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Study of BER for BPSK and DPSK (coherent and non-coherent) Modulation in Turbo-Coded OFDM with Channel Estimation

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Abstract— **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 adaptive equalizer is used here. In this paper we will design the OFDM system with channel Equalization under the powerful concatenated 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 which eventually degrades the efficiency of the system .This paper deals with the optimization to analyze the comparative study of BER for the BPSK and DPSK (coherent and non-coherent) modulation scheme to achieve higher data speed and less probability of error for robust and reliable communication under our proposed system model.**

Keywords— **OFDM, ISI, Rayleigh fading channel, Turbo-coding, Channel Equalization, BPSK and DPSK**

I. INTRODUCTION

One of promising techniques for high-speed data transmission is OFDM (orthogonal frequency division multiplexing), a kind of multicarrier modulation scheme. Digital modulation techniques contribute to the evolution of our mobile wireless communications by increasing the capacity, speed as well as the quality of the wireless network. In this paper, we focus on the BPSK and DPSK (coherent and non-coherent) modulation digital modulation technique over AWGN, Rayleigh and rician fading channels. Further high bit error rates of the wireless communication system require employing Robust and powerful forward error correction (FEC) methods on the data transferred to reducing the error in transmission**.** The turbo code can provide significant coding gain by utilizing two constituent convolutional codes and an interleaver. It has been confirmed that the turbo code achieves near Shannon-limit error correcting capability [1]. Channel equalization is proposed via LMS adaptive algorithm is used to mitigate the effects of ISI and decrease the probability of error that occurs at the receiver side. Our aim is to optimize and analyse the comparative study of BER for the BPSK and DPSK (coherent and non-coherent) modulation scheme through our proposed system under OFDM technique with channel equalization under turbo coded encoding.

II. REVIEW WORK

Literature survey shows that work has been done proposed to study the BER of the modulation scheme to achieve higher data speed and less probability of error for robust and reliable communication with many techniques employed for various modulation schemes under different environments with varied channel coding. The paper [2] presents the Matlab based study on the two kinds of modulation demodulations under the different noises. And focuses on the research for BER of BPSK coherent demodulation along with BDPSK coherent demodulation and BDPSK incoherent demodulation. In paper [3] aim is to analyze and compare the performance of COFDM in AWGN, Rayleigh, Rician & Nakagami fading environments. The channel coding used is Reed Solomon (RS) code with ½ and 2/3 convolution codes. The paper [4] presents the performance of different iterative decoding algorithms for turbo codes in new wireless systems is evaluated in realistic radio conditions, i.e., considering the transmission of an OFDM signal over a fading channel .In paper[5] the research is investigated in several aspects to evaluate the performance of turbo codes in Rician fading channel with low Rician K-factor, such as using different channel model, different coding rate, different internal interleavers, and different Rician factors. The simulation results give some demonstrations that are valuable for the application of turbo codes in Rician fading channel with low Rician K-factor. In[6] this paper aim is to analyze and compare the performance of COFDM using Turbo codes {with Log-MAP (Maximum A Posteriori) decoding} and Reed Solomon (RS) code with 1/2 and2/3 convolution codes (CC) as channel coding techniques in Rayleigh, Rician & Nakagami fading environments. The performance parameter is BER and the mapping schemes used are BPSK, QPSK, 16-QAM and 64-QAM.
In [7] this paper we address the problem of channel equalization and phase noise suppression in orthogonal frequency division multiplexing (OFDM) systems. For OFDM systems, random phase noise introduced by the local oscillator causes two effects: the common phase error (CPE), and the intercarrier interference (ICI). The proposed approach uses a pilot tone aided particle filter to track/estimate the effective dynamic channel in the time domain and equalizes in the frequency domain.

III. PROPOSED APPROACH

This review paper deals with the concept of Turbo coded OFDM (Orthogonal frequency division multiplexing) along with channel equalization using adaptive LMS (Least Mean Square) Equalizer which improves the system throughput. The study focuses on analysis BER (Bit error rate) of BPSK and DPSK (coherent and non-coherent) modulation scheme on the above designed communication system. 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[3]. In this paper we will see how performance of an OFDM system can be improved by adding turbo codes to it. The turbo coding also allows achieving the Shannon's bound Performance. 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 cyclic prefix and channel equalization through LMS equalizer.

