SIMULATION AND ANALYSIS PERFORMANCE OF TURBO CODES AND CONVOLUTIONAL CODES USING BPSK MODULATION TECHNIQUE IN WCDMA ENVIRONMENT

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Abstract - **This project illustrates the analysis performance of BPSK modulation between Convolutional Code and Turbo Code in WCDMA by using simulation technique. In this project, the WCDMA system is considered and the performance of both codes is investigated. Turbo Code and Convolutional Code are use to encode and decode the digital signal of the signal before modulation and after modulation process. The main objective is to compare the performance between both codes for digital communication system. The analysis performance is evaluated by means of bit error rates comparison of BPSK modulation between these codes in AWGN channel for WCDMA applications. This project is simulated by using MATLAB version 7.6.**

Keywords – **Additive White Gaussian Noise (AWGN), Binary Phase Shift Keying (BPSK), Bit Error Rate (BER). Convolutional Code, Turbo Code, Wideband Code Division Multiple Access (WCDMA)**

I. INTRODUCTION

A. Error Control Coding

Error control schemes are a fundamental component of every digital communications system. Channel coding is accomplished by inserting controlled redundancy into the transmitted digital sequence, thus allowing the receiver to perform a more accurate decision on the received symbols and even correct some of the errors made during the transmission.[3]. Their efficiency is measured in terms of the degree of error correction they provide. Choosing an optimum scheme is a challenging task. The choice depends, among other factors, on the type of application and its design considerations. Typical error control schemes used for continuous transmission include convolutional codes, interleaving, concatenated convolutional and block codes, and soft-decision decoding, whereas a combination of block coding and automatic repeat request (ARQ) is used for bursty data, and packet transmissions [4]. Concatenated encoder or decoder schemes involving Reed-Solomon and convolutional codes are used in most of the satellite systems. In 1948, Claude E. Shannon proved the theoretical existence of good error-correcting codes that allow data to be transmitted virtually error-free at rates up to the absolute maximum capacity (usually measured in bits per second) of a communication channel, and with surprisingly low transmitted power.

However Shannon's work left unanswered the problem of constructing such capacity-approaching channel codes. This problem has motivated intensive research efforts during the following four decades, and has led to the discovery of turbo codes. Turbo codes are one of the most powerful and recent forward error correction (FEC) coding schemes. They are being considered extensively for deep space and next-generation mobile radio communications. Turbo codes are known to be such very powerful codes achieving performance close to the Shannon bound on theoretical AWGN channel [5,6].

B. Turbo Code

Turbo code was first introduced by Berrou, Glavieux, and Thitimajshima in 1993 as in [4]. The particular turbo coding scheme is generally referred to as a parallel concatenated turbo-code. A parallel concatenated convolutional coding scheme consists of two constituent systematic convolutional encoders separated by an interleaver. The information bits at the input of the first encoder are scrambled by the interleaver before entering the second encoder. The global turbo code is built by applying the two constituent RSC codes to interleaved versions of the same information sequence u to be transmitted. In order to do this a pseudo-random interleaver is used: it realizes a random permutation of the latter input sequence. In other words, the two constituent encoders are coding the same information sequence u but in a different order. The codewords of the parallel concatenated code consist of the information bits followed by the parity check bits of both encoders. Parallel concatenated codes (turbo codes), decoded through an iterative decoding algorithm of relatively low complexity, have recently been shown to yield remarkable coding gains close to theoretical limits.

C. *Convolutional Code*

Convolutional code is a type of channel coding which is a practicable method to reduce information rate through the channel and increase reliability. Convolutional coding is applied to the multicast modulation system to provide better efficiency. This goal is achieved by adding redundancy to the information signal that produced a longer signal bits. It is distinguishable at the output of the channel. Convolutional code may be termed as (n,k,m) code where k is the number of bits taken into encoder, n is the number of bits output from the encoder and m is the maximum number of shift register stages in the path to any output bit. The code rate (k/n) used in this paper is 1/2 and the constraint length is 7.

