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Evaluation of Turbo Codes Varying Modulation on Turbo Codes Using BCJR Algorithm

[1]Manjeet Kaur

[1]PG Student, Dept. of ECE, Guru Nanak Dev University, regional campus, Jalandhar, Punjab, India

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Abstract: **Turbo codes are the most powerful and widely adopted error correcting codes in several communication applications. Turbo codes are used to detect and correct the error during transmission. Turbo codes were the first used codes that came close to the Shannon limit using reasonable effort. Firstly, the codes are interleaved. To reach a solution, the decoder can be divided into several simple decoders that exchange the information about the decoded bits. This paper presents the performance of turbo code system using BCJR algorithm under AWGN channel using different modulations. The performance results for the turbo code system through matlab simulation are considered which shows that the approximation to Shannon capacity can be achieved. The performance results for the turbo code system are obtained through matlab simulation channel.**

Keywords: **Encoder, Decoder, BCJR, BER.**

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1. INTRODUCTION

The objective of communication systems is to optimally utilize the scarce spectrum and the energy required to transmit a unit information bit while maintaining a certain performance measure in terms of bit error rate. Turbo codes achieve performances very close to the channel capacity which is the absolute physical limit as proved by Shannon. The information bits are coded using standard Turbo code algorithms then grouped into k-bit symbols to be modulated using the more spectrally efficient modulation.

1. *Turbo Encoder*

There are number of classes of turbo codes that make use of different component named as encoders, interleavers , input/output ratios, and puncturing patterns. The example encoder implementation defines the basic design of parallel turbo codes and also defines a classic turbo encoder [1]. Here three sub-blocks of bits are sent in the encoder implementation. There is different sub-block in the encoder. The first is the m-bit block of payload data. The second is n/2 parity bits for the payload data which is calculated using a recursive systematic convolutional code (RSC code) and the third one is n/2 parity bits for a known permutation of the payload data which is also calculated by using an RSC convolutional code. Therefore there are two redundant but different sub-blocks of parity bits which are sent with the payload. With a code rate of m/ (m + n), the complete block has m + n bits of data. A device named as interleaver calculates the permutation of the payload data [2]. According to Hardware, the turbo-code encoder consists of two identical RSC coders, C_1 and C_2, as shown in the figure that are connected to one another using a concatenation scheme which is called as parallel concatenation. In the figure it is shown that M is a memory register. The interleaver force input bits d_k to appear in different sequences [3]. At first iteration because of the encoder's systematic nature the input sequence d_k appears at both outputs of the encoder, x_k and y_{1k} or y_{2k}.If the encoders C_1 and C_2 are used in n_1 and n_2 iterations respectively then their rates are respectively equal to

$$R1=n1+n2/2n1+n2 \quad (1)$$

$$R2=n1+n2/n1+2n2 \quad (2)$$

2. Turbo Decoder

The decoder is designed in a same way as the encoder. In this the two elementary decoders are interconnected to each other serially not in parallel as in case of decoder. The decoder DEC1 operates on lower speed R1 and for encoder C1 and follows a soft decision that causes delay L1.Same is the case for decoder DEC2 which cause a delay L2. To scatter error bursts that are coming from DEC1 output an interleaver is installed between the two decoders [4]. DI block is a demultiplexing and insertion module. It works as a switch which is redirecting input bits to DEC1 at one time and to DEC2 at another. It feeds y1k and y2k inputs in OFF state with padding bits that are zeros.

3. BCJR Algorithm

For Forward error correction codes and channel equalization , BCJR algorithm IS implemented by SUSA framework. The BCJR algorithm is an algorithm for maximum a posteriori decoding of error correcting codes that are defined on trellises whose principal is based on convolutional codes[5]. The algorithm is named after its four inventors named as Bahl, Cocke, Jelinek and Raviv. This algorithm is critical to modern iteratively-decoded error-correcting codes including turbo codes and low-density parity-check codes. The output of this algorithm (soft output) gives the probability of each received bit of information to be one or zero**.** There are various steps involved in BJCR algorithm are:

- Compute Forward probabilities α.
- Compute backward probabilities β.
- Compute smoothed probabilities based on other information (i.e. noise variance for AWGN, bit crossover probability for Binary symmetric channel).

