IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 11, November 2016

Goodness Analysis of Generator Polynomial for Convolution Code with Varying Constraint Length

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Abstract: Convolutional codes play a vital role in reducing the error produced due to dispersive effect, fading, attenuation, interference and noise during transmission and reception of data. With a proper design, convolutional encoder and Viterbi decoder can jointly provide an acceptable performance with feasible decoding complexity. In this combination, a tradeoff on the error performance and decoding complexity resides on the choice of the constraint length. However, the increase in code constraint length leads to exponential increase in the computational complexity of the Viterbi decoder. In this paper, a simulink model with convolution encoder and viterbi decoder for ½ code rate is designed with varying constraint length from 3 to 10. The bit error rate performance has been analyzed for different generator polynomials and their goodness is examined with the motive of proposing the best generator polynomial at different SNR values.

Keywords: Convolutional codes, BPSK, AWGN, Viterbi Algorithm, Generator polynomial.

I. INTRODUCTION

In wireless communication, whenever data is transmitted or received, error is produced due to dispersive effect, fading, attenuation, interference, and channel noise. To receive errorless data, these effects can be overcome by channel coding techniques like block codes, convolutional codes and concatenated codes. Of all these coding techniques convolutional codes are the most efficient and adopted technique to reduce error [20].

For the online digital data transmission, convolution codes are the preferred choice. A message is convoluted, and then transmitted into a noisy channel. This convolution operation encodes some redundant information into the transmitted signal, thereby improving the error detection capacity of the channel.

These are used mostly for the channel encoding in latest wireless communication standards like 3GPP, GSM and WLAN to achieve low-error-rate.

A convolutional code is described using three parameters k, n and m. The integer 'k' represents the number of input bits for each shift of the register. The integer 'n' represents the number of output bits generated at each shift of the register and 'm' is the number of shift registers [13] [16]. The coding rate R is defined as R=k/n and it represents the amount of information coded per encoded bit.

The integer K is called the constraint length of the code and is defined by K = k (m-1), which represents the number of k bit stages present in the encoding shift register.

Each possible combination of shift registers together forms a possible state of the encoder. Generally, in commercial specifications convolutional codes are defined by code rate 'r' and constraint length 'K'. For a code of constraint length K, there exist 2K-1 possible states [5].

A convolutional code is described as CC(n,k,K). For 3 constraint length ½ rate coder, convolutional code is defined as (2, 1, 4). A typical ½ rate convolution coder is shown in Figure 1.1.

Generator Polynomials: The generator polynomial specifies the connections between the shift registers and the modulo-2 adders. It is defined by-
g(i)(d)=g0(i)+g1(i)(d)+ g2(i)(d2)+……..+gm(i)(dm)
where, d = unit delay variable
m = number of shift registers.

Poly2trellis:
Syntax:trellis=poly2trellis(ConstraintLength, CodeGenerator)

Viterbi algorithm is the best error correction method that provides tradeoff between complexity of hardware and power consumption. The Viterbi Algorithm (VA) was first proposed as a solution to the decoding of convolutional codes by Andrew J. Viterbi in 1967[1].

It operates on data stream and has memory that uses previous bits to encode. The algorithm tracks down the most likely state sequences the encoder went through in

IJARCCE
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Vol. 5, Issue 11, November 2016

encoding the message, and uses this information to determine the original message. Instead of estimating a message based on each individual sample in the signal, the convolution encoding and Viterbi decoding process packages and encodes a message as a sequence, providing a level of correlation between each sample in the signal.

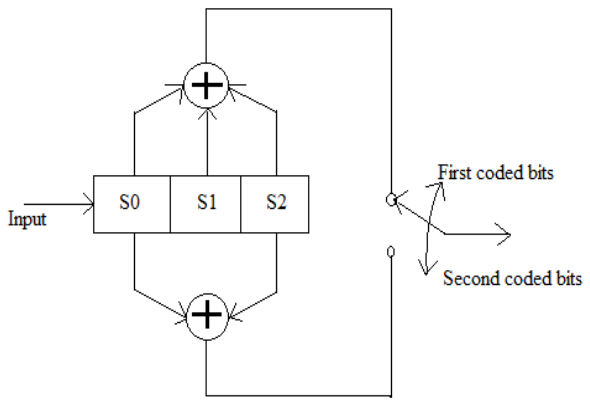

Fig.1.1: Rate ½ convolutional coder for constraint length=2

A combination of convolutional encoder and viterbi decoder can jointly provide an acceptable performance with reasonable decoding complexity. In this combination, the error performance and decoding complexity resides on the choice of the constraint length.

