Eng. &Technology, Vol.24, No.2, 2005

Performance Evaluation And Enhancement Of Third Generation Mobile System

*Muhanned I. Al-Farras**

Received on: 2/10/2004
Accepted on: 26/1/2005

Abstract

The goal for the next generation mobile communication system is to seamlessly integrate a wide variety of communication services such as high speed data transmission, video and multimedia traffic as well as voice signal. The technology needed to tackle the challenges is to make these services available, popularly known as the third generation (3G) cellular system. One of the most important promising approaches to 3G is to combine turbo coding and diversity in the system. Turbo codes are one of the most powerful types of error control codes currently available. Turbo encoder is built using a concatenation of two recursive systematic convolutional (RSC) codes. On the other hand, the decoder depends on the a posteriori algorithm. Diversity is a well-known technique for improving performance in mobile radio communication at a relatively low cost. The paper investigates the effect of turbo coding in the 3G system with diversity. The bit error rate performance of the system with AWGN channel is investigated to study the effect of number of iterations, frame size, code rate and memory size of the symmetrical convolutional code. It then assesses the performance of the system over mobile fading channel that exhibits Rayleigh multipath. In the performance assessment, the bit error rate for different mobile speeds, different frame sizes, different number of states in the encoder and different number of iterations in the decoding were also investigated. The assessment also compares the performance with and without diversity.

تحسين اداء منظومة الجيل الثالث من الهواتف النقالة

الخلاصة

أن هدف الجيل الثالث من الهواتف المتنقلة هو إرسال المعلومات بسرع فائقة جدا. لذالك فان التحديات التي تواجة الجيل الثالث هو كيفية التعامل مع متطلبات إرسال هذه المعلومات التي تتضمن صور متعددة الوسائط و فيلم تنقل في الوقت الحقيقي. لذلك تتجه البحوث نحو استخدام تقنيات تحسن أداء هواتف الجيل الثالث و ان واحد من أهم تقنيات الجيل الثالث هو عملية الجمع بين الترميز(Turbo code) و التنوع (Diversity) من اجل تحسين عمل المنظومة.الترميز من نوع (Turbo code) وهو واحد من أفضل من يواجة الأخطاء الناتجة في المعلومات نتيجة التأثيرات الخارجية و الضوضاء حيث يتكون من جمع اثنان من الترميز recursive systematic convolutional (RSC) على التوازي. أما عملية فك الترميز فتعتمد على نظرية posteriori algorithm. أما التنوع يستخدم لتحسين أداء الهواتف المتنقلة حيث يكون رخيص الثمن وسهل الاستخدام و النصب. أما هذا البحث يبحث ثاثير استخدام الترميز (Turbo code) مع التنوع(Diversity) في الجيل الثالث للهواتف النقالة وإيجاد النتائج وإيجاد العوامل التي تؤثر على عمل المنظومة من حيث عدد مرات تكرار فك الترميز وحجم الإرسال المعلومات في كل مرة وحجم الذاكرة المستخدمة وكذلك سرعة الهاتف النقال مع استخدام التنوع و بدون استخدام التنوع.

---

* Dept. of Electrical & Electronic Eng., University of Technology
e-mail:muhanned_alfarras@yahoo.com

https://doi.org/10.30684/etj.24.2A.10
2412-0758/University of Technology-Iraq, Baghdad, Iraq

I- INTRODUCTION

Proposed third generation wireless system, such as the *Universal Mobile Telecommunication System* (UMTS) have to provide an " *any where any time* " service have to support variable data rate from (348 kbps) for business (Indoor) to up(2 Mbps) for local high bit rate (Indoor). Some of the data services require highly reliable communication having bit error rates less than (10^{-5}) .*Turbo codes* are promising candidates for high-bit-rate data applications in Wide-bandwidth Code Division Multiple Access (W-CDMA) based third generation mobile radio system.[1, 2]

Parallel concatenated interleaved codes popularly know " *turbo codes* " introduce have been shown to perform near Shannon limit on the Additive White Gaussian Noise (AWGN) channel. This powerful channel coding technique has also been studied for digital communication system over more problematic wireless fading channels, but mainly for flat fading channel and short form speech transmission with narrow band direct sequence code division multiple access (DS – CDMA) system. [2, 3]

Diversity is a well-known technique for improving performance in mobile radio communications at reactively low cost. Furthermore, there are wide ranges of diversity implementations, many which are very practical and provide significant link improvement. There are different techniques for generating diversity paths one of which antenna diversity. In antenna diversity, antennas can be separated vertically or horizontally in the base station. Separations between antennas on the order of several tens of wave lengths are required [4, 5] sufficient separated (15 λ- 40 λ). [6] In this paper , performance of a turbo code in a *Rayleigh Multipath Channel*

is studied through simulation .Set of simulation parameters is chosen to closely match the 3rd generation UMTS requirements. The effects on bit error performance with AWGN and multipath fading is in investigated by high and low mobile speed with and without diversity , varying the size of frame length and memory size of systematic convolutional code (RSC). Several report in this filed and related subjects, such as Joson P Woodard and Lajos Hanzo[4] show the novel class of channel codes and the effect of range of system parameters is investigated. Israfil Bahceci and Tolga M. [7] use turbo code to-gether with unitary space time modulation. From which it was observed that the turbo code provides 10-15 dB coding gain at a BER 10^{-5} compared to the unitary space time modulation. Hamid R and Masoud Salehi [8] describes a new interleaver design for turbo codes with short block length. Fred Daneshgaran, and Marina Mondin [9] addressed the problem of interleaver design for serially concatenated convolutional codes

