ISSN:2278-1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

TO IMPROVE BIT ERROR RATE OF OFDM TRANSMISSION USING TURBO CODES

Ms Neetu Sharma[1], Prof. Rajeshwar Lal Dua[2]

[1] *M.Tech Scholar, Department of Electronics & Communication Engineering, Jaipur National University, Jaipur*
[2]*HOD, Department Electronics & Communication Engineering, Jaipur National University, Jaipur*
[1]neetusharma_pce2009@yahoo.com
[2]rndua43@gmail.com

***Abstract*— This review paper deals with the concept of Turbo coded OFDM (Orthogonal frequency division multiplexing) which improves the system throughput. Orthogonal frequency division multiplexing is a popular modulation method in high speed wireless transmission. It removes the detrimental effect of multipath fading by partitioning the wideband fading channel into flat narrow band channels. For this purpose simple one tap equalizer is used. In this paper we will see how performance of an OFDM system can be improved by adding turbo codes to it. This will help to maintain the system performance under a desired bit error rate, as there were errors occurring in burst form in OFDM which eventually degrades the efficiency of the system. Moreover, we can easily overcome the major disadvantages of OFDM i.e. ISI (inter symbol interference) and ICI (Inter carrier Interference) by implementing it. The turbo coding also allows achieving the Shanon's bound Performance. As clearly stated by M.K.Gupta, Vishwas Sharma, Dhiraj G. Agrawal, the simulation is done over AWGN and impulsive noise channels. The wideband system has 48 data subcarriers each is individually modulated according to channel state information during previous burst**.

***Keywords*— Bit error rate, COFDM, Orthogonal frequency division multiplexing, TC-OFDM, Turbo code,**

I. INTRODUCTION

In today's scenario there is growing need to transmit information wirelessly, quickly and accurately, So communication engineers have combined various technologies suitable for high data rate transmission with forward error correction techniques.[5]

As earlier stated by M.K.Gupta and Dhiraj G. Agrawal Orthonal frequency division multiplexing is a multicarrier modulation technique in which we devide a single high rate data into multiple low rate data stream. These low rate data streams are modulated using subcarriers which are orthogonal to each other.

According to study there are several benefits of OFDM

- Multipath delay spread tolerance.
- Efficient spectral usage by allowing overlapping in frequency domain.
- Modulation and demodulations are computationally efficient because for this purpose IFFT and FFT are used.[17]

In OFDM the bit errors occurs in burst rather than independently and according to our study the burst errors can degrade the performance of coding .The easiest solution to this problem is to use the strongest code. So we have used the turbo codes for this purpose.

The combination of parallel concatenation and recursive decoding allows this coding to achieve the performance near Shannon's limit.

This review paper is organised as follows- In Section-2, basic OFDM principles are briefly recalled. Section-3 briefly reviews the turbo code design criteria along with encoder and decoder. In section-4, the simulation model is presented along with their implementation issues. Simulation results are presented in section-5 and some conclusion and final work is drawn in section-6.

II. OFDM SYSTEM

The basic principle of OFDM is to split a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of orthogonal sub-carriers. Orthogonality is achieved by the fact that carriers are placed exactly at the nulls in the modulation spectra of each other. Here, the increase of symbol duration for the lower rate parallel subcarriers reduces the relative amount of dispersion in time caused by multi-path delay spread.

