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Performance of Turbo Codes with Iterative Decoding Scheme

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Abstract:

Turbo codes are developed by using two convolutional codes in parallel with interleaving in between. The performance of coding and decoding algorithm depend on the minimum distance between codes and the probability distribution of the code. This paper presents the performance of iterative decoding scheme. Simulation results has been presented for different iterations.

Key Words: Iterative Decoding, Space Time Block Coding, Turbo Codes, Trellis Code Modulation, Viterbi Algorithm.

I. INTRODUCTION

Space-time coding possesses the advantage of possible diversity both spatially and temporally. Extensive efforts have been made in designing space-time block coding (STBC) to achieve full rate and full diversity because of its relative simplicity of implementation. A more recent review of Space-Time coding scheme has been given in [3] [2]. Foschini [1] introduced a coding algorithm that took advantage of the added capacity in a MIMO channel. The algorithm encoded data across time and across all the transmitting antennas. Foschini [1] also presented a formula for evaluating the channel capacity of MIMO channels. Telatar [5] gives a detailed analysis of the capacity in multi-antenna Gaussian channels. STBC involves block encoding an incoming stream of data and simultaneously transmitting the symbols over M transmit antenna elements [4].

This technique was first proposed by Alamouti for M = 2 and N = 1, where N is the number of receive antenna elements. Alamouti space-time code is the simple transmit diversity scheme which improves the signal quality at the receiver on one side of the link by simple processing across two transmit antennas on the opposite side. The diversity obtained with Alamouti's scheme is equal to maximal-ratio receiver combining (MRRC) in which two antennas are at the receiver and one at the transmitter. The scheme may easily be generalized to two transmit antennas and receive antennas to provide a diversity order of 2M. This is done without any feedback from the receiver to the transmitter and with small computation complexity. The scheme requires no bandwidth expansion, as redundancy is applied in space across multiple antennas, not in time or frequency. Alamouti's code uses a complex orthogonal design, in which the transmission matrix is square and satisfies the conditions for complex orthogonality in both space and time dimensions. Tarokh, Jafarkhani and Calderbank [6] extended Alamouti's code to a generalized complex orthogonal design for M> 2.

These generalized codes are non-square, are complex orthogonal only in the temporal domain and suffer a loss in bandwidth efficiency. The STBC receiver linearly processes the received symbols and uses maximum likelihood decoding. The received signal is the linear superposition of the transmitted elements corrupted by fading. All these systems are still having a limitation that they require a proper or almost. There are some advantages of STBC for MIMO systems are transmit diversity at the base station is easier to implement because handheld mobiles always create a lot of problems in achieving antenna diversity at the receiver. Also, in STBC, easily increase the size of the code from two to three and to four, with a very little increase in decoding complexity, due to the fact that only linear processing is required for decoding. On the other hand STC for MIMO systems operate on one input symbol at a time producing a sequence of vector symbols whose length represents number of antennas. For a single antenna channel, space-time trellis code provides coding gain. Since they also provide full diversity gain, their key advantage over STBC is the provision of coding gain. The basic idea of Turbo code uses two convolutional codes in parallel with some kind of interleaving in between. The performance of code-decode schemes depend not only in the minimum distance between the output codes but also in the probability distribution of the output code. The convolutional codes decide the minimum distance of the code words.

A good designed interleaver can make it possible that the probability distribution of the output code is nearly uniform distribution. Similar to the structure of encoder of Turbo code, the decoder of Turbo code also is composed by two decoders for convolutional codes.

II. TURBO ENCODING

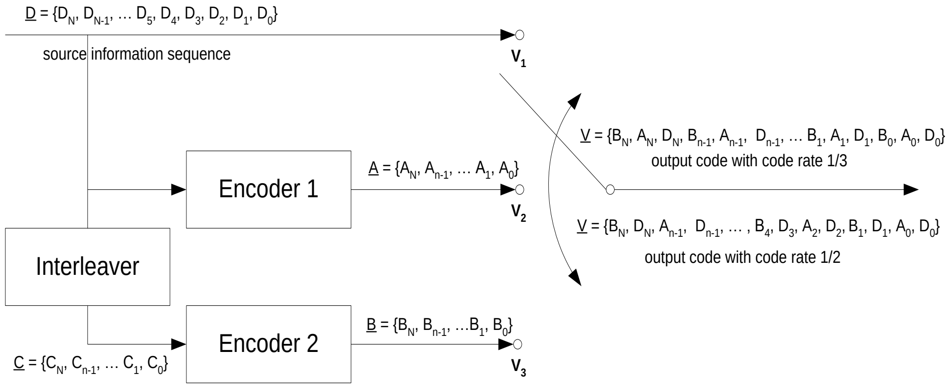

Figure 1. Turbo Encoder

The figure 1 shows the encoder structure of the Turbo Code. The binary sequence D is input information. The binary sequence C is the input information after interleaver. The A and B are the output of convolutional encoder corresponding to D and C. The final output sequence of Turbo Code is V. The figure 1shows two output Turbo Code sequences: one has code rate 1/2; another has code rate 1/3. General the both encoders are recursive systematic convolutional (RSC) encoders. The interleaver is the pseudo-random interleaver in general. The output sequence has near uniform distribution probability with well-designed interleaver.

The RSC code can be represented as:

$$G(z)=\begin{bmatrix}1 & \frac{g(z)}{h(z)}\end{bmatrix};\ g(z)=\sum_{i=0}^{n} g_i * z^{-i},\ h(z)=\sum_{i=0}^{n} h_i * z^{-i} \qquad (1)$$

Here z is the time delay. The signal flow graph of RSC encoder with n=4 is showed at figure 2.

