

Noise, multipath, selective fading and attenuation are well-known properties that hinder the performance of PLC systems. The noise in the PLC environment can be classified into five: colored background noise, narrowband noise, periodic impulsive noise asynchronous to the mains frequency, periodic impulsive noise synchronous to the mains frequency and asynchronous impulsive noise [2].

Periodic impulsive noise asynchronous to the mains frequency, consists of impulses of longer duration that occur periodically in time. They have significant spectral components in the band used by broadband power-line communication systems. Because of its high repetition rate i.e. between 50 and 200 KHz, it occupies frequencies that are too close to each other and therefore frequency bundles that are usually approximated by frequency bands [3].

Generally, OFDM systems are inherently robust to impulsive noise interference. Indeed, the longer OFDM symbol duration provides an advantage, since the impulse noise energy is spread among simultaneously transmitted OFDM subcarriers. However, it has been recognized that this advantage may turn into a disadvantage if impulse noise energy exceeds a certain threshold. The overall effect of impulse noise on OFDM system depends on both the design of the system and the characteristics of the noise [4]. Channel coding techniques are employed to improve the effects of various channel impairments [5]. Concatenated and turbo coding techniques have been presented in this paper.

II. OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for achieving high data rate and combating multipath fading in wireless communications. OFDM combines two communication concepts: multi-carrier modulation (MCM); and orthogonal frequency shift keying (FSK). MCM attains wideband data-rates by dividing a wideband data stream into parallel, lower rate data streams and transmitting them over multiple narrowband carriers. The benefits of this strategy are longer symbol intervals and narrowband channel characteristics. Orthogonal FSK enables each OFDM carrier to be orthogonal to all other carriers transmitted. This orthogonality is achieved by separating the carriers by an integer multiple of the symbol duration of the narrowband data stream. The effects of inter-symbol-interference (ISI) are mitigated via the use of longer symbol duration, as well as the use of a cyclic prefix (CP). The cyclic prefix is a copy of the tail of the symbol period that is appended to the start of the message as a guard interval [4].

The performance of OFDM system is degraded by the presence of periodic impulsive noise in the PLC environment because of its wide frequency component.

III. CHANNEL CODING

Channel coding transforms data sequences into "better sequences" having redundant bits. The redundant bits can be used for the detection and correction of errors referred to as forward error correction (FEC). Although it requires a larger bandwidth ,the advantage is that the Signal to Noise Ratio (SNR) can be reduced significantly (also referred to as coding gain).The encoding procedure provides the coded signal with better distance properties than those of their uncoded counterparts [5].

A. Concatenated Coding

A concatenated code is one that uses two levels of coding, an inner code and an outer code, to achieve the desired error performance. The inner code, the one that interfaces with the modulator/demodulator and channel, is usually configured to correct most of the channel errors. The outer code, usually a high rate (lower redundancy) code, then reduces the probability of error to the specified level. The primary reason for using a concatenated code is to achieve a low error rate with an overall implementation complexity which is less than that which would be required by a single coding operation. Interleaving is done between the two coding steps. This is usually required to spread any error bursts that may appear at the output of the inner coding operation. Here, we use one of the most popular concatenated coding systems that uses a Viterbi-decoded convolutional inner code and a Reed-Solomon (R-S) outer code, with interleaving between the two coding steps [6].

a. Reed Solomon Codes

Reed-Solomon (R-S) codes are nonbinary cyclic codes with symbols made up of 'm' bit sequences, where 'm' is any positive integer having a value greater than 2. It is represented as,

$$(n,k) = \left(2^m - 1, 2^m - 1 - 2t\right) \qquad (1)$$

where 'n' is the total number of code symbols in the encoded block and 'k' is the number of data symbols being encoded, 't' is the symbol error correcting capability of the code and 'n-k=2t' is the number of parity symbols. R-S codes achieve the largest possible code minimum distance for any linear code with the same encoder input and output block lengths and is given by,

$$d_{min} = n - k + 1 \qquad (2)$$

The code is capable of correcting any combination of 't' or fewer errors and is given by,

$$t = \frac{n-k}{2} = \frac{d_{min} - 1}{2} \qquad (3)$$

For each error, one redundant symbol is used to locate the error and another redundant symbol is used to find its correct value [7].

b. Convolutional Coding

Convolutional encoding of data is accomplished using a shift register and associated combinatorial logic that performs modulo-two addition. The combinatorial logic is often in the form of cascaded exclusive-or gates. A convolutional code is described by three integers :

n - number of bits produced at encoder output at each time unit,
k - number of bits input to encoder at each time unit,
K - is the constraint length that represents the number of 'k' tuple stages in the encoding shift register.