Specifically, the probability of the Viterbi decoding failure decreases exponentially as the code constraint length increases. However an increment of the code constraint lengths also exponentially increases the computational efforts of the Viterbi decoder [6].

In this work, for a given constraint length of 3 and 4, the most suitable generator polynomial has been analyzed using simulink based digital communication system. Further, higher constraint length codes up to 10 have been designed and tested so as to detect the possibility of a generator polynomial at lower constraint length having performance same as that of a higher constraint length polynomial.

The convolution encoder and viterbi decoder for ½ code rate is designed. All the simulations are conducted in MATLAB over AWGN channel using BPSK modulation scheme. The bit error rate performance has been carried out for different generator polynomials of different constraint lengths like 3 to10. The performance of all generated polynomials is analyzed in terms of BER for different signal to noise ratios.

II. DESIGNED MODEL

Using the MATLAB software as required and employing the knowledge of analytical theory of the coding fundamental principles, the convolutional encoder and Viterbi decoder is modeled as shown in Fig.2.1.

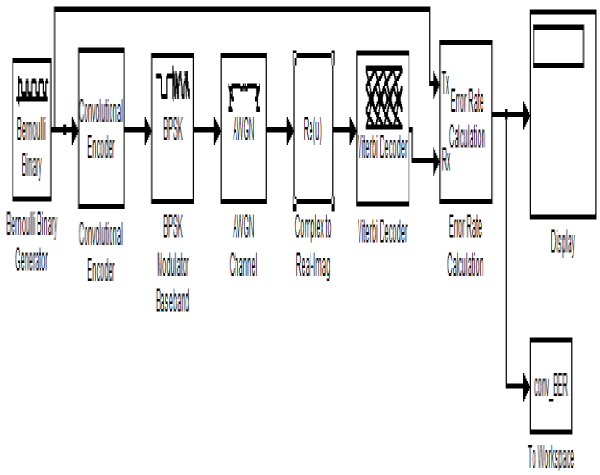

Fig.2.1: Simulink model for convolution encoder with viterbi decoder

Table 2.1: Parameters used in the design of convolution coding based digital communication system

Blocks	Parameters values used for simulations	
Bernoulli binary generator	Initial seed	61
	Output	Double
	Samples per frame	1
Convolutional Encoder	Code rate	½
AWGN Channel	Initial seed	113
	Mode parameter	E_s/N_o
	Input signal power	1 watt
	Symbol period	0.5 sec
	Range of E_s/N_o	0-10dB
Viterbi decoder	Inputs	Unquantized
	Traceback depth	96

III. PERFORMANCE ANALYSIS

In this work, a convolution code based digital communication System as shown in Figure2.1 has been designed using simulink platform in MATLAB. The performance of the same has been tested-

❖ For different constraint lengths of the ½ rate convolution encoders. The selection of best polynomial in terms of lower BER performance has been carried out. The constraint lengths considered for the purpose are 3 and 4.

❖

❖ In addition, the impact of different type of generator polynomials and constraint length on the performance of the system has been investigated in terms of BER. The constraint length is varied from 3 to 10 for the ½ rate convolution encoders.

IJARCCE

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A. Most Suitable Generator Polynomial

a) For Constraint Length = 3:

For the constraint length =3, the simulated results as obtained by using parameter as shown in Table 2.1 are presented in presented in Fig 3.1 in terms of BER. The results for all possible combination of constraint length 3 for ½ code rate are analyzed. For constraint length 3, three bits are used to encode data.

