Optimum Interlever Design For Turbo Codes

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ABSTRACT
Recently new class of codes, called Turbo codes has emerged out as a popular choice for third generation wireless system & they are used in wireless applications where higher and higher speeds are preferred . This is a new and very powerful error correction technique which out performs all previous coding schemes. New digital communication applications, such as multimedia, require very powerful error correcting codes that deliver low error rates while operating at low to moderate signal-to-noise ratios (SNRs). Turbo codes have reasonable complexity and can achieve very low error rates if a proper interleaver design is in place. The use of well-designed interleavers result in very low error rates, especially for medium to long interleavers where turbo codes offer the greatest potential for achieving high minimum distance values. It can be used in any communication system where a significant power saving is required or the operating signal–to–noise ratio (SNR) is very low

The interlever design plays a significant role in the performance of Turbo codes, particularly for higher signal-to-noise ratio. The performance of Turbo codes with short block length depends critically on the interlever design. The design criteria of an interlever depends on two major parameters one is the distance spectrum of the code & second correlation between the information input data & the soft output of each decoder corresponding to its parity bits. This paper describes the classification, roles of the interlever, effect of frame length, effect of puncturing on the performance of interlever.

Keywords
Interlever , Puncturing , frame length , signal-to-noise ratio, bit error rate.

1 INTRODUCTION
Turbo codes were first introduced by Berrou, Glavieux and Thitimajshima and found that bit error rate (BER) performance of 10^{-5} approaches at an bit energy/ noise (Eb/No) of 0.7dB at only half code rate. Turbo codes are special class of concatenated codes and are consist of inner and outer codes. Turbo encoder consist of two encoders separated by a device called interlever[1][13].

Turbo coding exhibit an excellent coding gain results, approaching Shannon's predictions. The information sequence is encoded twice, with an interleaver between the two encoders serving to make the two encoded data sequences approximately statistically independent on each other. Often half rate Recursive Systematic Convolutional (RSC) encoders are used, with each RSC encoder producing a systematic output which is equivalent to the original information sequence, as well as a stream of parity information. The two parity sequences are punctured before being transmitted along with the original information sequence to the decoder. This puncturing of the parity information allows a wide range of coding rates to be realized, and often half the parity information from each encoder is sent along with the original data sequence this results in an overall coding rate of half. An interleaver is a device that rearranges the ordering of sequences of symbols in a deterministic manner .and permutes symbols according to a mapping. A corresponding deinterleaver uses the inverse mapping to restore the original sequence of symbols. Interleaving and deinterleaving can be useful for reducing errors caused by burst errors in a communication system. The major challenge with Turbo codes is the inherent delay with interlever & the iterative decoding algorithm. Puncturing increase the convolutional rate . In this paper the effect of interleaving and puncturing on Turbo codes performance are discussed. The most critical part in the design of Turbo codes is the interlever. There are two main parameters in the design to be focus i.e. size and map. The size of the interlever plays an important role in the trade off between performance and time delay since both are directly proportional to the size whereas the map of the interlever play role in setting code performance. Turbo codes have superior performance over convolutional code when length of the interlever is very large (several thousands bits). For large block length/size, random interlever perform better. The proposed interlever reduce hardware reqirements for interleaving & de-interleving operations. For short interlevers the performance of Random interlevers for Turbo codes degrades for BER is lower than convolutional codes having similar complexity. Selection of interlevers has significant effect on the performance of Turbo codes for short block length interlevers. For applications like voice, delay is the important parameters in selection of block of interlevers with acceptable BER performance. Interlever size increases with decoder latency, since the entire code word must be received before decoding can be completed Turbo codes possess an inherent tradeoff between performance and latency. Particularly for higher signal-to-noise ratio, the interlever design plays a significant role in the performance of Turbo codes . In general randomly chosen interlever design have good performance while highly structured interlevers such as the "block interlever" should be avoided .

Key role of an interlever are to feed the encoders with permutations since generated redundancy sequence is a function of the particular interlever used & the second role is to shape the weight distribution of the code which control its performance to decide which word of the second encoder will be concatenated with the current word of first encoder. The aim is to produce whole code words with the overall weight as large as possible. Turbo code makes the distribution of the weight more important than minimum distance. The termination of the trellis of both convolutional encoder by properly designing the map of the interlevers to force both encoder to all-zero state with specified memory length [2] [18] [17].

