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Performance Evaluation and Comparative Analysis of Various Concatenated Error Correcting Codes Using BPSK Modulation for AWGN Channel

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Abstract

This paper presents the performance evaluation and comparison of various concatenated error correcting codes using Binary Phase Shift Keying (BPSK) modulation scheme. Three concatenated error correcting code pair i.e. Convolutional-Hamming, Convolutional-Cyclic, Convolutional-Bose, Chaudhuri Hocquenghem is designed and the BER performance was measured for an Additive White Gaussian Noise (AWGN) channel. All pairs of concatenated codes have been compared in terms of bit error rate & energy per bit to noise power ratio and their performance reflects their error correcting capability. All simulation was done using MATLAB R2009a Simulink software. In general Convolutional-Bose Chaudhuri Hocquenghem demonstrate better performance compared to Convolutional-Hamming and Convolutional-Cyclic concatenation pairs.

Keywords: Additive White Gaussian Noise (AWGN) , Convolutional Code, Bose Chaudhuri Hocquenghem (BCH) Code, Hamming code, Cyclic Code, Energy per Bit to Noise Power (E_b/N_o) , Bit Error Rate (BER) , Codeword Length (n) , Message Length (k) , Constraint Length (L) .

Introduction

A reliable transmission of data is the need of every communication system. In communication systems the channel is most evil part. Here signal can get corrupted by noise, distorted and attenuated with many possibilities. The receiver must do its best to produce a received message that resembles the original message as much as possible. However there is always some ambiguity in reception.

Shannon in his paper published in 1948, has given the fundamental theory of information theory which states that "it is possible to transmit information through a noisy channel at any rate less than the capacity with an arbitrarily small probability of error " [1]. Error correcting codes adds redundancy to the original message in such a manner that at the receiver we could detect & correct the received message [2]-[4].

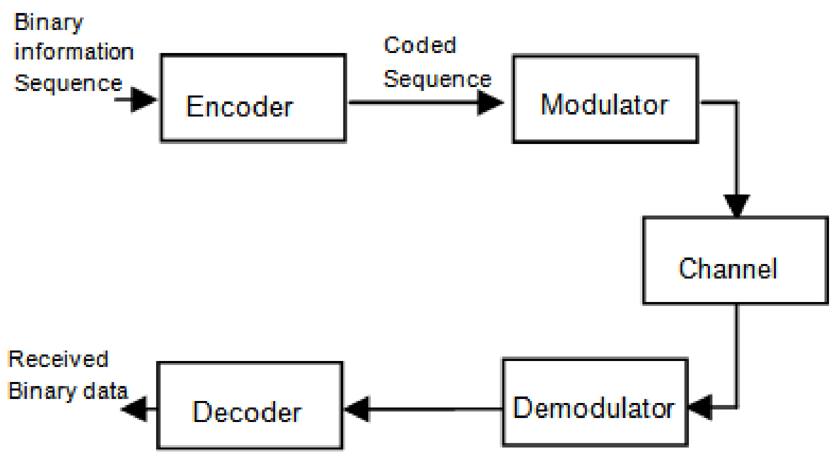

Figure 1: Generic Block diagram of digital communication system

A generic block diagram of digital communication system is shown in figure 1[5]. The input to the encoder is binary information sequence at a rate R bits/sec. There are mainly two types of channel encoding techniques namely Block coding and Convolutional coding. In block coding, a block of k information bits is encoded into a block of n bits known as codeword (n>k) . So for k bits there could be total 2^k possible code words. The code rate defined as the ratio R_c=k/n is a measure of amount of redundancy introduced by block coding. In convolution coding each k bit information symbol to be encoded and transformed into n bit called as codeword such that n>k and transformation is a function of the last L information symbols where L is the constraint length of the code. The codeword can be generated using finite state shift register approach. Thus code rate R_c would be same as that of block codes [6]. Hence a good code is the one that ensure a certain error correcting capability at minimum R_c or maximum output encoder rate R/R_c.

