Performance of Turbo Codes Using Code Generator [13, 15] and [31, 17] in AWGN and Fading Channel

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Abstract—Turbo coding is a very powerful error correction technique that has made a tremendous impact on channel coding in the last few years. They are recommended for increased capacity at higher transmission rates due to their superior performance over conventional codes. Turbo codes use any one of the decoding algorithms, Maximum a posteriori Probability (log MAP), Soft Output Viterbi Algorithm (SOVA), modified log MAP (MMAP) and modified SOVA (MSOVA) for decoders in Forward Error Correction (FEC), because it produces error correction near to Shannon’s limit. This paper presents the performance analysis of turbo codes using code generator (13, 15), (31, 17), rate 1/3. The results are compared to turbo codes (7, 5) and rate 1/2. An emphatically determined optimal scaling factor is used for MAP and SOVA to derive MMAP and MSOVA, which improve the performance in terms of bit error rate (BER) at turbo decoder. A typical BER is in the order of 10^-2 for Additive White Gaussian Noise Channel (AWGN). Similar analysis is done for the fading channel and performance improvement in BER is found to be 10^-5.

Index Terms—Turbo codes, MAP, SOVA, FEC.

I. INTRODUCTION

This paper presents the performance analysis of turbo codes using code generator (13, 15), (31, 17), with rate 1/3. The results are also compared to turbo codes (7, 5) with rate 1/2. In the decoding part four decoding algorithms log MAP, SOVA, modified SOVA and modified MAP are considered for the performance analysis. The modified SOVA and modified MAP are in which the scaling factors introduced. For modified MAP the scaling factors are 0.90 and 0.755 respectively for outer decoder (decoder 1) and inner decoder (decoder 2). Similarly for modified SOVA the scaling factors are 0.56 and 0.98. This chapter explains performance analysis of log MAP, SOVA, modified SOVA and modified log MAP with and without modulation channel wise and code generator wise analysis

II. TURBO ENCODER

A basic turbo encoder is a recursive systematic encoder [1] that employs two convolutional encoders in parallel, where the second encoder is preceded by an interleaver. The coding gain achieved by a turbo code is due to the reduction in the number of nearest neighboring code words that result from interleaving. It is observed that the nominal rate at the output of the turbo encoder is RC=1/3. This increases the redundant bits and hence the error probability decreases.

![Turbo Encoder Diagram](image1)

Figure 1. Turbo Encoder (rate 1/3)

III. TURBO DECODER

A soft decision decoder outputs a real number which is a measure of the probability of a correct decision. This real number is called the a posteriori probability (APP). MAP and SOVA are the two types of soft decision decoding algorithms. A modification in Viterbi [3] or MAP [4] algorithm achieves further improvement towards Shannon’s limit. This is achieved by scaling the extrinsic information. However, the MAP algorithm results in better performance at low SNR due to a more accurate evaluation of the APP.

![Turbo Decoder Diagram](image2)

Figure 2. Turbo Decoder

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IV. DECODING ALGORITHMS

Log MAP

MAP is a bidirectional Viterbi algorithm. Once this bidirectional computation yields state and branch metrics for the block, the APPs and MAP can be obtained for each data bit represented within the block.

SOVA

In this section, we describe a variation of the Viterbi algorithm, referred to as the SOVA [2]. This algorithm has two modifications over the classical Viterbi algorithm which allows it to be used as a component decoder for turbo codes. Firstly the path metrics used are modified to take account of a-priori information when selecting the ML path through the trellis. Secondly, the algorithm is modified so that it provides a soft output in the form of the a-posteriori LLR for each decoded bit.

Modified MAP and Modified SOVA

A modification in SOVA [3] or MAP [4] algorithm achieves further improvement towards Shannon’s limit. This is achieved by scaling the extrinsic information as shown in Figure 3. The scaling factors for MMAP and MSOVA are given in the table 1.

