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Turbo Code with OFDM in Powerline Communication Channel (PLC)

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ABSTRACT: Powerline Communication (PLC) technology enables to transmit data via the electrical supply network. As the power line was designed to distribute power, it is not a good medium for communication purpose and advanced communication methods are needed to have an effective communication over the channel. In this paper a PLC – Orthogonal Frequency Division Multiplexing (OFDM) Transceiver system integrated with turbo code is proposed. The effect of multipath and noises are also considered. The simulation results show that our proposed system with Max-Log-Map decoding algorithm provides good Bit Error Rate (BER) performance in the powerline communication channel. Also the system utilizes less processing resources than those required to implement the MAP-BCJR algorithm.

KEYWORDS: Powerline Communication, Orthogonal Frequency Division Multiplexing, Turbo code, Max-log-Map algorithm, Bit Error Rate

I.INTRODUCTION

Creation as well as dispersion of information is the focus area of present age information technology. Telephone lines, optical fibre, ethernet cabling and satellite technologies are some of the popular techniques in information dispersion. The limitations include high cost and low effective communication area. In almost each building powerline networks exist which is mainly used for the supply of electric power. It becomes interesting if these powerlines can be used for information transmission.

Powerline communication is not a new technology. It is as old as telegraph systems but there was a question of reliability. The medium is actually harsh for communication purposes due to multipath effects at branching points, impedance variation, background and impulsive noises. So it is difficult to ensure reliable powerline communication. Cable modem and other forms of digital subscriber lines (DSL) were of great interests at first but the low upload and download speed created high traffic congestion.

Powerline is a vast infrastructure that is found in the most remote area of the world. They offer the convenience of already being deployed and easy access as power outlets are available in almost all locations in houses. Even wireless devices need to be connected to the power outlets to charge their batteries. So powerline communication offers mobility close to wireless communication.

The basic principal of powerline communication lies in superimposing a high frequency signal (message signal) which is 1.6 – 30 MHz over the powerline which is 50 Hz. The signal is transmitted through the powerline and can be received at any power outlets. Thus PLC eliminates the need for running a dedicated cable for communication purpose. A wide range of power-line communication technologies are needed for different applications, ranging from home automation to Internet access which is often called broadband over power lines (BPL). Most PLC technologies limit themselves to one type of wires, but some can cross between two levels. Typically transformers prevent propagating the signal, which requires multiple technologies to form very large networks. Various data rates and frequencies are used in different situations.

Several International Standards exists for PLC. The IEEE 1901 supports high speed data transmission up to 500 Mbps in powerlines. Narrow band and broadband PLC which are the two basic classes of PLC are supported by ETSI.

As stated above PLC systems are not free of problems. The channel is notorious for high noise fluctuations as electric devices connected to mains network injects significant noise back into network. Also uncontrolled nature of wiring

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results in technical problem. Advanced modulation technique like Orthogonal Frequency Division Multiplexing (OFDM) and Forward Error Correction (FEC) schemes like turbo coding can be used to improve the BER performance. Turbo coding works efficiently with low SNR compared to other coding techniques.

In the existing literature different forward error correction (FEC) and modulation schemes for PLC Transceiver in the powerline channel have been introduced. In [1], it is shown that the turbo codes with code rate 1/3 shows better performance compared to LDPC code. This paper considers only the AWGN environment. In [2], the authors proposed LDPC codes in powerline communication channel which is modelled as a Cyclostationary Gaussian process. In [3], an M-ary/DS powerline communication method is examined. This method focuses on low cost broadband communication.

In this article an attempt is made to simulate an OFDM Transceiver section on a PLC channel that is modelled as a cyclostationary channel impaired with impulsive and AWGN noises.

II.POWERLINE COMMUNICATION CHANNEL

Powerline channel has now become a multipurpose medium. The PLC channel has a tree like topology. Additional wires taper from the main path, having various line section lengths, different cable types and are terminated with loads of different impedances. Hence signal suffers from multipath reflections. Furthermore, the noises like impulsive and AWGN (Additive White Gaussian Noise) need to be considered [4]. A large number of model proposals can be found in literature, the model described in [5] is taken in this paper for channel simulation. The network topology is shown in fig 1. It comprises seven line sections, from which three are stubs. Load impedances are located at the end of these stubs. The network topology parameters include only seven line lengths: t_i (i €{1 2 3 4}) and S_i (i €{1 2 3 4}).