A. OFDM Principle

Orthogonal frequency division multiplexing (OFDM) is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower rate subcarriers.OFDM is most preferred for high speed communication in multipath environment due to its immunity to ISI. OFDM avoids ISI problem by sending many low speed transmissions simultaneously. It can make the high-speed transmission of data flow through the
string and converted into the number of orthogonal narrowband parallel sub-channels which transmit the
low-speed data streams [8].

OFDM technology can make the transmission of data distributed to each sub-carrier, making the symbol period and longer than the multi-path delay, so as to effectively combat multi-path fading. Since orthogonality is important property for an OFDM system, so synchronization in frequency and time must be extremely good. Once orthogonality is lost we experience inter-carrier interference (ICI). This will introduce interference from one subcarrier to another. There is another reason for inter-carrier interference (ICI) in OFDM system. If we add the guard time with no transmission then it creates problems for IFFT and FFT, which results in inter-carrier interference (ICI)[9]. A delayed version of one subcarrier can interfere with another subcarrier in the next symbol period. This can be avoided by extending the symbol into the guard period that precedes it. And this is known as a cyclic prefix. It ensures that delayed symbols will have integer number of cycles within the FFT integration interval[13]. This removes ICI so long as the delay spread is less than the guard period.

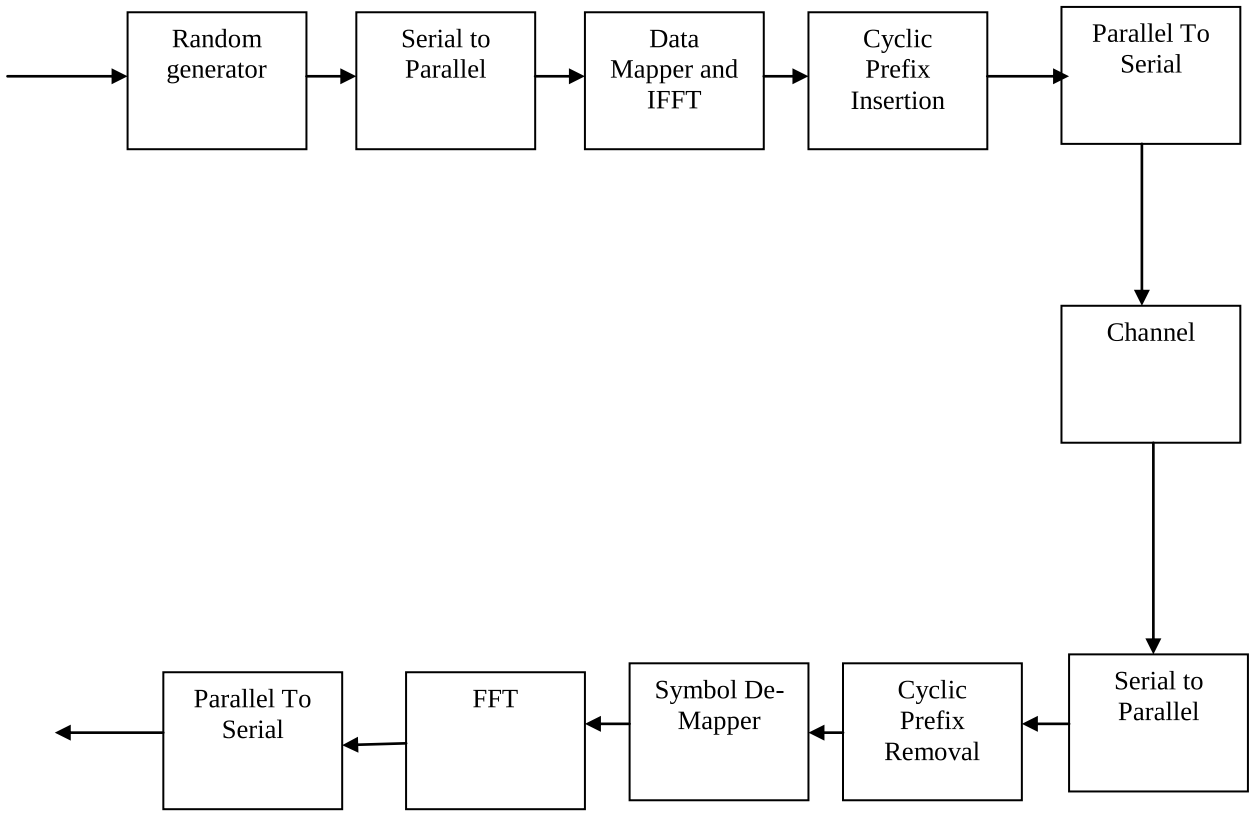


Fig. 1 OFDM Block Diagram

TABLE I
OFDM Specification

Parameter	**Value**
FFT size	64
Number of sub-carrier	52
FFT sampling Frequency	20 MHZ
Cyclic prefix duration	0.8 us
Number of OFDM symbols	100
Modulation	BPSK and DPSK (coherent and non-coherent)

The block diagram shows the transmitter section that converts digital data to be transmitted, into a mapping of subcarrier amplitude and phase by using modulation techniques. Its then transforms this spectral representation of the data into the time domain *using* an inverse fast Fourier transform (IFFT) as it is much more computationally efficient, and so is used in all practical systems [11]. The addition of a cyclic prefix to each symbol solves both ISI and ICI [12]. Digital data is then transmitted over the channel. After the time-domain signal passes through the channel, it is broken back into the parallel symbols and the prefix is simply discarded. The receiver performs the reverse operation of the transmitter. The amplitude and phase of the subcarriers are then picked out and converted back to digital data.

B. Channels

