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Evaluation of Turbo Codes Varying Various Parameters Using BCJR Algorithm

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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. 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.The BPSK techniques are used along with different interleavers and good BER is achieved under random interleaver.

KEYWORDS: BCJR, BER, Decoder,Encoder.

I. 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

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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:
   a. Compute Forward probabilities α.
   b. Compute backward probabilities β.
   c. 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

5. **Block Interleaver-**A block interleaver is a type of interleaver which accepts a set of symbols and rearranges them without repeating any of the symbols in set. The number of symbols in each set is fixed for a given interleaver. Each set f interleaver operates in an independent way irrespective of other sets [7]. An interleaver arrange the symbols according to mapping and on the receiver side a deinterleaver is present which uses inverse mapping to restore the original sequence of symbols. The interleaver/Deinterleaver pair is useful for reducing errors caused by burst error in communication system.
   a. Helical Interleaver-This is a special type of interleaving which support a special case of convolutional interleaving that fills an array with symbols in a helical fashion and empties the array row by row [8]. To configure this interleaver, use the Number of columns of helical array parameter to set the width of the array.

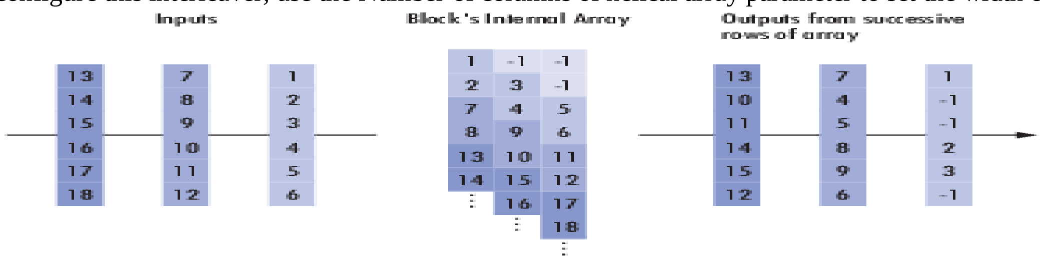

Fig.1. Helical interleaver

   b. Helical Scan Interleaver-The Matrix Helical Scan Interleaver block performs block interleaving by filling a matrix with the input symbols row by row and then sending the matrix contents to the output port in a helical

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fashion. Helical fashion means that the block selects output symbols by selecting elements along diagonals of the matrix. The number of elements in each diagonal matches the Number of columns parameter, after the block wraps past the edges of the matrix when necessary. The block traverses diagonals so that the row index and column index both increase. Each diagonal after the first one begins one row below the first element of the previous diagonal [9]. The Number of rows and Number of columns parameters are the dimensions of the matrix that the block uses internally foits computations as shown in figure.

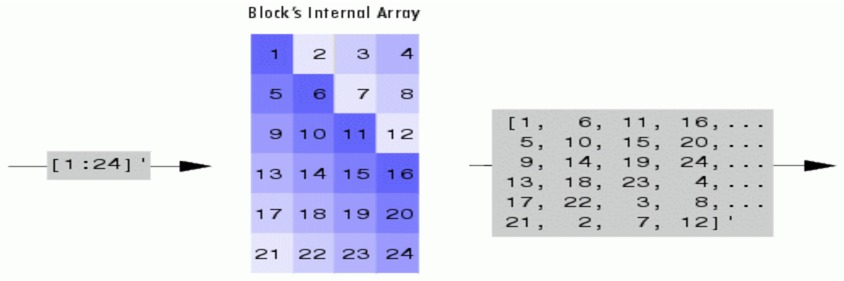

Fig.2. Helical Scan interleaver

III. 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

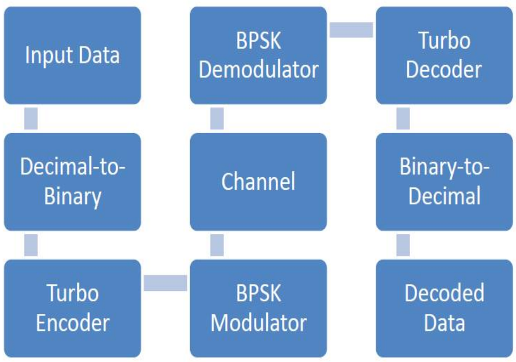

Fig.3. Simulation model

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

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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 INTERLEAVERS HAVING AWGN CHANNEL AND BPSK MODULATION USING BCJR ALGORITHM

The fig.4 shows 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.