2 TURBO ENCODER

A Turbo code is constructed as shown in Fig 2.1.The Turbo code consists of two parts, the systematic bits (uncoded information) and a set of parity sequences generated by passing interleaved versions of the information bits through convolutional encoders. The encoders used are Recursive Systematic encoders; also, in most Turbo codes the encoders used are the same (making the Turbo code symmetric), and two sets of parity check bits Pk1 and Pk2 are used, one which is generated from the non-interleaved data sequence, and one which is generated from an interleaved sequence.. The parity bits are usually punctured in order to raise the code rate too. The data sequence may or may not be terminated, depending on the type of interleaver used . Interleaver design considerations and the performance of the turbo codes is dependent on different parameters like the frame length, number of iterations, selection of different encoders and use of different interleavers. Interleaving is basically the rearrangement of the incoming bit stream in some order specified by the interleaver module [3] [9].

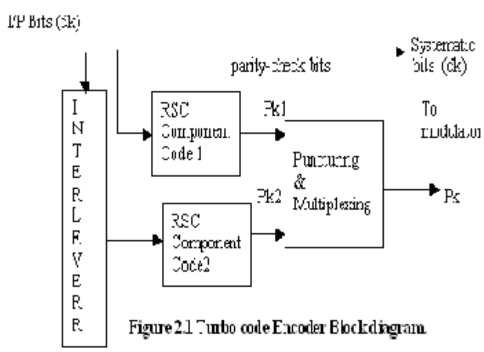

Figure 2.1 Turbo code Encoder Blockdiagram.

2.1 Classification of interlever

2.1.1 BLOCK INTERLEVER

Block interlever writes in column wise from top to bottom and left to right and reads out row wise from right and top to bottom. Figure 2.2 shows a block interlever .It writes in [00…101……0…101…01] and reads out [01…100…1…1…000…11].

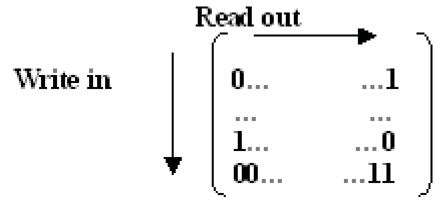

Fig 2.2 Block Interlever

2.1.2 PSEUDO-RANDOM INTERLEVERS

The Pseudo-Random interlevers maps the input sequence according to the fixed permutation order. Figure 2.3.shows pseudo–random interlever with input sequence length L=8.

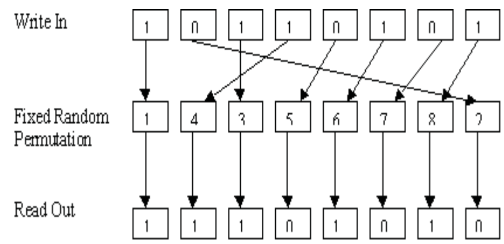

Figure 2.3. A psuedo-random interlever

2.1.3 CIRCULAR- SHIFTING INTERLEVER

The permutation p of the Circular- Shifting Interlever is defined by

$P(i) = (a i + s) \bmod L$

Satisfying $a < L$, a is relatively prime to L, and $s < L$

Where i is the index, a is the step size and s is the offset.

Figure 2.4. Shows a circular-shifting shifting interlever with L =8, a =3, and s = 0

The interlever writes in [10101001] and reads out [10011000]. The adjacent bit separation is either 3 or 5 due to regularity. It performs a very good job of permuting weight up to 2 of input sequence having low code weight in to weight-2 input of higher codeword weight.

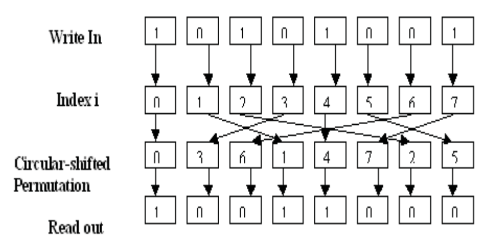

Figure 2.4 Circular-Shifting Interlever

2.1.4 SEMI-RANDOM INTERLEVER:

It is a compromise between random interlever and designed interlever like Block and circular- shifting interlever. A permuting algorithm for semirandom Interlever is given below.

Step 1: Select random integer $i \in [0, L-1]$.

Step 2: Select a positive integer S < √L/2.

Step 3: Compare i with S and see if is lies between - $^{+}$S.

