Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

6th International Conference
on Electrical Engineering
ICEENG 2008

Modified random interleaver for turbo codes

By

Alaa Eldin.S.Abdelaziz * M.Shokair ** A. Abou Elazm **

Abstract:

The interleavers used in Turbo codes play a major role in the performance of turbo codes. Therefore, it is necessary to design turbo codes with good interleaver structure. In this paper the performance of Turbo codes for proposed interleaver was analyzed in terms of the bit error rate (BER) Vs Eb/No for SOVA(Soft Output Viterbi Algorithm) and MAP (Maximum A Posteriori Probability) decoding algorithms and compared with the result for block interleaver and random interleaver. This proposed interleaver uses the hamming weight as a design criterion to improve the performance of the turbo codes. The channel is subjected to Additive White Gaussian Noise (AWGN) in terms of the Signal to noise ratio (Eb/N0) in db. Moreover, Comparison between the proposed interleaver to block interleaver and ordinary random interleaver will be made.

Keywords:

Interleavers, turbo codes, and Bit error rate

---

* National Authority for Remote Sensing and Space Science,Cairo,Egypt
** Faculty of Electronic Engineering, Menouf, Egypt

1. Introduction:

Turbo codes play a major role in the error channel coding scheme used in wireless communication. Turbo codes emerged in 1993 [1] and since this year it become a popular area of communications research. Due to their performance, turbo codes are being accepted as standards by many organizations such as (CCSDS) Consultative Committee For Space Data Systems to be used in satellite channel coding after it achieved many successions in a lot of missions. Different applications have been studied such as QoS (quality of service) requirements in terms of the data rate, Bit Error Rate (BER), frame size and the frame error rate. A Turbo code is the most adaptable error coding scheme used to fulfill this requirement. It can give performance very close to shannon's capacity with large interleavers; the performance of turbo codes is determined by different factors: constituent encoder design, interleaver design, decoder algorithm, interleaver size and number of decoder iterations. Thus one of key parameters to improve the performance is the interleaver design. Sloane [2] prove that for large frame size, most random interleavers perform well, But For short frame length a deterministic or semi random interleaver can be more effective than random interleavers.

In this paper proposed random interleaver will be suggested. It uses the hamming weight as a design criterion to improve the performance of the turbo codes. The amount of performance improvement about 0.1 db with respect to normal random interleaver and about 0.5 db with respect to Block random interleaver at BER equal to 10^{-3}.

This paper is organized as follows, the basics of turbo coding is done in Sect.2. Explanations of interleavers design will be made in Sect.3. Investigation of proposed interleaver algorithm will be achieved in Sect.4. The analysis of the results is done in Sect.5. Conclusions will be made in Sect. 6.

2. Turbo Codes

The structure of Turbo encoder is shown in Figure (1) A turbo encoder is formed by parallel concatenation of two Recursive Systematic Convolutional (RSC) encoders separated by an interleaver [4]. In that Figure, g_0 (D) and g_1(D) are feedback polynomial and feedforward polynomials, respectively. These polynomials can be obtained from Equation 1 and 2 as follows,

$$g_0 = 1 + D + D^2 \qquad \text{(Feedback polynomial)} \qquad (1)$$

$$g_1 = 1 + D^2 \qquad \text{(feedforward polynomial)} \qquad (2)$$

The generator polynomial for turbo code is G(D) and can be given by,

$$G(D) = \frac{g_1(D)}{g_0(D)} \qquad \text{(Generator polynomial)} \qquad (3)$$

In the encoder, the same information sequence is encoded twice but in a different order. The first encoder operates directly on the block of length N. The second encoder operates on the same set of data interleaved in a different order. After achieving the reception, the data is decoded by the turbo decoder. The important characteristics of turbo codes are the small BER achieved even at low Signal to noise ratio (SNR).

