RESEARCH ARTICLE OPEN ACCESS

# Performance Analysis of Turbo Coded OFDM System

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**ABSTRACT**
Orthogonal Frequency Division Multiplexing (OFDM) has become a popular modulation method in high speed wireless communication system. By partitioning a wideband fading channel into a 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.
Engineers have already combine techniques such as OFDM suitable for high data rate transmission with forward error correction (FEC) methods over wireless channels. In this thesis, we enhance the system throughput of a working OFDM system by adding turbo codes. The smart use of coding and power allocation in OFDM will be useful to the desired performance at higher data rates. Simulation is to be done over Rayleigh and additive white Gaussian noise (AWGN) channels. Here we also compare the two different generator polynomials. This project increases the system throughput at the same time maintaining system performance. The performance is improved by convolution coding [1].
**Keywords**: Orthogonal Frequency Division Multiplexing, Turbo codes, Bit error rate

## I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi carrier modulation technique in which a high rate data stream is divided into multiple low rate data stream and is modulated using subcarriers which are orthogonal to each other. Some of the main advantages of OFDM are its multi path delay spread tolerance and modulation/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 [2,3].OFDM is a symbol based and can be thought of a large no. of low bit carriers transmitting in parallel. Since these multicarrier, forms a single OFDM transmission, they are commonly referred to as subcarriers.

## II. TURBO CODES

The combination of Turbo code with the OFDM System transmission is called as Turbo coded OFDM (TC-OFDM) which can yield significant improvement in terms of lower energy needed to transmit data[4][5].

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 to it. Parallel concatenated codes, as they are

also known, can be implemented by using either block codes (PCBC) or convolution codes (PCCC). A trellis structure or state diagram is used at the encoder side and with using a hard decision we decode the data stream required.

FANO Algorithm under Sequential decoding is used in this thesis.

### 2.1 Turbo Encoding

The encoder for a Turbo code is parallel concatenated convolution code [6,7,8].The block diagram of encoder is shown in Figure 1.The binary input data sequence is represented by $dk$=($d$1,…….dN).The input sequence is passed into the input of a convolutional encoder.ENC1 and a coded bit stream, $x^p$k1 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 position of the input bits. The bits are often taken out in a pseudo random manner. The interleaved data sequence is passed to

Second convolution encoder ENC2, and a second coded bit stream,$x^p$k2 is generated.The code sequence that is passed to the modulator for transmission is a multiplexed stream consisting of systematic code bits $x^s$k and parity bits from both the first encoder $x^{p\ k1}$ and the second encoder $x^p k2$.

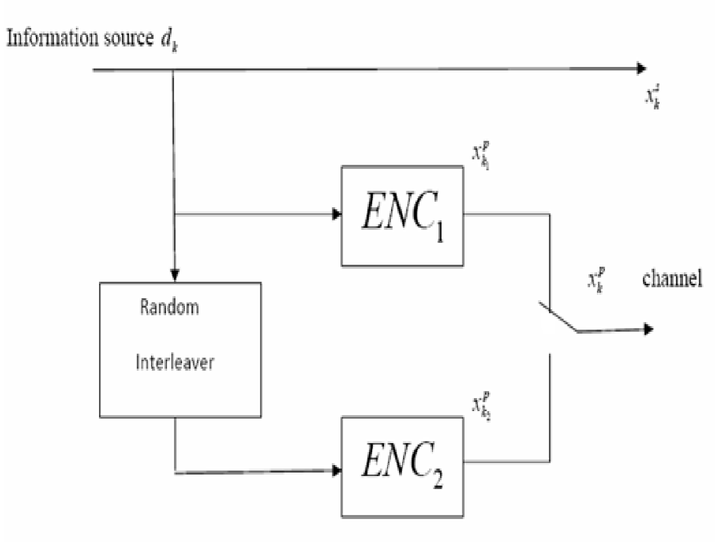


Figure 1 - Structure of a turbo Encoder

**2.2 RSC Components Codes**

Encoder1 and Encoder 2 are recursive systematic convolution codes (RSC) that is, convolution codes which use Feedback and in which the un coded data bits appear in the transmitted code bit sequence.