There is always a need for good codes that ensures reliable communication with minimum redundancy. If we concatenate the block and convolutional codes together then the resultant performance of the code improves with the same amount of redundancy. Typically, at inner side we use convolutional codes with small constraint length and at outer side we use block codes with larger block size (k) . The larger symbol size makes the outer code more robust to burst errors that may occur due to channel impairments, and because erroneous output of the convolutional codes itself is busty [7]-[8]. In this paper we are trying to verify the above fact with the simulated results.

The authors of [2] have evaluated performance of Phase Shift Keying modulation scheme using BCH Code, Cyclic Code & Hamming Code through AWGN Channel. In this paper, the performance comparison of these Coding techniques with the various Concatenated pairs i.e. Hamming, Cyclic, BCH, Convolutional-Hamming, Convolutional-Cyclic, Convolutional-BCH are compared to represent the best performance in AWGN environment. The performance is evaluated in terms of BER & symbol error capability.

Methodology

The simulation was divided into three parts; Simulation without error correcting code as shown in figure 2, simulation with error correcting codes namely: Hamming, Cyclic, BCH and Convolutinal code as shown in figure 3 and finally simulation with concatenation of Convolutional-Hamming, Convolutional-Cyclic, Convolutional-BCH codes as shown in figure 4 using BPSK modulator and demodulator in AWGN environment. All simulations were done using MATLAB Simulink software.

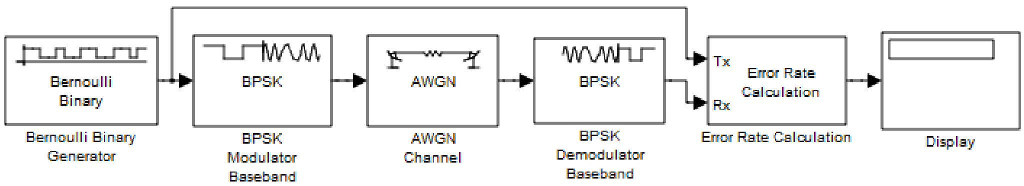

Figure 2: Simulation without Error Correcting Codes

In this simulation the Bernoulli binary generator block generates the random binary numbers using a Bernoulli distribution. This block acts as a information source. Here we are using BPSK modulation scheme. The signal is passed through the AWGN channel. This is acting as a noise source.

During the simulation, the performance is evaluated for various Eb/No i.e. 0 to 10 dB. The characteristics of the AWGN channel are changed by varying Eb/No from 0 to 10 dB to observe the BER performance. The Error rate calculation block compares the input data and the data received after demodulation and calculates the error rate. The display will show the BER at the end of simulation.

For second part of simulation to implement block codes we need to set frame size for Bernoulli random generator, message block size (k) for block code and codeword size (n) for encoder & similar settings for decoder.

For convolutional codes we need to set the rate & constraint length parameters for convolutional encoder. For concatenated codes we need to configure the blocks as we configure it in the above cases. The value of various design parameters has been shown in the Table I.