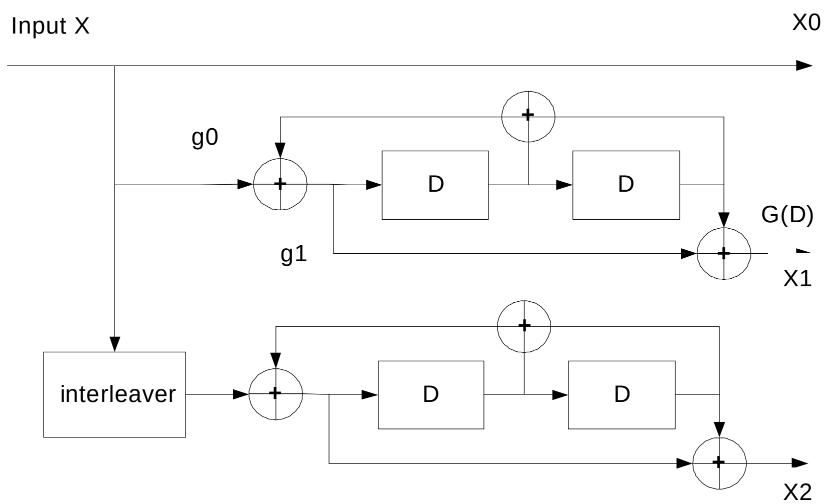

Figure (1): *General Turbo Encoder*

<u>***3. Interleavers***</u>

Interleaving is a process of rearranging the ordering of data sequence. The inverse of this process is called deinterleaving which restores the received sequence to its origin order. Interleaving is a practical technique to enhance the error correcting capability of coding even in a noisy channel [3]. In turbo coding, interleaving is used before the information data is encoded by the second constituent encoder to rearrange the data in different order, therefore It has the job of spreading out long bursts of errors [5]. The interleaver provides scrambled information data to the second constituent encoder and decorrelates inputs to the two component decoders. Therefore an iterative suboptimum-decoding algorithm based on uncorrelated information exchange between the two component decoders can be applied. The final role of the interleaver is to break low weight input sequences, and hence increase the code free Hamming distance or reduce the number of code words with small distances in the code. The size and structure of interleavers play a major role in the performance of turbo codes. Types of interleavers briefly explained in next subsections.

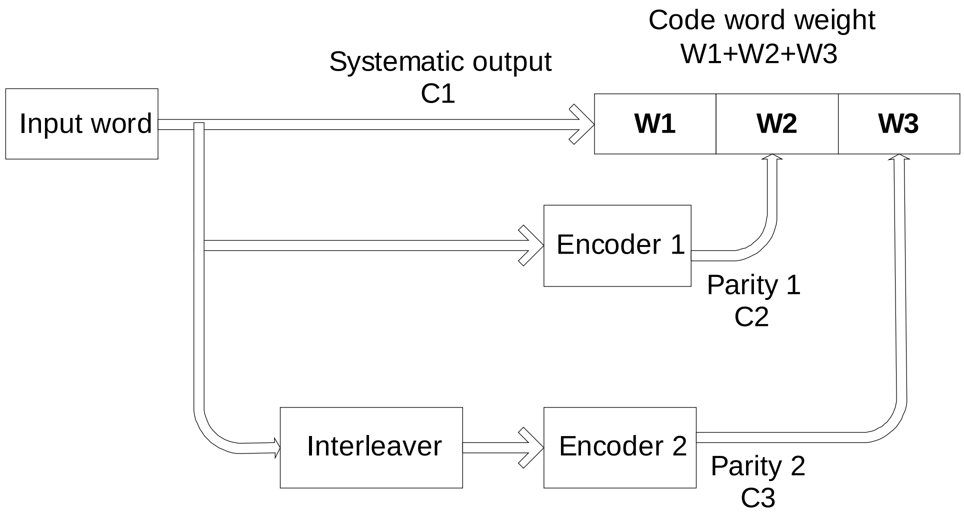

Figure (2): *Turbo Encoder Coded Word Weight*

3.1 . Block Interleaver

The block interleaver is the most commonly interleaver used in communication systems. It writes in column wise from top to bottom and left to right and reads out row wise from left to right and top to bottom. Figure (3) shows a block interleaver.

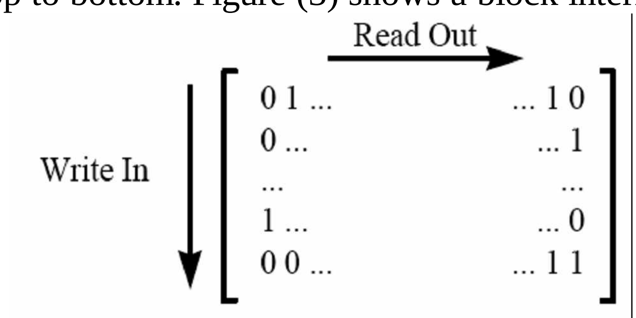

Figure (3): *Block Interleaver Reading And Writing Algorithm*

3.2. Odd-Even Interleaver

The odd-even interleaver design is specifically for (encoder rate r) r =1/2 turbo code. A rate r=1/2 turbo code is obtained by puncturing the two coded (nonsystematic) output sequences of a r=1/3 turbo code. Table (1) shows the Odd Even Interleaver.