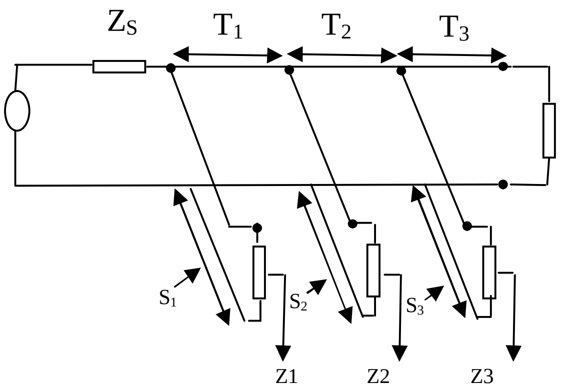

Fig.1. Network topology of the model

Table 1: Characteristics of indoor power network cables. R = $R_0 .10^{-5}$ p (Ω/m) and G = $G_0.5.10^{-14} . 2\pi f$ (S/m).

Cable Type	**1**	**2**	**3**	**4**	**5**
Section(mm^2)	1.5	2.5	4	6	10
Eeq	1.45	1.52	1.56	1.73	2
Z_o(Ω)	270	234	209	178	143
C(pF/m)	15	17.5	20	25	33
L(µH/m)	1.08	0.96	0.87	0.78	0.68
R_o	12	9.34	7.55	6.25	4.98
G_o	30.9	34.7	38.4	42.5	49.3

The transmission line parameters *R, L, G* and *C* (per unit length) are listed in Table 1. Low impedance is set as 5Ω, RF standard as 50Ω, Transmission line Z_0 150Ω, High impedance 1000Ω and Open circuit impedance is infinite. For the frequency-selective impedances, the model is a parallel RLC resonant circuit,

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$$Z(\omega) = R \div (1 + jQ((\omega / \omega_0) - (\omega_0 / \omega))) \quad (1)$$

The three parameters are: *R*, resistance at resonance; w_0, resonance angular frequency; and *Q*, quality factor which determines selectivity.

III.TURBO CODES

In the 1993 International Conference in Communications, Berrou and Glavieux proposed turbo codes. Turbo codes have remarkable power efficiency in AWGN and flat fading channel for moderately low BER [6]. The features of Turbo codes include Parallel concatenated coding, Recursive Convolutional coders, Pseudorandom interleaving and iterative decoding. Instead of concatenating in serial, codes can also be concatenated in parallel. The original turbo code is a parallel concatenation of two Recursive Systematic Convolutional (RSC) coders.

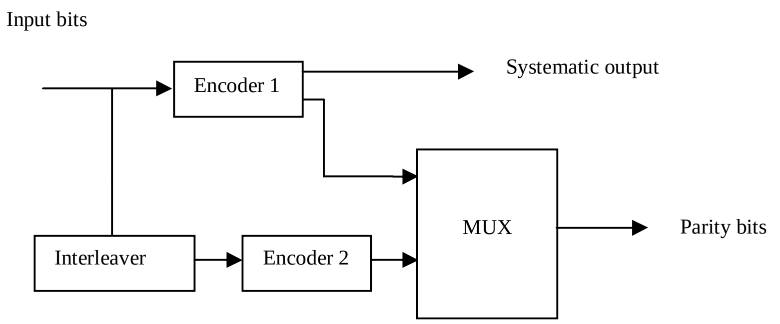

Fig.2. Turbo encoder –General Structure

Random codes with large block length can achieve channel capacity. However these random codes must have a structure for decoding with reasonable complexity. Pseudorandom interleaver helps in randomizing the code maintaining enough structure to permit decoding. A RSC (Recursive Systematic Coder) encoder can be constructed from a standard convolutional encoder by feeding back one of the outputs. An RSC encoder produces codes with low weights with fairly low probability. But same inputs may still cause low weight outputs. The probability that both encoders have inputs that cause low weight output is very low. A parallel concatenation of both encoders can be used to enhance the performance. The general structure of turbo code is shown in fig 2.

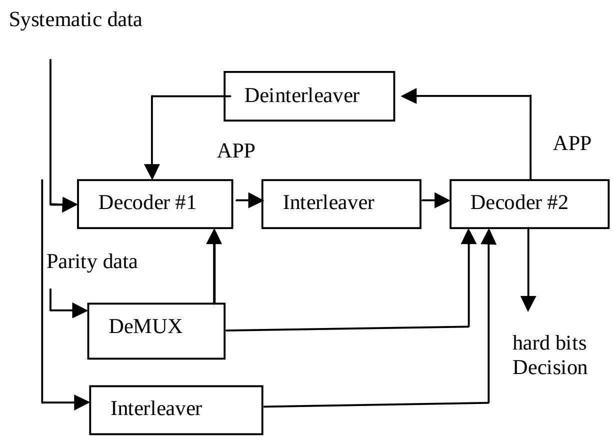

Fig. 3. Turbo decoder –General Structure

In the decoding section there is one decoder for each elementary encoder. The structure is shown in fig 3. The a posteriori probability of each data bit is estimated by each decoder. The second decoder uses these APP's as a priori information and the decoding continue for a set of number of iterations. The performance usually improves from iteration to iteration.