D. *Binary Phase-Shift Keying (BPSK)*

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and they are on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes serious distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications when bandwidth is limited. This way of representing a bit stream by changing the bit changes the sign of the transmitted signal is known as *binary phase shift keying* and abbreviated BPSK. The name comes from concisely expressing this popular way of communicating digital information. The word "binary" is clear enough (one binary-valued quantity is transmitted during a bit interval). Changing the sign of sinusoid amounts to changing or shifting the phase by π (although we don't have a sinusoid yet). The word "keying" reflects back to the first electrical communication system, which happened to be digital as well: the telegraph.

II. SCOPE OF WORK

This project is focused on the study of identifying the performance and development of BPSK modulation using Turbo code and Convolutional code in WCDMA environment. The third generation of mobile communication systems will offer different services, going from voice transmission to high rate packet data transmission. The latter service will work at a very low bit error rate (BER) and requires therefore a powerful channel coding. In this project, turbo code and convolutional code are being used to encode and decode the signal. The performance between both codes for BPSK modulation in AWGN channel is being analyzed. This analysis is being done since the performance of turbo codes are known to be such very powerful codes achieving performance close to the Shannon bound on theoretical AWGN channel. Before implementation of this project, several important tasks must have been done to make sure that the objective of this project could be achieved. Theory of communication must be well acknowledged by doing some literature review on digital communication system especially for modulation technique of BPSK by using both turbo code and convolutional code. Besides, a study of MATLAB programming is very important to design the desired program to run this simulation project.

III. METHODOLOGY

Figure 1 shows the program flow chart for the simulation process. The program start with generating input binary signal to be transmitted. In this project, for turbo code, the data frame sizes which consist of information bits plus tail bits equal to 1024 for WCDMA application is being generated. The simulation process carried out for Turbo code is formed by using number of bits, n=7 while constraint length, K=5. Then, turbo code is used to perform the encoding process. After that, the signal is being modulated using BPSK modulation in Wideband Code Division Multiple Access (WCDMA) to convert the digital signal to analog signal before transmitting. Then the analog signal is added with Additive White Gaussian Noise (AWGN) at the air interface. At the receiver, demodulation process will convert back the analog signal to digital signal. The signal will be decoded using the turbo Log-MAP decoder. After that, the output bits will be compared with the input bits to compute the bit error rate performance for turbo codes. The bit error rate by using turbo code will then be compared with convolutional code so that the analysis performance of both codes could be done. For convolutional code, the code rate (k/n) used is 1/2 and the constraint length is 5. The simulation of convolutional code also been done in AWGN noise channel so that both codes will experience the same noise.

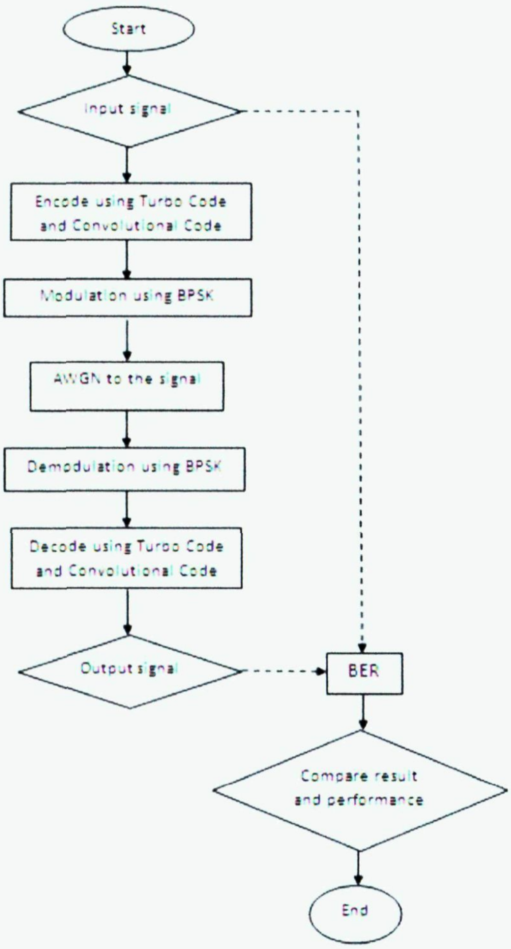

Figure 1: Program flow chart for the simulation process

TABLE 1
SIMULATION PARAMETERS FOR TURBO CODES AND CONVOLUTIONAL CODES

Types of Coding	Constraint Length	Code Rate	Modulation	Data Frame Size
Turbo	5	½	BPSK	1024
Convolutional	5	½	BPSK	1024