II-MOBILE CHANNEL

A fading multipath channel is generally characterized as a linear, time-varying system having an (equivalent low pass) impulse response $c(t , \tau)$ (or a time-varying frequency response $c(t, f)$) which is a wide - sense stationary random process in (t) variable .Time variations in the channel impulse response or frequency response result in frequency spreading, generally called Doppler spreading .By assuming that the multipath signals propagating through the channel at different delays are uncorrelated a doubly spread channel may be characterized by scattering function S(τ , λ) which is a measure of power spectrum of the channel at delay (τ) and frequency offset (λ), there for the delay power spectrum of channel by simply a varying S(τ , λ) over (λ), i.e

$$S_c(\tau)=\int_{-\infty}^{\infty}S(\tau,\lambda)d\lambda \quad ....(1)$$

Similarly, the Doppler power spectrum is

$$S_c(\tau)=\int_{0}^{\infty}S(\tau,\lambda)d\lambda \quad ....(2)$$

The range of values over which delay power spectrum $S_c(\tau)$ is nonzero is defined as multipath speared (T_m) of the channel similarly the range of values over which the *Doppler Power Spectrum* S_c (λ) is non zero is defined as the *Doppler Spread* (B_d) *of the Channel* Another channel parameter called the *Channel Coherence Time* (T_{coh}) where can be defined as

$$T_{coh} = 1/B_d \quad .... (3)$$

Thus a slowly fading channel has large coherence time and fast fading channel has small coherence time. In a similar manner , we define the channel coherence band -width (B_{coh}) as the reciprocal of multipath speared i.e,

$$B_{coh} = 1/T_m \quad ....(4)$$

The product (T_m B_d) is called the spread factors of the channel .

If (T_m B_d)<1,the channel is said to be under spread otherwise ,it is overspread.

Let us now consider the effect of the transmitted signal characteristic on the selection of the channel model that is appropriate for specific signal, let x(t) be the equivalent low pass signal transmitted over the channel , the equivalent low pass received signal , exclusive of additive noise , is

$$r(t)=\int_{-\infty}^{\infty}c(t,\tau)x(t-\tau)d\tau \quad ....(5)$$

Now, suppose that the bandwidth (w) of x(t) is much small the coherence bandwidth of the channel i.e (w<< B_{coh}) . Then all the frequency components in X(f) undergo the same attenuation and phase shift in the transmission through the channel . But this implies that , within the bandwidth (w) occupied by X(f) the time - variant transfer function c(t ,f) of the channel is constant in frequency variable .Such channel is called *Frequency - Non Selective* or *Flat Fading* .

The *Flat Fading channel* used in this paper is with deferent Doppler spread.

For the frequency - non selective channel, the received signal r(t) is equal to

$$r(t)=c(t,0)\int_{\infty}^{\infty}x(f)e^{j2\pi ft}df \quad ....(6)$$

$$=c(t)x(t) \quad .... (7)$$

$$=\alpha(t)e^{j\theta(t)}x(t) \quad .... (8)$$

where , by definition

$$c(t,0)=\alpha(t)e^{j\theta(t)} \quad ....(9)$$

α(t) represents the envelope and θ(t) represents the phase of the equivelent low pass channel responcse [10].

III-TURBO CODE

A turbo code encoder with two component codes is shown in fig(1). Special types of convolutional codes, called *Recursive Systematic Convolutional Codes*(RSC) ,are used as the building blocks of turbo code encoder. The encoder ENC_1 and ENC_2 of the two component RSC, encode the the same input information bits (U_k) but in different order, because of the interleaver before the ENC_2 appropriate puncturing of parity bits from two encoders can produce a turbo code of desired rate . A Fired *Peseudo Random Interleaver* is used .It has been selected a many randomly generated interleaver based on frequency of low-weight output code words for weight-two sequence.Fig (2) shows the structure of turbo code decoder . The two decoder DEC_1 and DEC_2 corresponding to the contained encoders ENC_1 and ENC_2 are serially connected through the sum interleaver that used in the encoder .

In Fig (2) an interleaving is denoted by (π) whereas (π^{-1}) denotes the inverse permutation (deinterleaving).

In this paper iterative turbo decoding is implemented using *Log-MAP Algorithm Soft Input Soft Output* (SISO) decoders. Appropriate soft outputs from the demodulator $C_{soft,ch}$ are used as distution for information bits $I_{Apriori}$ are initialized for the first iteration by assuming information bits to be equally probable . However after the first decoding step. $I_{Apriori}$ will be a available from soft outputs of information bits I_{ext} computed in the previous decoding stage. The SISO decoder can be used to compute extrinsic information corresponding to both information bits I_{ext} and coded bits C_{ext} in general.