Step4: Go back to step 1 until all L positions have been filled

2.1.5 ODD-EVEN INTERLEVER DESIGN

Odd-even interlever design specially for code rate r=1/2 turbo code. Each information bit has its own coded bits.

2.1.6 OPTIMAL INTERLEVER

Optimal interlever produces very few low weight output coded sequences.

Algorithum:

1. Generate a random interlever.

2. Generate all possible input information sequences.

3. Encode each of the input information sequences and determine the resulting codeword weight, weight distribution of the code.

4. Determine the minimum codeword weight and the number of codewords with that weight [4].

Turbo Code Performance :-

The BER performance of a Turbo code in AWGN channel consists of three main regions: At high SNR, the performance is dominated by the free distance of the Turbo Code and is very close to that predicted by the Union bound. can be shown that this error floor depends heavily on the interleaver used . At low to moderate SNR, there is a sharp drop in BER. At very low SNR, the overall code performance is poor, and the BER is beyond the normal operating region for most communication systems]. The superior performance of Turbo codes over convolutional codes is achieved only when the length of the interleaver is very large, on the order of several thousand bits. For large block size interleavers, most random interleavers perform well. On the other hand, for some applications it is preferable to have a deterministic interleaver, to reduce the hardware requirements for interleaving and de-interleaving operations [5] [6].

2.1.7 THE EFFECT OF THE INTERLEVER

Some of the most important parameters of a good interleaver are one increasing the block size i.e. the size of the interleaver, results in improved performance and .the another interleaver should randomize the input sequence in order to avoid particular low-weight patterns mapping onto themselves, reducing the effective free distance of the resulting Turbo Code. The interlever permutes the frame of information bits in the first dimension prior to their encoding by the encoder in the second dimension, results in to Low weight events occur in only one dimension . Thus interlever can affect both the distances and the multiplicities of error events depends on the choice of the permutation low weight turbo code words produce when the interlever maps low weight information frames that produce low-weight parity in the second dimension . Therefore interlever avoids certain permutations of bit positions .

Turbo code consist of two RSC encoders separated by a device called Interlever. Interlever provides randomness to the input sequence. Interlever shuffles the input sequence and introduce to the second RSC encoder which produce high weight code. The input sequence x produce a low-weight RSC code Sequence C2 for RSC Encoder1. Other RSC Encoder produces a high-weight RSC Code sequence C3 due to induction of interlever through RSC Encoder2.Thus Turbo code's code weight is moderate, combined from RSC encoder1's low-weight code and RSC encoder2's high-weight code shown in fig. 2.5 [7] [4].

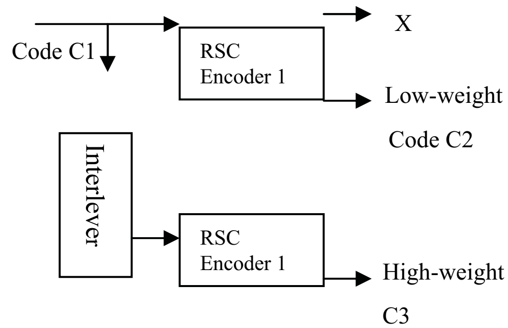

Fig 2.5. Effect of Interlever on the weight of the code

3 EFFECT OF VARYING FRAME LENGTH ON CODE PERFORMANCE

The increase in size of the input frame length has an impact on the interlever size. When size of the interlever increases it adds to the complexity of the design. It increases latency and the power consumption. For many applications such as speech transmission requires coding with short-frame length is desirable since it gives excellent results with Turbo coding having short- frame length. From the plot it is clear that random interlever with long frame length gives better performance where as for block interlever having odd rows and columns with short frame length system gives best results for Turbo codes.

Impact of Various Frame/Interlever size N= 1200,2400,3600,4800,5100 on the performance of Turbo codes for eight iterations and No.of frames=10 for AWGN Channel .for log-map-decoder for AWGN Channel are shown by the following figures3.1,3.2,3.3,3.4,3.5. Shows how the performance of the Turbo code depends on the frame length N used in the encoder. It is observed from the simulation results that as interlever frame/size increases SNR also increases but BER decreases and attained more error floor, thus Turbo code exhibit a better performance when frame length increases. For the larger size interlever, coding rate decreases where as for small size interlever coding rate increases [8].