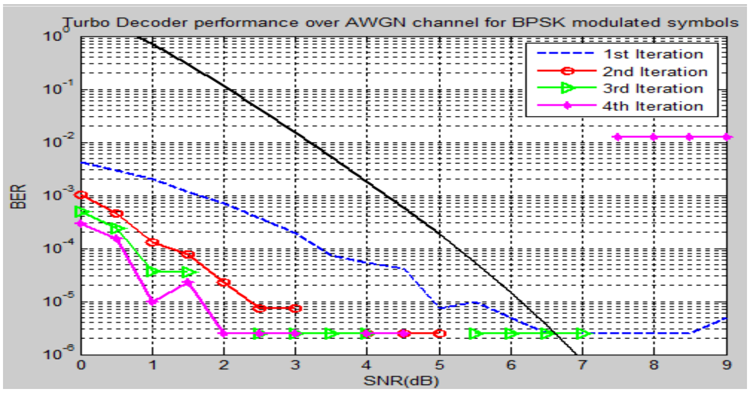

Fig.4. BER Vs SNR using block interleaver

The results also explain the efficiency of the proposed design. The fig.5 shows that 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.

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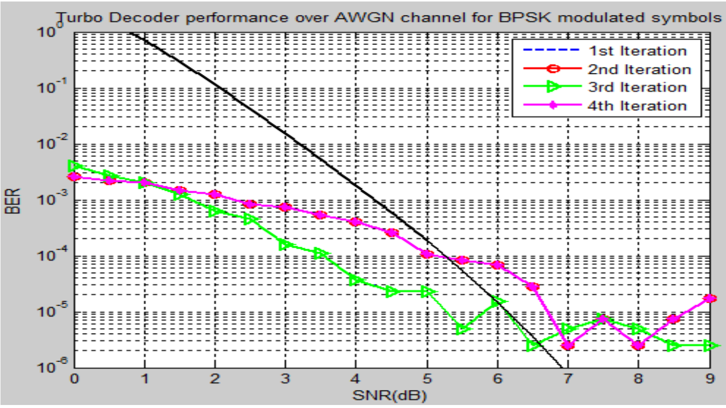

Fig.5. BER Vs SNR using random interleaver

The soft decision is then passed to the turbo decoders that run the BCJR algorithm to do an iterative decoding of the received data. The results obtained illustrate the efficiency of the proposed design. Fig 6 shows that the first iterations are capable of improving the BER. The improvements can also be made in the iterative turbo decoding algorithm to adjust with the soft demodulation technique and to improve the soft demodulation technique to improve the performance of the turbo BCJR decoders.

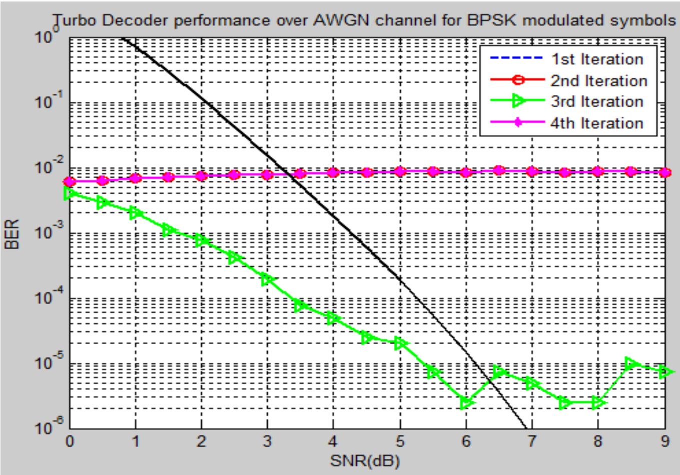

Fig.6. BER Vs SNR with helical interleaver

From the above results it is clear that good BER of 10^{-6} can be achieved at 5dB for random interleavers respectively.

IV. CONCLUSION

We can conclude that BER of 10^{-6} can be achieved at 2dB, 5dB, 6dB for block, random and helical interleavers respectively. we see that after each iterations error is reduced which is at 5^{th} iteration and this type of modulation reached the error of 10^{-2} at Eb/No of 9db and we see that after each iterations error is reducing which is at 5^{th} 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

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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.

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