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The decoding algorithm used is Max - Log - Map algorithm. Exponential operation and storage are required by the Map algorithm. Map algorithm uses an approximation to reduce the computations of the summation of numerous exponentials. Max-Log-Map algorithm can be termed as a sub-optimum decoding algorithm. This algorithm actually gives a slight degradation in performance compared to Map algorithm due to an approximation used which is described in [7].

IV.SYSTEM MODEL - TURBO CODES WITH OFDM

The principle objective of this study is to examine the performance of turbo codes in powerline communication channel. An overview of the PLC – OFDM Transceiver is shown in fig 4. Each individual block is modelled in Matlab.

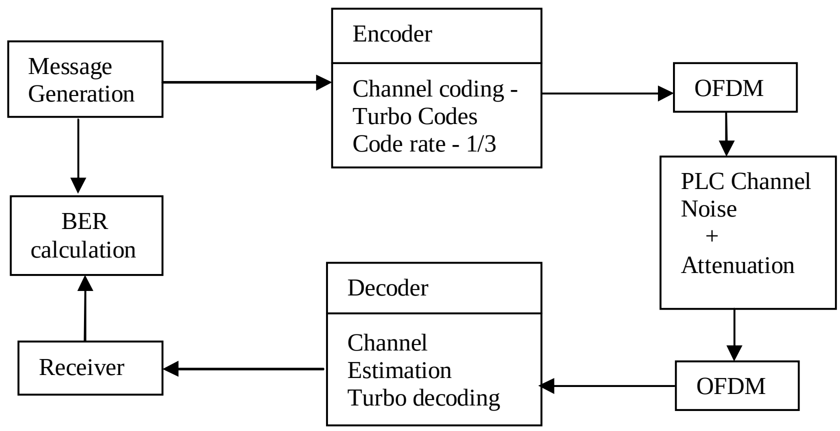

Fig. 4. PLC-OFDM Transceiver block

Once the message is generated, it is fed to the turbo encoder with code rate 1/3. The base modulation used is QAM. The coded message is then fed to the OFDM block where the serial bit stream is converted to parallel bit stream and the subcarriers generated are fed to the IFFT processor . In the channel, the message is distorted due to noise and multipath effects. At the receiver, the message is demodulated and decoded. The performance of the PLC – OFDM Transceiver system is analysed by calculating the Bit Error Rate (BER).

IV. RESULT AND DISCUSSION

The proposed turbo code implementation was tested and the simulations were carried out with Matlab Ver. R2013a. The specifications for the simulated PLC – OFDM Transceiver is shown in Table 2.

Table 2. Specification for PLC OFDM Transceiver

Parameters	**Value**
Number of subcarriers	64
Carrier Modulation	QAM
Channel modulation	OFDM
Coding scheme, Code Rate, Encoder size	Turbo,1/3, RSC (7,5)
Interleaver size	1000,2000,3000,4000,5000

Three powerline channel conditions are considered in this paper. A comparison of the amplitude response of the three channels is shown in fig 5. As shown, the medium case channel has an average attenuation of 33.6 dB. The best case channel is having the lowest attenuation and delay spread. The average attenuation is about 20 dB. Higher attenuation and delay spread is seen in the worst case channel having an average attenuation as 46 dB. The parameter values to obtain the three channels are shown in Table 3. l and t corresponds to the vectors of line section lengths and cable types respectively. Z1, Z2 and Z3 are the impedances as in fig. 1.

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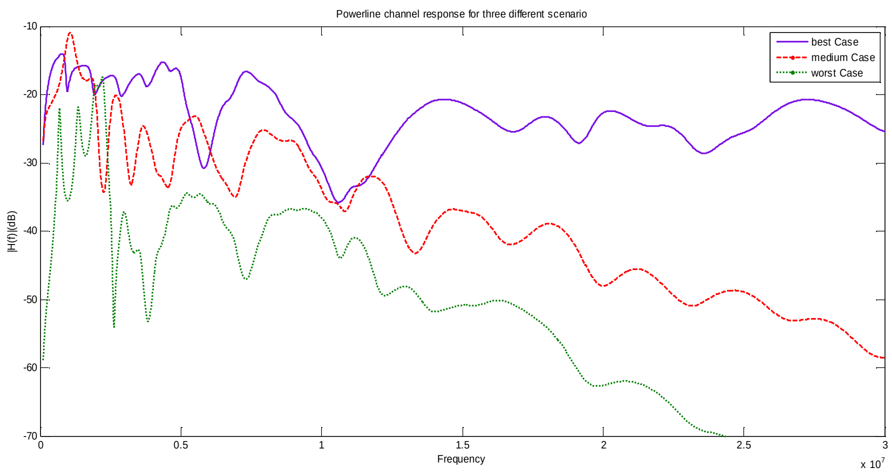
Table 3. Parameter values of Best, Medium and Worst channel conditions