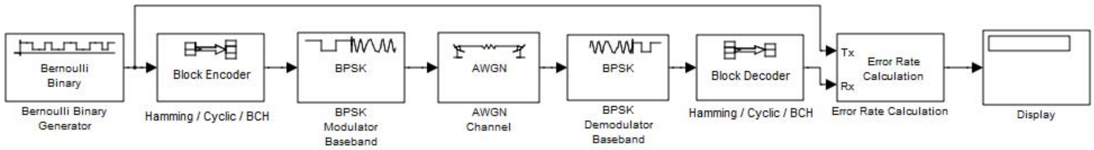

Figure 3: Simulation with Hamming, Cyclic and BCH Error Correcting Codes

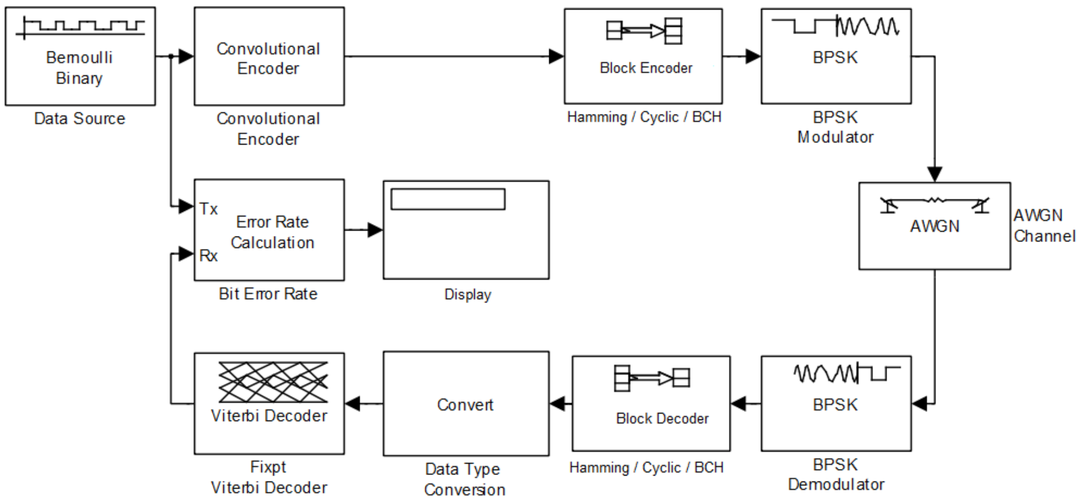

Figure 4: Simulation with Concatenated Error Correcting Code

Table I: Design Parameters

S.No	Experiment Parameters	Value
1.	Data Size	1000000 bits
2.	Message for Block Codes	4 bits
3.	Code length for block Code	7 bits
4.	Message length for Convolutional Code	2 bits
5.	Code length for Convolutional Code	4 bits
6.	Constraint Length	7
7.	Range of Eb/No	0-10 dB

Results and Discussion

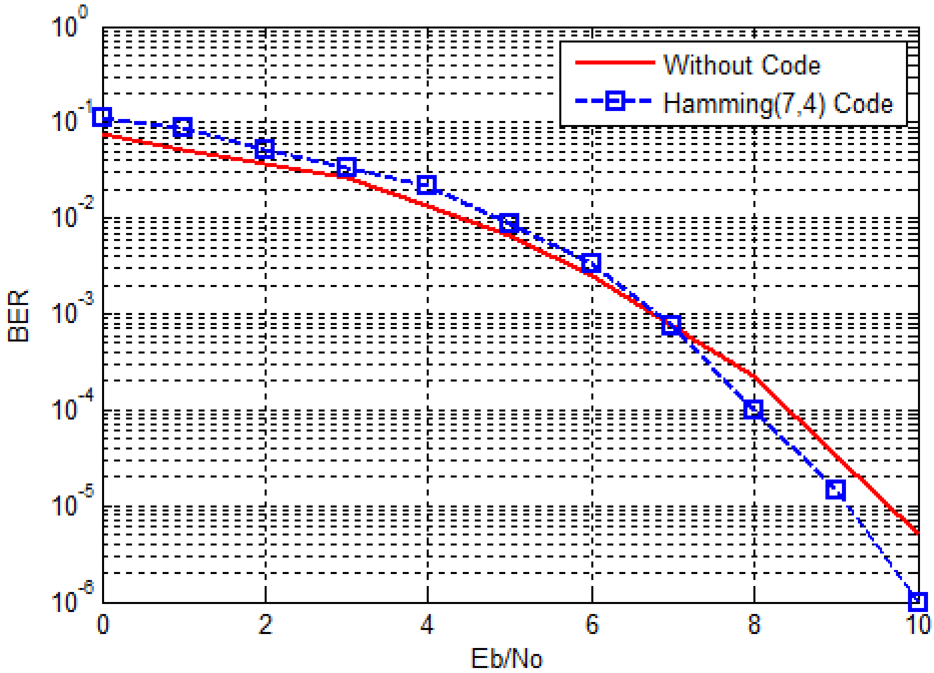

Figure 5: Performance comparison without error correcting codes, with Hamming (7, 4) codes