Here, Inter symbol interference (ISI) is eliminated almost completely by introducing a guard time in every

OFDM symbol. In the guard time, the OFDM symbol is cyclically extended to avoid inter carrier interference.[16]

According to Srabani Mohapatra Figure-1, shows a block diagram of an OFDM system, where the upper path is the transmitted chain and the lower part corresponds to the receiver chain. Here, first the user information bit sequence is mapped to symbols of either 16-QAM or QPSK. Then the symbol sequence is converted to parallel format. Then, the IFFT modulator modulates a block of input modulated values onto a number of subcarriers. After this the OFDM modulated symbol is again converted to the serial format. Then guard time and cyclic prefix is inserted between OFDM symbols, so that ISI and ICI can be eliminated. Resulting sequence is then converted to an analog signal using DAC and passed on the RF modulation stage. The resulting RF modulated signal is then transmitted to the receiver using the transmit antennas Here, we can use antenna array to achieve directional beam-forming, which allows spectrum reuse by providing spatial diversity.[17]

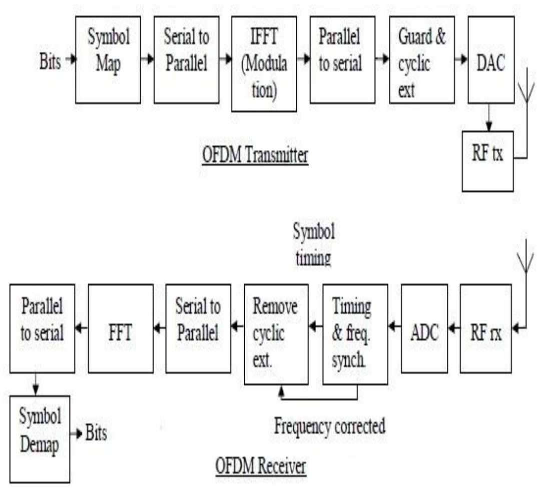

Figure 1. Block diagram of OFDM

At the receiver reverse operation is performed, first RF demodulation is performed. Then, the signal is digitized using an ADC. Then, timing and frequency synchronization are performed. Then, the guard time is removed from each OFDM symbol and the sequence is converted to parallel format.

At the receiver, the carriers are demodulated by an FFT, which perform a reverse operation of an IFFT. The output is then serialized and symbol de-mapping is done to get back the user bit sequence.

Here, Time and frequency synchronization are important because without correct frequency the orthogonality will not exist among the carriers which leads to an increse in BER. Without correct timing synchronization it is not possible to identify start of frames.[17]

III. TURBO CODES

Turbo codes were first presented at the International Conference on Communications in 1993. Until then, it was widely believed that to achieve near Shannon's bound performance, one would need to implement a decoder with infinite complexity or close.[3]-[8] Parallel concatenated codes can be implemented by using either block codes (PCBC) or convolutional codes (PCCC). According to B.Balaji Naik, M.K. Gupta and Dhiraj G. Agrawal-PCCC resulted from the combination of three ideas that were known to all in the coding community:

- Transform commonly used non-systematic convolutional codes into systematic convolutional codes.
- Use of soft input soft output decoding. Here, the decoder uses the probabilities of the received data to generate soft output which contain information about the degree of certainty of the output bits,
- This is achieved by using an interleaver. Encoders and decoders working on permuted versions of the same information.[1]-[3]-[5]-[15]

A. Encoders for Turbo codes

As clearly stated by several authors, the encoder for a turbo code is a parallel concatenated convolutional code. Berrou gave the model for turbo encoders as shown in Figure 2. [10]

Here, the binary input data sequence is represented by dk = (d1….dN). This input sequence is passed into the input of a convolutional encoder ENC1 and a coded bit stream x_{k1}^{p} is generated. Then the data sequence is interleaved. This means, the data bits are loaded into a matrix and read out in a way so that the positions of the input bits are spreaded. The bits are often read out in a pseudo-random manner.