BEST CASE	
Parameters	**Values**
Vector of line section lengths (in mm) – l	l=[4.2,129.4,8.3,10.3,0.3,20.9,4.8]
Vector of cable types – t	t=[4,1,3,4,5,2,4]
Z1 impedance; RLC resonator	(1293,40,4.98e6)
Z2 impedance; RLC resonator	(978,42,20.51e6)
Z3 impedance; RLC resonator	(1752,38,23.68e6)
MEDIUM CASE	
Parameters	**Values**
Vector of line section lengths (in mm) – l	l=[0.8,32,13.8,37.6,46.8,50.1,37.2]
Vector of cable types – t	t=[5,5,2,2,5,2,4]
Z1 impedance; RLC resonator	(863,6,2.7e6)
Z2 impedance; RLC resonator	(394,34,10.7e6)
Z3 impedance; RLC resonator	(1312,9,10.07e6)
WORST CASE	
Parameters	**Values**
Vector of line section lengths (in mm) – l	[14.9,29.1,11.9,9.8,138.8,2.2,8.5]
Vector of cable types – t	[3,4,5,1,5,1,1]
Z1 impedance; RLC resonator	(552,46,11e6)
Z2 impedance; RLC resonator	(1705.3,19,7.7e6)
Z3 impedance; RLC resonator	(674,39,2.1e6)

Fig 6 shows the performance results of turbo code in the PLC channel impaired by AWGN and Impulsive noise. Medium case PLC channel conditions are used here. A comparison of four different interleaver sizes is presented with the same channel conditions. The BER performance of interleaver size N equal to 1000 was poor even with increase in SNR. For Interleaver size 2000 and 3000, it is observed that the results were very similar, although with little difference at high SNR values. The BER performance was best when the interleaver sizes were 4000 and 5000. The interleaver used is Pseudorandom interleaver which improves the turbo code performance as the block size increased. As a result, BER performance of turbo code is high for large data block. Use of pseudorandom interleaver needs two memory buffers but it can be achieved easily with the available hardware platforms. It is clear that the use of turbo code with OFDM modulation in PLC channel improves the BER significantly.



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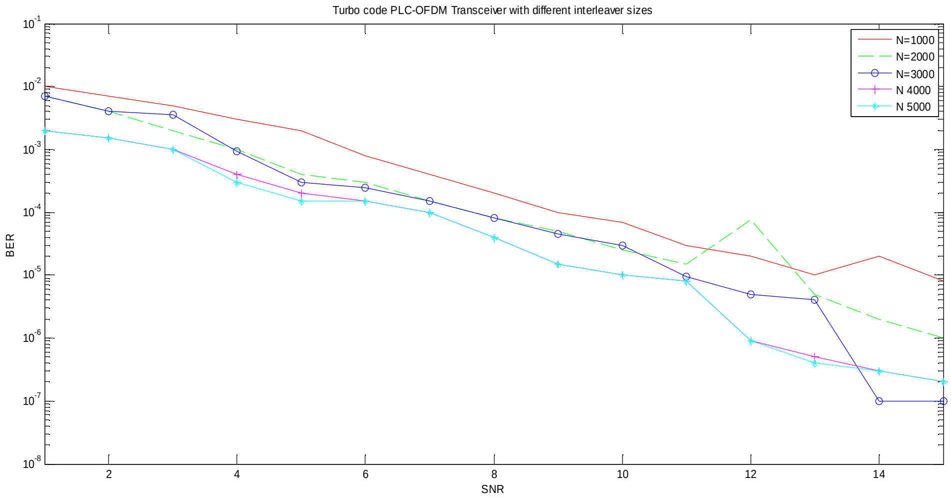

Fig. 6. Comparison of interleavers with different size in PLC – OFDM Transceiver.

V.CONCLUSION

In this work, the performance of Turbo code with OFDM modulation in PLC channel in the presence of AWGN and Impulsive noise was investigated. Simulations were carried out with different interleaver sizes in turbo code in the PLC – OFDM Transceiver and the results obtained show that turbo code performance in the PLC channel improved with an increase in the interleaver size.

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