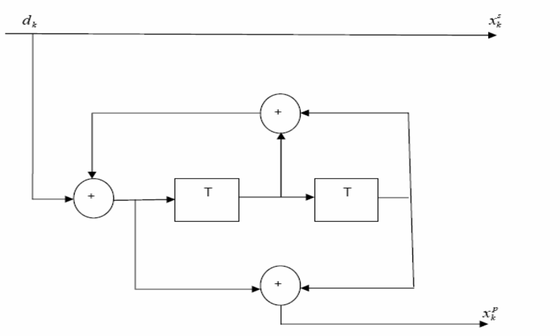


Figure 2- RSC

The encoder has two output sequence ;
One is the data sequence: $x_k^s$= {$x_1^s$ ,…..$x_N^s$ },
Other is the parity sequence: $x_k^p$= { $x_1^p$ ….$x_N^p$ }.

**2.3 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,$R_k$={$y_k^s, y_k^p$ } from the demodulator. The turbo decoder consist of a two component decoder-DEC1 to decode sequence from ENC1 and DEC2 to decode sequence from ENC2. DEC1 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 ENC1.The output of a DEC1 is a sequence of hard estimates EXT1 of the transmitted data is $d_k$. EXT1 is called extrinsic data, that does not contain any information which was given to DEC1 to DEC2. This information is interleaved and passed to the second DEC2. The inter leaver is identical to that in the encoder (Figure1).DEC2 takes as its input the (interleaved) systematic received values $y_k^s$ or the sequence of received parity values $y_{k2}^p$ from the second ENC2**,** along with the interleaved form of the extrinsic information EXT1 provided by the first encoder ENC1.DEC2 outputs a set of values, which when de-interleaved using an inverse form of inter leaver, constitutes hard estimates EXT2 of the transmitted data sequence $d_k$. This extrinsic data formed without the aid of parity bits from the first code is feedback DEC1.This procedure is repeated in a iterative manner. The iterative decoding process adds greatly to the BER performance of turbo codes.DEC2 outputs a value ^($d_k$), a likelihood representation of the estimate of $d_k$.This maximum likelihood value takes the account of transmitting a bit '0' or '1' based on the systematic and parity information from both component codes. For this we used FANO algorithm under the sequential decoding.

We set a particular threshold value and initiate the process accordingly. If the accumulate error crosses or at the threshold level, TRACEBACK is applied in order to minimize the error rate