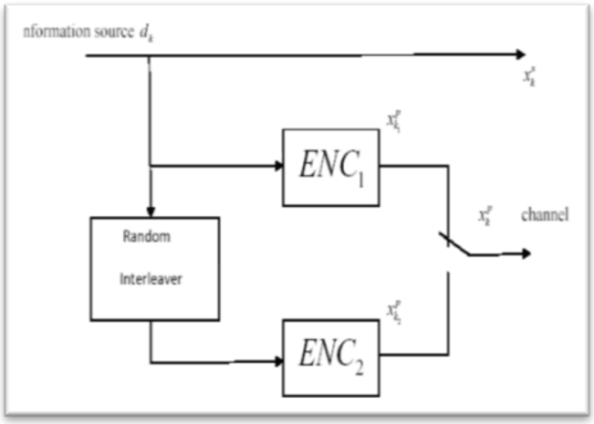

Figure 2. Structure of a turbo encoder

Then the interleaved date sequence is passed to the second convolutional encoder ENC2, and a second coded bit stream x_{k2}^p 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_k^s and parity bits from both the first encoder x_{k1}^p and the second encoder x_{k2}^p[1]-[5]-[15].

B. Decoder for Turbo codes

Valuable efforts have been devoted by several authors to turbo decoding. Some of them proposed the block diagram of a turbo decoder as shown in "Figure 3". Here, the input to this turbo decoder is a sequence of received code values, $Rk = \{y_k^s , y_k^p\}$ from the demodulator. The turbo decoder consists of two component decoder – *DEC*1 to decode sequence from *ENC*1, and *DEC*2 to decode sequences from *ENC*2. Each of these decoders is a Maximum A Posteriori (MAP) decoder. *DEC*1 takes as its input the received sequence systematic values y_k^s and the received sequence parity values y_{k1}^p belonging to the first encoder *ENC*1. The output of *DEC*1 is a sequence of soft estimates *EXT*1 of the transmitted data bits d_k.. *EXT*1 is called extrinsic data, 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 DEC2.

The interleaver is identical to that in the encoder (Figure2). *DEC*2 takes as its input the (interleaved) systematic received values y_k^s and the sequence of received parity values y_{k2}^p 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

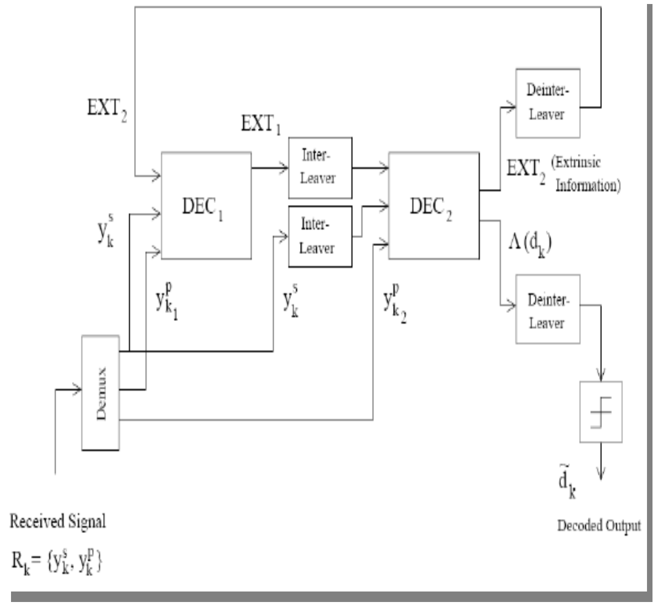

Figure 3 Structure of Turbo Decoder

Here, 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 ∧ (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 ∧(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. ∧ (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 EXT1 and EXT2 do not necessarily converge to a correct bit decision. If a set of corrupted code bits form a pair of error sequences that neither of the decoders is able to correct, then EXT1 and EXT2 may either diverge, or converge to an incorrect soft value. In the next sections, we will look at the algorithms used in the turbo decoding process, within DEC1 and DEC2. [1]-[5][15]++

IV. The Simulation Model

Roma K. Paliwal, Priti Subramanium and Vishwas Sharma based their work on the simulation model provided below. The main goal of this model was to simulate the COFDM system by utilizing turbo code in MATLAB. This program simulates a 64 subcarrier OFDM system. This system supports up to 2 transmit and 2 receive antennas, a convolutional code generator with rates 1/2, 2/3, and 3/4. The code is punctured to IEEE specifications.