For iterative decoding of a turbo code only I_{ext} is required , and it is passed to next decoder after each decoding step to improve the correction capacity of decoding . Detection is made after final iteration by adding the a posteriori probability values of information bits I_{App} from the output of the last decoding stage to the values of a priori distributions I Apriori . [11, 12, 13]

IV- ***DIVERSITY COMBINERS***

There are two main issues in reviewing the properties of alternative diversity combiners ,the first is related to where the combining process takes place in the system and the second is how to combine the diversity path. [14]

In practical application ,a linear combiner is most often used .

The output of a linear combiner for (L) diversity paths can be expressed as :

$$r(t)=\sum_{K=1}^{L}a_k r_k(t) \qquad \text{..................(10)}$$

Where a_k is the weight assigned to the signal component in the k-th diversity path respectively .

In the *Selection Diversity Combiner* (SDC) the diversity path having the strongest signal is selected, so the output of combiner is the same as that of strongest diversity path. In this case only one $a_k=1$ at any time is chosen, others are all zero . as shown in fig(3).

The inputs to branches in fig (3) are the *Rayleigh signal* $S_1$and S_2 .The signals $S_1$and S_2 are received with amplitude r_1 and r_2 with phass θ_1 and θ_2 respectively. Both branches are corrupted by additive noise sources n_1 and n_2 respectively; n_1 and n_2 are identically distributed *White Gaussian Noise Sources*. The statistics for n_1 and n_2 are executed to de equivalent with zero mean and a variance, or noise power of (N).

The signal to noise ratio after selection combining is simply the maximum of both branches or equivalently

$$SNR=Max[r_1/\sqrt{N},r_2/\sqrt{N}] \qquad \text{.......(11)}$$

$$=1/\sqrt{N}Max(r_1,r_2) \qquad \text{.........(12)}$$

Since the noise power N is assumed to be constant N=1 in eq. (12) becomes

$$SNR=Max(r_1,r_2) \qquad \text{............(13)}$$

V- ***DATA COMUNICATION SYSTEM MODELING***

The low pass-equivalent simulation models for synchronous transmission used in this paper is shown in fig(4) .

The transmitter section consists of turbo code encoder , followed by BPSK modulation specified by UMTS.

Data bit rate for each frame generated by random data generated and passed to turbo code encoder.Since ideal time synchronization is assumed; band limiting transmitter and receiver filter are omitted in the simulation models.

Rayleigh fading channels considered assuming a typical Urban Flat Fade. Complex Gaussian Samples are filtered by a classical Doppler Filter (5 Order Bassel Filter) to introduce correlated fading typical high and low (50,100 and 150) mile/km mobile speeds are consider . Hence maximum Doppler frequency shifts for high and low mobile speeds are calculated by using :

$$Fd = |v/\lambda| \qquad \ldots\ldots\ldots\ldots\ldots(14)$$

Where (v) is speed of mobile and (λ) is the wave length of carrier .

A two antennas used for diversity to select best paths by using selection diversity, the best signal passed to BPSK demodulator specified by UMTS, Eb / No is calculated from the exact variance used in noise source of the simulation model-channel soft outputs are then passed to the turbo decoder . Iterative turbo decoding is implemented using the Log-MAP algorithm in the SISO decoders as described in the previous section.

VI- SIMULATION RESULT

Performance is evaluated by estimating bit error rate (BER) versus signal to noise ratio E b / No based on system model. The simulation results was carried out using Matlab 5.6. This paper pursues three goals :

1- performance of turbo code related to memory size, frame length, and number of iterations

2- effect of mobile speed on turbo code and effect of correlated fade .

3- performance of turbo code in mobile radio communication with different diversity techniques.

The turbo code performance under AWGN and fading channel environments were tested. The results under the AWGN serve as a reference. The simulation uses the turbo recursive systematic convolutional encoder with generator matrices [1,7,5]2 and shift register memory 3,4. The frame size is either 5000 or 10000 bits/frame.To investigate the effect of number of iterations of turbo decoder with frame length 5000 bits / frame are shown in Fig.(5) with different number of iterations 2, 4, 6, and 8 with a transfer function [1,7,5]2 over AWGN. It is clear that the BER decreases and number of iteration with increasing, the advantage gained in performance between 8 iterations and 6 iterations is small comper with 4 and 2 iterations. This advantage comes from sharing the information from one decoder with another. In this work, the first decoder does not have the information of the second encoder output in the first iteration. After the first iteration, the output of the second decoder will feed back into the input of the first decoder. Thus first decoder has the more information in the second iteration and decoding performance should be improved.Furthermore to evaluate the effect of frame length on the performance of turbo code over AWGN channel, another frame length has been chosen equal to 10000 bits / frame to show the performance difference in the case 2, 4, 6, and 8 iterations with transfer function $[1,7,5]_2$ over AWGN. However, these results show that significant improvement in performance can be observed for increase in frame length and number of decoding iterations. From the above, it is observed that the performance of the turbo code increases with increasing number of iterations. However, the time used will also increase linearly with an number of iterations. This increases in decoding time per bits will lead to increase in latency.