Similarly, Results in the Figure 6, depicts that initially the performance of BPSK without codes is better than the BPSK with Cyclic (7, 4) codes. At Eb/No=2 dB BER without codes is found to be 0.03771 while with Cyclic code it is 0.0636. After that the performance improves when Eb/No is greater than 6.2 (dB) . At Eb/No=8 dB the BER without codes is found to be 0.0002273 while with Cyclic code it is 0.0001041.This shows that cyclic codes have better performance over hamming codes. Similarly the performance of BCH codes is analysed in Figure 7.Initailly the performance of BCH is found degraded than BPSK without codes. At Eb/No=2 dB BER without codes is 0.03771 while it is 0.06211 with BCH code. The BCH BER curve crosses when Eb/No equals to 6.8 (dB) and there after performance improves. At Eb/No=8 dB the BER without codes is found to be 0.0002273 while with BCH code it approaches to $1x10^{-005}$. Performance of BCH codes could be further improved by adding more redundant bits. From the analysis it is found that among Hamming and Cyclic, BCH is the most effective code in terms of error correcting and detecting capability.

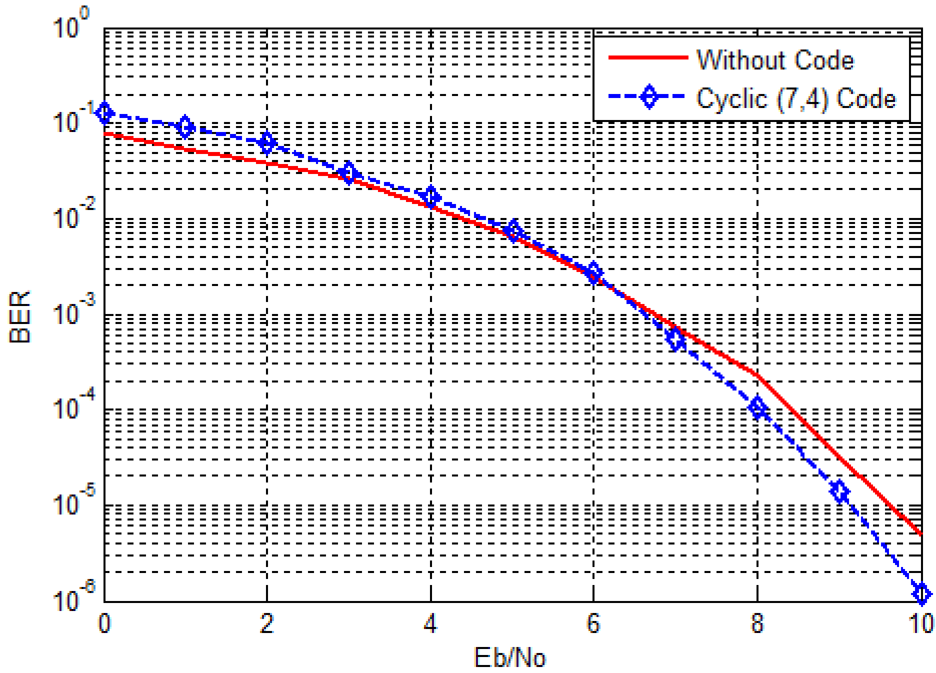

Figure 6: Performance comparison without error correcting codes, with Cyclic (7, 4) codes