Table (1): Output Element from Odd Even Interleaver

Input X0	$X0_1$	$X0_2$	$X0_3$	$X0_4$	$X0_5$	$X0_6$	$X0_7$	$X0_8$
Out	$X0_1$X1	$X0_2$ X2	$X0_3$ X1	$X0_4$ X2	$X0_5$ X1	$X0_6$ X2	$X0_7$ X1	$X0_8$ X2

3.3. Circular-Shifting Interleaver

The permutation p of the circular-shifting interleaver is defined by

$$p(i) = (ai + s) \bmod L \tag{4}$$

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 (4) shows a circular-shifting interleaver with L=8, a=3, and s=0

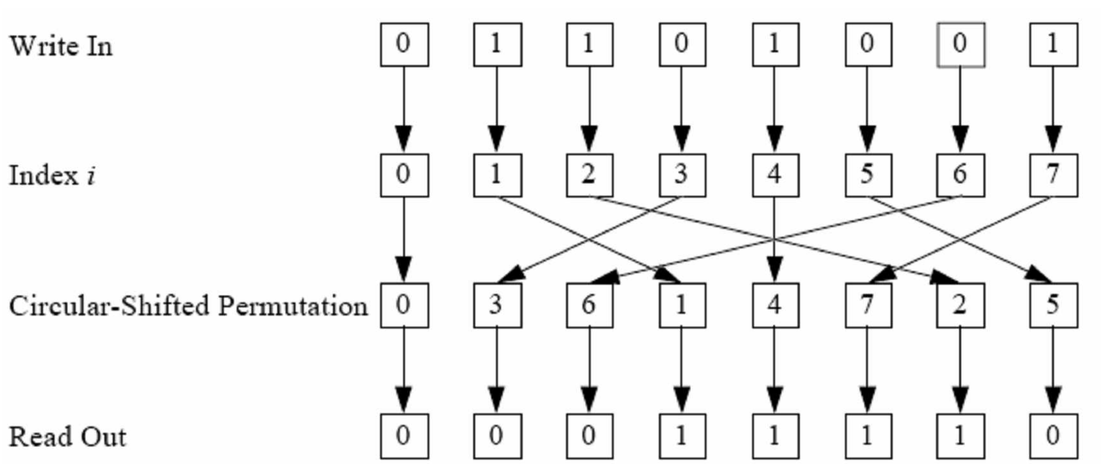

Figure (4): *Circular Interleaver*

3.4. Random Interleaver

The random interleaver uses a fixed random permutation and maps the input sequence according to the permutation order, The length of the input sequence is assumed to be L. Figure(5) shows a random interleaver with L=8.

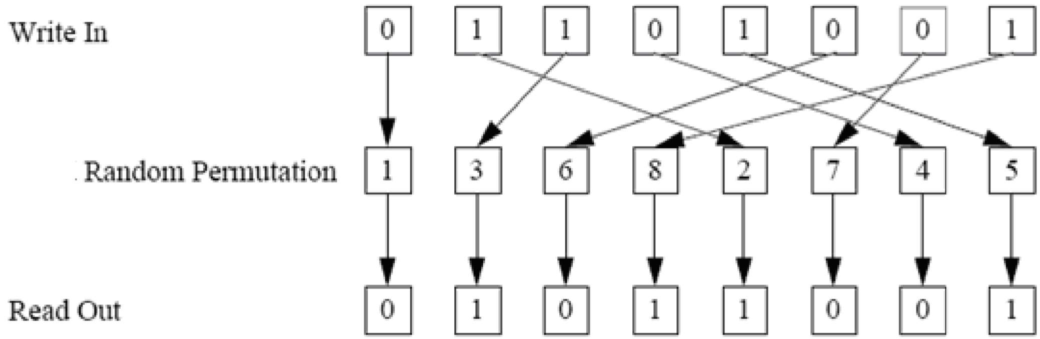

Figure (5): Random Interleaver

4. Proposed Random Interleaver

The error correcting capability of block codes is closely related to the hamming weights of its set of code words. The turbo code which is proposed in [1] uses the hamming weights of the code words. These are composed of three parts as shown in fig (2); the weight of the input word W1, the weight of the parity words from each constituent encoder W2 and W3. Among pervious interleavers, the random interleaver is the best choice for large frame size [2]. Performance of random interleaver can be improved if we try to raise the weight of the code word. Thus the permutation order to get high weight code word from low weight code word should be searched. In this paper, the set of parity words from the second constituent encoder is mapped and select the order which gives the encoder high weight. Thus after combined the systematic bits and first encoder parity, it give us high probability for error correction in the decoder side.