When 'q' two-input exclusive-or gates are cascaded, with the output of the first one feeding one of the inputs of the second one, the output of the second one feeding one of the inputs of the third one, etc., the output of the last one in the chain is the modulo-two sum of the q + 1 inputs. An important characteristic of convolutional encoder is that the encoder has memory – the 'n' tuple emitted by the convolutional encoding procedure is not only a function of an input k-tuple, but is also a function of the previous K-1 input 'k' tuples [6].

B. Turbo Coding

A turbo code can be thought of as a refinement of the concatenated encoding structure plus an iterative algorithm for decoding the associated code sequence. It is also an effective way of saving hardware, as it replaces the need of using two encoders with a single one. Turbo codes are in fact a parallel concatenation of two recursive systematic Convolutional (RSC) codes. The fundamental difference between convolutional codes and turbo codes is that while for the former, performance improves by increasing the constraint length, for turbo codes it has a small value which remains pretty much constant. Moreover, it achieves a significant coding gain at lower coding rates. The turbo encoder consists of two rate half RSC encoders. The data block is first encoded by the first encoder. The same data block is also interleaved and encoded by the second encoder. The main purpose of the interleaver is to randomize bursty error patterns so that it can be correctly decoded. It also helps to increase the minimum distance of the turbo code [8].

IV. ADAPTIVE IIR NOTCH FILTER

Adaptive IIR notch filters are used to estimate/track frequencies of sinusoidal components in noise to cancel a periodic interference. In order to identify or cancel a sinusoidal interference in a signal, a stop band filter with strong rejection of the desired frequency should be used [9]. The transfer function of a second order IIR notch filter is given by,

$$H(Z) = b_0 \frac{1 - 2\cos(\omega_0) Z^{-1} + Z^{-2}}{1 - 2\rho\cos(\omega_0) Z^{-1} + \rho^2 Z^{-2}} \qquad (4)$$

$$\omega_0 = \frac{2\pi f_i}{f_s}$$

where ‘b_0’ is the filter gain, ‘ρ’ is the rejection bandwidth of the notch filter, ‘f_s’ is the Nyquist sampling frequency and ‘f_i’ is the notch centre frequency of the IIR notch filter [10].

V. SYSTEM MODEL

Fig.1. shows the block diagram of the impulsive noise mitigation using adaptive IIR notch filter. Initially, the data are subjected to concatenated (Reed Solomon - Convolutional) encoding. The encoded data are modulated using 16-QAM (Quadrature Amplitude Modulation). The IFFT operation imparts orthogonality to the OFDM symbol . Cyclic prefix is appended to combat ISI. While passing through the channel, the data gets corrupted with impulsive and background (modeled as AWGN) noises. At the receiver side, the initial step is noise detection.

A. Noise Detection

The periodic impulsive noise is modeled as a damped sinusoid.

$$x(t) = Ae^{-\tau t}\cos(2\pi f_0 t) \qquad (5)$$

where ‘A’ is the peak value of the amplitude of the periodic impulsive noise, ‘τ’ is the damping factor, ‘f_0’ is the frequency of the periodic impulsive noise. Therefore, the received signal is the sum of transmitted signal, background noise modeled as white Gaussian noise (WGN) and periodic impulsive noise. Here, the band of the OFDM – based PLC system is divided into 96 subcarriers. For noise detection, initially the power value of each subcarrier is calculated and the maximum power value ‘P_{max}’ is found out. Then a threshold value ‘P_{th}’ is set. If ‘P_{max}’ is greater than ‘P_{th}’, the presence of periodic impulsive noise can be confirmed. Since the power spectral density (PSD) of the periodic impulsive noise is much greater than the information signals, it is easy to find out the position of the interfered subcarrier. The position of the interfered subcarrier represents the frequency of periodic impulsive noise. Thus, the noise detection algorithm is simplified.

Once the noise is detected and located, an adaptive IIR notch filter is designed to mitigate the periodic impulsive noise since every subcarrier may be affected by the noise.