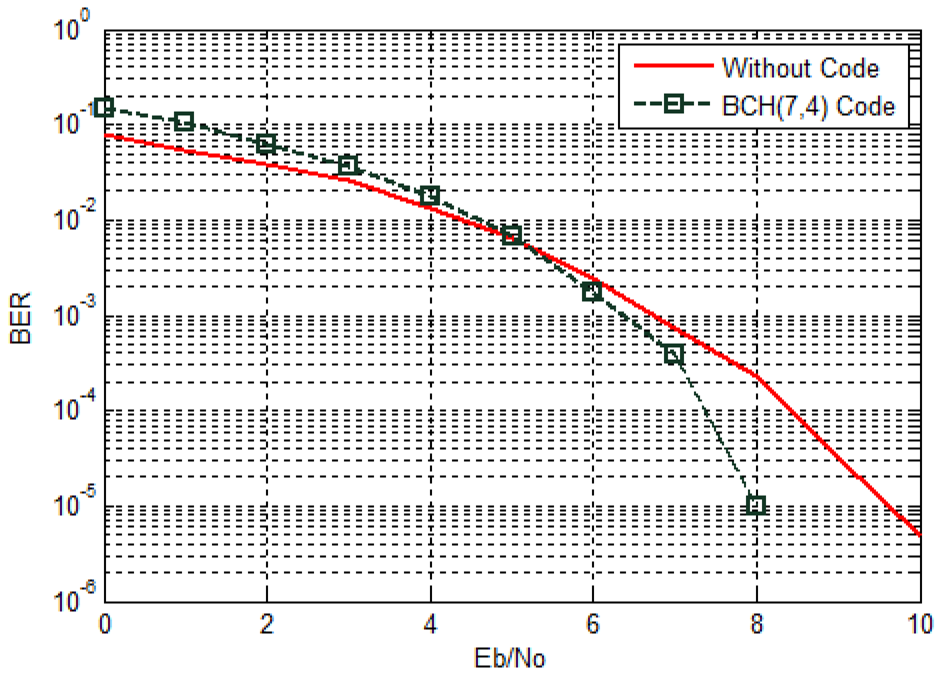

Figure 7: Performance comparison without error correcting Codes, with BCH (7, 4) codes

From the graph in Figure 8, Initially the performance of BPSK without codes is better than the BPSK with Concatenated Convolutional (2, 1, 7) -Hamming (7, 4) codes as what observed in the previous cases. At Eb/No=2 dB BER without codes is found to be 0.03771 while with Convolutional (2, 1, 7) -Hamming (7, 4) codes it is 0.4469. The BER curve of Convolutional (2, 1, 7) -Hamming (7, 4) crosses the BER curve without codes at Eb/No equals to 6.8 (dB) . At Eb/No=7 dB the BER without codes is found to be 0.0007426 while with Convolutional (2, 1, 7) -Hamming (7, 4) codes it is 0.00014. It is quite clear that on concatenation with convolution code the performance of Hamming code has been improved.

Results in Figure 9 depicts that initially the performance of BPSK without codes is better than the BPSK with Concatenated Convolutional (2, 1, 7) -Cyclc (7, 4) codes. Later on the BER curve intersects at Eb/No =5.6 (dB) . These results are in agreement with the fact that concatenation of codes improves the performance.

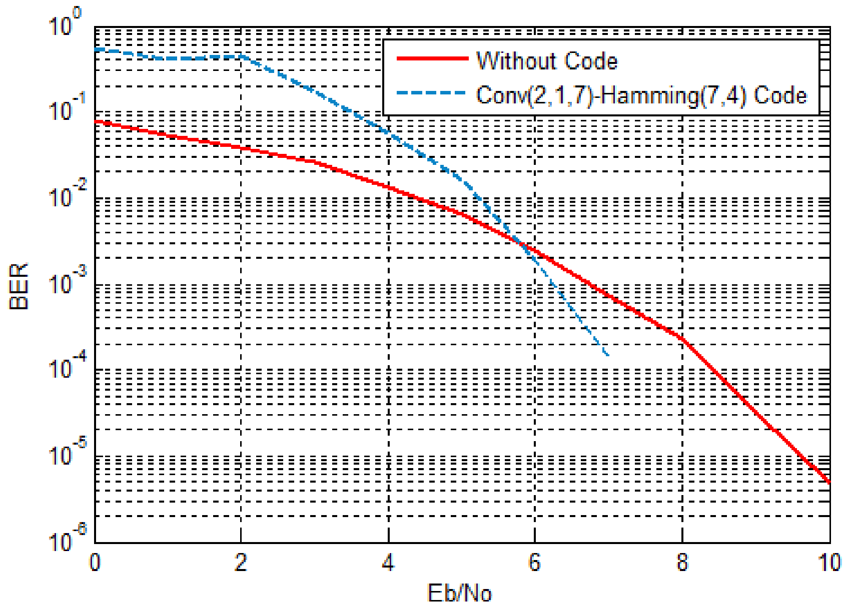

Figure 8: Performance comparison without error correcting Codes, with Concatenated Convolutional-Hamming codes

Thus it is quite clear that on concatenation with convolution code the performance of Cyclic code has been improved.