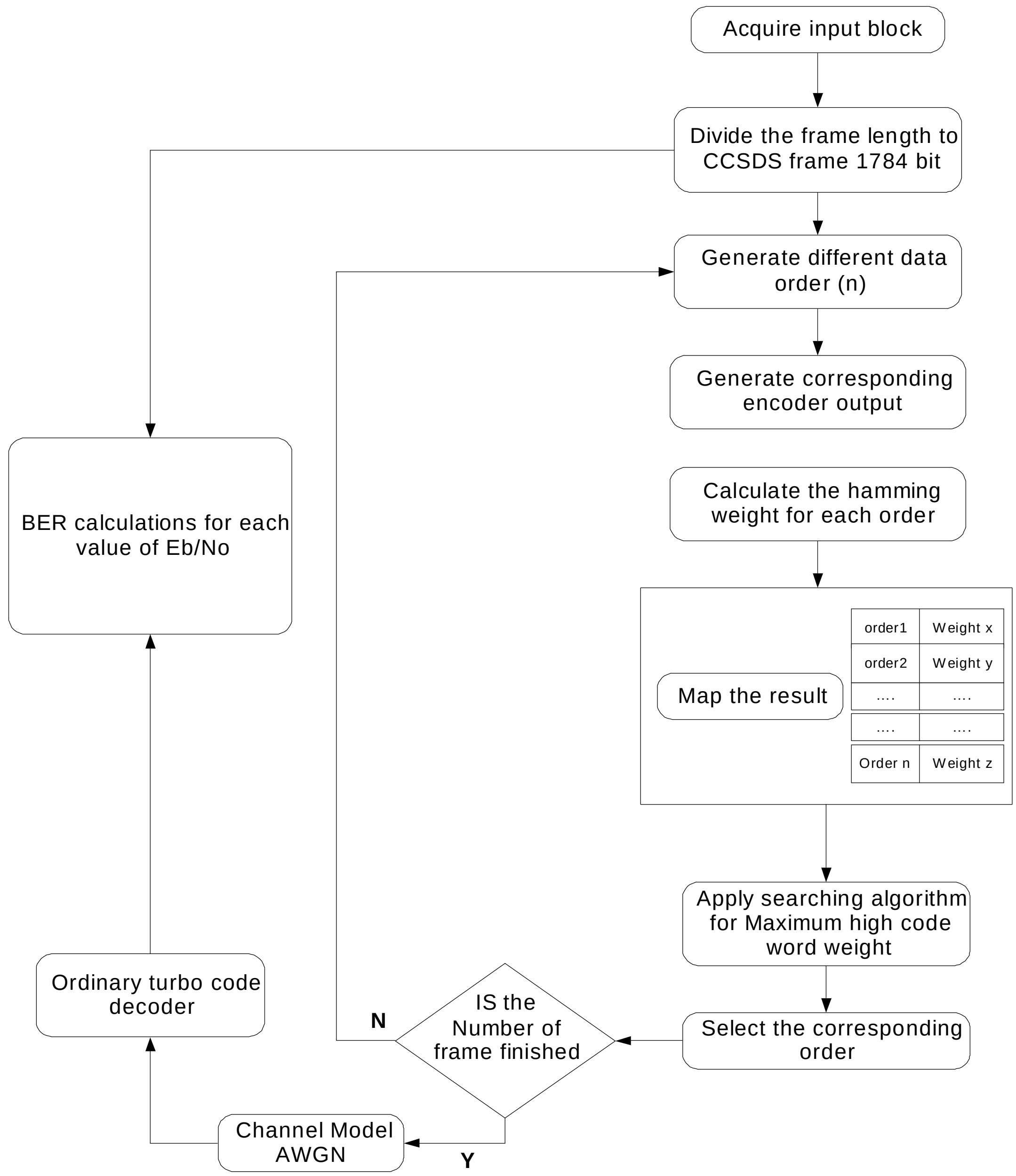

***Figure (6):** Flow Chart of the Modified Interleaver searching Algorithm*

5. Simulation Results

Simulation parameters:

1) Generator polynomial (5, 7), g_0=111, g_1=101.
2) Coder rate r=½.
3) Frame length =1784 (CCSDS frame) long frame
4) Number of iteration =8.