4. Interleavers and Interleaving

Turbo codes with short block length perform adequately only if they have appropriate interleaver design. There performance is critically dependent on interleavers we use. The criteria used in design of interleaver are:

a. Distance spectrum of code.

b. The correlation between the information input data and the soft output of each decoder corresponding to its parity bits.

Interleaving is a process in which data bits are arranged in a random or one of the deterministic format. There are many types of Interleavers which we can use in our turbo codes can be classified into two types [6].

a. Block Interleaving

b. Convolutional Interleaving

II. SIMULATION SETUP

The standard description of the system is defined in the block diagram, where each block represents a signal processing operation. WCDMA standard parameters are used for this investigation and the output bits of the turbo encoder are then modulated using a Binary Phase Shift Keying (BPSK) modulator and then BCJR algorithm is used at the decoder side [10]. Each block contains the algorithm and equations needed to implement the block functions within the simulation. MATLAB has been used in my thesis

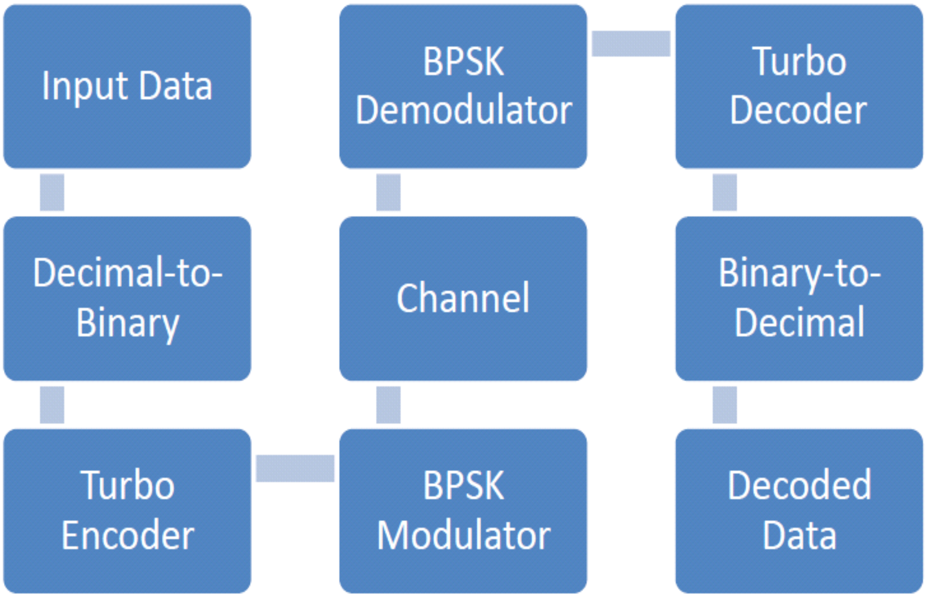

Fig.1. Simulation Model

The whole procedure defines that initially demodulator calculates the bit metrics using the Log Likelihood Ratio. In BPSK, the signals received are directly fed into the turbo decoders. Between the two decoders , decoder I receives the message bits and the corresponding parity bits which are generated by the encoder I and generates an extrinsic information about the systematic bits [10] The extrinsic information is then passed to decoder II after being interleaved. Decoder II uses this interleaved extrinsic information as a priori information along with the systematic information and the corresponding parity bits (generated by the encoder II) to generate its own extrinsic information. This extrinsic information is then deinterleaved and passed back to decoder I. This process involves one iteration. Before starting turbo decoding if we use a soft output demodulator then the decoder I have a priori information about the transmitted data during the first turbo decoding cycle. The process of decoding can have number of iterations. Every iteration improves the BER until we achieve a certain limit. On achieving the certain limit, iterations will not introduce much improvement in BER so a hard decision is made and decoding terminates. Here the BPSK symbols are transmitted through AWGN channels so the BCJR decoders deal with the soft output [11]. It does not give us optimal results, because the iterative BCJR decoding algorithm is used to generate bit metric for BPSK symbols [12]. In BPSK modulation only the extrinsic information is communicated between the two turbo decoders. However, when using PPM signals both the systematic information and the extrinsic information must be exchanged between the two decoders. This is because both the parity bit and the systematic bit are used to specify the pulse position [13].

III. RESULTS AND DISCUSSIONS

Comparison of Different Modulation Having AWGN Channel on Turbo Codes Using BCJR Algorithm

A. QAM MODULATION

The use of QAM Modulation leads to reduction of the error rate. It is used in conjunction with Turbo codes to assist in mapping binary bits into QAM symbols. At the transmitter, the structure is similar to a semi-soft mapper but it also includes an added parity generator. The structure at the receiver is totally different. Turbo codes are the powerful error correcting codes over AWGN channels which can be used over Rayleigh fading channels. Turbo decoder like the MAP decoder or the Soft-Output Viterbi Decoder (SOVA). These show substantial gains over other error correcting code

(ECC) methods while using the available bandwidth more efficiently. The simulation showed as much as 6 dB gain over a Reed Solomon (RS) code which is the same rate and using the same modulation for an error rate of 10^(−5) . The gains, however, come at an increased computational cost, especially for large interleaver sizes. This method is very complex.

