Performance of Iterative Soft Output Viterbi Algorithm (SOVA) Decoder on Turbo Coding under Fading Channel

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Abstract

Classical turbo coding base on Parallel Concatenated Convolutional Code has been used for forward error correcting (FEC). From some research reports [1,2,3,5] this technique show new hope to get the coding technique at near Shanon limitation. This paper explains how SOVA decoder works on classical turbo coding. Performance analysis of SOVA decoder is observed by measure the number of bit error (BER). The simulation is set up under Rayleigh Fading channel, where two types Rayleigh fading generation are considered, that are correlated and uncorrelated Rayleigh fading. Simulation parameters to evaluate the decoder performance are signal to noise ratio (Eb/No), frame size, code rate, and number of iteration. In this paper the effect of additional interleaver to interleave the code word on BER also discussed.

From simulation, we found that increasing number of iteration not much helpful in the low region of Eb/No. In the middle to high region (Eb/No > 3 dB) the performance of SOVA decoder improve drastically. Increasing frame size it will produce larger distance by using an interleaver, and resulting a better decoder performance. Increasing the parity check bit also increases the decoder performance significantly, but consequently the requirement bandwidth also increases.

Key words:
iterative SOVA decoder, correlated and uncorrelated Rayleigh fading

1. Introduction

The classical structure of turbo coding base on Parallel Concatenated Convolutional Code has been implemented for forward error correcting (FEC). From some research reports [1,2,3,4,5] this technique show new hope to get the coding technique at near Shanon limitation.

This paper explain the SOVA Decoder performance on classical structure of turbo coding through evaluate the value of BER. The simulation parameters are: number of decoding iteration, ratio of energy bit and noise power spectral (Eb/No), frame sizes, and application of additional interleaver.

FEC technique base on this structure was proposed for the first time at 1993 on coding community [6]. The important point in this technique is the possibility to develop the excellent communication system with power efficiency near to Shannon region. Under AWGN channel, with code rate of 1/2 the performance of this system is 10^{-5} of BER on 0.7 dB of Eb/No. Jian-Qi [7] reports that the performance of turbo code under AWGN channel is better than under Rayleigh fading channel.

2. Classical Turbo Coding

The Classical structure of turbo coding consists of two recursive systematic convolutional (RSC) which are parallel concatenated, PAD block, interleaver block, puncturing block, and data multiplex block.

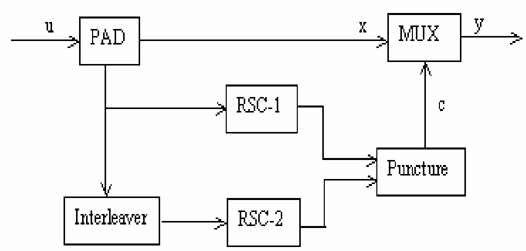

Figure 1. Structure of classical turbo encoding

Data block u enters the turbo code system. PAD will add tail bit to reset the encoder state. Each data block enters RSC1 and RSC2. Interleaver is a block for interleaving data sequence on pseudo random sequence. The output bit from RSC acts as a parity check bit, c_i. Through puncturing block the parity check bit will be punctured or un-punctured resulting on difference code rate. The parity check bit is multiplexed with original data and resulting a code word. After transmitting through fading channel, the receiving data are decoded by iterative SOVA decoder.

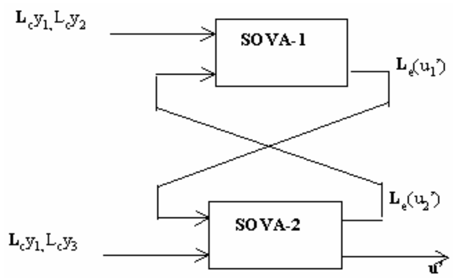

Figure 2. Structure of iterative SOVA decoder

3. Iterative SOVA Decoder

The SOVA decoder is a modification of classical Viterbi Algorithm (VA). In VA, the maximum likelihood (ML) path is considered by survivor path only. But in the SOVA, the ML path is considered by both of survivor and competition paths. The SOVA decoders evaluate the a-priori value of information sequences u, L (u) and weighted signal, L_cy. The a-priori value is obtained from previous decoder. If there is no previous a-priori value then L (u) is set to zero. The output from SOVA decoder is estimated value (u') and extrinsic value, L (u') that will be iterated to the other SOVA decoder. The structure of SOVA decoder is depicted on Figure 2.

4. Simulation Model

A model used in this paper is as shown in Figure 3. The simulation procedure could be explained as follows:

The source block generates random information u, $u \in \{0,1\}$ then the random information is encoded by turbo encoding, $x \in \{-1,1\}$. Using optional interleaver, the code word is interleaved on pseudo random sequence {-1,1}, then the modulated code word, $X \in \{-\Lambda,\Lambda\}$ is transmitted through the fading channel [8,9]. The received signal, y is expressed as:

$$y = aX + n \qquad \ldots (1)$$

Where a is fading coefficient which has Rayleigh distribution, X is transmitted data, and n is white Gaussian noise. Figure 4 is probability density function and collective density function of Rayleigh distribution generation (dash line) and theoretical (solid line).