As depicted in earlier cases initial performance of BPSK without codes is better than the BPSK with Concatenated Convolutional (2, 1, 7) -BCH (7, 4) codes.In figure 10 at Eb/No=2 dB BER without codes is found to be 0.03771 while with Convolutional (2, 1, 7) --BCH (7, 4) codes it is 0.3717. The performance further improves when Eb/No is greater 5.8 (dB) . At Eb/No=7 dB the BER without codes is 0.0007426 while with Convolutional Convolutional (2, 1, 7) --BCH (7, 4) codes it is $2.4x10^{-005}$.

The results shown in figure 10 represents that the over all performance of Concatenated Convolutional (2, 1, 7) -BCH (7, 4) is among all codes used in the simulation. It is approximately 10db better then the performance of BPSK without codes. After that here comes Convolutional (2, 1, 7) -Hamming (7, 4) then finally Convolutional (2, 1, 7) -Cyclic (7, 4) .

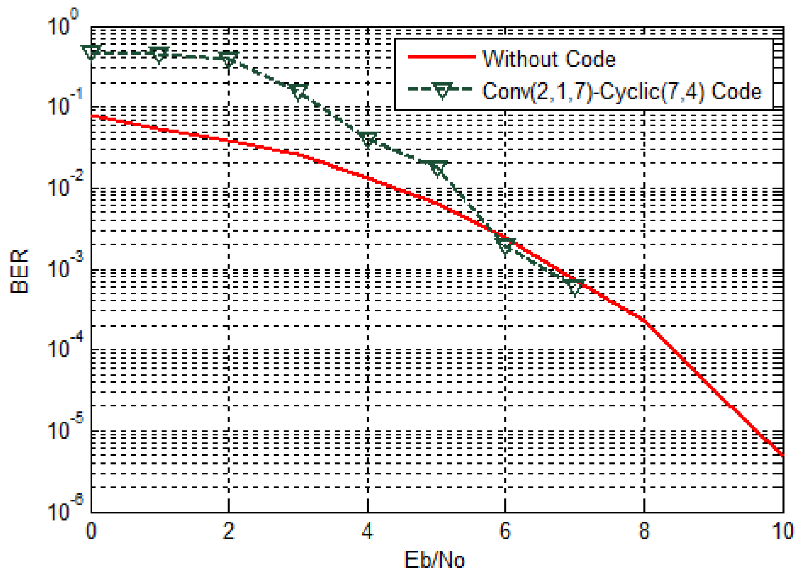

Figure 9: Performance comparison without error correcting codes, with Concatenated Convolutional (2, 1, 7) -Cyclic (7, 4) codes

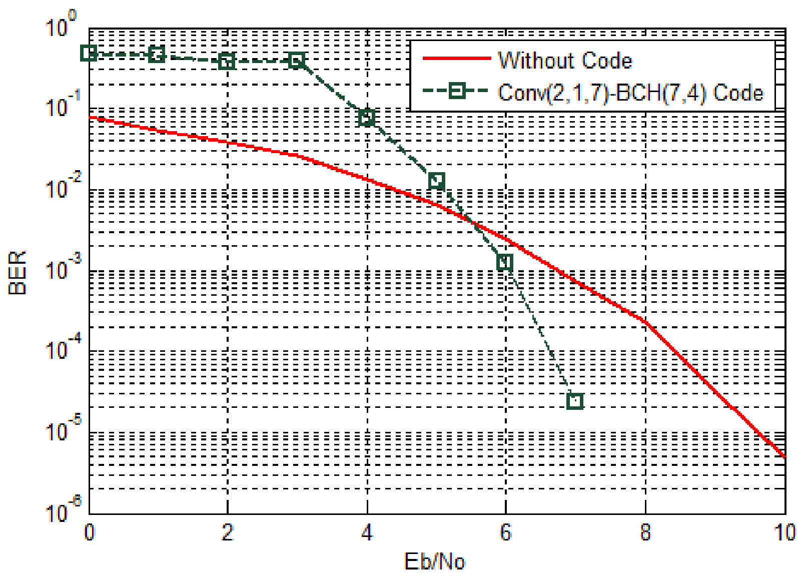

Figure 10: Performance comparison without error correcting codes, with Concatenated Convolutional (2, 1, 7) -BCH (7, 4) codes