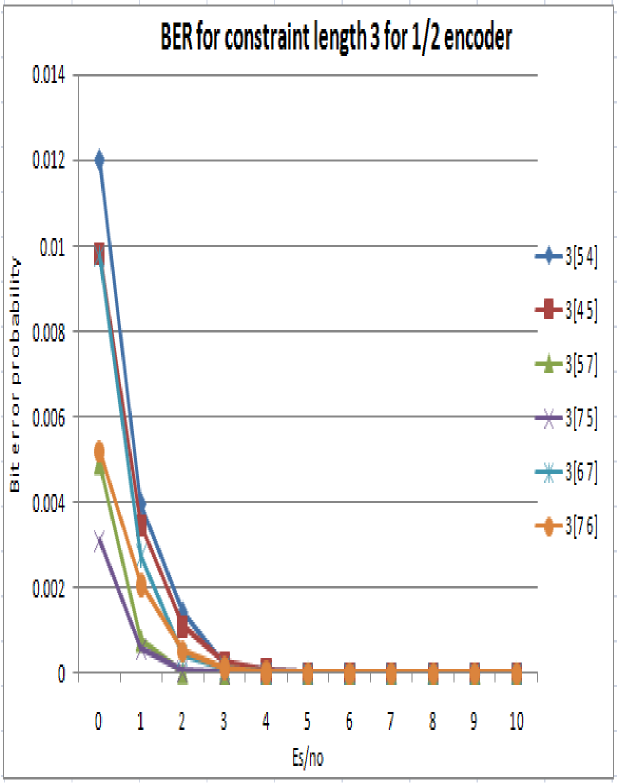

Fig. 3.1: BER performance of different generator polynomials at 3 constraint length

There are 12 possible combinations of generator polynomials for constraint length 3 at ½ code rate. The calculated figures shows that four generator polynomials 3[7 5], 3[5 7], 3[4 7] and 3[7 6] gives very small BER thus these polynomials can be selected for errorless transmission of data.

The polynomial 3[7 5] can be selected as the most appropriate polynomial as it has least BER (0.01525). Further, beyond Es/No 3dB the transmission is quite reliable as indicated by negligible or near zero BER.

b) For constraint Length =4

For constraint length 4, four bits are used to represents data that is used to encode the information data bits.

Fig.3.2 shows the results for different generator polynomials of constraint length 4 which are calculated in terms of BER by using the parameters shown in Table 2.1**.**

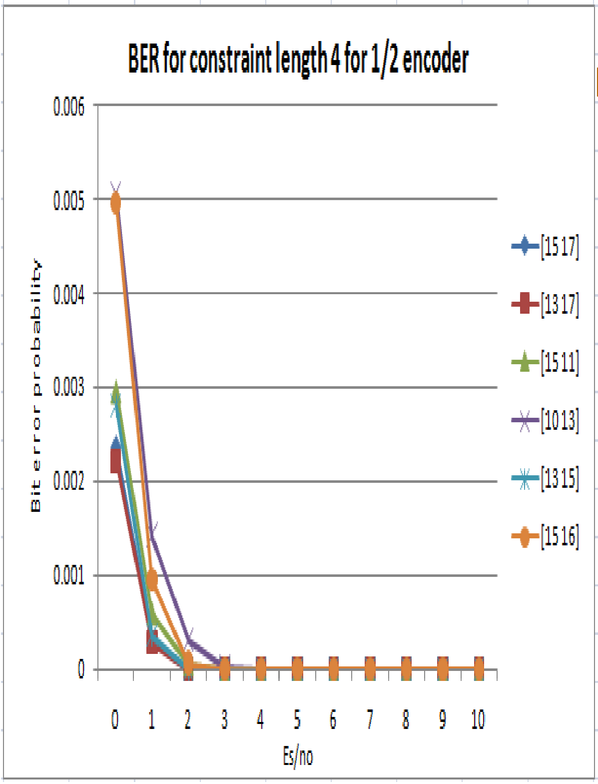

Fig.3.2: BER performance of different generator polynomials at 4 constraint length

There are 48 possible combinations of polynomials at constraint length 4 for code rate ½. Some selected polynomials have been plotted to detect the logical generator polynomial.

The polynomial 4[15 16] and 4[10 13] gives quite high BER at lower values of Es/No but these rapidly decreases beyond 2dB and it is concluded that all polynomials provide reliable transmission beyond this value of Es/No as BER is negligible. The polynomials 4[15 17] and 4[13 17] proved as valid generator polynomials as they have zero BER at 2dB.

B. Performance of Different Constraint Length Codes

The performance of the system largely depends on selection of generator polynomial for particular constraint length. The results of different generator polynomials for constraint length 3 to 10 calculated in terms of BER are shown below.