Here, We can chose to interleave the transmit bits for added protection. This system supports 4 modulation schemes, binary phase shift keying, quadrature phase shift keying, sixteen quadrature amplitude modulation, and sixty four quadrature amplitude modulation. Frequency jitter can also be added to this system that supports two channel models- namely additive white Gaussian noise, AWGN and flat Rayleigh fading.

Here, we can input the desired length of the delay spread. The cyclic prefix is 16 samples long. We can also request a specific average signal to noise ratio. Transmit power amplifier effects and phase noise distortion can be added to the transmit signal. The simulator also comes with a series of synchronization algorithms including packet detection, fine time synchronization, frequency synchronization, pilot phase tracking, channel estimation, all of that if we wish to simulate IEEE 802.11 standards. There is also a switch to add a receiver timing offset [1]-[2]-[15].

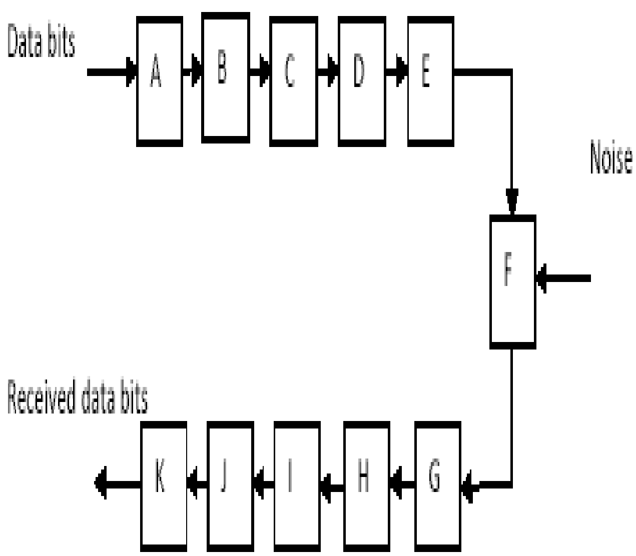

Figure 4. Simulation model of TC OFDM

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.

A. Simulation Parameter

During the simulations, in order to compare the results, the same random messages were generated in MATLAB. The following parameter are used for simulation-

TABLE I
SIMULATION PARAMETERS

Simulation Parameters	**Values**
Digital Modulation	QPSK,16-QAM 64-QAM
Turbo code rates	½
SISO Decoder	Log-MAP
Code Generator	{111, 101}
Interleaver Size	1x 100

B. Algorithm of Simulation

Here, 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. Perform 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. Here, We assumed that the signals are transmitted over an AWGN channel. The noise is modelled as a Gaussian 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 can be used to generate 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.[1]-[5]-[15].

ISSN:2278-1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

V. Performance Analysis Of TCOFDM

Here, All the simulations are done to achieve a desired BER of 10^{-3}.Two noise models are considered here 1)AWGN 2)Time Markov model. Both models use the same parameter defined in simulation parameters.

Here, the BER performance of turbo coded OFDM system is compared with respective uncoded system under the AWGN channel.

According to the study, it is known that bursty errors can deteriorate the performance of any communication system. The burst errors can happen either by deep frequency fades or by impulsive noise. Power line channel suffers from both of these deficiencies. Here, in figure-5 we can see, that for the required BER of 10^{-3} AWGN channel gives better performance as compared with Markov channel. AWGN channel gives a gain of approximately 22 dB over Markov channel.[1]-[2]-[6]-[15]