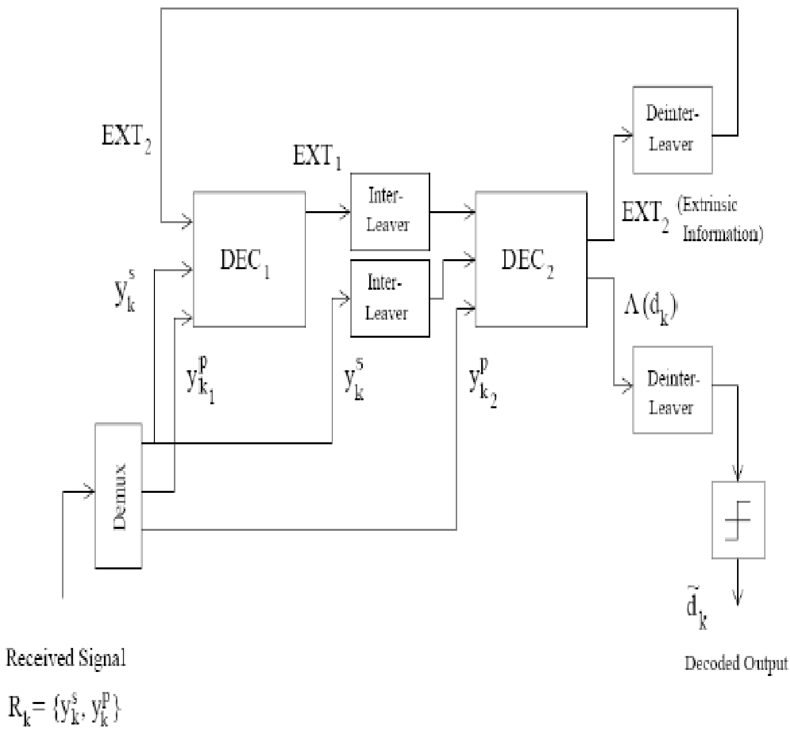


Figure 3 - Turbo Decoder Structure

## III. SIMULATION

### 3.1 SIMULATION MODEL

Since the main aim of this research paper is to simulate the COFDM system by utilizing turbo codes. The block diagram of the entire system is shown in "Figure 4".

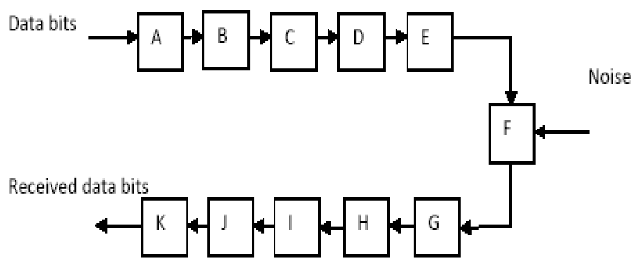


Figure 4- Simulation Model of TCOFDM

Here A=turbo encoder, B=QAM/QPSK modulation, C=Serial to parallel converter, D=IIFT, E=Parallel To serial converter, F=Channel with Noise, G=Serial to parallel converter, H=FFT, I=Parallel to serial converter, J=QAM/QPSK demodulation and K=turbo decoder.

### 3.2 SIMULATION PARAMETERS

During the Simulations, in order to compare the results, the same random messages were generated. For that radiant function should be in MATLAB.

Table 1 Shows all the parameters used for the simulation of the Turbo coded OFDM. Although these parameters can vary from time to time in order to improve the overall performance of the system.

| Parameters | Values |
|---|---|
| Digital Modulation | QPSK , QAM |
| Turbo Code Rate | 1/3 |
| Code Generator | 1101 1111 |
| Interleaver Size | 2 * 16 |
| No. of Subcarriers | 4 |
| Decoding Algo | Fano Sequential Decoding |

Table 1 – Simulation Parameters

## IV. RESULTS

All the simulations are done to achieve a desired BER. For simulation results, two noise models were considered: the AWGN and the Rayleigh Channel. The TCOFDM having (7,5) generator polynomial is compared with (13,15) generator polynomial. Also the BER performance of the TCOFDM system is compared with the respective un-coded system under the AWGN and Rayleigh channel.

“Figure 5 and 6 ”shows the BER Vs SNR for Un-coded and Turbo Coded OFDM (13,15 and7,5)respectively.