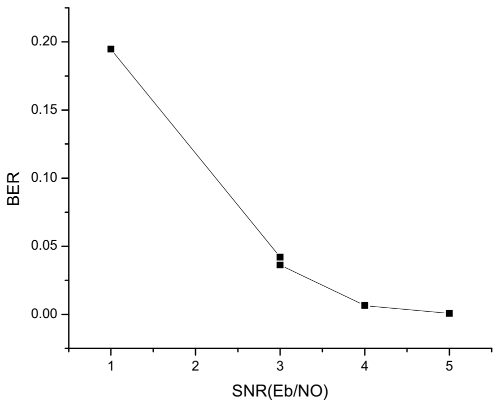

Figure 3.1. Impact of Frame/Interlever size N=1200 on the performance of Turbo codes for eight iterations and No .of frames=10 for AWGN Channel for log-map-decoder

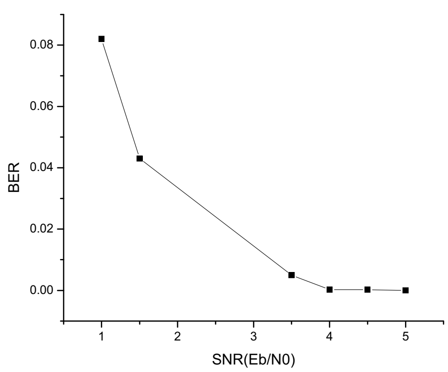

Figure 3.2.Impact on performance of Turbo code for N=2400 frame –length used for eight iterations and No.of frames=10 in AWGN Channel for log-map decoder

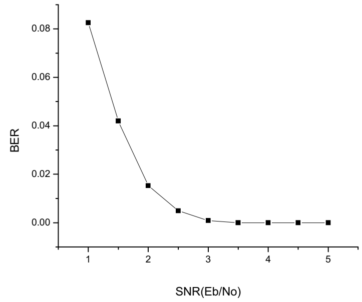

Figure 3.3. Impact of Frame/Interlever size (N=3600)on the performance of Turbo codes for eight iterations and No .of frames=10 for AWGN Channel for log-map-decoder for AWGN Channel .for log-map-decoder

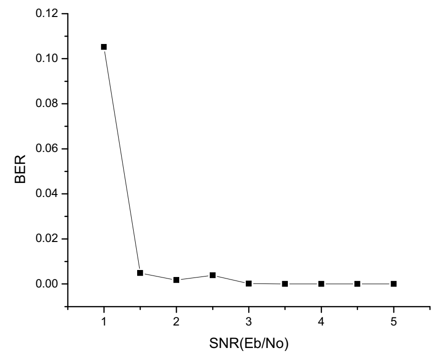

Figure 3.4. Impact of Frame/Interlever size (N=4800) on the performance of Turbo codes for eight iterations and No. of frames=10 for AWGN Channel for log-map-decoder for AWGN Channel for log-map-decoder.

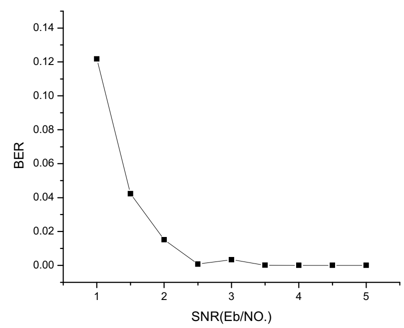

Figure 3.5. Impact of Frame/Interlever size (N=5100) on the performance of Turbo codes for eight iterations and No. of frames=10 for AWGN Channel for log-map-decoder for AWGN Channel for log-map-decoder.

3.1 Effects of Puncturing :-

In a turbo encoder two or more component encoders are used for generating parity information from an input data sequence. In our work we have used two RSC component encoders, and this arrangement is most commonly used for turbo codes having coding rates below two-thirds. In order to generate a half-rate code, half the parity bits from each component encoder are punctured. Puncturing is introduced to increase the rate of Turbo code .

4 CONCLUSION

The performance of the turbo codes is dependent on different parameters like the frame length, number of iterations, selection of different encoders and use of different interleavers .The simulation results shows that the performance of the Turbo codes depends mostly on the length of the interlever. The interlever having large frame length exhibit better performance. It is observed from the simulation results that as interlever frame/size increases SNR also increases but BER decreases and attained more error floor, thus Turbo code exhibit a better performance when frame length increases. For the larger size Interlever, coding rate decreases where as for small size interlever coding rate increases. Puncturing increases the rate of the Turbo code. Interleaver reduce the hardware requirements for interleaving and de-interleaving operations.

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