Improving BER using turbo codes in OFDM systems

Inderjeet Kaur, Dr. Y.K.Mathur

Abstract— Orthogonal Frequency Division Multiplexing (OFDM) has been successfully applied to a wide variety of digital communication applications over the past several years. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels. 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 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.

Index Terms— Turbo codes, bit error rate, OFDM, AWGN, Bit Error rate, orthogonal frequency division multiplexing, Signal to Noise Ratio

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1 INTRODUCTION

With the rapid growth of digital communication in recent years, the need for high speed data transmission is increased. Moreover, future wireless systems are expected to support a wide range of services which includes video, data and voice. One way to transmit this data rate information is to employ well-known conventional single carrier systems. However, since the transmission bandwidth is much larger than the coherence bandwidth of the channel, highly complex equalizers are needed at the receiver for accurately recovering the transmitted information. It has been noticed, that the multi-carrier techniques can solve this problem significantly if designed properly. Optimal and efficient design leads to the adaptive implementation of multicarrier systems. During the last decade, OFDM has been the core technology in the physical layer of many wireless communication standards, including WLAN standards such as IEEE802.11g and HIPERLAN/2, as well as digital broadcasting systems such as Terrestrial Digital Video Broadcasting (DVB-T) [1]. Orthogonal frequency division multiplexing (OFDM) is a promising candidate for achieving high data rate transmission in mobile environment. OFDM transmission system offers possibilities for alleviating many of the problems encountered with single carrier systems [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. It has the advantage of spreading out a frequency selective fade over many symbols. This effectively randomizes burst errors caused by fading or impulse interference so that instead of several adjacent symbols being completely destroyed; many symbols are only slightly distorted.

This paper enhances the throughput of an existing OFDM system by implementing adaptive modulation and turbo coding. The new system guarantees to reach a target performance BER of 10^{-2} over a slow time-varying fading channel. The system automatically switches from lower to higher modulation schemes on individual subcarriers, depending on the state of the quasi-stationary channel. In conjunction with the adaptive design, forward error correction is performed by using turbo codes. The combination of parallel concatenation and recursive decoding allows these codes to achieve near Shannon's limit performance in the turbo cliff region [2]. All this is simulated in MATLAB programming.

2 PROPOSED OFDM MODEL

Orthogonal frequency division multiplexing (OFDM) is nowadays widely used for achieving high data rates as well as combating multipath fading in wireless communications. In this multi-carrier modulation scheme data is transmitted by dividing a single wideband stream into several smaller or narrowband parallel bit streams.At the transmitter side, N symbols each representing m coded bits are mapped by an m -ary mapper and the output symbols are multiplexed into N parallel branches and modulated each by a subcarrier through the normal OFDM modulation (IFFT). The transmitter output consists of the superposition of N signals in the time domain. At the receiver, the received signal of a generic subcarrier after the FFT stage can be written as [2]:

$r(n) = h(n)e(n) + w(n)$

Where r(n), e(n), h(n) and w(n) are the received signal, transmitted signal, complex flat-fading channel response and additive white Gaussian noise (AWGN) all at subcarrier (n), where n = 1,2,…N , respectively. The channel is assumed to be perfectly known at all subcarrier positions. The data recover process involves equalisation, demapping and decoding of the

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received signal. In this paper, the encoder and decoder are based on either a CTC or a BTC. Fig 1 shows the OFDM system architecture.

3 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. Parallel concatenated codes, as they are also known, can be implemented by using either block codes (PCBC) or convolutional codes (PCCC). 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.

This is achieved by using an interleaver. Encoders and decoders working on permuted versions of the same information.

An iterative decoding algorithm centered around the last two concept would refine its output with each pass, thus resembling the turbo engine used in airplanes.

