Performance of Turbo codec OFDM in Rayleigh Fading Channel for wireless communication

Arjuna Muduli, R. K. Mishra

Electronic Science Department, Berhampur University, Odisha, India

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) has become a popular modulation method in high speed wireless communications. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels. In this paper, the system throughput under a desired bit error rate (BER) of a working OFDM system has been enhanced by adding turbo coding. Simulation is done over Rayleigh fading channels with BPSK scheme.

1.   INTRODUCTION

Wireless communication, is the transfer of information between two or more points that are physically not connected. Distances can be short, as a few meters in television remote control or long ranging from thousands to millions of kilometers for deep-space radio communications. For this we need to transmit information wirelessly, quickly, and accurately. Multiple techniques schemes are used in wireless communication to allow many mobile users to share simultaneously a finite amount of radio spectrum. The sharing is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users. For the quality communications, this must be done without severe degradation in the performance of the system. FDMA [1], TDMA and CDMA are the well known multiplexing techniques used in wireless communication systems. Using these techniques various problems encountered are (1) multi-path fading (2) inter symbol interference (ISI) (3) lower bit rate capacity (4) requirement of larger transmit power for high bit rate and (5) less spectral efficiency. Disadvantage of FDMA technique is its Bad Spectrum Usage. Disadvantages of TDMA technique is Multipath Delay spread problem [2]. Since multiple versions of the signal interfere with each other, it becomes difficult to extract the original information. This creates a challenge for   reliable communication.

Orthogonal Frequency Division Multiplexing (OFDM) is the standard being used throughout the world to achieve the high data rates [3]. OFDM is a combination of modulation and multiplexing. In OFDM the signal itself is first split into independent channels, modulated by data and then re multiplexed to create the OFDM carrier. As long as orthogonally is maintained, it is still possible to recover the individual subcarrier signals despite their overlapping spectrums. Also one other significant advantage is that the modulation and demodulation can be done using IFFT and FFT operations, which are computationally efficient. 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. In a single OFDM transmission all the subcarriers are synchronized to each other, restricting the transmission to digital modulation schemes [3]. In this paper forward error correction is performed by using turbo codes. The combination of OFDM and turbo coding and recursive decoding allows these codes to achieve near Shannon's limit performance in the turbo cliff region.

2.   TURBO CODES

The researchers 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 or convolutional codes [4, 5]. The principle of turbo code comes from turbo engine principle. For wireless communication this code was first proposed by Berrou in 1993 [6]. This code has been widely considered to be the most powerful error control code of practical importance. Turbo codes have error correcting capability very close to the theoretical performance limits. This turbo code resulted from the combination of three ideas. (1) The transforming of commonly used non-systematic convolutional codes into systematic convolutional codes. (2) the utilization of soft input soft output decoding. Instead of using hard decisions, (3) 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 which is achieved by using an interleaver [7].

2.1 TURBO ENCODING

For design of a turbo encoder we need (i) Recursive systematic convolutional encoders, (ii) A random interleaver, (iii) A puncture with multiplexing technology as shown in figure 1.
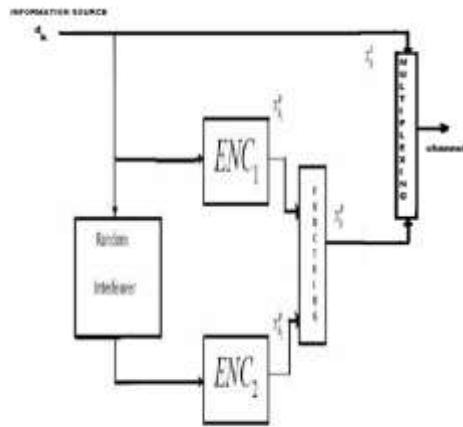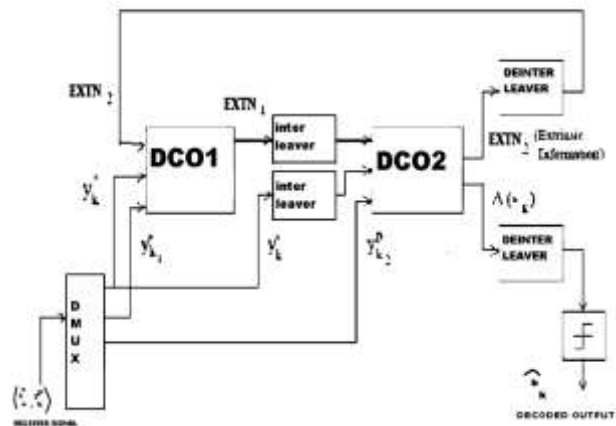
Figure 1: Block diagram of a turbo encoder   **Figure 2: Block diagram of Turbo Decoder**

The binary input data sequence is represented by $b_k = (b_1....b_N)$. The input sequence is passed into the input of a convolutional encoder *ENC1* (recursive) and a coded bit stream, $x_{k1}{}^q$ 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 (recursive), and a second coded bit stream, $x_{k2}{}^q$ is generated at the output. The code sequence that is passed to the modulator for transmission is a multiplexed and punctured stream consisting of systematic code bits $x_k{}^s$ and parity bits from both the first encoder $x_{k1}{}^q$ and the second Encoder $x_{k2}{}^q$.