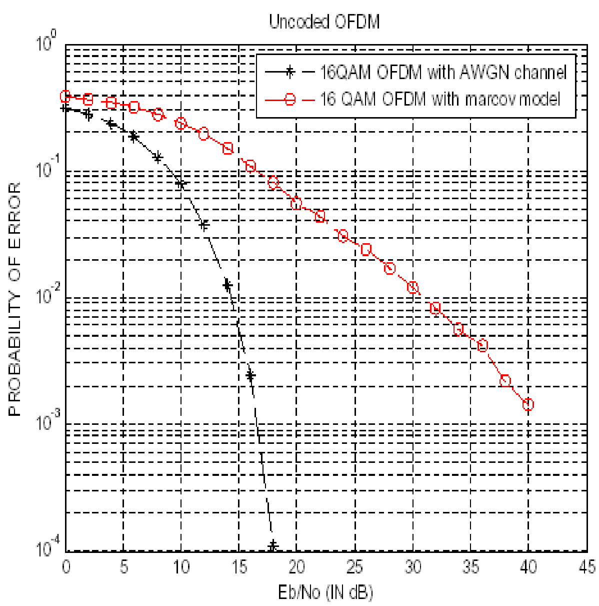

Figure 5. Performance of Uncoded OFDM System in Channel with Impulsive Noise

Here, we can see that there is little gain at lower SNR between 0 to <10 dB, and more gain at high SNR<40 dB. [1]-[15].

Earlier discussed result was for simple OFDM. Now to improve the performance of this OFDM system we can use FEC code. Convolution code is a good example of FEC code. This result is shown in figure-6. Here, we can see that by adding convolution code in OFDM gives performance improvement of some 5 db over the uncoded OFDM system on the same AWGN channel at required BER. The convolution code used here are based on the rate ½, constraint length 3 and (7,5) generator matrix convolution code.

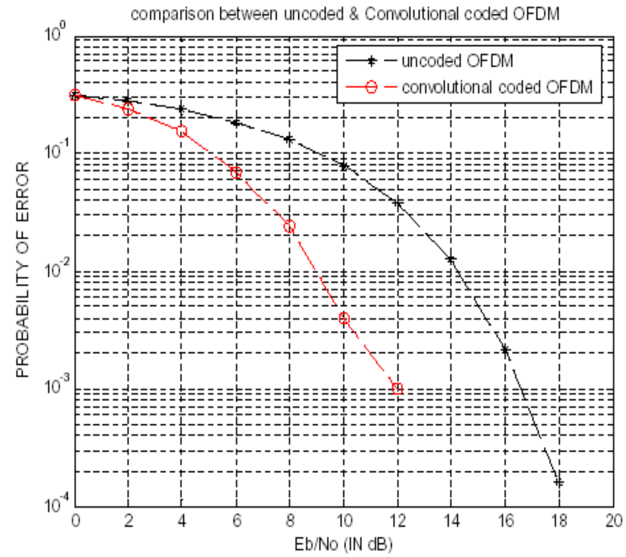

Figure 6. Performance Analysis Between Uncoded and Convolutional Coded OFDM System

Now, if we add turbo codes instead of convolution code, further improvement in the performance can be obtained. [13] These turbo codes give better performance at low SNR. Now, we will compare the BER performance of TCOFDM system with the respective uncoded OFDM over the same AWGN channel.

From figure-7, we can observe that both turbo codes (1, 15/13) and (1, 5/7) give considerably good BER performance compare to un coded OFDM. When we compare (1,15/13) codes with (1,5/7), we observer little gain at higher SNR.