This study focuses on considering AWGN, Rayleigh and Rician channel for the implementation of our system model.

1) AWGN Channel: Additive white Gaussian Noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts par hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency, selectivity, interference, nonlinearity or dispersion.

2) Rayleigh Channel: In a multipath environment, it is reasonably intuitive to visualize that an impulse transmitted from the transmitter will reach the receiver as a train of pulses. When there are large numbers of paths, applying Central Limit Theorem, each path can be modelled as circularly complex Gaussian random variable with time as the variable [4]. This model is called Rayleigh fading channel model. . The channel model is reasonable for an environment where there are large numbers of reflectors [11]. The channel is modelled as n-tap channels with each the real and imaginary part of each tap being an independent Gaussian random variable. The impulse response is,

$$h(t)= \frac{1}{\sqrt{n}} \quad h(t-t_1) \ + \ h(t-t_2) + \dots\dots\dots\dots h(t-t_n)$$

Where, $h(t-t_1)$ is the channel coefficient of the first tap, $h(t-t_2)$ is the channel coefficient of the second tap and so on. The real and imaginary part of each tap is an independent Gaussian random variable with mean 0 and variance 1/2. The term $1/\sqrt{n}$ is for normalizing the average channel power over multiple channel realizations to 1.

3) Rician Channel: Rician fading is similar to Rayleigh fading except for the fact that there exists a strong line of sight component along with reflected waves [5]. In the presence of such a path, if the *kd* is the strength of the LOS component.

The envelope in this case has a Rician density function given by:-

$$f(r)= \frac{r}{\sigma^2} \quad \frac{-r^2+k_d}{2\sigma^2} \quad I_O \quad \frac{r\,k_d}{\sigma^2} \qquad ,r > 0$$

Where *I0*(.) is the 0th order modified Bessel function of the first kind.

C. Equalization

Equalizer is a digital filter that provides an approximate inverse of channel frequency response. Equalization is to mitigate the effects of ISI to decrease the probability of error that occurs without suppression of ISI, but this reduction of ISI effects has to be balanced with prevention of noise power enhancement[7]. An adaptive equalizer based on LMS algorithm is an equalizer that automatically adapts to time-varying properties of the communication channel. It is frequently used with phase shift keying, mitigating the effects of multipath propagation and spreading he receiver does not have access to the transmitted signal x when it is not in training mode[10]. If the probability that the equalizer makes a mistake is sufficiently small, the symbol decisions d_k made by the equalizer may be substituted for x.

