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STUDY OF BER PERFORMANCE OF TURBO CODE USING DIFFERENT MODULATION SCHEME

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Keywords: BPSK, QAM, Convolution Code, Turbo Code, BER

Abstract

The customary job for error-control coding was to build a channel tolerable by reducing the occurrence of error actions. The various errors arise in the communication systems are bit errors, message errors or invisiblenoiseerrors from channels. To avoid these errors, there are number of error control codes such as hamming code, cyclic code, convolution code and turbo codes are available. This paper presents the comparison of performance of bit error rate of convolution codes and turbo codes using BPSK and QAM Modulation in AWGN Channel.

Introduction

There are two types of communication namely analog and digital communications are available. The summary of various digital communication systems are listed here as in [10]. In digital communication, digital data is transmitted through the channel. In channel noise is added with the digital data. To eliminate the effect of noise in digital data, digital data is transmitted via carrier which is meant by modulation. Since carrier takes the digital data, this modulation technique is called digital modulation. The various digital modulation techniques are available in digital communication system. BPSK modulation is the simplest form of modulation technique which uses only two phases with 180^o phase shift. The product modulator is enough to undergo the BPSK modulation system. By using the same carrier used in the transmitter, we recover the original message signal at the receiver. But in DPSK, there is no need of carrier to recover the original message at the receiver. Bandwidth used for the DPSK modulation is very less compared to BPSK modulation. But bit error rate of the BPSK modulation is very less compared to DPSK modulation. QPSK modulation is a modulation technique which uses four phase hence it can encode two bits per symbol. Since it uses four phase, the bit error rate is reduced twice compared to BPSK modulation. In BPSK modulation, the receiver needs the reference signal due to phase ambiguity problem. But in QPSK, the receiver does not needs the reference signal due to the use of differential QPSK. On the other hand the QPSK modulation technique produces large Inter Symbol Interference (ISI) compared to BPSK modulation technique.Quadrature Amplitude Modulation is used to increase the transmission efficiency in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. The lowest order of the QAM is 16QAM since 2QAM is similar to BPSK and 4QAM is similar to QPSK. The 8QAM is not used because of similarity of 16QAM. 16QAM is used to code 4 bits per symbol and 64QAM is used to code 6 bits per symbol.

The various error control codes used in the communication systems are hamming code, Reed Soloman code, convolution code and turbo code. Convolution code is used to detect and correct the error in the message after passing through the channel. The coded bits are transformed to the original message signal using Viterbi Algorithm which is similar to maximum likelihood algorithm. The paper [5] implements the convolution code and Viterbi decoder with the constraint length of 7 and bit rate of ½. This paper implements this convolution code and Viterbi decoder in Verilog HDL.Mostly the convolution codes are used to avoid the errors generated due to the transmission of message through channel. The paper [6] analyze the bit error rate performance of the coded signal through the AWGN channel. This paper compares the coded modulation with uncoded modulation system. The signals taken for the simulation are digital signals and digital images. Through this paper, it is clear that for the digital signal 3dB improvement in coding gain for the bit error rate of 10^{-2}. Also it shows that the bit error rate performance degrades when the code rate is increased. For the image 5dB improvement in coding gain for the bit error rate of 10^{-2}.The paper [4] design a reconfigurable Viterbi decoder is designed for coded signal to decode to recover original signal and implemented in FPGA kit. This paper concludes that the reconfigurable Viterbi decoder saves the silicon area compared to normal Viterbi decoder.

Turbo Coding is the coding technique in which the parallel concatenation ofrecursive systematic convolution (RSC) codes in which (a) digital data, (b) the digital information is first encoded by an RSC encoder (RSC1)and (c) random rearrangement of digital information using a pseudorandom interleaveris done andencoded with the same RSC encoder (RSC2). The digital data and output of RSC1 and RSC2 encoder are then transmitted over the channel. The output of RSC1 and RSC2 encoder output are the parity bit. This parity bits is used to produce higher rate turbo codes.The paper [8] designs a list decoder for the coded signal coded by Turbo coding. This paper analyze the bit error rate performance of the list decoder with L=3 over AWGN and flat

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Rayleigh channel and it compares with the conventional Turbo decoder and 2^k list decoder with L=64. In both channel, it is clear from this paper that the list decoder with L=3 provides the better bit error rate performance.