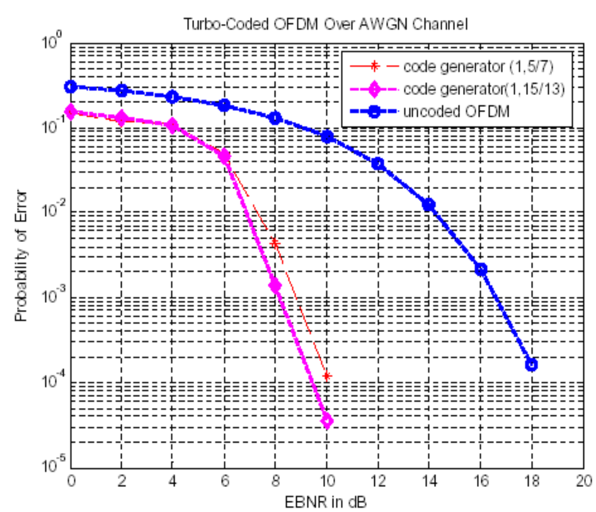

Figure 7. Performance of Turbo Coded OFDM with Different Generators Polynomial

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 dB	~ 8.9 dB
(1.15/13)	~ 6.8 dB	~ 8.3 dB

Now in figure 8, we can see that turbo code of length 200, with QPSK modulation, can give performance improvement of some 8dB on AWGN channel, over the convolution codes of same code rate.

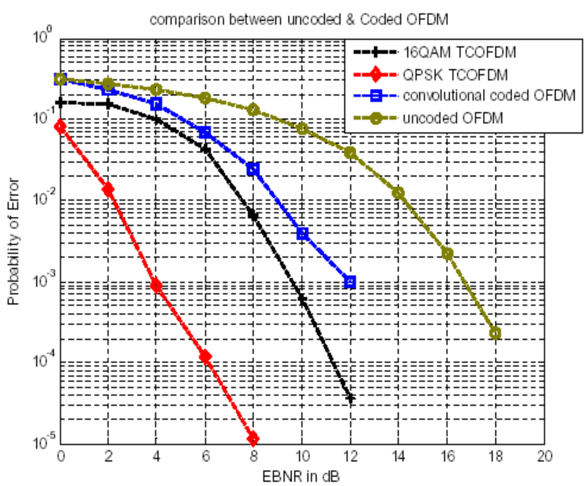

Figure 8. Different coded and uncoded OFDM system analysis over AWGN channel

TABLE 3
COMPARISON OF TURBO CODED OFDM AND CONVOLUTION 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

Earlier we discussed two models AWGN and Markov, now we will discuss two models i.e. Marcov and Asynchronous Impulsive noise. The ansynchronous implusive noise model is based on the fact that time domain impulse noise spread over the carrier by DFT operation in reciver. These implusive noises caused by switiching transient in the network.

A large impulse causes the entire symbol to be corrupted and it can be devastating the overall system performance.

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

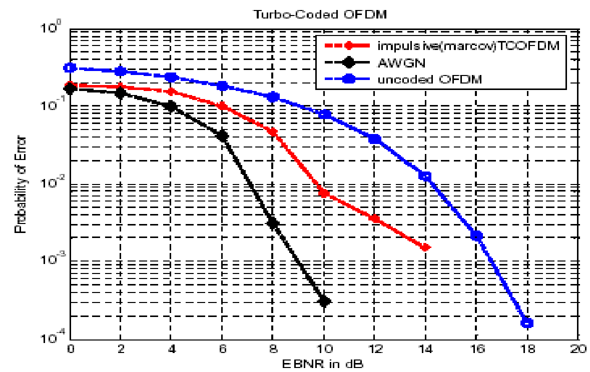

Figure 9. Performance of Turbo Coded OFDM with Different Generators Polynomial

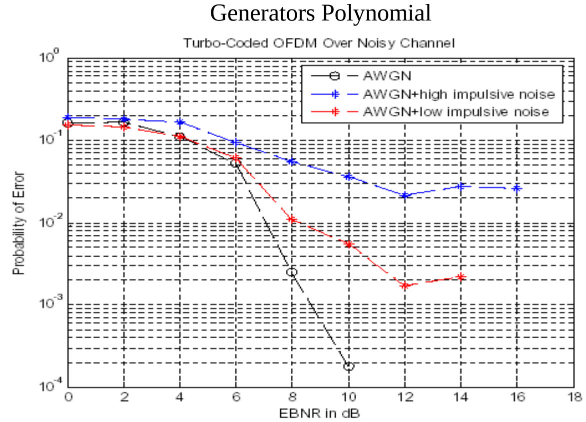

Figure 10. Performance of Turbo Coded OFDM over AWGN and Impulsive Noise Channel.