Turbo code with different frame length at 8-iteration decoder on AWGN with transfer function $[1,7,5]_2$ are compared in fig. (7). It can be seen that the gain in advantage between 10000 bits and 5000 bits at each frame equale 0.2 dB at BER 10^{-4} as shown in fig.(7) .

Fig(8) and fig(9) show the performance of turbo code with different number of iteration 2, 4, 6, and 8 with transfer function $[1,11,15]_2$ and different frame length 5000 bits/frame and 10000 bits/frame respectively. Fig (10) showsthe performance of turbo code with rate 1/3 with the same frame length 10000 bits and different transfer function $[1,7,5]_2$ and $[1,11,15]_2$. The performance has an advantage 0.2dB between them at BER 10^{-4}. Memory size of encoder depends on transfer function. Each encoder has memory to store the preceding bits/state information. The memory size of encoder is the number of bit/state can be stored in the encoder, therefore more advantage can be gained. The size of trellis formed is exponentially proportional to the encoder memory size. The exponential increase in complexity of the decoding algorithm will cause the decoding time to increase dramatically with memory size.

To evaluate the performance of turbo code on correlated fading channel with 10000 bits/frame, 2 iterations and different mobile speed, the correlated fading channel used Jacks fading simulation model. Fig(11) shows three curves corresponding to speed 50, 100, and 150 mile/h with *Channel Coherence Time* (T_{coh}) 0.0045, 0.0022, and 0.0015 sec. when carrier frequency 2 GHz. The low *coherence time* results less correlation of fading processes, hence the better performance.

To investigate performance of turbo code in correlated Rayligh multipath fading channel with rate 1/3 and transfer function $[1,7,5]_2$ having memory size equal to 3 and frame length equal to 10000 bits without diversity and different number of iterations 2, 4, 6, and 8. The effect of increase in number of iterations can be observed in fig (11). that gives more advantage at mobile speed of 50 mile/h. Fig (12). and Fig (13) show the performance of turbo code in Rayleigh fading channel with channel coherence time (T_{coh}) 0.0045 sec. used with two antenna diversity combiners with different number of iterations 2,4,6, and 8 and frame length 5000 bits/frame and 10000 bits/frame respectively.

The effect of memory size on performance of turbo code is shown in Fig. (14) with memory size 4 and transfer function $[1,11,15]_2$ with different number of iterations with diversity. To compare between performance of turbo code in Rayeigh fading channel with channel coherence time (T_{coh}) 0.0045 sec. with two antenna diversity combiners and without diversity, the results show the diversity giving advantage of (4 dB) at BER equal 10^{-4} with 8 iterations and 10000 bits/frame as shown in fig.(15).

Fig.(16) shows the effect of transfer function on the performance over Rayeigh fading channel with channel coherence time (T_{coh}) 0.0045 sec. with two antenna diversity combiners, the gain advantage is equal to 0.8 dB at BER 10^{-4} when the memory size increases from 3 to 4.

VII-CONCOLUSIONS:

The paper presents the computer simulation of 3rd generation mobile communication system that show the effect of inclusion of turbo coding and diversity in the system. Furthermore, it studies the effect of turbo coding and diversity parameter on the BER performance of the system together with change in the channel condition from AWGN to Rayleigh multipath fading mobile channel.

The simulation results show that the turbo code achieves a significant advantage in tolerance to AWGN over system without turbo coding. The most important conclusion points that have be drawn from there test results are:

The number of iterations will yield low BER but the delay in the decoding becomes longer.

The large frame length will give better performance but the delay in decoding also increases.

Large memory size of encoder results in low BER but the disadvantage is long delay.

The memory size of encoder is more effective in mobile channel than AWGN.

The low coherence time results less correlation of fading processes, hence the better performance

Diversity with turbo code offers better performance and the diversity is compact multipath fading effect.

REFRENCES

1. Berrou ,C., Glavieux ,A., and Thitima –Jshima, p. " Near Shannon Limit Error - Correcting Coding And Decoding Turbo Codes" IEEE Transactions On Velticular Technology , vol.29, no.8, Nov., 2001, pp1098-1108.

2. Zhao, Y , " Standardization of mobile phone positioning for 3G system " IEEE communication magazine, July 2002.

3. [3] Jung ,P. " Comparison Of Turbo-Code Decoders Applied To Short Frame Transmission System " IEEE Journal On Selected Areas In Communications ,vol . 14 ,no.3, April ,1999 pp.530-537.

4. Jason P.W, and Lajos H, " Comparative Study Of Turbo Decoding Techniques" IEEE Transactions On Velticular Technology , vol.49, no.6, Nov., 2000, pp.2208-2232.

5. Sebastien R. and David D.F."A Diversity Channel Model Using Multiple Tapped-Delay Linear Characterized By Lag-Delay Correlation" IEEE Transactions On Velticular Technology, vol.67, no.5, May , 2000

6. Sklar B "Digital communication fundamental and application" Prentice Hall Inc, 2002 .

7. Israfil B. and Tolga M. "Combined Turbo Coding and Unitary Space-Time Modulation" IEEE Transactions On communication, vol.50, No.8, August, 2002

8. Hamid R. and Masoud S. "Interleaver Design for Turbo Codes" IEEE Journal on Selection Areas in Communications, vol.19 ,No.5,May, 2001

9. Fred D. and Massimiliano L." Interleaver Design for Serial Concatenated convolutional Code" IEEE Transactions On Information Theory, Vol.50,No.6,June.2004.

