Journal of Theoretical and Applied Information Technology

www.jatit.org

TO IMPROVE BIT ERROR RATE OF TURBO CODED OFDM TRANSMISSION OVER NOISY CHANNEL

[1]M. K. GUPTA, [2]VISHWAS SHARMA

[1]Department of Electronic Instrumentation and Control Engineering, Jagannath Gupta Institute of engineering and Technology, Jaipur.

[2]Department of Electronics and Communication Engineering, Jagannath Gupta Institute of engineering and Technology, Jaipur.

E-mail: mkgupta72@gmail.com , Vishwas.ece@gmail.com

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) has become a popular modulation method in high speed wireless communications. By partitioning a wideband fading channel into flat narrowband channels, OFDM is able to mitigate the detrimental effects of multipath fading using a simple one-tap equalizer. There is a growing need to quickly transmit information wirelessly and accurately. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels. In this research paper, the system throughput of a working OFDM system has been enhanced by adding turbo coding. The use of turbo coding and power allocation in OFDM is useful to the desired performance at higher data rates. Simulation is done over additive white Gaussian noise (AWGN) and impulsive noise (which is produced in broadband transmission) channels. The wideband system has 48 data sub-channels; each is individually modulated according to channel state information acquired during the previous burst. This research paper is to increase the system throughput while maintaining system performance under a desired bit error rate (BER). To improve the performance of the uncoded OFDM signal by convolution coding.

Keywords: Bit error rate, Orthogonal frequency division multiplexing, Turbo codes,

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other [1]. Some of the main advantages of OFDM are its multi-path delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Also one other significant advantage is that the modulation and demodulation can be done using inverse fast fourier transmission (IFFT) and fast fourier transmission (FFT) operations, which are computationally efficient.

In a single OFDM transmission all the subcarriers are synchronized to each other, restricting the transmission to digital modulation schemes [1, 2]. OFDM is symbol based, and can be thought of as a large number of low bit rate carriers transmitting in parallel. All these carriers transmitted using synchronized time and frequency, forming a single block of spectrum. This is to ensure that the orthogonal nature of the structure is maintained [3, 4]. Since these multiple carriers form a single OFDM transmission, they are commonly referred to as ‘subcarriers’, with the term of ‘carrier’ reserved for describing the RF carrier mixing the signal from base band. There are several ways of looking at what make the subcarriers in an OFDM signal orthogonal and why this prevents interference between them.

2. TURBO CODES

It was widely believed that to achieve near Shannon’s bound performance, one would need to implement a decoder with infinite complexity or close. Parallel concatenated codes, as they are also known, can be implemented by using either block codes (PCBC) or convolutional codes (PCCC) [5, 6,]. PCCC resulted from the combination of three ideas that were known to all in the coding community. The transforming of commonly used non-systematic convolutional codes into systematic convolutional codes, the utilization of soft input soft output decoding. Instead of using hard decisions, the decoder uses the probabilities of the received data to generate soft output which also contain information about the degree of certainty of the output bits, Encoders and decoders working on permuted versions of the same information. This is achieved by using an interleaver.

2.1 Turbo Encoding

The encoder for a turbo code is parallel concatenated convolutional code [7, 8, 9]. the block diagram of the encoder is shown in “Figure 1”. The binary input data sequence is represented by $d_k = (d_1 , …….. d_N)$. The input sequence is passed into the input of a convolutional encoder. ENC_1 and a coded bit stream, $x^{\mathrm{p}}_{\mathrm{k}_1}$ is generated. The data sequence is then interleaved. That is, the bits are loaded into a matrix and read out in a way so as to spread the positions of the input bits. The bits are often out in a pseudo-random manner. The interleaved date sequence is passed to a second convolutional encoder ENC_2, and a second coded bit stream, $x^{\mathrm{p}}_{\mathrm{k}_2}$ is generated. The code sequence that is passed to the modulator for transmission is a multiplexed (and possibly punctured) stream consisting of systematic code bits x^s_k and parity bits from both the first encoder $x^{\mathrm{p}}_{\mathrm{k}_1}$ and the second encoder $x^{\mathrm{p}}_{\mathrm{k}_2}$.