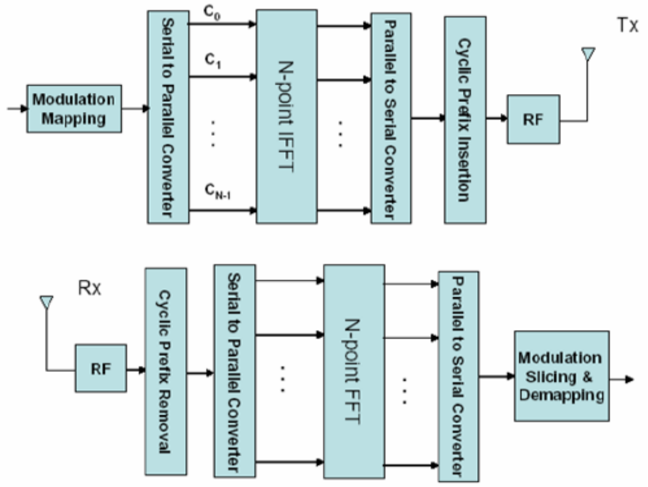

Fig. 1. OFDM System Architecture

3.1 Turbo Encoding

The encoder for a turbo code is parallel concatenated convolutional code [3]. The block diagram of the encoder is shown in "Figure 2". The binary input data sequence is represented by *dk* = (*d*1 , …….. *dN*). The input sequence is passed into the in- of a convolutional encoder. *ENC*$_1$ and a coded bit stream, $x^p_{k_1}$ 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.

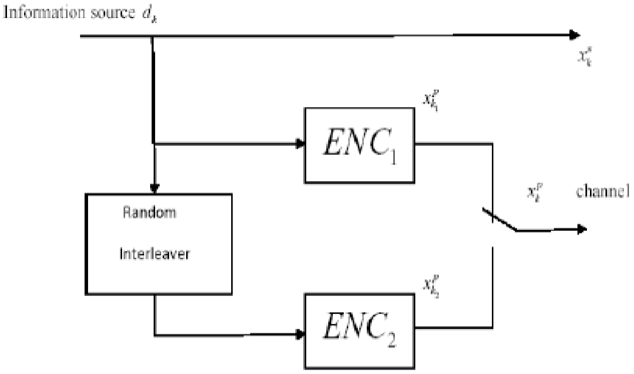

Fig. 2 Turbo encoder

The interleaved date sequence is passed to a secor onvolutional encoder ENC$_2$, and a second coded bit stream, $x^p_{k_2}$ is generated. The code sequence that is passed to the modulator for transmission is a multiplexed (an ssibly punctured) stream consisting of sys atic code bits x^s_k and p y bits from both the first encoder $x^p_{k_1}$ and the second encoder $x^p_{k_2}$.

3.2 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 [5]. 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) decode DEC$_1$ takes as its input the received seque systematic values y^s_k and the received sequence parity values $x^p_{k_1}$ 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. EXT1 is called extrinsic data, in that it does not contain any information which was given to DEC$_1$

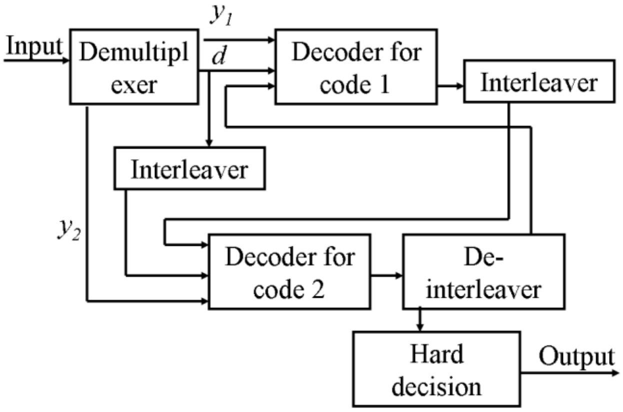

Fig3. Turbo decoder

DEC$_2$ outputs a set of values, which, de-inter
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_k^s and the sequence of received parity values $x^p_{k_2}$ from the second encoder ENC2, along with the interleaved form of the extrinsic information EXT1, provided by the first decoder.

leaved 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 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. If a set of corrupted code bits form a pair of error sequence 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, the algorithms used in the turbo decoding process, within $DEC1$ and $DEC2$.

4 TURBO CODED OFDM SYSTEM

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 is in personnel communication devices [1].