10. Ezio B.,John P.and Shlomo S. "Fading Channel Information-Theoretic And Communication Aspects" IEEE Transactions On Information Theory, vol.44, no.6, Oct.,1998.

11. Mathew C.V. "An Introduction ToTurbo Codes" IEEE Transactions On Information Theory, vol.52, no.2, April, 1999.

12. Ruoheng l. perdrance S." Punctured Turbo code Ensembles" ITW 2003, paris, france, Marach – april 4, 2003.

13. Benedotto, S., Divsalar, D.,Montorsi, G., And Pollara, F. "A Soft-Input Soft- Output Maximum A. Posteriori (MAP) Module To Decode Parallel And Serial Concatenated Code" The Telecommunication And Data Acquisition Progress Report Jut Population Laboratory, Report 24-127, Nov.,1996, pp.1-20

[14] Herman Y., "Capacity Analysis Of Base Station Diversity "Ph.D Thesis, University Of South Austeria,Oct.,1999

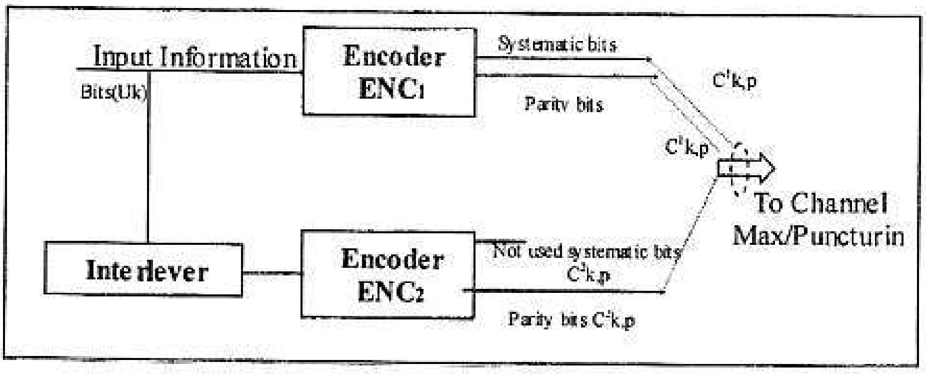
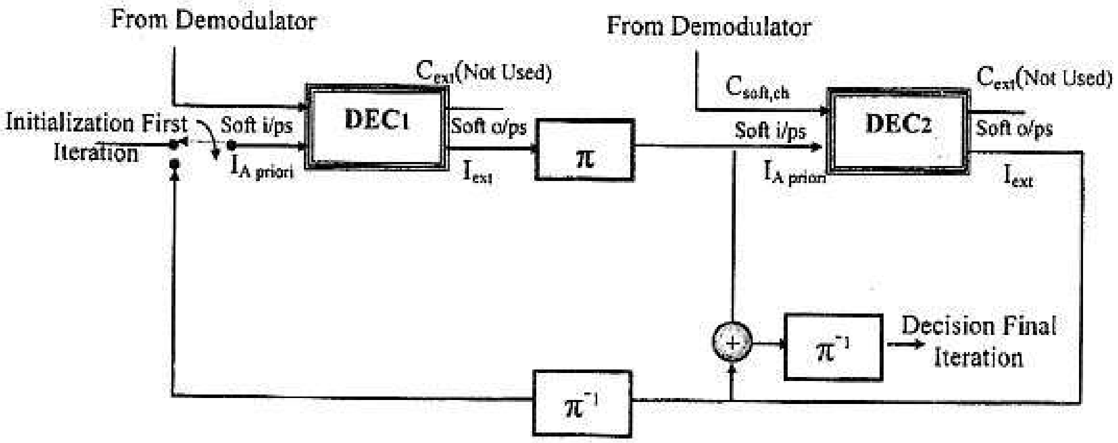
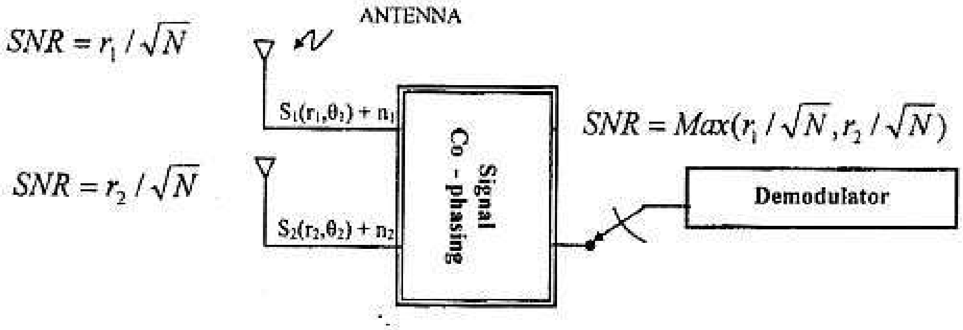