<table>
<thead>
<tr>
<th>Decoding Algorithm</th>
<th>Decoder1</th>
<th>Decoder2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified log MAP</td>
<td>0.90</td>
<td>0.755</td>
</tr>
<tr>
<td>Modified SOVA</td>
<td>0.56</td>
<td>0.98</td>
</tr>
</tbody>
</table>

V. SIMULATION RESULTS

In this section we present some simulation results of the MSOVA along with SOVA, MAP and MMAP. The simulation parameters are given below:

Channel: AWGN and Fading
Modulation: Quadrature Phase shift Keying (QPSK)
Component encoder: Recursive convolution codes (RSC)
Rate = 1/3
Interleaver: 2048 bit random interleaver
Iteration: 8
Frame limit: 1140

RESULTS FOR (13,15) CODE

1. AWGN CHANNEL

In AWGN without modulation, up to 1.5dB, MAP and MMAP produce better performance. After 1.5dB MSOVA performance is comparatively good. Their performance for various decoding algorithms is shown in figure 4.

In AWGN with QPSK modulation, MAP and MMAP are analogous to each other. Up to 1.5dB MAP and MMAP outperforms SOVA and MSOVA. Then MSOVA improves in performance in the range of $10^2$. Their performance for various decoding algorithms is shown in figure 5.

2. FADING CHANNEL

In fading channel without modulation, performance of SOVA and MSOVA do better than MAP and MMAP compared to that of AWGN. The performance is shown in figure 6.

While using QPSK modulation, SOVA and MSOVA offer enhanced performance. Up to 1dB SOVA and MSOVA are analogous. SOVA outperforms MSOVA after 1dB, which is shown in figure 7.

RESULTS FOR (31,17) CODE

3. AWGN CHANNEL

In AWGN channel without modulation, MAP and MMAP give improved performance. The performance of SOVA and MSOVA increases with increase in Eb/No, which is shown in figure 8.

SOVA and MSOVA perform better for AWGN channel with QPSK modulation. Their performance is shown in figure 9.
In fading channel without modulation, up to 2dB, the performance of MAP and MMAP is poor. At 2.5dB it shows improvement in the range of 10^{-3}. SOVA and MSOVA outperforms MAP and MMAP. The graph is shown in figure.10

Up to 1.5dB, the performance of MAP and MMAP is poor. At 2.0dB MMAP shows improvement in the range of 10^{-3} and MAP shows improvement in the range of 10^{-2}. SOVA and MSOVA outperforms MAP and MMAP, is shown in figure.11

VI. CONCLUSION

On comparing the decoding algorithms in terms of BER for turbo code with code generator (13, 15) in AWGN channel, log MAP and modified MAP perform better than SOVA and modified SOVA by the order of 10^{-2} for lower Eb/No. Turbo code with code generator (13, 15) in fading channel, SOVA and modified SOVA perform better than log MAP and log MAP by the order of 10^{-4}.

Turbo code with code generator (31, 17), in AWGN channel, log MAP and modified MAP give better performance, whereas for Fading Channel without modulation modified SOVA performs better.

While comparing the code generator (13, 15), rate 1/3 with (5, 7) with rate 1/2, in the AWGN channel, (13, 15) gives good performance for log MAP and modified log MAP with typical BER in the order of 10^{-3}.

For Fading channel, (13, 15) gives improved performance for log MAP and modified log MAP at lower Eb/No, whereas SOVA and MSOVA give better performance at slightly higher Eb/No.

Code generator (5, 7), rate 1/2 gives the least performance for all decoding algorithms.

Turbo code with generator (31, 17) SOVA and modified SOVA give better performance than log MAP and modified log MAP by the order of 10^{-2} and 10^{-3} for AWGN and fading channels respectively.

On comparing the code generators (13, 15) and (31, 17), with QPSK modulation in AWGN channel, code generator (13, 15) gives good improvement in BER by the order of 10^{-3} for log MAP and modified log MAP.

SOVA and modified SOVA perform nearly equal in AWGN channel for both (13, 15) and (31, 17) codes. In Fading channel SOVA with double scaling factor (modified SOVA) produce better performance in all code generators.

REFERENCES