In this simulation there are two types of Rayleigh fading generations, they are correlated and uncorrelated Rayleigh fading. Correlated Rayleigh fading is generated by Jack model, while uncorrelated Rayleigh fading; a_R is generated by equation 2:

$$a_R = \sqrt{\frac{n_1^2 + n_2^2}{2}} \qquad \ldots 2$$

Where n_1 and n_2 are Gaussian random number.

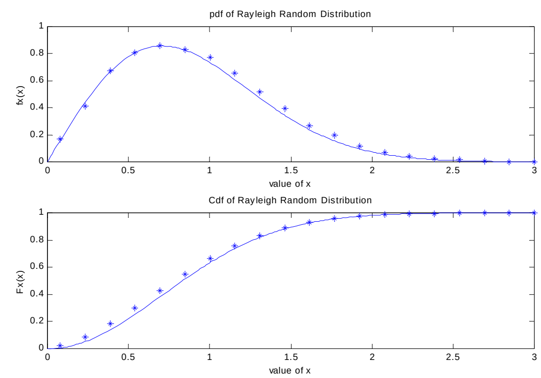

Figure 4. pdf and Cdf of Rayleigh random distribution

After demodulation and deinterleaver, iterative SOVA decoder decodes the received code word. The SOVA decoder steps is shown as on below flowchart [10].

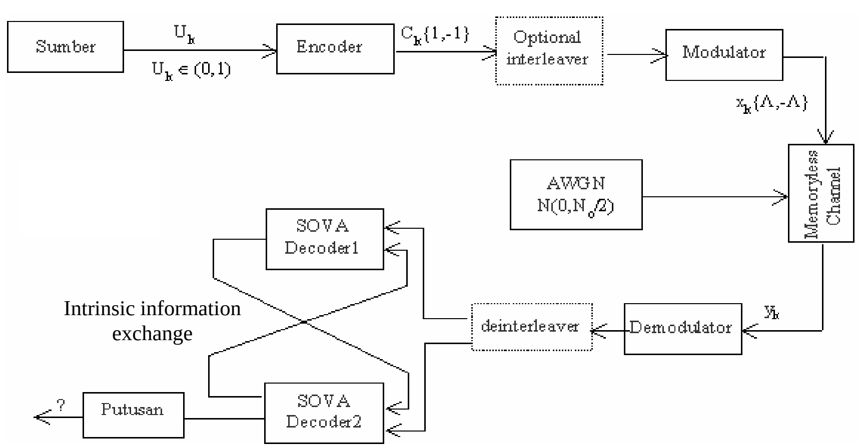

Figure 3. Simulation Model

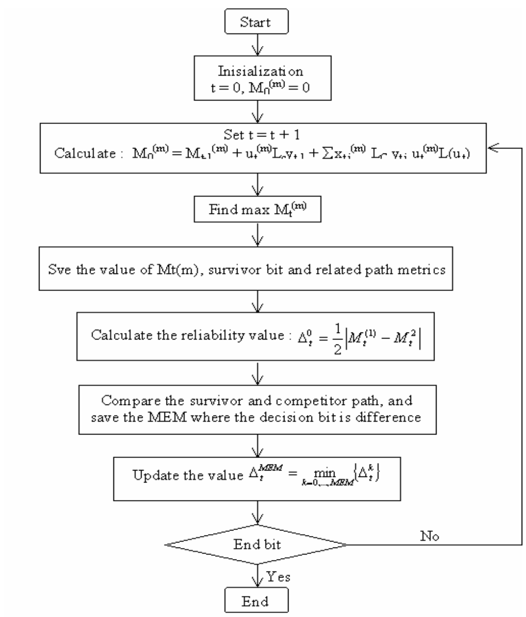

Figure 5. The SOVA decoder flowchart

5. Simulation Result and Data Analysis

After developing and running the simulation program under Matlab environment, the simulation result can be observed through Figure 6 to Figure 11. Figure 6 and Figure 7 give an impression that increasing number of iteration not much helps in the low region of Eb/No. In the middle to high region (Eb/No > 3 dB) the performance of SOVA decoder improves drastically. This is due to the decoder 1 and decoders 2 shares the information and makes decision more accurate.