System model

Any digital communication system consists of digital transmitter and digital receiver. Consider digital transmitter consists of Encoder and Modulator and digital receiver consists of Demodulator and decoder.

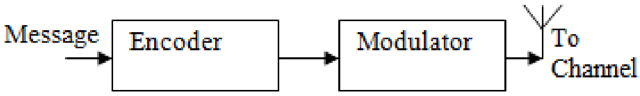

Figure 1: Digital Transmitter

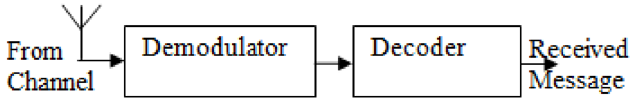

Figure 2: Digital Receiver

The digital transmitter and digital receiver are shown in figure 1 and 2 respectively. This paper uses the Turbo code for encode the message signal and decodes the encoded signal using Viterbi decoder. The block diagram of the turbo code is shown in figure 3.

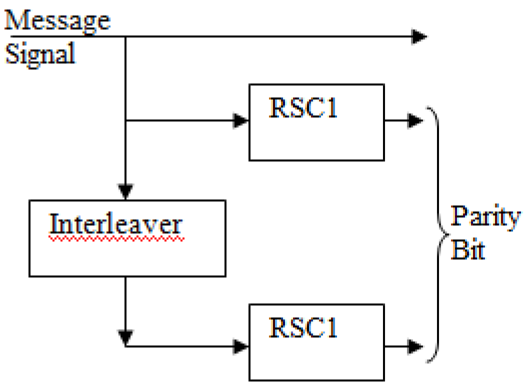

Figure 3: Turbo Encoder

The RSC stands for Recursive systematic convolution code. The output of the two RSC encoder act as a parity bit which is concatenated with the original message signal. This encoded signal can be decoded using Viterbi decoder Algorithm which is described as below:

Algorithm: Viterbi Decoder for Turbo Coding

Input: Message Signal (M) and Parity Bits (P0 and P1)

Input matrix, $I_{nM} = \begin{bmatrix} -1 & 1 \\ -1 & 1 \\ -1 & 1 \\ -1 & 1 \end{bmatrix}$

Parity Check Matrix, $I_{pM} = \begin{bmatrix} -1 & 1 \\ 1 & -1 \\ -1 & 1 \\ 1 & -1 \end{bmatrix}$

Step 1: Apply the message signal (M) to the Interleaver and let its output is assumed to R0.

Step 2: Set BCJR=0 and number of iteration as I.

Step 3: Compute Apriori = 0.5*ones(2, N) where N is the number of bits in the message signal.

Step 4: Calculate the gamma value as below

$$GAMMA(m',m) = P(X=i) * P(S(k+1)=m|S(k)=m',X=i) * P(R_0(k)R_1(k)|S(k+1)=m,S(k)=m',X=i))$$

Step 5: Calculate the alpha (α)value recursively as follow

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$$\alpha_{1,i} = (\gamma_{1,j} * \alpha_{1,i-1}) + (\gamma_{3,j+1} * \alpha_{3,i-1})$$
$$\alpha_{2,i} = (\gamma_{3,j} * \alpha_{3,i-1}) + (\gamma_{1,j+1} * \alpha_{1,i-1})$$
$$\alpha_{3,i} = (\gamma_{2,j} * \alpha_{2,i-1}) + (\gamma_{4,j+1} * \alpha_{4,i-1})$$
$$\alpha_{4,i} = (\gamma_{4,j} * \alpha_{4,i-1}) + (\gamma_{2,j+1} * \alpha_{2,i-1})$$

where$i = 2\ to\ N$ and $j = 1, 3, 5, 7, \ldots \ldots .$
Step 6: Calculate the beta (β)value recursively as follow

$$\beta_{1,i} = \gamma_{1,j} * \beta_{1,i+1} + \gamma_{1,j+1} * \beta_{2,i+1}$$
$$\beta_{2,i} = \gamma_{2,j} * \beta_{3,i+1} + \gamma_{2,j+1} * \beta_{4,i+1}$$
$$\beta_{3,i} = \gamma_{3,j} * \beta_{2,i+1} + \gamma_{3,j+1} * \beta_{1,i+1}$$
$$\beta_{4,i} = \gamma_{4,j} * \beta_{4,i+1} + \gamma_{4,j+1} * \beta_{3,i+1}$$