The two decoding algorithms MAP & SOVA are applied for Block interleaver (○curves), random interleaver (curves) and proposed random interleaver (Δcurves). Figure (7) shows bit error rate (BER) Vs Eb/No for MAP decoding algorithm for the three types of interleavers while Figure (8) shows bit error rate (BER) Vs Eb/No for SOVA decoding algorithm for the three types of interleavers, From those figures an improvement can be seen for the proposed random interleaver compared to block interleaver and random interleaver. This improvement comes from using high codeword weight which effect on the properties of the code.

Figure (7): *Turbo Code Performance for MAP Algorithm*

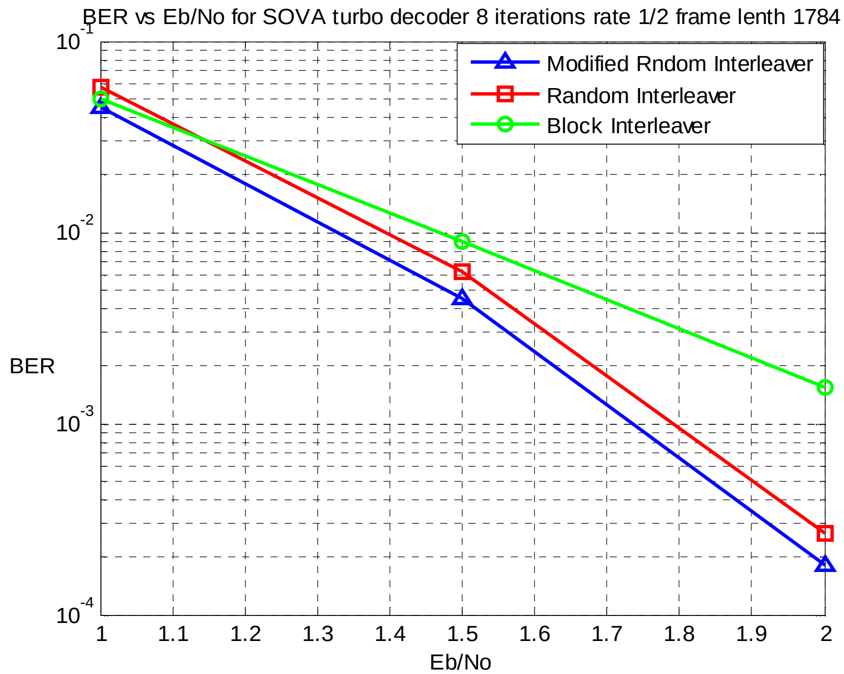

***Figure (8):** Turbo Code Performance for SOVA Algorithm*

6. Conclusions:

This paper presents how The performance for turbo codes can be improved as a result of increasing codeword weight, which can be done by searching algorithm applied for random interleaver which searching for the high code word weight. The structure of the modified random interleaver affects the distance properties of the code. By avoiding low-weight code words, the BER of a turbo code can be improved. Moreover, the interleaver influence on the convergence rate of iterative decoding of turbo codes.

From the simulation results, it is clear that at the same value for the BER, for example 10^{-3}, there will be performance improvement about 0.5 db with respect to Block interleaver and about 0.1 db with respect to normal random interleaver.

References:

[1] c. Berrou and A. Glavieux, “Near optimum error correcting coding and decoding: turbo codes,”IEEE transactions on communications, vol.44, PP 1261-1271, October 1996.

[2] Sadjadpour, H.R. Sloane, N.J.A. Salehi, M.; Nebe,G, "Interleaver design for turbo codes" Selected Areas in Communications, IEEE Journal on Volume 19, Issue 5, May 2001 Page(s):831 – 837

[3] M.sun chuen PHD thesis, "Serial and parallel concatenated turbo codes" university of South Australia, November 2002.

[4] S. Dolinar and D.Divsalar,” Weight distribution of Turbo codes using Random and Non random permutations,” JPL TDA progress report 42-122 August 1995.

[5] Shobha Rekh, S.Subha rani ,A.Shanmugam "Optimal choice of interleaver for turbo codes". Academic Open Internet Journal, Volume 15, 2005 http://www.acadjournal.com/2005/v15/part6/p7/

[6] J.P. Nasshan. ”Performance evaluation of turbo codes for short frame transmission systems” Electronics Letters 20th January 1994 vol. 30 no. 2

Nomenclatures:

AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CCSDS	Consultative Committee For Space Data Systems
Eb/No	Energy per Bit Per Noise
MAP	Maximum A Posteriori Probability
r	code rate
RSC	Recursive Systematic Convolutional
SNR	Signal to Noise ratio
SOVA	Soft Output Viterbi Algorithm