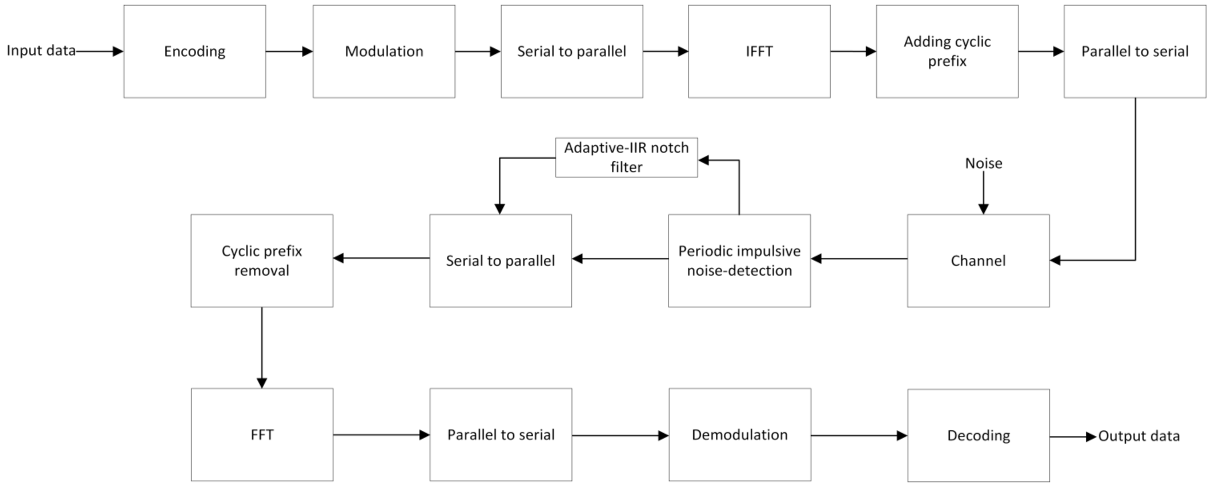

Fig. 1. Block diagram of impulsive noise mitigation algorithm

5.2. Noise Mitigation

The band of the system is divided into 96 subcarriers, therefore 96 notch filters are designed, each of whose notch centre frequencies is the centre frequency of the interfered subcarrier. The notch filter coefficients are calculated according to (4). So, once the position of the interfered subcarrier is located and the frequency of the periodic impulsive noise is confirmed, the notch filter whose notch centre frequency is the interfered subcarriers centre frequency, is chosen to mitigate the noise. After filtering, the operations carried out at the transmitter are reversed i.e., removing cyclic prefix, performing FFT, demodulation and decoding to obtain the output data. Then, the concatenated encoder/decoder has been replaced by the turbo encoder/decoder and the operations carried out at the transmitter and receiver in the concatenated coding case are also done while using turbo coding, maintaining the same noise scenario.

VI. SIMULATION RESULTS AND DISCUSSIONS

The parameters for simulating the OFDM system are described below in Table 1.

TABLE 1. SIMULATION PARAMETERS

Modulation Technique	16 QAM
No. of subcarriers	96
Size of cyclic prefix	16
FFT length	512
Encoder	RSCC, Turbo

The performance analysis of the system with and without using adaptive IIR notch filter for removing periodic impulsive noise using concatenated coding and turbo coding is simulated. Following are the simulation results :

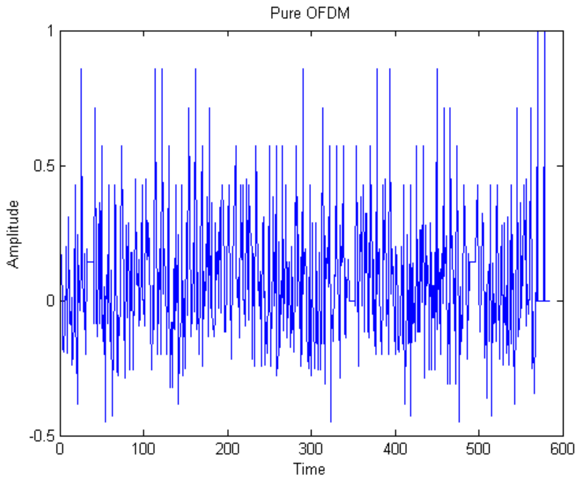

Fig. 2. Pure OFDM

Fig.2. shows pure OFDM after concatenated coding.

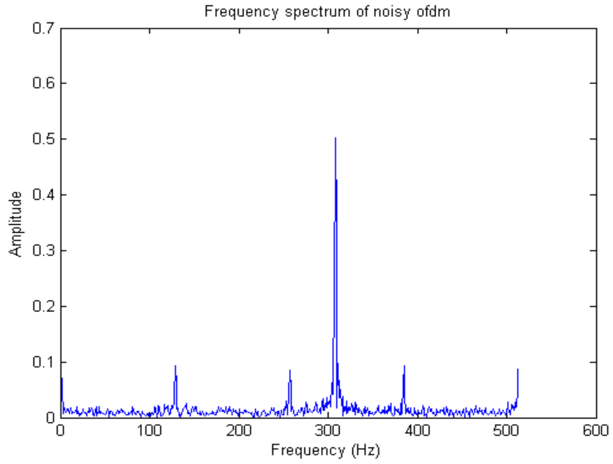

Fig. 3. Frequency spectrum of noisy OFDM

Fig.3. shows OFDM corrupted by periodic impulsive noise of frequency 300Hz.