A. Simulation Result

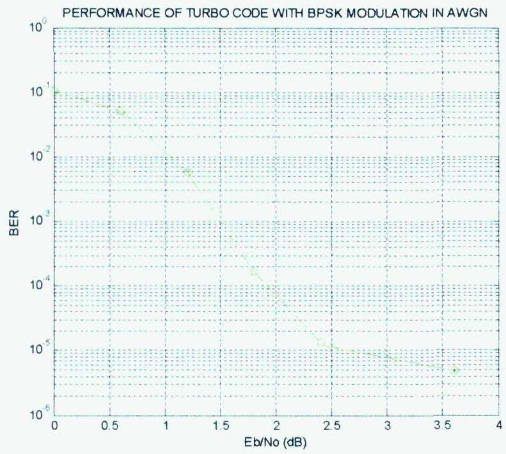

Figure 2: Performance of Turbo Codes with BPSK modulation in AWGN channel

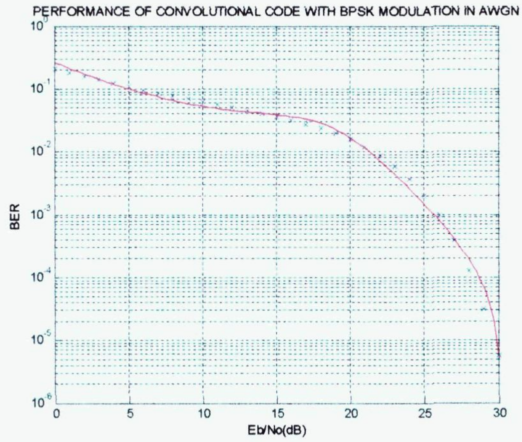

Figure 3: Performance of Convolutional Codes with BPSK modulation in AWGN channel

IV. RESULT AND ANALYSIS

The performance of Turbo code and Convolutional code with BPSK modulation in AWGN channel are studied through MATLAB simulation. The data frame sizes of 1024 information bits plus tail bits are chosen which is suitable for WCDMA applications. Constraint length for Turbo code equal to 5 is the most suitable because for K greater than 5, the BER is slightly worst at the first decoding step and the feedback decoding is inefficient to improve the final BER [6].

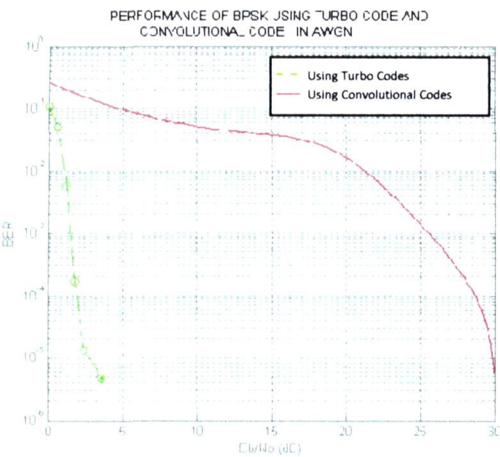

Figure 4: Performance of BPSK using Turbo Codes and Convolutional Codes in AWGN

B. Tabulated Result

TABLE 2
COMPARISON OF Eb/No FOR TURBO CODES AND CONVOLUTIONAL CODES

Value	Eb/No (dB)				
BER	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
Using Turbo Code	0	1.1	1.5	1.8	2.6
Using Convolutional Code	5	22	26	29	30