Fig.(1)
Structure of turbo encoder



Fig(2)
Structure of turbo code



Fig(3)
Block diagram of two – branches selection diversity system for equal noise power in both branches

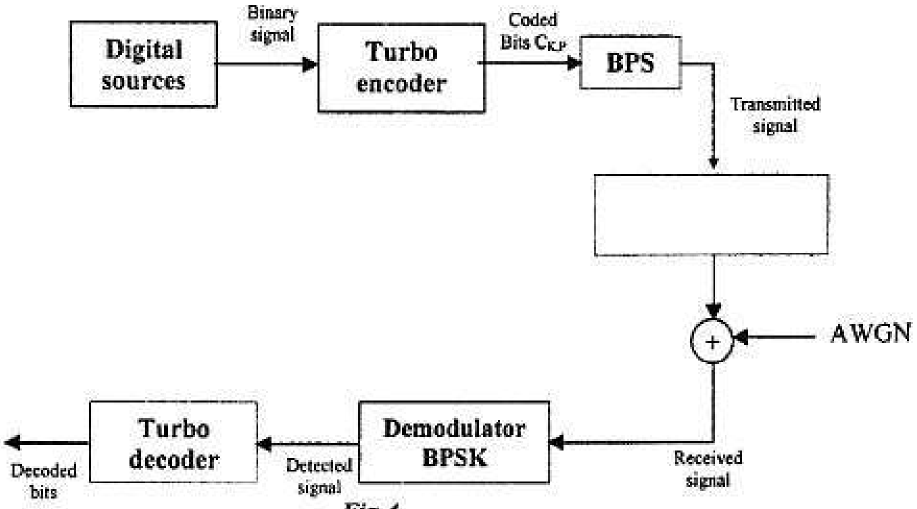
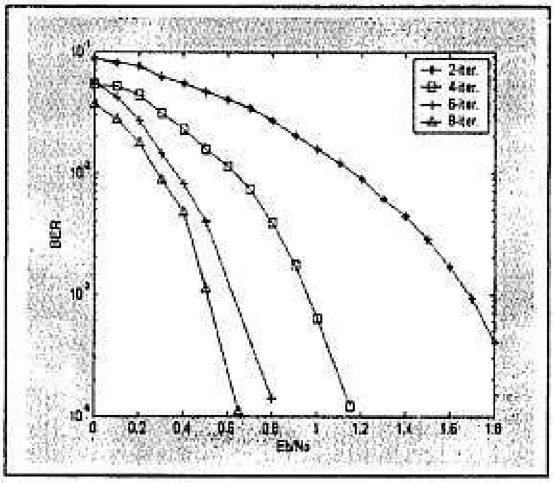


Fig 4

System model for simulation turbo code for Rayligh fading channel



Fig(5) Performance of turbo code with rate 1/3, transfer function$[1,7,5]_2$ frame length 5000 bits on AWGN

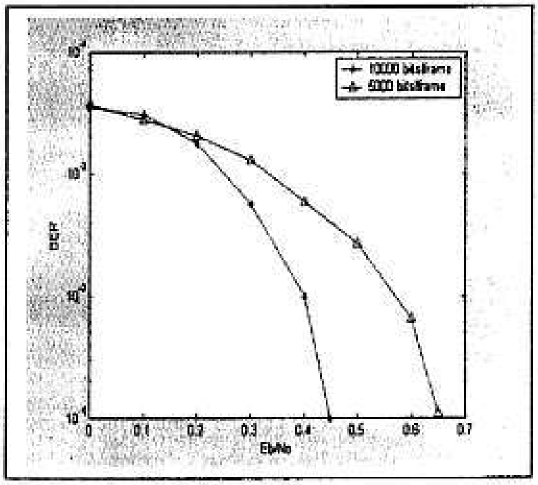
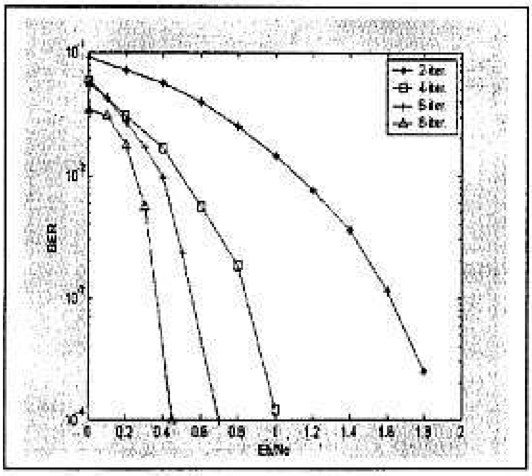


Fig.(7) Performance of turbo code with rate 1/3 ,transfer function $[1,7,5]_2$, 8 iteration on AWGN



Fig(6) Performance of turbo code with rate 1/3 ,transfer function $[1,7,5]_2$, frame length 10000 bits on AWGN