$$e_k= d_k - d'_k = x_k - d'_k$$

D. Turbo Coding

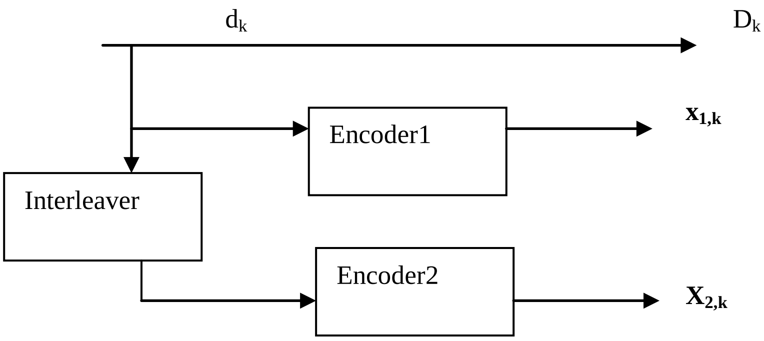
In order to achieve higher coding gains, the concatenated coding scheme has been proposed. In a concatenated coding scheme, probability of error decreases .The turbo code is a kind of concatenated code which consists of two or more constituent codes.

TABLE II

Turbo Codes Specification

Parameter	**Value**
Turbo codes Rate	½
SISO decoder	Log -MAP
Code generator	K=5; $G=(21)_8$; $F=(37)_8$
Number of iterations	2

Turbo codes perform well due to the attractive combination of the code's random appearance on the channel together with the physically realisable decoding structure. MAP algorithm achieves soft decision decoding on a bit by-bit basis by making two passes of a decoding trellis, as opposed to one in the case of the Viterbi algorithm. The analyzed iterative decoding algorithms Max-Log-MAP and the soft since it has a relative low computational complexity [4], simplifying its bit error rate performance and implementation in cost efficient terminals.



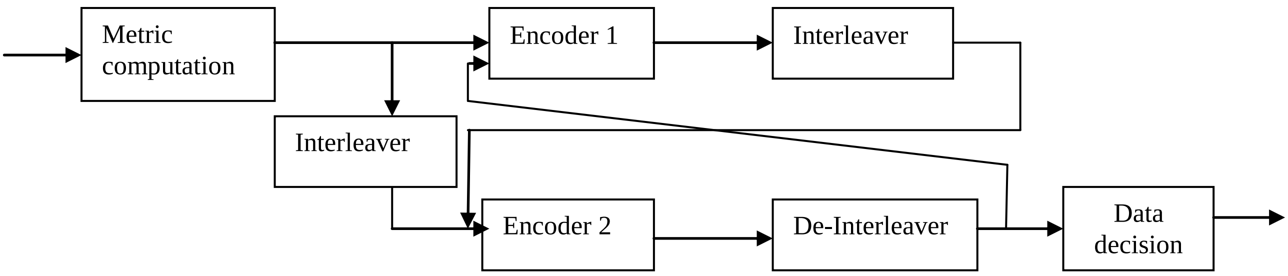


Fig 2.Turbo encoder and decoder

The input sequence $\mathbf{d_k}$ produces a low-weight recursive convolutional code sequence $\mathbf{x_{1,k}}$ for RSC Encoder 1. To avoid having RSC Encoder 2 produce another low-weight recursive output sequence, the interleaver permutes the input sequence $\mathbf{d_k}$ to obtain a different sequence that hopefully produces a high weight recursive convolutional code sequence $x_{2,p.}$

Typically, two recursive systematic convolutional codes are used as the constituent codes. In general, turbo code consists of two or more constituent codes and an interleaver [8]. The first decoder passes the extrinsic information (a part of the soft output provided by a posteriori probability algorithm) to the next decoding stage. For every iteration process, a single decoding is performed using the observation as well as reliability information delivered by the other decoders that were acting before. The MAP (maximum a posteriori) decoding algorithm is known to be an optimal algorithm for turbo decoding process.

E. System model

Here, we propose our designed algorithm for the system focussed with OFDM technique with channel equalization under turbo coded encoding. Our aim to optimize and analyse the comparative study of BER for the BPSK and DPSK (coherent and non-coherent) modulation scheme is achieved through our proposed algorithm which can be simulated by the MATLAB tool.

In an OFDM system with channel equalization under LMS equalizer with turbo coding as shown in Fig. 3,input data sequence is first encoded by turbo encoder and then by OFDM/ BPSK and DPSK (coherent and non-coherent) modulation encoder. The Phase shift keying techniques BPSK and DPSK (coherent and non-coherent) encodes data sequence into phase and differential encoding, where *m* is the number of. The groupings of data are encoded as polar values bits assigned to the subcarrier.