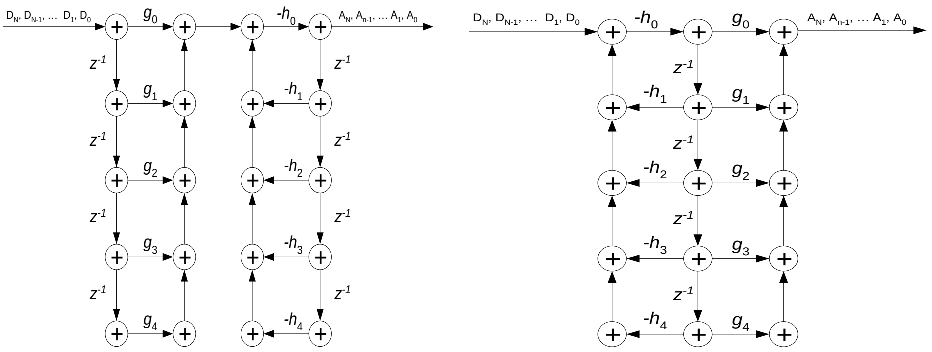

Figure 2. Signal Flow Graph of RSC Encoder

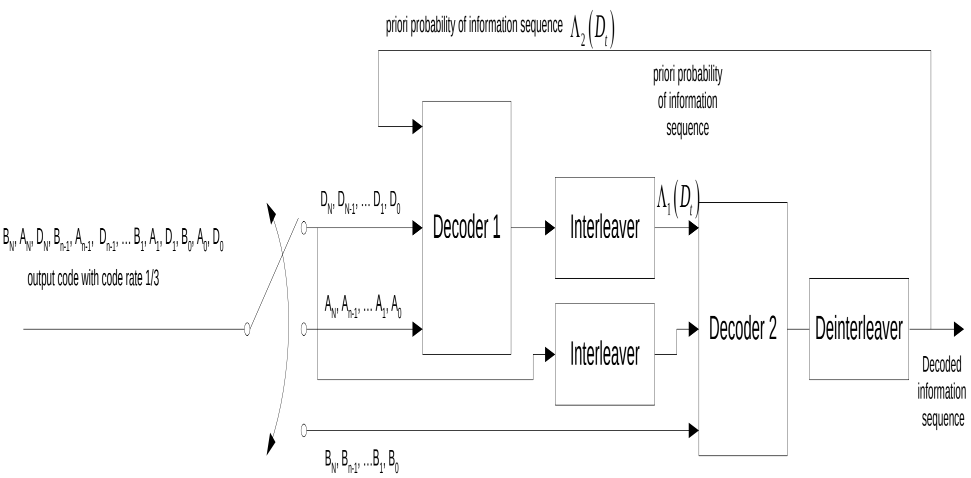

Figure 3. The Iterative Turbo Code Decoder Based on MAP Algorithm

The iterative turbo decoding consists of two component decoders serially concaztenated via an interleaver. The structure of iterative decoder of Turbo code based on the MAP algorithm is showed at figure 3.The first decoder will take the input sequence D & A and produces a soft output $\Lambda_1(D_t)$ which contains prior probability information of original sequence. Then the second decoder will take the input sequence D & A and prior probability $\Lambda_1(D_t)$ and produce another soft output $\Lambda_2(D_t)$ which will be taken by the first encoder at next iteration. The interleaver between two decoders is the same interleaver in the encoder of Turbo Code. For the simulation we have varied SNR from 0 dB to 9 dB. Plot for simulated Bit Error Rates iteration-vise are shown in Figure 4.

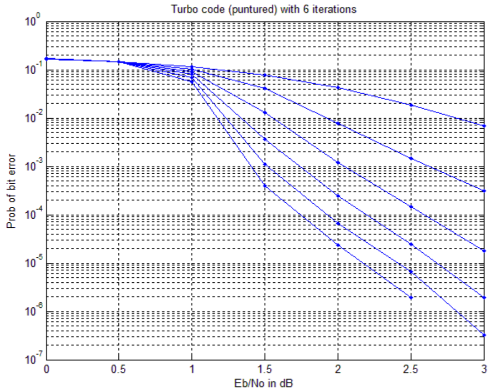

Figure 4. Performnce of Turbo Codes with Iterative Decoding

From the plot it has been concluded that performance of Turbo codes is much better than STBC and Trellis we also conclude that the performance of iterative decoder is much better than the decoding using Viterbi algorithm for the convolution code.

Table I. Performance of Turbo Encoder with Iterative Decoding

	Frame Error Rate					
Iteration / **SNR**	1	2	3	4	5	6
0	0.10	0.1	0.1	0.1	0.1	0.1
0.5	0.17	0.17	0.16	0.16	0.16	0.16
1	0.1	0.09	0.08	0.07	0.06	0.05
1.5	0.07	0.04	0.02	0.0030	0.001	0.0003
2	0.04	0.008	0.002	0.0003	0.00006	0.00002

From the above table, it is concluded that the frame error rate decreases with the increasing SNR and the number of iterations.

III. CONCLUSION

Iterative decoding can be used to increase the performance of a wireless communication system. In this work the performance of an iterative decoder for Turbo coding has been presented. Simulation results show that iterative decoder increases the performance of the communication system.

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