In Figure 2 and 3, Bit Error Rate (BER) is computed with respect to signal to noise ratio Eb/No where Eb is the energy received per information bit and No is the noise density. The performance for both Turbo code and Convolutional code with Binary Phase-Shift Keying (BPSK) modulation in an Additive White Gaussian Noise (AWGN) channel could be analyzed. It can be seen that Turbo code produced better performance due to lower value of bit error rates compared to Convolutional code. In Figure 2, it is observed that the BER curve is very steep. It shows that turbo code will decrease BER rapidly from low value to high value of signal strength of Eb/No. For example, at BER equal to 10^{-5}, Eb/No for Turbo code equal to 2.6 dB while for Convolutional code, Eb/No is about 30 dB. Shannon limit for a binary modulation with R=1/2, is $Pe=0$ (several authors take $Pe=10^{-5}$ as a reference) for Eb/No=0 dB [6]. With this Turbo code, the performance is at 2.6 dB from Shannon's limit. Therefore, the performance of Turbo code is close to Shannon limit.

V. DISCUSSION

From the comparison performance for both Turbo Code and Convolutional Code, it is proved that Turbo Code will give the better performance with BPSK modulation in AWGN channel. The excellent performance of Turbo Code is due to the main fundamental concepts which it is based on the concatenated coding and iterative decoding. As it can be seen, the global Turbo Code is built by applying the two constituent Recursive Systematic Convolutional (RSC) codes to interleaved versions of the same information sequence to be transmitted. With this Turbo Code, a parallel concatenated RSC codes are being used. So, as stated in [6], it performed better than Non Recursive Systematic Code (NSC) code which is used by Convolutional Code at SNR with high code rate.

Besides, the interleaver which is being used by Turbo Code also contributes to its good performance. This is because the interleaver uses square matrix and bits are written row by row and read pseudo-randomly. This will spread the residual error blocks of rectangular form and give the greater free distance as possible to the parallel concatenated code. [6]

For decoding process, turbo decoding is done in an iterative algorithm based on the maximum a posteriori (MAP) principle. The turbo decoder produces extrinsic information for the systematic bits, which are used in the next iteration. Performance of a turbo decoder also depends on the number of iterations since higher number of iterations will give better BER performance. In this project, log-MAP decoding algorithm with 5 iterations is being used. This is because higher iterations will cause latency and energy consumption. [11] The performance of turbo codes was influenced by many factors such as the number of iterations, constraint length, interleaver design and puncturing. [12, 13]

VI. CONCLUSION

The objective of this project is accomplished. All simulation process is being done effectively using MATLAB. The result shows that performance of BPSK modulation using Turbo Code is better than Convolutional Code in AWGN channel for WCDMA application. From the error performance results, it is evident that turbo codes are suitable for the wireless communications applications under consideration with mentioned requirements. The major disadvantage pertaining to additional complexity and delay has to be dealt with in order to achieve the desired objectives. However, this code is still significantly better than Convolutional code, which can meet this delay requirement [15]. In WCDMA environment, Turbo code is expected for the system of high rate data transmission in view of performance and hardware complexity compared to Convolutional code. Turbo decoder also has better BER performance at high E_b/N_0 than conventional Viterbi decoder which is very useful for WCDMA uplink layer. The high rate data transmission in WCDMA environment will require a powerful channel coding with a very low bit error rate such as Turbo code. The table below shows the advantages, disadvantages and applications of Turbo Code and Convolutional Code in WCDMA.

TABLE 3
COMPARISON BETWEEN TURBO CODES AND CONVOLUTIONAL CODES

Types of Coding	Turbo Code	Convolutional Code
Advantages	-Higher network data capacity -Power efficiency -Lower bit error rate	-Shorter delay -Low complexity
Disadvantages	-Higher delay -High complexity	-Lower network capacity -Higher bit error rate
Applications	-cellular (UMTS/HSDPA) -satellite (DVB) -broadband wireless (WiMAX) -deep-space exploration	-wireless 3G -satellite (DVB)

VII. FUTURE WORKS

Turbo Code is proved to have good performance in AWGN channel. Other future research will include:

- The effect of noise and multipath fading channels such as Rayleigh Fading, Rician Fading and Nakagami Fading channels on the performance of Turbo Code.
- The performance of Turbo Code with other modulation techniques such as Differential Quadrature Phase Shift Keying (DQPSK), 8PSK and 16PSK and QAM.
- The performance of Turbo Code with various interleaver designs.

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