Then, the output of turbo encoder is serial-to parallel converted. The OFDM scheme allows spectral overlap of adjacent subcarriers using orthogonal property, which results in high spectral efficiency. The subcarrier frequencies are selected to be spaced at symbol rate.

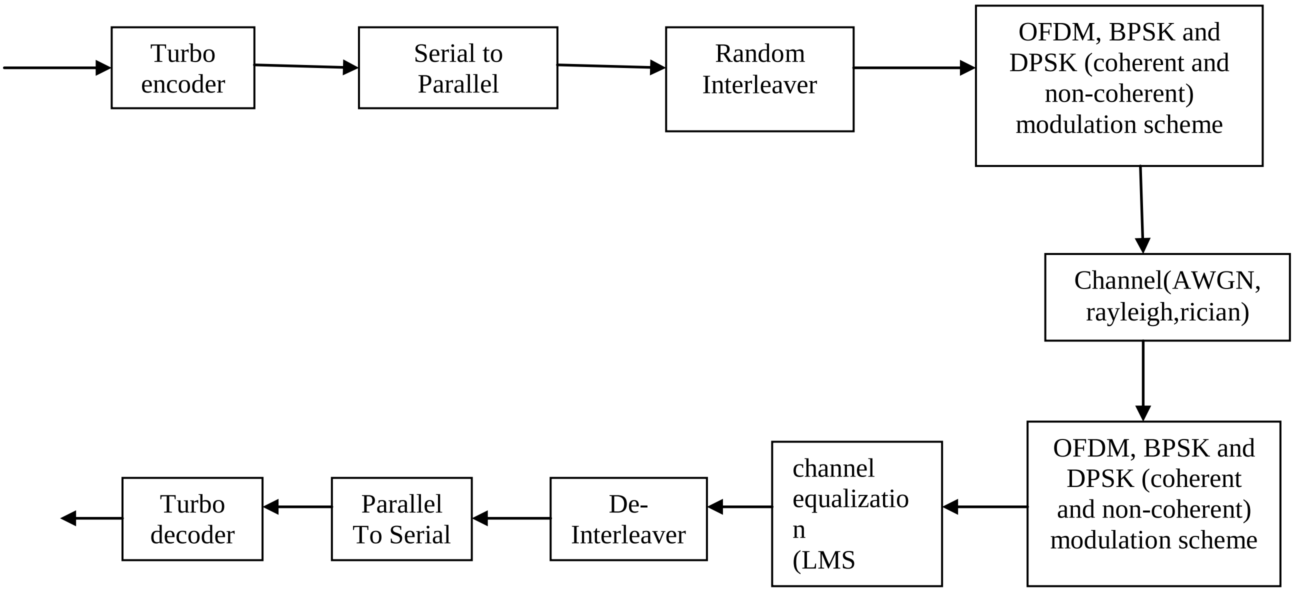


Fig 3.System model.

The OFDM modulation and demodulation is efficiently done using FFT and IFFT algorithms. The IFFT output is converted into analog modulating waveform using D/A (digital-to-analog) converter, and then transmitted. At the receiver is a adaptive Equalization with LMS algorithm provides an approximate inverse of channel frequency response to elimiminate ISI and ICI interference in multipath Fading channels. For each subcarrier, the transmitted data is estimated through signal point closest to the point corresponding to the received subcarrier. The output of parallel-to-serial converter is decoded in the turbo decoder to estimate transmitted bit data sequence.

IV. CONCLUSIONS

The growth in use of the information networks lead to the need for new communication technique with higher data rate. Orthogonal Frequency Division Multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications. Various techniques have been proposed to study the BER of the modulation scheme to achieve higher data speed and less probability of error for robust and reliable communication. In, this paper we try to optimize and analyse the comparative study of BER for the BPSK and DPSK (coherent and non-coherent) modulation scheme through our proposed system under OFDM technique with channel equalization under tubo coded encoding to achieve better bit error rates for long distance reliable communication.Futher this work can be extended to MIMO systems for varied technologies to improve the bit error rate performance of the modulation scheme.

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