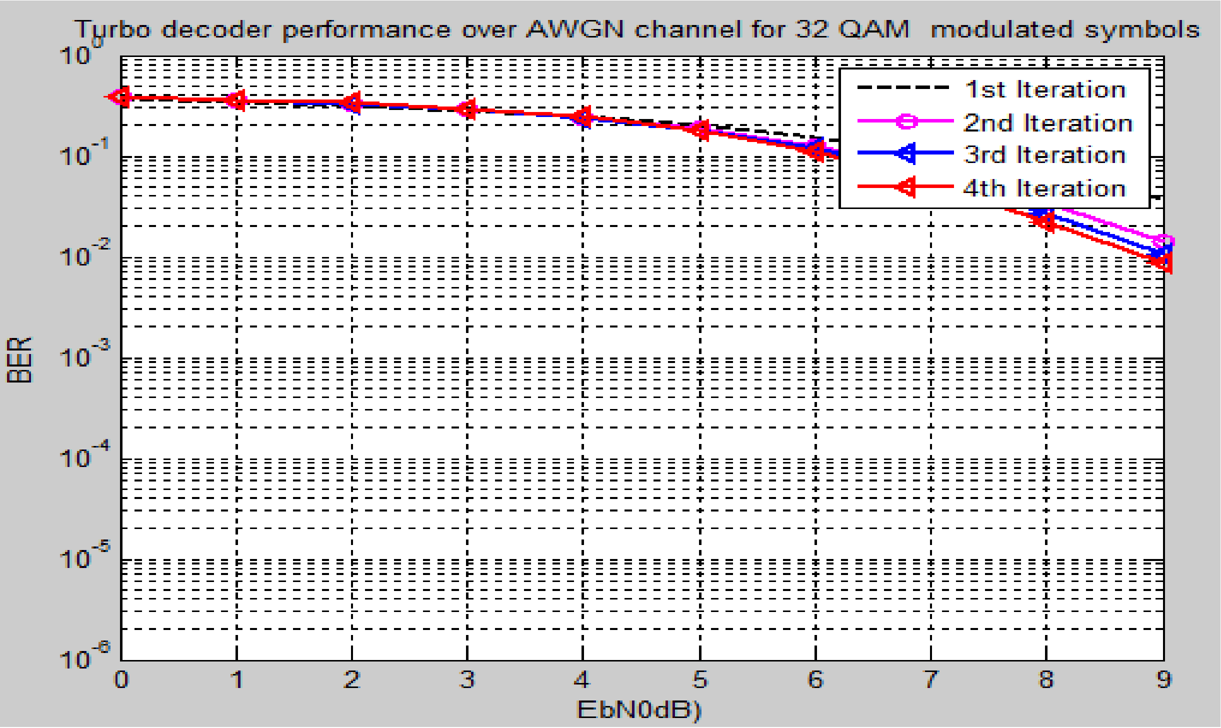

Fig. 2. BER of a system using 32 QAM Modulation

From the simulation it is clear that in order to map turbo codes to QAM we need

1.) Development of symbol based Turbo codes with reduced complexity decoding algorithms.

2.) Development of efficient algorithms for decoding binary or symbol based Turbo codes.

3.) Improving the block-based Turbo codes and their corresponding decoding algorithms.

4.) Finding Turbo codes that perform well for short interleaver sizes.

5.) Combining Turbo codes with MIMO systems and evaluating their performance.

B.) PSK MODULATION

The BER performance of the Simplified-Log-MAP algorithm is compared to that of the MAP, Log-MAP, and MaxLog-MAP algorithms. The simulation results for a Turbo code with 1/2 code rate, N =1024, rn = 3, and the feedback and feed forward generator polynomials equal to I 5oct and I 7oct respectively. Four iterations are used for the simulations and the results for QPSK are shown in figures. We can see from the results, the Log-MAP decoding algorithm has similar performance to the MAP algorithm .The performance loss for the MAX-Log-MAP is being compared to the MAP algorithm which is from 0.2 dB. For QPSK. The SNR requirement for a given BER is higher at larger constellation sizes; therefore, the approximation of the logarithm has more significant effect on the BER performance of the MAX-Log-MAP algorithm. The Simplified Log-MAP has negligible performance degradation as compared to the MAP algorithm for QPSK constellation. It can be concluded from the above results that Simplified Log-MAP algorithm together with the new hardware implementation are an appropriate choices for implementing Turbo decoders in practice without any significant loss in performance. In this we have fed back data for calculating output 5 times and we see that after each iterations error is reducing as shown by a red line which is at 5th iteration and this type of modulation reached the error of 10^ (-5) at Eb/No of 7db which show that errors are becoming more compare to 4, 8, 16 PSK.