where$i = N - 1\ to\ 1$ and $j = 2N - 1, 2N - 3, 2N - 5, \ldots \ldots .$
Step 7: Calculate the LAPPR value by

$$lappr(i) = log\left(\frac{p_{x1}(i)}{p_{x0}(i)}\right)$$

where,

$$p_{x1}(i) = \big(\alpha(1,i) * \gamma(1,2*i) * \beta(2,i)\big) + \big(\alpha(2,i) * \gamma(2,2*i) * \beta(4,i)\big) + \big(\alpha(3,i) * \gamma(3,2*i) * \beta(1,i)\big) + \big(\alpha(4,i) * \gamma(4,2*i) * \beta(3,i)\big)$$

$$p_{x0}(i) = \big(\alpha(1,i) * \gamma(1,2*i-1) * \beta(1,i)\big) + \big(\alpha(2,i) * \gamma(2,2*i-1) * \beta(3,i)\big) + \big(\alpha(3,i) * \gamma(3,2*i-1) * \beta(2,i)\big) + \big(\alpha(4,i) * \gamma(4,2*i-1) * \beta(4,i)\big)$$

where$i = 1\ to\ N$
Step 8: If LAPPR value is greater than one, then the decoded bits is set as 1 and if it is not greater than one, then it is set as 0.

Results and Discussion

Figure 4 shows that the theoretical bit error rate performance of convolution code and turbo code using Quadrature Amplitude Modulation (QAM) over additive White Gaussian Noise (AWGN) channel and Binary Symmetric Channel (BSC). From the figure 4, it is clear that the performance of bit error rate is improved in using turbo code compared to convolution code. Also it is clear that the when code rate of turbo code or convolution code is changed from ½ to 1/3, the bit error rate performance is degraded.

Figure 5 shows that the bit error rate performance of convolution code using binary Phase Shift Keying (BPSK) modulation and Quadrature Amplitude Modulation (QAM) technique over an AWGN channel. From the figure 5, it is clear that the convolution code with QAM modulation has better bit error rate performance than BPSK modulation. Here the modulation is done using both binary and gray code. It is clearly shown that the gray code modulation has better bit error rate performance than binary code modulation.

Figure 6 shows that the bit error rate performance of the Turbo code using BPSK modulation. The encoding using turbo code is done by means of number of iterations to reduce the number of bit errors. From the figure 6, it is clear that the bit errors are reduced when the number of iterations is increased. Figure 7 shows that the comparison of bit error rate performance of turbo code using BPSK and QAM modulation technique over an AWGN channel. From the figure, it is clear that the bit error rate performance is improved very much in QAM modulation compared to BPSK modulation

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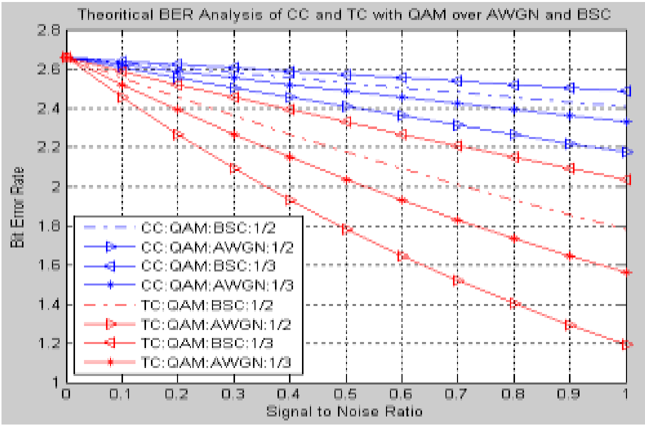

Figure 4 Theoretical BER performance of Convolution and Turbo Code with QAM over AWGN and BSC channel

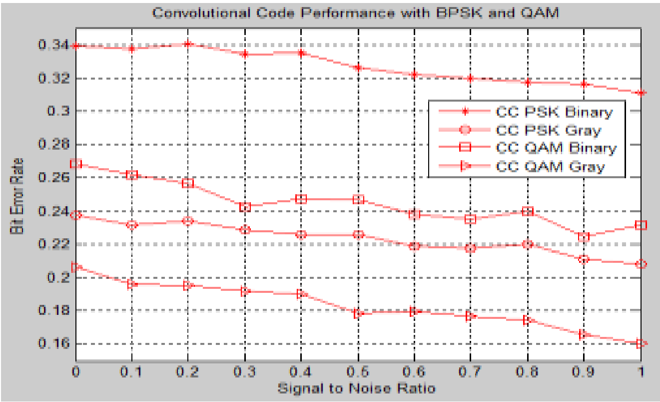

Figure 5 BER performance of Convolution code using BPSK and QAM modulation over an AWGN channel