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, $R_k = \{y_k{}^s, y_k{}^p\}$ from the demodulator[8, 9, 10]. The turbo decoder consists of two component decoder *DCO*1 to decode sequences from *ENC*1, and *DCO*2 to decode sequences from *ENC*2. Each of these is log Maximum. A Posteri ri (MAP) decoder [11]. *DCO*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 *DCO*1 is a sequence of soft estimates *EXTN*1 of the transmitted data its b_k. *EXTN*1 is called extrinsic data, in that it does not contain any information which was given to *DCO*1 by *DCO*2. This information is interleaved, and then passed to the second decoder *DCO*2. The interleaver is identical to that in the encoder (Figure1). *DCO*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 *EXTN*1, provided by the first decoder. *DCO*2 outputs a set of values, which, when de-interleaved using an inverse form of interleaver, constitute soft estimates *EXTN*2 of the transmitted data sequence b_k. This extrinsic data, formed without the aid of parity bits from the first code, is feedback *DCO*1. This procedure is repeated in an iterative manner. The iterative decoding process adds greatly to the BER performance of turbo codes. However, after several iterations, the two decoders' estimates of b_k will tend to converge. At this point *DCO*2 outputs a value $^\wedge(b_k)$; a log likelihood representation of the estimate of b_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 $^\wedge(b_k)$ 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. $^\wedge(b_k)$ is deinterleaved 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, b_k, for the transmitted bits.

The decoding estimates *EXTN*1 and *EXTN*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 *EXTN*1 and *EXTN*2 may either diverge, or converge to an incorrect soft value.

3. TURBO CODED OFDM

Coded OFDM (COFDM) is a term used for a system in which the error control coding and OFDM modulation processes work closely together. COFDM, systems are able to achieve excellent performance on frequency selective channels because of the combined benefits of multicarrier modulation and coding[12]. The effect of ISI on an OFDM signal can be further improved by the addition of a guard period (cyclic prefix) to the start of each symbol. This guard period is a cyclic copy that extends the length of the symbol waveform.

But the effects of noise and multipath fading in the channel are not minimized. Therefore the transmitted signal arrives at the receiver with some errors (mostly brust error). The errors in the demodulated data are characterized in terms of a BER, which is directly proportional to the symbol rate and inversely proportional to transmitter power. Therefore, in order to design a communication system with an acceptable BER, error correction coding must be used to protect the data from transmission errors. As long as the signal-to-noise ratio (SNR) is high and the channel is relatively flat, error correction coding may be unnecessary in OFDM systems. However, uncoded OFDM systems do not perform well in fading channels. 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 & ANALYSIS

4.1 Simulation model

The block diagram of the entire COOFDM system is shown in Figure 3. The simulation parameters are in Table 1.
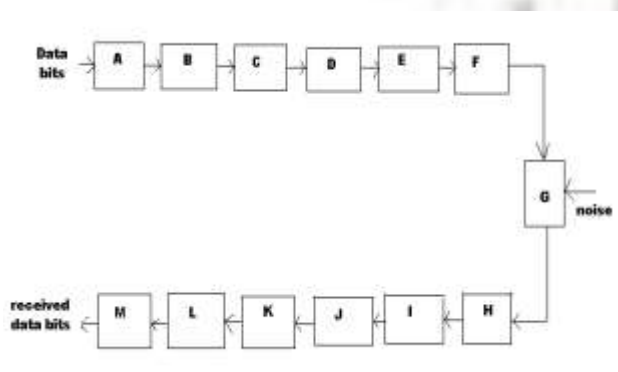
Table 1: Simulation parameters

parameters	values
Modulation scheme	BPSK
Turbo code rate	1/2
SISO decoder	Log MAP
Code generator	{11111,10001}
interleaver	Pseudo random
Channel	Rayleigh fading

Figure 3: block diagram of OFDM system

Here A = turbo encoder, B = BPSK modulator, C = serial to parallel converter, D = IFFT, E = parallel to serial convertor, F=cyclic prefix adder G=Rayleigh fading channel, H= cyclic prefix remover I= serial to parallel Converter, J = FFT, K = parallel to serial converter, L=BPSK demodulator and M= turbo decoder.

4.2 Algorithm of Simulation

Through MATLAB simulation we evaluate the performance of the turbo coded OFDM for the Rayleigh fading channel. The simulation follows the procedure listed below:

1. The information bit s are generate randomly

2. The information bit are encoded using RSC turbo encoder with the specific generator matrix

3. Then the encoded bits are modulated with BPSK modulation scheme.

4. Serial bits are converted to parallel bit stream.

5. We use IFFT to generate OFDM signals; zero padding is being done before IFFT.

6. Then we use parallel to serial convertor to transmit signal serially.

7.   Introduce noise to simulate Rayleigh fading channel with different Doppler shifts.

8. At the receiver side, we perform reverse operations to decode the received sequence.

9. Then Count the number of erroneous bits by comparing the decoded bit sequence with the original one

10. Then we calculate the BER and plot it versus E_b/N_0.

5. RESULTS

All the simulations are done to achieve a desired BER 10^{-4}. For simulation results, Rayleigh fading noise models were considered: The BER performance of turbo coded OFDM system is compared with the respective uncoded system and convolutional coded OFDM system under the Rayleigh fading channel. No source codes are considered in this paper.
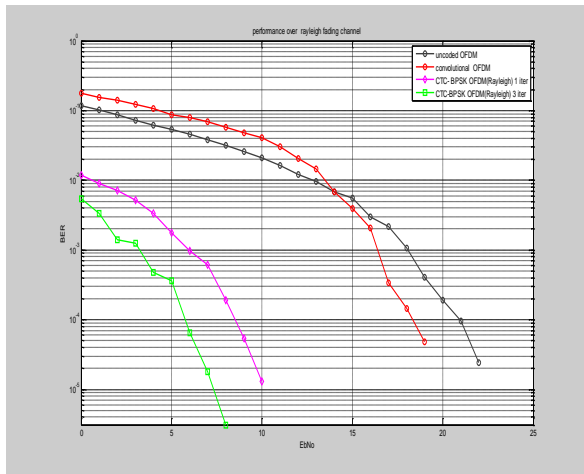
Type of coded OFDM	Gain at 10^{-4} Over uncoded OFDM
Convolutional coded OFDM	~3db
Turbo coded OFDM with iteration 1	~12.5db
Turbo coded OFDM with iteration 3	~15db

Figure 4: E_b/N_0 Performance of turbo coded OFDM over Rayleigh fading channel (f_d=100Hz)

Figure 4 shows the BER performance results of turbo coded OFDM over Rayleigh fading channels with Doppler shift (f_d) 100 Hz for one iteration and three iterations. These results show that the turbo coded OFDM over Rayleigh fading channel achieves a gain of 15dB at BER of 10^{-4} taking consideration of 3 iterations.
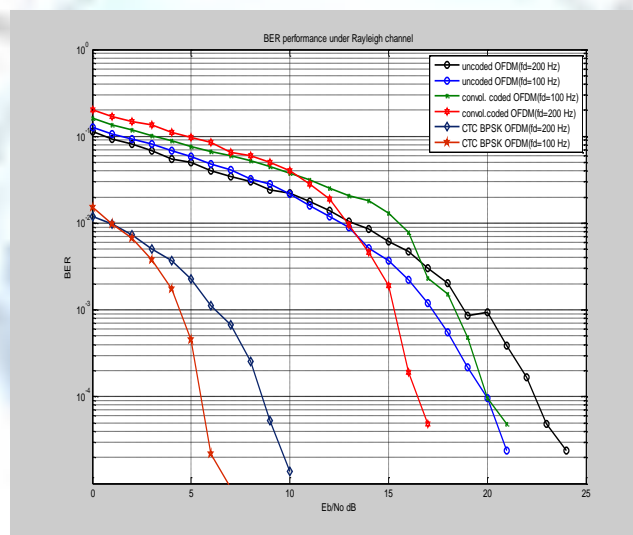

Figure 5: Performance of turbo coded OFDM over Rayleigh fading channel different (fd)

Figure 5 shows the BER performance results of turbo coded OFDM over Rayleigh fading channels for different Doppler frequencies (fd =100 Hz, 200 Hz) with three iterations. Turbo coded OFDM over Rayleigh fading channel achieves a gain of 17dB at BER of 10^{-4} taking consideration of 3 iterations.

Table 3: E_b/N_0 Performance of TC OFDM over Rayleigh fading channel with different f_d

Type of coded OFDM	Gain at 10^{-4} Over uncoded OFDM(f_d=200Hz)
UncodedOFDM(fd=100Hz)	~3db
ConvolutionalcodedOFDM(f_d=200Hz)	~3db
ConvolutionalcodedOFDM(f_d=100Hz)	~7db
Turbo coded OFDM(f_d=200Hz)	~14.5db
Turbo coded OFDM (f_d=100Hz)	~17db

6. CONCLUSION

This paper gives the detail knowledge of a current issue in the field of communications named Orthogonal Frequency Division Multiplexing (OFDM). We focused our attention on turbo codes and their implementation. We elaborated on the performance theory of the codes Then we tied concepts of OFDM and turbo coding with a target-based, modulation scheme. The simulation of the entire work is done on MATLAB. First we developed 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 we are able to improve the performance of uncoded OFDM by convolutional coding scheme. Further improvement on the performance has been achieved by applying turbo coding to uncoded OFDM system with adding of cyclic perfix. Turbo codes with low order decoding iterations have been evaluated. The SNR performances for BER $10^{-4,}$ that are suitable for speed and data applications, are analysed. As a result, the TCOFDM system with least number of decoding iterations, 1 to 3 iterations are shown to be sufficient to provide good BER performance in Rayleigh fading channel. Here we take maximum 3 iterations in turbo coded OFDM for which the time taken for decoding should reduced. Also at this iteration we get good performance. We can also focus on different modulation scheme and channel estimation technique to improve the performance.

7. ACKNOWLEDGMENT

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