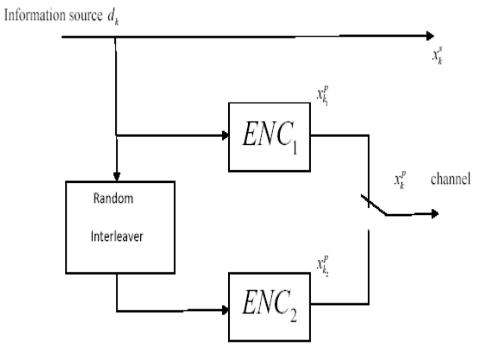

Figure 1. Structure of a turbo encoder

2.2 Turbo decoding

A block diagram of a turbo decoder is shown in “Figure 2”. The input to the turbo decoder is a sequence of received code values, $R_k = \{y^s_k , y^p_k\}$ from the demodulator [10, 11, 12]. The turbo decoder consists of two component decoder – DEC_1 to decode sequences from ENC_1, and DEC_2 to decode sequences from ENC_2. Each of these decoders in a Maximum A Posteriori (MAP) decoder. DEC_1 takes as its input the received sequence systematic values y^s_k and the received sequence parity values $y^p_{k_1}$ belonging to the first encoder ENC_1. The output of DEC_1 is a sequence of soft estimates EXT_1 of the transmitted data its d_k. EXT_1 is called extrinsic data, in that it does not contain any information which was given to DEC_1 by DEC_2. This information is interleaved, and then passed to the second decoder DEC_2. The interleaver is identical to that in the encoder (Figure1). DEC_2 takes as its input the (interleaved) systematic received values y^s_k and the sequence of received parity values $y^p_{k_2}$ from the second encoder ENC_2, along with the interleaved form of the extrinsic information EXT_1, provided by the first decoder. DEC_2 outputs a set of values, which, when de-interleaved using an inverse form of interleaver, constitute soft estimates EXT_2 of the transmitted data sequence d_k. This extrinsic data, formed without the aid of parity bits from the first code, is feedback DEC_1. This procedure is repeated in a iterative manner. The iterative decoding process adds greatly to the BER performance of turbo codes. However, after several iterations, the two decoders’ estimates of d_k will tend to converge. At this point, DEC_2 outputs a value $\wedge(d_k)$; a log-likelihood representation of the estimate of d_k. This log likelihood value takes into account the probability of a transmitted ‘0’ or ‘1’ based on systematic information and parity information from both component codes. More negative values of $\wedge(d_k)$ represent a strong likelihood that the transmitted bit was a ‘0’ and more positive values represent a strong likelihood that the transmitted bit was a ‘0’ more positive values represent a strong likelihood that a ‘1’ was transmitted. $\wedge(d_k)$ is de-interleaved so that its sequence coincides with that of the systematic and first parity streams. Then a simple threshold operation is performed on the result, to produce hard decision estimates, d_k, for the transmitted bits.

The decoding estimates EXT_1 and EXT_2, do not necessarily converge to a correct decision.

If a set of corrupted code bits form a pair of error sequence that neither of the decoders is able to correct, then EXT_1 and EXT_2 may either diverge, or converge to an incorrect soft value. In the next sections, the algorithms used in the turbo decoding process, within DEC_1 and DEC_2.