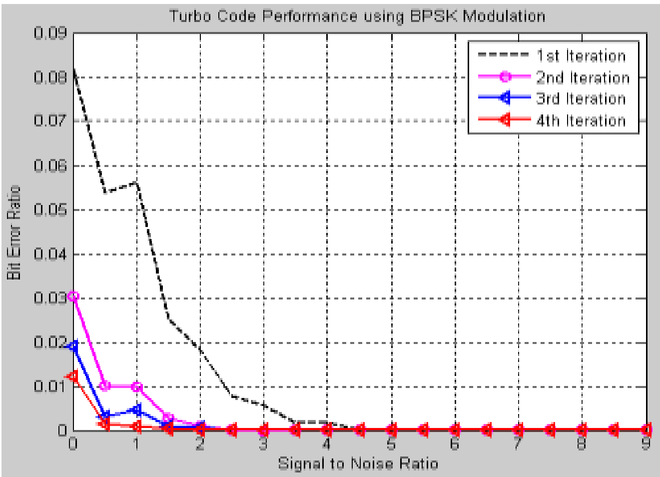

Figure 6 Bit Error Rate performance of Turbo Code using BPSK Modulation with 4 iterations over an AWGN channel

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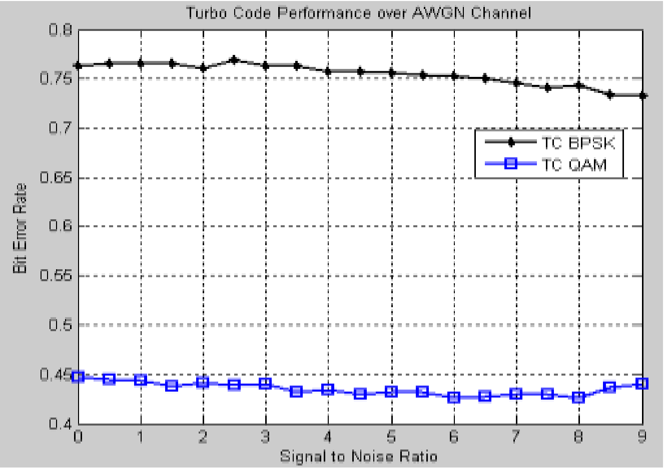

Figure 7 Comparison of Bit Error Rate performance of Turbo Code using BPSK and QAM modulation over an AWGN channel

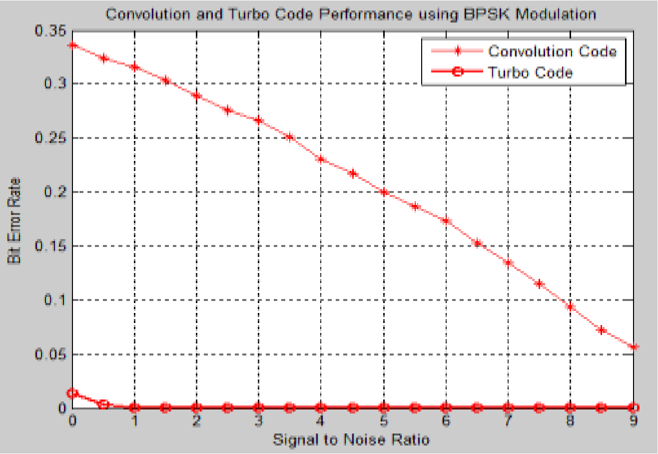

Figure 8 Comparison of BER performance of Convolution and Turbo Code using BPSK Modulation over an AWGN Channel

Figure 8 shows that the comparison of bit error rate performance of convolution and turbo code using BPSK modulation technique over an AWGN channel.From the figure 4.5, it is clear that in the BPSK modulation, the Bit Error Rate becomes very less in Turbo Code than the Convolution code.

Conclusion

This paper analyzed the turbo code using BPSK modulation and QAM modulation over an AWGN channel. This paper concludes that the bit error rate performance of turbo code using QAM modulation gives better performance than BPSK modulation.

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