Simulation results are shown in figure 9 and 10, which shows the influence of asynchronous impulsive noise on TC-OFDM system. We can see from the figure that the influence of impulsive is distributed over the whole carriers by applying DFT in the receiver.[1]-[12]-[15]

CONCLUSION

We have investigated the orthogonal frequency division multiplexing used for high data rate transmission and reviewed the latest development on OFDM and Parallel concatenation turbo codes. A wide investigation showed that the OFDM inherently suffers from high Inter symbol interference (ISI) (caused by a dispersive channel), Inter channel interference (ICI) (caused by frequency offset) and Peak-to-Average power ratio (PAPR) (caused by time domain OFDM signal). In order to combat ISI and ICI we have proposed a cyclic prefix and guard time insertion between OFDM symbols, in which the length of the guard time is made longer than the length of delay spread.

We have also investigated that in OFDM bit errors occur in burst form rather than independent, and burst errors extensively degrade the performance of the system. To solve this problem we have proposed a method to use the stronger FEC techniques like convolution codes and turbo codes. By the study, we jump to the conclusion that better performance of uncoded OFDM is achieved by using turbo codes rather than convolution codes.[1]-[2]-[6]

To conclude, this review paper gives the detail knowledge of the current key issues of Orthogonal Frequency Division Multiplexing. We focused our attention to improve the performance of OFDM by eliminating its shortcomings like ISI, ICI and adding FEC like convolution codes and turbo codes. That's why, we focused our attention to the turbo encoder and decoder architectures especially parallel concatenation codes which is iteratively decoded by log – MAP decoder. Moreover, we have studied the performance on different channels like AWGN and Markov and got the result that better performance can be achieved on AWGN channel.

Future Aspects Specific topics for further work have been investigated throughout the paper and focus of the development should be PAPR reduction techniques in TC-OFDM. Pulse shaping technique can be applied to the turbo coded OFDM system for PAPR and ICI removal.

Additionally, to further improve the performance, other FEC techniques like golay codes, complementary codes, LDPC and TCM codes can also be applied to the OFDM system.

References

[1] M. K. Gupta, Vishwas Sharma "To improve BER of turbo coded OFDM channel over noisy channel" in Journal of Theoretical and Applied Information Technology © 2005 - 2009 JATIT.

[2] Lou I Ilunga, Research Work on "Adaptive, turbo coded OFDM" © 2005.

[3]"Block Turbo Code And Its Application to OFDM For Wireless Local Area Network" Phd thesis submitted by Hrudananda Pradhan.

[4]Liu Na Shi Wenxiao Wu Jiang "A Model of Turbo Code Based on OFDM-CDMA" in IEEE journal of 2006.

[5] B.Balaji Naik "Performance Of Turbo Coded OFDM In Wireless Application" in partial fulfillment of the requirements for the award of Master of Technology degree in Electronics and Communication Engineering with specialization in "VLSI Design & Embedded system" during session 2007-2008 at National Institute Of Technology, Rourkela (Deemed University).

[6] Md. Dulal Haque1, Shaikh Enayet Ullah2, and Md.Razu Ahmed3 "Performance evaluation of a wireless Orthogonal Frequency Division Multiplexing system under various concatenated FEC channel-coding schemes" in Proceeding of 11th International conference on Computer and Information Technology (ICCIT 2008) 25-27 December, 2008, Khulna Bangladesh.

[7] Arun Agarwal, S. K. Patra, Senior Member IEEE "Performance prediction of OFDM based Digital Audio Broadcasting system using Channel protection mechanisms" in IEEE journal © 2011.

[8] 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..