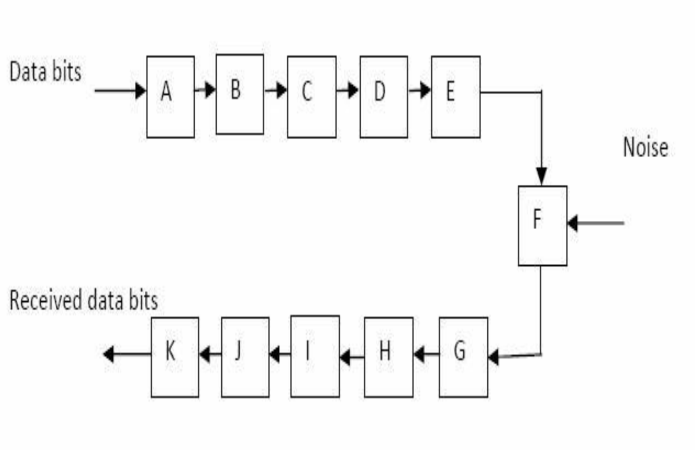

Fig 4. TCoded OFDM system

Fig 4 shows the simulation model for turbo coded OFDM that is used for implementing the various iterations. In the model shown in fig 4, A = turbo encoder, B = BPSK/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 = BPSK/QPSK demodulation and K = turbo decoder.

For plotting the BER curves the different parameters are set for simulation.

4.1 Simulation Algorithm

The performance of the turbo coded OFDM has been measured 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 (Additive White Gaussian Noise) and Rayleigh channel.
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.

4.2 Simulation papramters

TABLE 1 SIMULATION PARAMTERS

Parameters	Values
Digital Modulation	BPSK QPSK, QAM
Turbo code rates	1/3
SISO Decoder	Log-MAP
Code Generator	{111, 101}
Interleaver	pseudo random interleaver

Table 1 shows the various simulation parameters used in MATLAB. During the simulations, in order compare the results, the same random messages were generated. For thet radiant function is in MATLAB.

5 SIIMULATION RESULTS

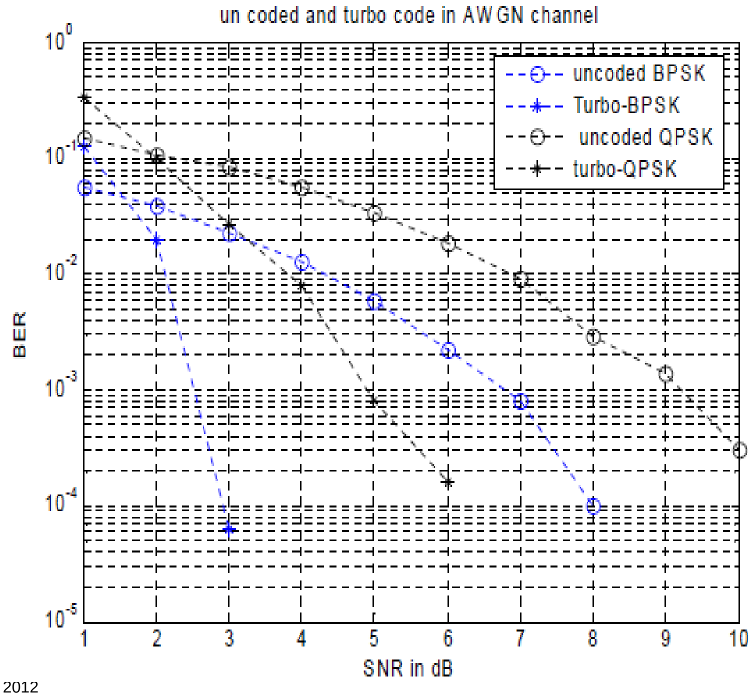

Fig 5: BER vs. SNR plot for uncoded and turbo coded OFDM using BPSK and QPSK.

All the simulations are done to achieve a desired BER 10^{-3}. For simulation results, two noise models were considered:

1. The AWGN and the time-Markov model. Both models are utilized by the parameters defined above.
2. 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.