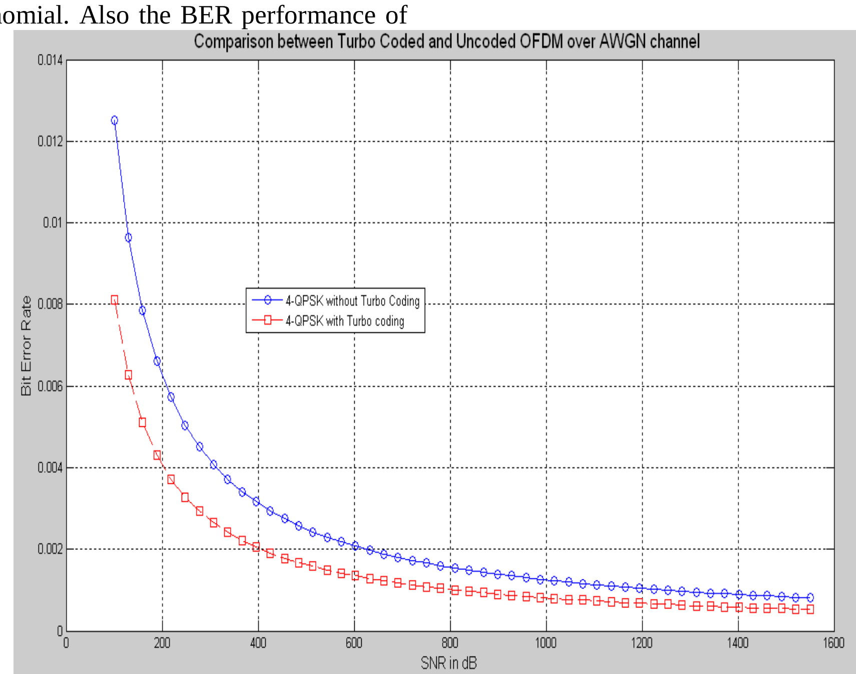


Figure 5- Comparison of Un-coded and Turbo coded(13 15) OFDM

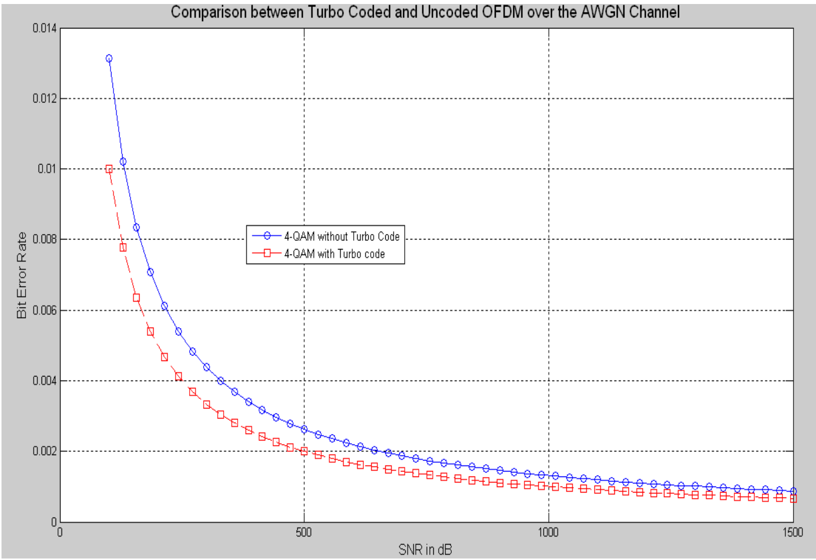


Figure 6- Comparison of Un-coded and Turbo coded (7 5) OFDM

From the above two figure we can see that When we are using (13 15) Generator Polynomial the BER is approx 0.008 which is smaller as compared to (7 5) generator polynomial, which is about 0.001.

"Figure 7" shows the comparison of different generator Polynomials.