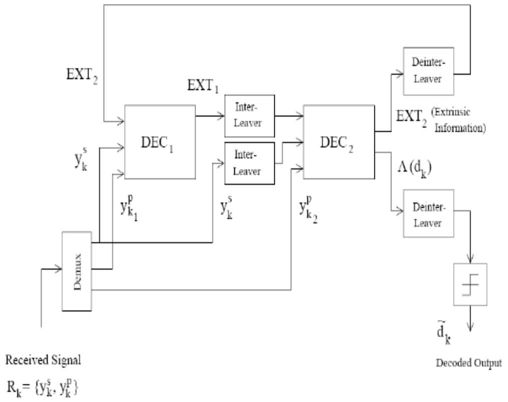

Figure 2. Turbo Decoder Structure

3. ANALYSIS OF TURBO CODES OFDM

The combination of turbo codes with the OFDM transmission is so called Turbo Coded OFDM (TC-OFDM) can yield significant improvements in terms of lower energy needed to transmit data, a very improvement issue in personal communication devices [12, 13]. Unfortunately, the majority of existing papers treating the TC-OFDM assumes that the channel estimation using only the pilot symbols is sufficient (or even that the channel is perfectly known). It is shown, however, that there is a large potential gain in using the iterative property of turbo decoders where soft bit estimates are used together with the known pilot symbols. The performance of such an iterative estimation scheme proves to be of particular interest when the channel is strongly frequency- and time- selective.

Similar to every other communications scheme, coding can be employed to improve the performance of overall system. Several coding schemes, such as block codes, convolutional codes and turbo codes have been investigated within OFDM systems. Moreover, the deep fades in the frequency response of the channel cause some groups of subcarriers to be less reliable than other groups and hence cause bit errors to occur in bursts rather than, independently. The burst errors can extensively degrade the performance of coding. To solve this problem, several ways are considered. The easiest method is to use stronger codes, in fact an interleaving technique along with coding can guarantee the independence among errors by affecting randomly scattered errors. We use turbo code to improve the performance . For analysis of the OFDM system, first we examine the uncoded situation and then we will analyze the effect of coding under turbo coded OFDM condition.

4. SIMULATION

4.1 Simulation Model

Since the main goal of this research paper was to simulate the COFDM system by utilizing turbo code. The block diagram of the entire system is shown in “Figure 3”.

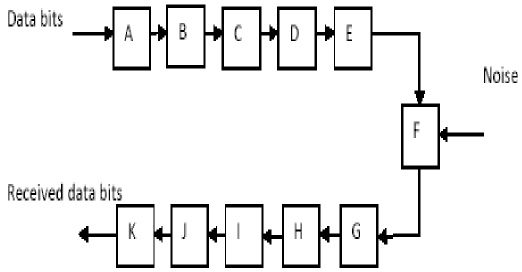

Figure 3. Simulation model of TC OFDM

Here A = turbo encoder, B = QAM/QPSK modulation, C = serial to parallel converter, D = IFFT, E = parallel to serial converter, F = channel with noise, G = serial to parallel converter, H = FFT, I = parallel to serial converter, J = AM/QPSK demodulation and K = turbo decoder.

4.2 Simulation Parameters

During the simulations, in order to compare the results, the same random messages were generated. For that radiant function is in MATLAB.

Table 1. Simulation parameters

Parameters	Values
Digital Modulation	QPSK,16-QAM 64-QAM
Turbo code rates	1/2
SISO Decoder	Log-MAP
Code Generator	{111, 101}
Interleaver Size	1 x 100

4.3 Algorithm of Simulation

We measured the performance of the turbo coded OFDM through MATLAB simulation. The simulation follows the procedure listed below:

1. Generate the information bits randomly.
2. Encode the information bits using a turbo encoder with the specified generator matrix.
3. Use QPSK or different QAM modulation to convert the binary bits, 0 and 1, into complex signals (before these modulation use zero padding)
4. Performed serial to parallel conversion.
5. Use IFFT to generate OFDM signals, zero padding is being done before IFFT.
6. Use parallel to serial convertor to transmit signal serially.
7. Introduce noise to simulate channel errors. We assume that the signals are transmitted over an AWGN channel. The noise is modeled as a Guassian random variable with zero mean and variance σ^2. The variance of the noise is obtained as

   $$\sigma^2 = \frac{1}{2 * E_b / N_o}$$

   A built-in MATLAB function randn to generate a sequence of normally distributed random numbers, where randn has zero mean and 1 variance. Thus the received signal at the decoder is :X' = noisy (X)Where noisy (X) is the signal corrupted by noise.
8. At the receiver side, perform reverse operations to decode the received sequence.
9. Count the number of erroneous bits by comparing the decoded bit sequence with the original one.
10. Calculate the BER and plot it.