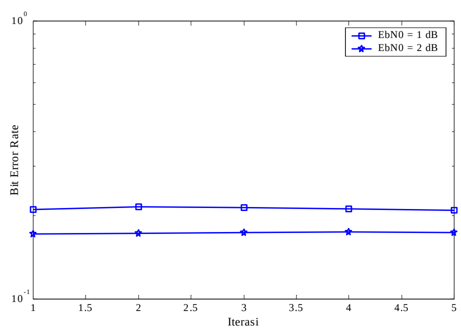

Figure 6. Effect of decoder number iteration On BER. Frame size = 5000 (uncorrelated fading) at EbN0 = 1 and 2 dB

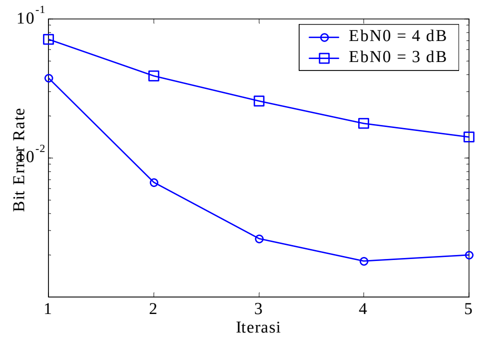

Figure 7. Effect of decoder number iteration on BER. Frame size = 5000 (uncorrelated fading) at EbN0 = 3 and 4 dB

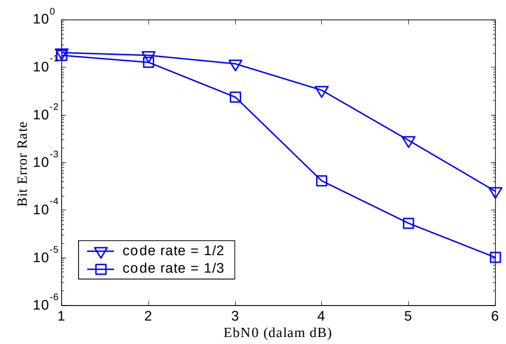

Figure 8. Effect of code Rate on.

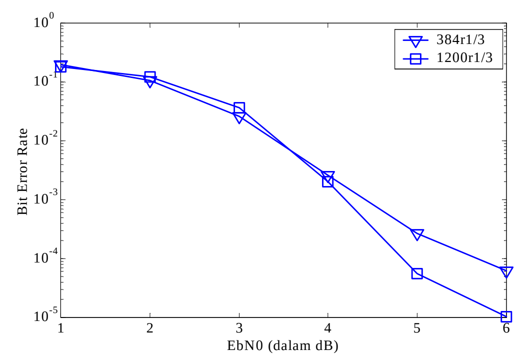

Figure 9. Effect of frame size on BER

Figure 8 gives information that changing the code rate from 1/2 to 1/3 will increase SOVA decoder performance significantly. This is because of the parity check bit on 1/3 rate larger then on 1/2 rate; hence the code word is rather immune to noise. As a consequence the requirement bandwidth will increase.

Figure 9 illustrates the effect of frame size on BER of SOVA decoder. From this figure we found that increasing frame size resulting better decoder performance. This is due to the larger frame size produce the larger distance caused by interleaver. The disadvantage of increasing frame size is delay time before getting complete decoder also increase.

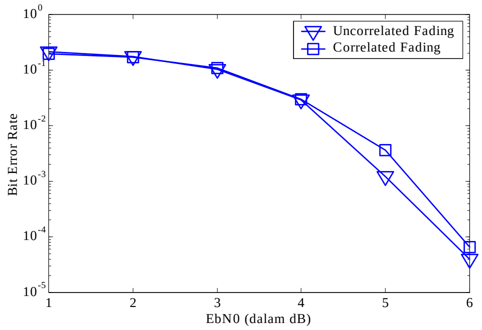

Figure 10. Effect of Rayleigh generator on BER. The simulation parameter are, Frame size = 5000, code rate = 1/2, number of iteration = 3.

From Figure 10, it can be shown that the performance of decoder under uncorrelative Rayleigh generator better than correlative Rayleigh generator. This means the less correlation of fading process will give the better decoder performance.

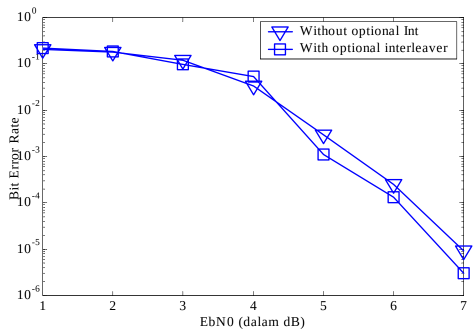

Figure 11. Effect of optional interleaver on BER. The simulation parameter, frame size 1.200, code rate 1/3, after 4 iteration

Figure 11 gives the illustration that the use of optional interleaver can increase the decoder performance. As a general sense that the burst error is hard to be corrected by viterbi algorithm. The using of optional interleaver can produce a high-weighted code, especially for the large frame size.

6. Conclusion

After making discussion the following conclusion could be drawn:

1. As an error correcting technique, performance of SOVA decoder on turbo coding is good enough.

2. Effect of number of decoder iteration is much helpful especially on the middle to high region of Eb/No (> 3 dB)

3. Increasing frame size also increasing the decoder performance, even though the delay time will also increase.

4. Increasing code rate also can reach better decoder performance, but the requirement bandwidth must be considered.

5. Because the less correlation of fading process, the decoder performance under correlative Rayleigh generator is worse than under uncorrelative Rayleigh generator.

6. Optional interleaver can increase the decoder performance especially for the large frame size.

7. References

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