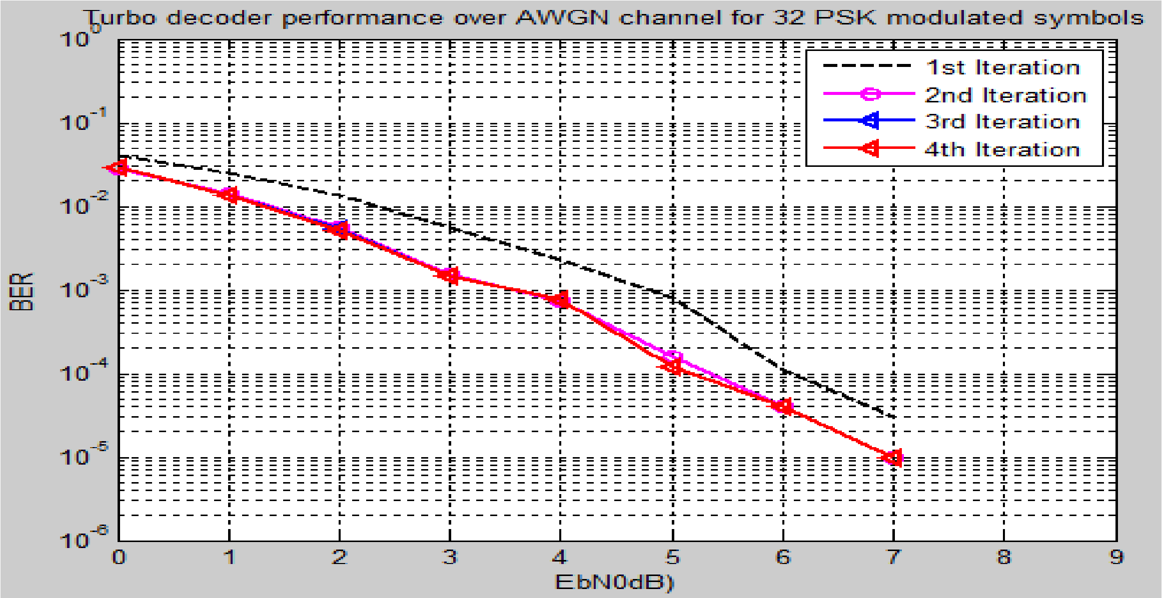

Fig. 3. BER of a system using 16 PSK Modulation

C.) DPSK MODULATION

In this we have fed back data for calculating output 5 times and we see that after each iterations error is reducing as shown by a red line which is at 5th iteration and this type of modulation reached the error of 10^ (-3.9) at Eb/No of 9db which show that errors are becoming less compare to 4, 8 and 16 DPSK.

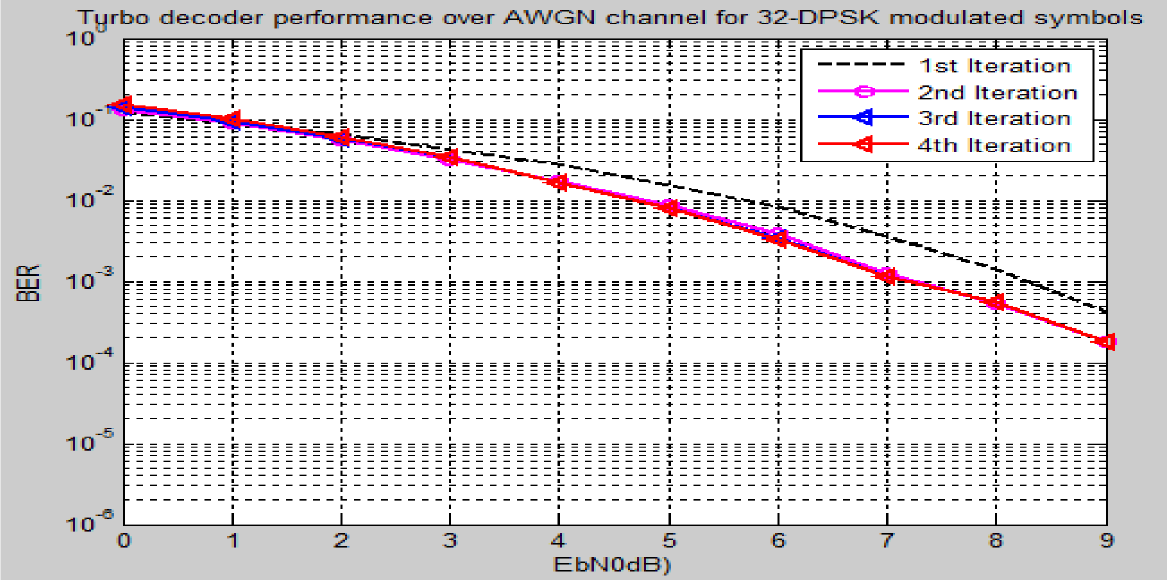

Fig. 4. BER Vs EbN0

D.) BPSK MODULATION

The figure show the Bit Error Rate with respect to the Signal to Noise Ratios which are in dB. The figures show that the turbo codes are improving the BER up to certain limit after which further iterations become useless. Another important observation is that the first turbo decoding iteration improves the BER more for PPM symbols, however, further decoding iterations applied on PPM symbols result in no improvement. In other words, the waterfall region in figure is steeper from the first iteration decoding of the received data.