In a multipath environment, it is reasonably spontaneous to visualize that an impulse transmitted from transmitter will reach the receiver as a train of impulses.The phase of each path can change by 2π radian when the delay $\tau_n(t)$ changes by $1/f_c$. If f_c is large, relative small motions in the medium can cause change of 2π radians. Since the distance between the devices are much larger than the wavelength of the carrier frequency, *it is reasonable to assume that the phase is uniformly distributed between 0 and* 2π *radians and the phases of each path are independent.* When there are large number of paths, applying Central Limit Theorem, each path can be modelled as **circularly symmetric complex Gaussian random variable** with time as the variable. This model is called **Rayleigh fading channel model**. The figure 6 shows the BER plot for turbo coded OFDM under one path rayleigh channel

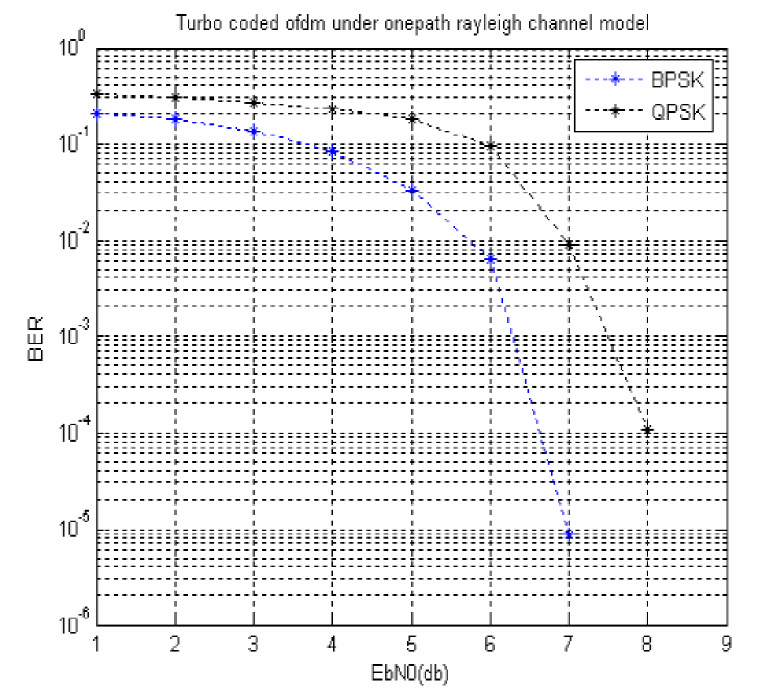

Fig 6. BER vs. SNR plot for turbo coded OFDM under one path rayleigh channel

Orthogonal frequency division multiplexing (OFDM) combines the advantage of high achievable rates and relatively easy implementation. In this their iscombined use of the turbo codes (TC) and the orthogonal frequency division multiplexing in Rayleigh fading channel.

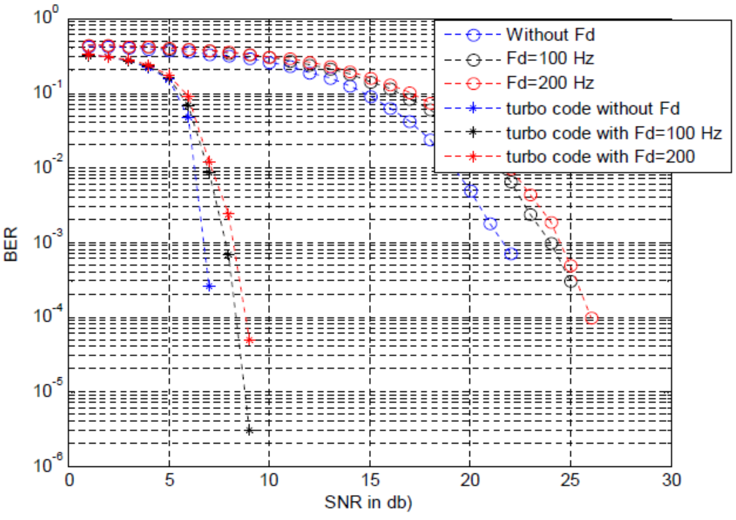

Fig 7. BER VS SNR plot for uncoded and coded OFDM

The system is called TC-OFDM with Rayleigh fading environment.The simulation results of TC-OFDM show that three iterations are sufficient to provide good BER performance. The figure 7 shows the gain of 5 dB at 10^{-5} in Rayleigh Fading channel is achieved.

All the simulations are done to achieve BER. For simulation results two channels are AWGN and RAYLEIGH are used. The BER performance of TCOFDM system is compared with uncoded OFDM system. 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.

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