5. RESULTS

All the simulations are done to achieve a desired BER 10^{-3}. For simulation results, two noise models were considered: the AWGN and the time-Markov model. Both models are utilized by the parameters defined above. The BER performance of TCOFDM system is compared with the respective uncoded system under the AWGN channel. No other channel codes are considered in this paper as the iterative decoding scheme easily outperforms conventional codes, or in other words non-iterative decoded codes.

As mentioned before, bursty errors deteriorate the performance of the any communications system. The burst errors can happen either by impulsive noise or by deep frequency fades. Powerline channels suffer from both of these deficiencies. “Figure 4” shows the performance of uncoded OFDM system with AWGN and impulsive noise (which is modeled as marcov noise).

In this “figure 4” it is shown that, for the required BER 10^{-3} AWGN channel gives better performance as compared with marcov channel. AWGN gives a gain of approximately 22 db over marcov channel. We observe a little gain at lower SNR between 0 to <10dB, and more gain at higher SNR < 40dB.

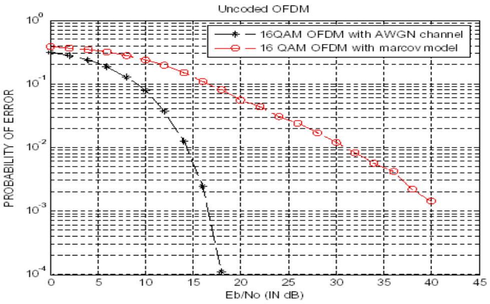

Figure 4. Performance of uncoded OFDM system in channel with impulsive noise

To improve the performance of this system FEC code can be used. Convolutional code is a good example of FEC code. It is shown in “Figure 5” that convolutional coding in OFDM can give performance improvement of some 5 db on AWGN channel over the uncoded OFDM system at required BER. Here the convolutional codes are based on the rate ½, constraint length 3 and (7, 5) generators matrix convolutional code.

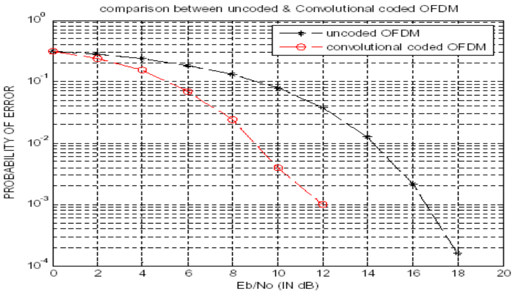

Figure 5. Performance analysis between uncoded and convolutional coded OFDM system

Further improvement in the performance can be obtained by applying turbo coding instead of convolutional code [13]. The turbo codes give better performance at low SNR. The BER performance of TCOFDM system is compared with the respective uncoded system under the fading AWGN channel. No other channel codes are considered in this report as the iterative decoding scheme easily outperforms conventional codes. Simulating the turbo codes with polynomial generators, (1, 15 /13)8 and (1, 5 / 7)8 which are iteratively decoded by Log-MAP for a number of decoding iterations. Simulated the polynomial (1, 5 / 7)8 as a reference. The simulated results are shown in Figure 6 From the results, we observe that both turbo codes (1, 15 /13)8 and (1, 5/7)8 give considerably good BER performance. Comparing (1, 15 /13)8 codes with (1, 5 / 7)8, we observe a little gain at higher SNR between 8 to <10dB. The overall performance is considered very well in operation under fading channel which is also efficient in terms of power consumption as compared to the uncoded system.

Table 2. Comparison of SNR for different code generators

Code Generator	SNR for BER 10^{-2}	SNR for BER 10^{-3}
(1, 5/7)	~ 7.2	~ 8.9 db
(1, 15/13)	~ 6.8 db	~ 8.3 db

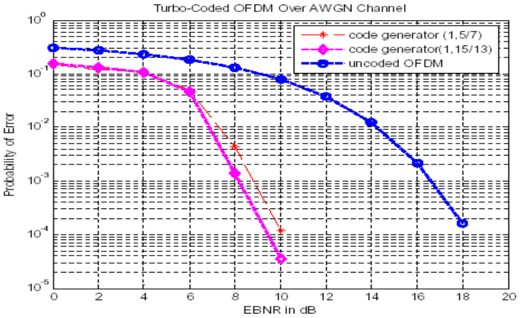

Figure 6. Performance of turbo coded OFDM with different generators polygonial

In "Figure 7" it is shown that turbo-codes of length 200, with QPSK modulation, an give performance improvements of some 8db on AWGN channel, over the conventional convolutional codes of the same code rate. Results are shown in table,

Table 3: Comparison of turbo coded OFDM and convolutional coded OFDM over uncoded OFDM.