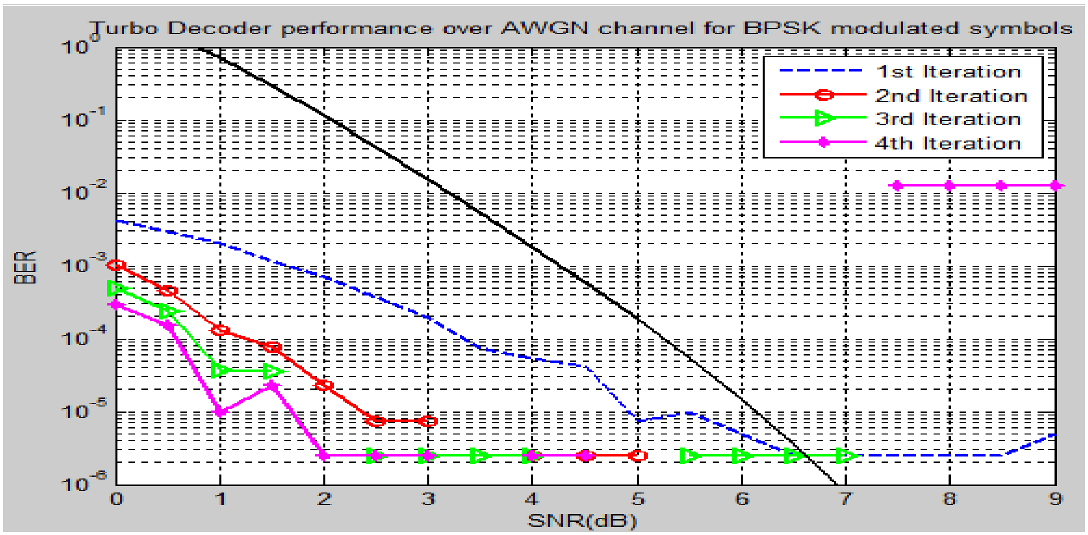

Fig.5. BER Vs SNR using block interleaver

The results also explain the efficiency of the proposed design. The first iterations are capable of improving the BER; further iterations do not improve much. The improvements can also be made in two fields as the iterative turbo decoding algorithm can be modified to adjust with the soft demodulation technique and to improve demodulator technique that is capable of making a soft decision about the received bits.

IV. CONCLUSION

BER of a system using 32-QAM modulation shows that in order to calculating output 5 times and we see that after each iterations error is reduced which is at 5th iteration and this type of modulation reached the error of 10^(-2) at Eb/No of 9db which is more error than 8 and 16 QAM modulation we can calculate output 5 times and we see that after each iterations error is reducing which is at 5th iteration and this type of modulation reached the error of 10^(-5) at Eb/No of 7db which show that errors are becoming more compare to 4 ,8, 16 PSK. Finally to calculate the BER of DPSK modulation to calculate output 5 times we can see that after each iterations error is reducing which is at 5th iteration and this type of modulation reached the error of 10^(-3.9) at Eb/No of 9db which show that errors are becoming less compare to 4 ,8 and 16 DPSK. All these can reach approximately equal to Shannon capacity.

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AUTHOR’S PROFILE:

Manjeet kaur received degree of B.tech in Electronics and communication engineering from khalsa college of engineering and technology, Amritsar She is pursuing M.tech in Electronics and communication engineering from Gndu regional campus, Jalandhar. Her research area is wireless communication.

Harmandar kaur received degree of M.tech in Electronics and communication engineering and is a gold medalist in it.She is pursuing Phd in the same field.She is specialized in optical fiber communication and wireless communication. She has published 14 papers.She is a asst. professor in guru nanak dev university,regional campus,jalandhar.