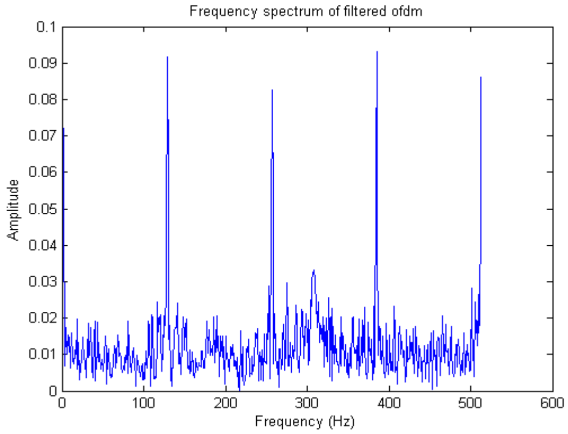

Fig. 4. Frequency spectrum of filtered OFDM

Fig. 4. shows the frequency plot of OFDM, filtered using adaptive IIR notch filter.

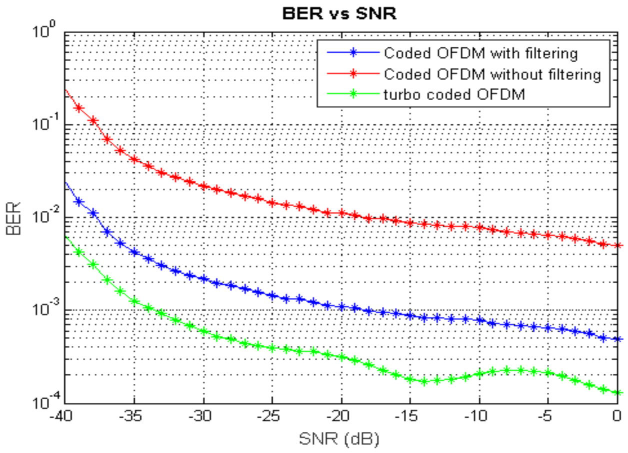

Fig. 5. BER vs SNR

Fig. 5. shows that under concatenated coding, BER of the PLC system is less when the adaptive IIR notch filter is used when compared to the BER value when no such filtering is done. This proves that the noise mitigation algorithm is effective in mitigating the periodic impulsive noise in the PLC channel. A better BER plot is obtained when the concatenated coding is replaced by a turbo coder under the same noise and filtering scenario, thus proving the efficiency of the turbo coder.

VII. CONCLUSION

High data rate and low cost makes PLC an attractive communication technique. But its performance is severely degraded by the presence of periodic impulsive noise arising in the channel. An adaptive IIR notch filter is used to mitigate the periodic impulsive noise. First, the noise is detected in the frequency domain. Then it is suppressed using an adaptive IIR notch filter. To find out the effectiveness of the algorithm, BER vs SNR plot for both the cases is simulated. The simulation results show that the filtering technique is effective in mitigating the periodic impulsive noise. The simulation results also show that the turbo coding has a better performance than concatenated coding in the context of mitigating the periodic impulsive noise using the adaptive IIR notch filter.

REFERENCES

[1] Y. C. Kim, J. N. Bae, and J. Y. Kim, "Novel noise reduction scheme for power line communication systems with smart grid applications," in *Proc. IEEE. ICCE*, Jan. 2011, pp. 791–792.

[2] V. Degarding, M. Lienard, A. Zeddam, F. Gauthier, and P. Degauque, "Classification and characterization of Impulsive noise on indoor power line used for data communications," *IEEE Trans. Consum. Electron*., vol. 48, no. 4, pp. 913–918, Nov. 2002.

[3] M.Zimmermann and K.Dostert,"Analysis and modeling of impulsive noise in broad –band powerline communications," *IEEE Trans. Electromagn. Compat*., vol. 44, no. 1, pp. 249–258, Feb. 2002.

[4] Ramjee Prasad, "OFDM for Wireless Communications systems", Artech House Publishers, 2004.

[5] B. Sklar, "Digital Communications: funda-mentals and applications", 2nd ed, Prentice Hall, London, 2001.

[6] Proakis John G.;Digital Communications 4th Edition, The McGraw-Hill Companies Inc.; New York, NY 2001.

[7] Gulliver, T. Aaron; "Performance Evaluation of Reed Solomon Codes", Department of Systems and Computer Engineering, Carleton University, Ottawa ON, 1993.

[8] S. A. Barbulescu and S. S. Pietrobon, "Inter-leaver Design for Turbo Codes," *Electronic Letters*, vol. 30, pp. 2107–2108, Dec 1994.

[9] J. Zhou and G. Li, "Plain gradient based direct frequency estimation using second-order constrained adaptive IIR notch filter," *Electron. Lett*., vol. 40, no. 5, pp. 351–352, Mar. 2004.

[10] G. Ren, S. Qiao, H. Zhao, C. Li and Y. Hei, "Mitigation of periodic impulsive noise in OFDM-based power-line communications," *IEEE Trans. Power Del*., vol. 28,no. 2, pp. 825- 834, 2013.