Type of Coded OFDM	Gain at 10^{-2} over Uncoded OFDM	Gain at 10^{-3} over Uncoded OFDM
Convolutional coded OFDM	4.8 db	5.2 db
16 QAM TCOFDM	6.5 db	7.5 db
QPSK TCOFDM	11.5 db	13 db

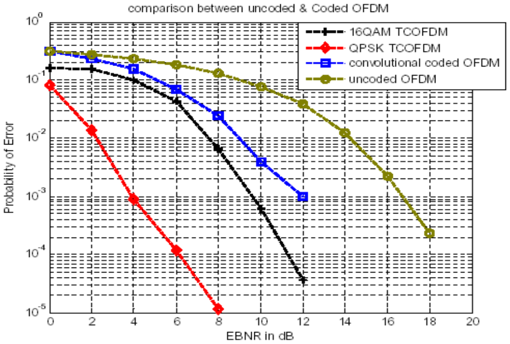

Figure 7. Different coded and uncoded OFDM system analysis over AWGN channel

Broadband communications for indoor power-line networks with impulsive noise using OFDM is considered. This channel is distorted by impulsive noise. A large impulse often causes the entire transmitted symbol to be corrupted and it can be devastating to the overall system performance. Here simulation is done on two type of impulsive noise model. The first is marcov and second is asynchronous impulsive noise is modeled by the fact that the time domain impulse noise, spreads over the whole carriers by the discrete fast fourier transform (DFT) operation in the receiver. Asynchronous impulsive noise is caused by switching transients in the network. Especially influence of the impulse noise whose amplitude is large is very severe. For simulation generated a random impulsive noise. Simulation also shows the performance of marcov noise. Simulation results are shown in "Figures 8 and 9" shows the influence of asynchronous impulsive noise on turbo coded OFDM system. As shown in figure, the influence of the impulse noise is distributed over the whole carriers by applying DFT in the receiver.

Table 4. Performance of turbo coded OFDM in noisy channel

Type of noise in TCOFDM	Gain at 10^{-2} over Uncoded OFDM	Gain at 10^{-3} over Uncoded OFDM
AWGN	7.5 db	7.8 db
Impulsive (Marcov)	5.0 db	2.4 db

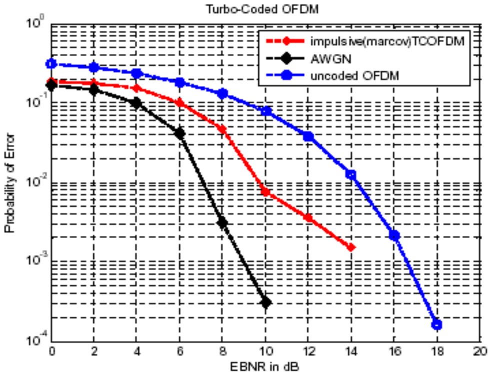

Figure 8. Performance of turbo coded OFDM over AWGN and impulsive noise (Marcov) channel

Therefore, data symbol on each sub-carrier is degraded under the case where large impulse noise is added or many impulses are added to the OFDM symbol whereas small impulse noise affect less data symbols on sub-carrier, hence less affective. If there are so many symbol errors in the symbols, then whole OFDM symbol will be lost.