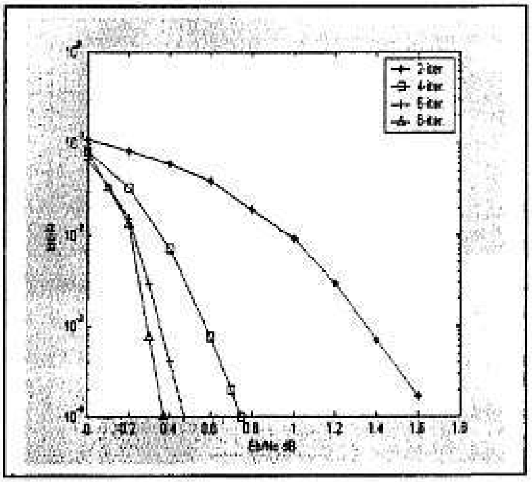


Fig.(8) Performance of turbo code with rate 1/3 ,transfer function $[1,11,15]_2$, frame length 5000 bits on AWGN

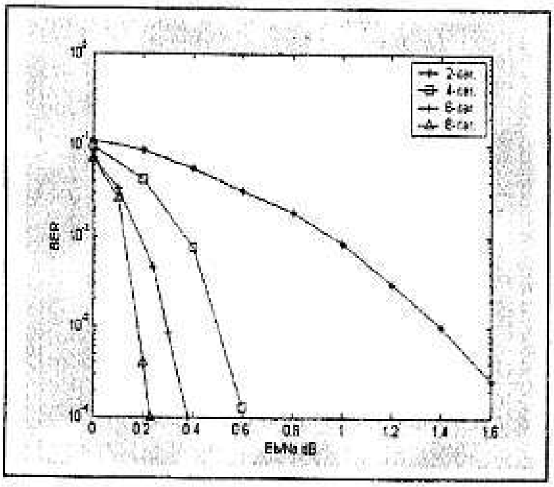


Fig.(9) Performance of turbo code with rate 1/3 , transfer function [1,11.15]$_2$, frame length 10000 bits on AWGN

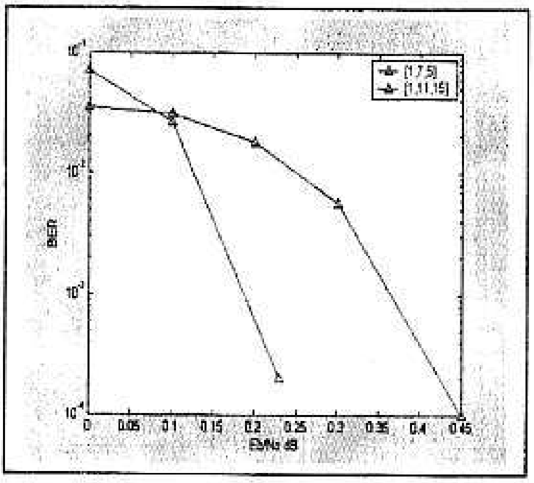


Fig.(10) Performance of turbo code with rate 1/3, 8 iteration , 10000 bits/ frame on AWGN

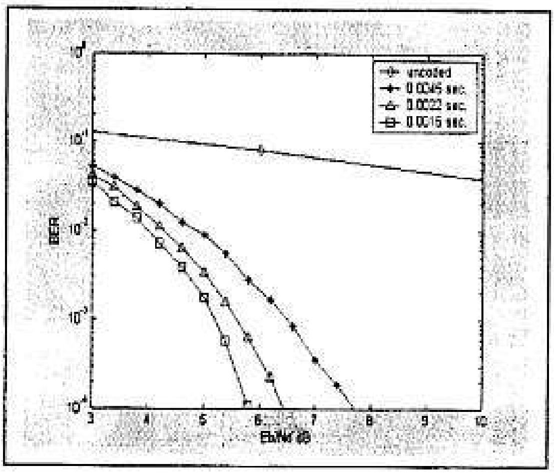


Fig.(11) Performance of turbo code in Rayleigh multipath fading Channel at different channel coherence time with rate 1/3 ,transfer function [1,7,5], frame length 10000 bits , 2 iteration

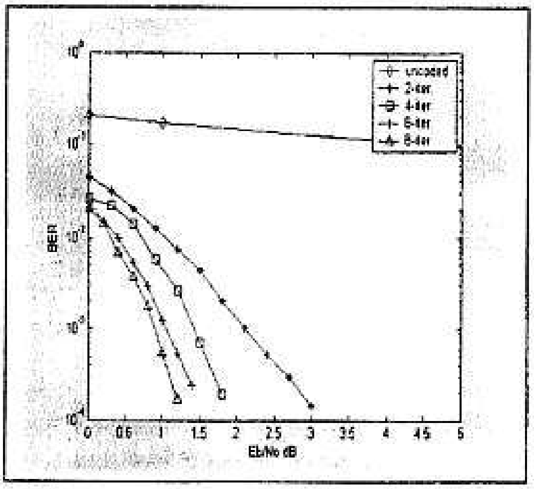


Fig.(12)
Performance of 2antenna diversity with turbo code inRayleigh multipath fading channel at channel coh. time 0.0045 sec. with rate 1/3 ,transfer func [1,7,5]$_2$frame length 5000 bits.