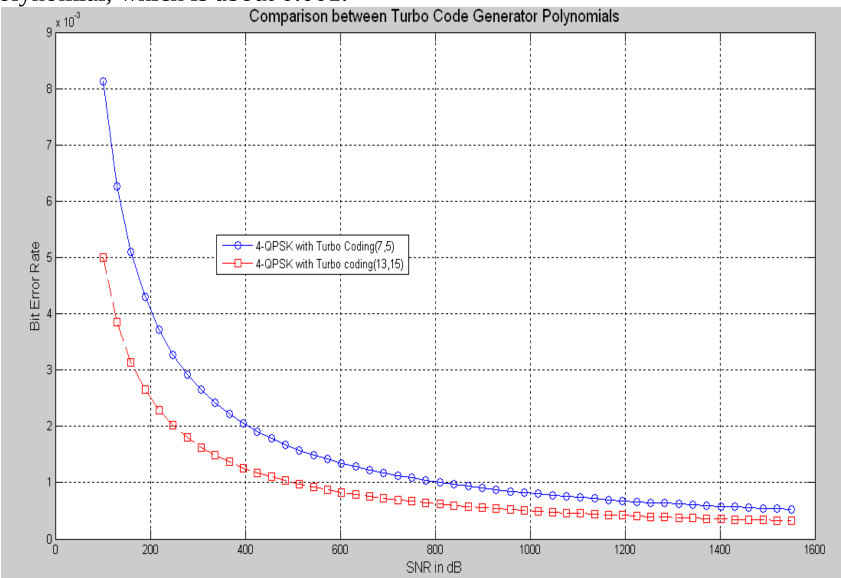


Figure 7- TCOFDM having (13 15) and (7 5) Generator polynomials

It is clear from the figure that (13 15) gives comparatively better performance as compared to (7 5) as Bit Error Rate of(13 15) is quite low. The Modulation scheme we used here is QPSK. Now we use some other scheme let we take Quadrature Amplitude Modulation.

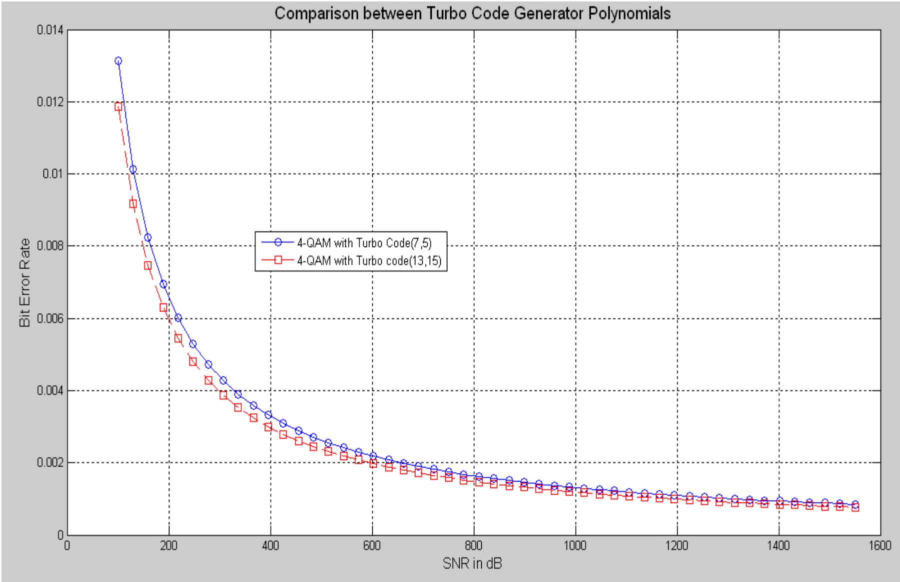


Figure 8- TCOFDM having (13 15) and (7 5) Generator polynomials (QAM)

In case of QAM , the two different generator polynomials have quite similar BER but still the (13 15) Generator Polynomial gives slightly better performance.

## V. CONCLUSION

To conclude, Identification of some factors that could result in the OFDM system not performing to its potential. These factor included Inter-symbol Interference (ISI) caused by a dispersive channel, Inter-channel Interference ICI 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 and equalization made easy thanks to the wideband nature of the OFDM. Presentation of a result in both AWGN and Rayleigh environments, shows the actual nature or performance of Turbo coded system. The simulation of entire work is done on MATLAB 7.7. First developing an OFDM system model and then apply a Turbo code in order to improve the performance of overall system. Also, by using different generator polynomial we can say that the higher or greater the generator polynomials, the better system we get. The system model developed is quite flexible and can be easily modified or extended to study the performance of this scheme.

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