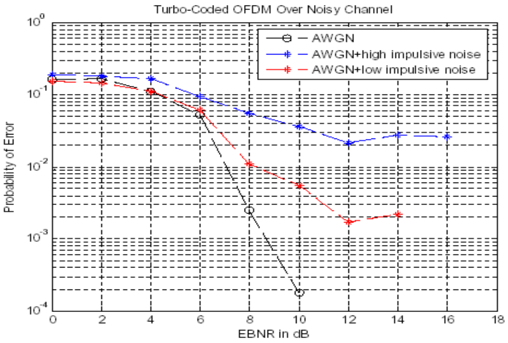

Figure 9. Performance of turbo coded OFDM over AWGN and impulsive noise channel

6. CONCLUSION

To conclude, Identification of some factors that could result in the OFDM system not performing to its potential. These factors included intersymbol interference (ISI) caused by a dispersive channel, interchannel interference (ICI) and its deleterious effects, and the issue of PAPR which is crucial for proper functionality. Exploration of techniques to combat some of these problems such as the use of a cyclic prefix (longer than the channel delay spread), and equalization made easy thanks to the wideband nature of the OFDM. As long as the subcarrier spacing is kept smaller than the coherence bandwidth, taking advantage of the high correlation between adjacent sub carriers. Presentation of a few results in both AWGN and Raleigh environments, as we needed to validate our modified, simplified simulator.

The concept of OFDM and turbo coding with a target-based, modulation scheme by introducing the noises, which occurs in power line communication networks is done by analyzing the performance of power line networks. The simulation of the entire work is done on MATLAB 7. First developing an OFDM system model then try to improve the performance by applying forward error correcting codes to our uncoded system. From the study of the system, it can be concluded that improving the performance of uncoded OFDM by convolution coding scheme.

Further improvement on the performance has been achieved by applying turbo coding to uncoded OFDM system. The system model developed is quite flexible and can be easily modified and/or extended to study the performance of this scheme.

REFERENCES

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

[2] L. Hanzo, M. Munster, B.J. Choi, T. Keller, "OFDM & MC-CDMA for Broadband Multiuser Communications, WLANs and Broadcasting" John Wiley Publishers, 2003.

[3] John G. Proakis, Masoud Salehi, "communication system using MATLAB" Thomson Asia Pvt. Ltd., Singapore, 2003

[4] Anibal Luis Intini, "orthogonal FrequencyDivision Multiplexing For Wireless Networks" Standard IEEE 802.11a, University Of California, Santa Barbara.

[5] W. J. Blackert, E. K. Hall, and S. G. Wilson, "Turbo Code Termination and Interleaver Conditions", IEE Electronics Letters, vol. 31, no. 24, pp. 2082-2084, Nov 1995.

[6] P. Robertson, "Improving Decoder and Code Structure of Parallel Concatenated Recursive Systematic (Turbo) Codes", in IEE Trans. of International Conference on Universal Personal Communications, San Diego, Sept. 1994, pp. 183-187.

[7] C. Berrou, A. Glavieux, and P. Thitimajshima, "Near Shannon Limit Error-Correcting Coding: Turbo Codes", Proceedings of the IEEE International Conference on Communications, ICC '93, Geneva., pp. 1064-1070, May 1993.

[8] G. D. Forney, "The Viterbi Algorithm", Proceedings IEEE, vol. 61, no. 3, pp. 268-278, March 1973.

[9] L.Bahl, J.Cocke, F.Jelinek, and J.Raviv, "Optimal Decoding of Linear Codes for Minimizing Symbol Error Rate", IEEE Trans. on Information Theory, vol. 20, pp. 248-287, March 1974.

[10] T. A. Summers and S. G. Wilson, "SNR Mismatch and Online Estimation in Turbo Decoding", IEEE Trans. on Communications, vol. 46, no. 4, pp. 421-423, April 1998.

[11] A. G. Burr, G. P. White, "Performance of Turbo-coded OFDM" in IEE Trans. of International Conference on Universal Personal Communications, 1999.

[12] J. Erfanian, S. Pasupathy, and G. Gulak, "Reduced Complexity Symbol Detectors with Parallel Structures for ISI Channels", IEEE Trans. Communications, vol. 42, pp. 1661-1671, Feb. Mar. Apr. 1994.

[13] O. G. Hooijen, "On the channel capacity of the residential power circuit used as a digital communications medium," IEEE Commun. Lett., vol. 2, no. 10, pp. 267-268, Oct. 1998.