[9] Yung-Chih Tsai, Yeong-Luh Ueng, "A Tail-biting Turbo Coded OFDM System for PAPR and BER Reduction" ©2007 IEEE.

[10] D. Rajaveerappa, Abdelsalam Almarimi "RSA/Shift Secured IFFT/FFT Based OFDM Wireless System" in 2009 Fifth International Conference on Information Assurance and Security.

[11] Hanjong Kim," Performance improvement of Block Turbo Coded OFDM System Using channel state information" the 23rd international conference on circuits/systems, computers and communications (ITC-CSCC 2008).

[12] J. Terry, and J. Deiskala, OFDM Wireless LANs: A Theoretical and Practical Guide, Sams Publishing, Indiana, 2002.

[13] Haixa Zhang, Feng Zhao, Dongfeng Yuan, Mingyan Jiang, "Performance of turbo code an WOFDM system on rayleigh fading channels," Proceedings, IEEE, vol. 2, pp.1570-1573, Sept 2003.

[14] J.W. Blakert, E.K. Hall, S.G. Wilson, "Turbo code termination and interleaver conditions," Electronics Letters, Vol. 31, Issue 24, 1995,

[15] Dhiraj G. Agrawal, Roma K. Paliwal, Priti Subramanium,"Effect of Turbo Coding on OFDM Transmission to improve BER".in International Journal of Computer Technology and Electronics Engineering(IJCTEE) Volume2, Issue 1, February 2012.

[16] Sami Ahmed Haider, Khalida Noori, "Adaptive Turbo Coded OFDM" in Journal of Digital Information Management, Volume 5 Number 6, December 2007.

[17] Srabani Mohapatra "A new approach for performance improvement of OFDM system using pulse shaping" in partial fulfilment of the requirement for the award of Master of Technology degree in Electrical Engineering during session 2009-2010 at National Institute Of Technology, Rourkela (Deemed University).

ISSN:2278-1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

Neetu Sharma - A life member of ISTE and student of M.Tech final semester at Jaipur National University, Jaipur. I completed B.E. from Poornima college of Engineering, Jaipur from University Of Rajasthan in Electronics and Communication in 2009. Then, I joined Poornima College of Engineering as a lecturer in EC department. I had worked there for 2 years. I have keen interest in subjects like Signal System, Digital Communication, Fibre Optic Communication, Microcontroller and Embedded system. I attended training programs like "Energy Meter" with GPIL and "Embedded System and Robotics" with Webcom Technologies.

Professor Rajeshwar Lal Dua a Fellow Life Member of IETE and also a Life member of I.V.S & I.P.A, former "Scientist F" of the Central Electronics Engineering Research Institute(CEERI), Pilani has been one of the most well-known scientists in India in the field of Vacuum Electronic Devices for over three and half decades. His professional achievements span a wide area of vacuum microwave devices ranging from crossed-field and linear-beam devices to present-day gyrotrons. He was awarded a degree of M.Sc (Physics) and M.Sc Tech (Electronics) from BITS Pilani. He started his professional carrier in1966 at Central Electronics Engineering Research Institute (CEERI), Pilani. During this period he designed and developed a specific high power Magnetron for defense and batch produced about 100 tubes for their use. Trained the Engineers of Industries with know how transfer for further production of the same.

In 1979 he visited department of Electrical and Electronics Engineering at the University of Sheffield (UK) in the capacity of independent research worker, and Engineering Department of Cambridge University Cambridge (UK) as a visiting scientist. He has an experience of about 38 years in area of research and development in Microwave field with several papers and a patent to his credit. In 2003 retired as scientist from CEERI, PILANI & shifted to Jaipur and joined the profession of teaching. From last eight years he is working as professor and head of electronics department in various engineering colleges. At present he is working as head and Professor in the department of Electronics and communication engineering at JNU, Jaipur. He has guided several thesis of M.tech .of many Universities.