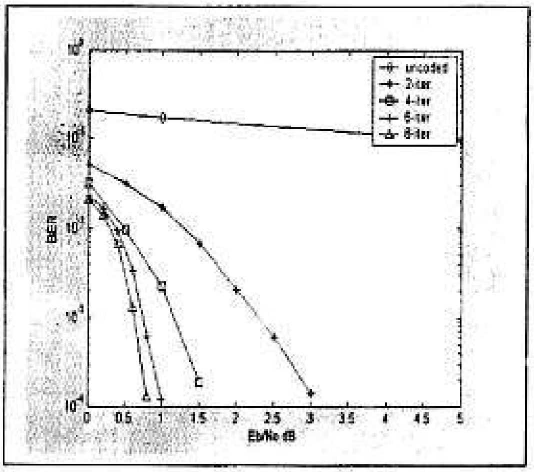


Fig.(13) Performance of 2 antenna diversity with turbo code in Rayleigh multipathfading channel at channel cohe. time 0.0045 sec. with rate 1/3 , transfer func. [1,7,5]$_2$, frame length 10000 bits.

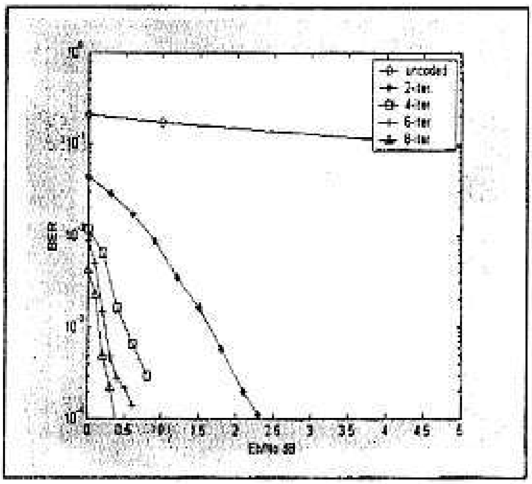


Fig.(14)Performance of 2 antenna diversity with turbo code in Rayleigh multipath Fading channel at channel cohe. time 0.0045 sec. with rate 1/3,transfer func. [1,11,15]$_2$, frame length 5000 bits.

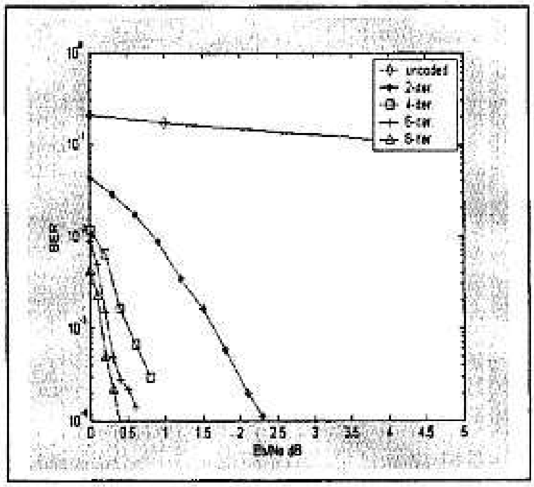


Fig.(15) Performance of two antenna diversity with turbo code in Rayleigh multipath fading channelat channel coherence time 0.0045 sec. with rate 1/3,transfer function $[1,11,15]_2$, frame length 5000 bits

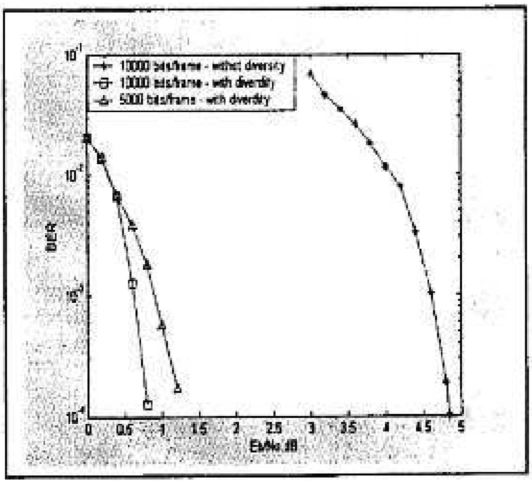


Fig.(16) Performance turbo code in Rayleigh multipath fading channel at channel coherence time 0.0045 sec. with rate 1/3, ,transfer function $[1,7,5]_2$

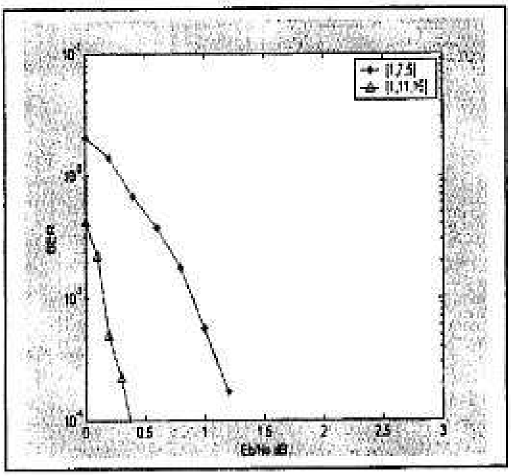


Fig.(17) Performance turbo code in Rayleigh multipath fading channel at channel coherence time 0.0045 sec. with rate 1/3, frame length 5000 bits