Conclusion and Future Scope

The simulation shows that the performance of concatenated block and convolutional Error control codes compared to single codes is better. The performance of Convolutional (2, 1, 7) -BCH (7, 4) is best among Hamming (7, 4) , Cyclic (7, 4) , BCH (7, 4) , Convolutional (2, 1, 7) -Hamming (7, 4) , Convolutional (2, 1, 7) -Cyclic (7, 4) codes. The performance could be further improved by adding more redundancy. This confirms the fact that by concatenation of Error correction codes we can improve the correction capability of codes and could reach near to the Shannon limit. However this increases the complexity of the communication system. But for reliable communication there must be some trade-off between system complexity and correction capability of the codes. Hence the objective of the research is successfully achieved in which this paper, success to analyse and simulates the performance of BPSK using different types of concatenated error control codes through AWGN channel.

In future, this research paper can be extended by evaluating the performance of these concatenated error correcting codes over higher order modulation schemes. Further we could also extend our work to hybrid ARQ codes which will be of great use now days.

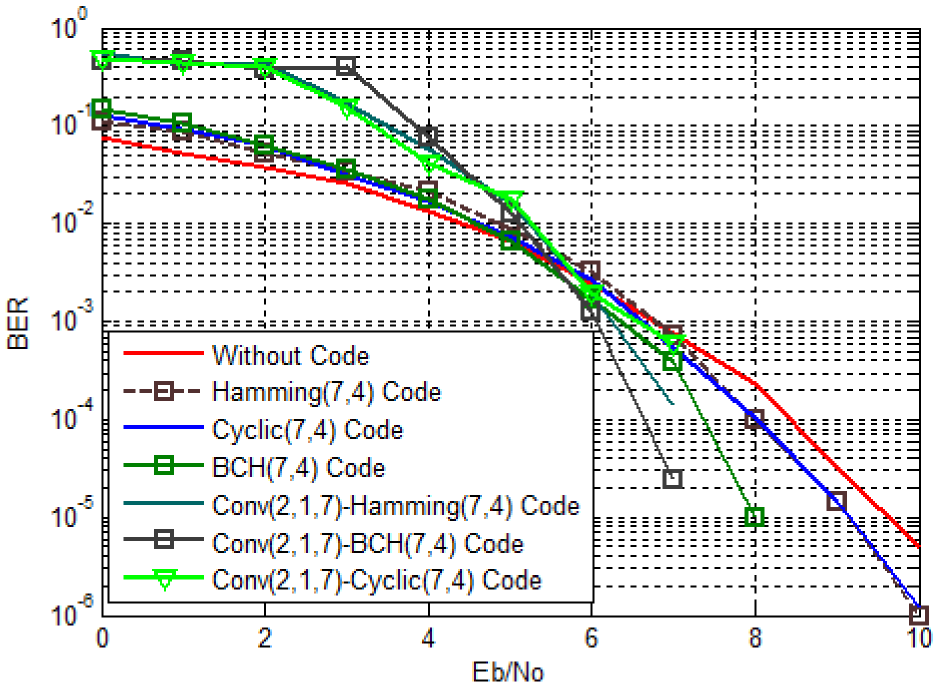

Figure 11: Performance comparison without error Correcting Codes , with Hamming (7, 4) , Cyclic (7, 4) , BCH (7, 4) , Convolutional (2, 1, 7) -Hamming (7, 4) , Convolutional (2, 1, 7) - BCH (7, 4) codes, Convolutional (2, 1, 7) - Cyclic (7, 4)

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