Table 3.1: Suitable generator polynomials for ½ rate convolutional coder for constraint length 3 to 10

Constraint length	Tested polynomials	Best polynomial	BER
3	3[5 4], 3[4 5], 3[5 7], 3[7 5], 3[6 7], 3[7 6], 3[7 4], 3[6 5], 3[5 6], 3[4 7], 3[7 7], 3[5 5]	3[7 5]	**0.01525**

4	4[11 10], 4[13 10], 4[15 10], 4[17 10], 4[10 11], 4[15 11], 4[12 11], 4[13 11], 4[14 11], 4[15 11], 4[16 11], 4[17 11],4[11 12], 4[13 12], 4[15 12], 4[17 12], 4[10 13], 4[11 13], 4[12 13], 4[13 13], 4[14 13],4[15 13], 4[16 13], 4[17 13], 4[11 14], 4[13 14], 4[15 14], 4[17 14], 4[10 15], 4[11 15], 4[12 15], 4[13 15], 4[14 15],4[15 15], 4[16 15], 4[17 15],4[11 16], 4[13 16], 4[15 16],4[17 16], 4[10 17], 4[11 17],4[12 17], 4[13 17], 4[14 17],4[15 17], 4[16 17], 4[17 17]	4[13 17]	**0.01583**
5	5[32 35], 5[25 31], 5[31 25], 5[36 25], 5[25 36], 5[34 23], 5[21 20], 5[26 21], 5[20 21], 5[36 37], 5[35 32]	5[36 25]	0.01297
6	6[65 73], 6[73 65], 6[56 67], 6[43 65], 6[63 54], 6[43 72], 6[76 65], 6[65 76], 6[67 56], 6[54 63], 6[72 43]	6[43 65]	**0.005463**
7	7[171 133], 7[176 135], 7[171 131], 7[177 133], 7[133 171], 7[126 145], 7[177 131], 7[162 145], 7[165 165], 7[145 162], 7[177 113]	7[177 133]	**0.005516**
8	8[267 356], 8[267 363], 8[337 216], 8[216 337], 8[377 225], 8[315 210], 8[275 356], 8[225 377], 7[356 275], 8[363 267], 8[210 315]	8[315 210]	0.008114
9	9[670 715], 9[715 670], 9[453 572], 9[572 453], 9[735 534], 9[534 735], 9[547 746], 9[746 547]	9[453 572]	0.002811
10	10[1563 1631], 10[1631 1563], 10[1035 1276], 10[1276 1035], 10[1625 1437], 10[1437 1625], 10[1356 1163], 10[1562 1347]	10[1631 1563]	0.00139

Table 3.1 shows the BER value of some good generator polynomials selected by testing various generator polynomials for different constraint lengths. The polynomials are categorized on the basis of BER and the performance has been tested by varying signal to noise ratio. The graphical representation of the performance of the detected polynomials has been shown below in the Fig.4.1.

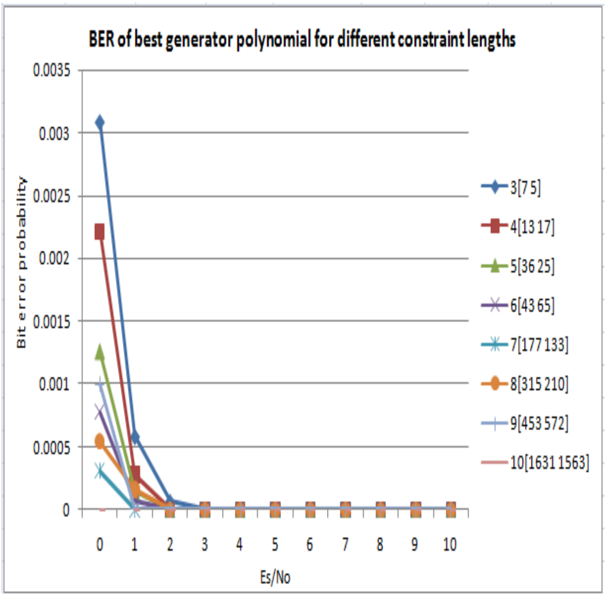

Fig. 4.1: BER performance of best generator polynomials at different constraint lengths

From the results it is depicted that the constraint length 10 polynomials have least BER. Thus it can be said that as the constraint length increases the BER decreases. The system at constraint length can perform better than the lower constraint length system but at the cost of increasing complexity.

As it is noticed from the results that the polynomial 3[7 5] and 4[13 17] and the polynomials 6[43 65] and [177 133] has same BER thus instead of using polynomial of constraint length 4 we can use the polynomial of constraint length 3 and in place of 7 constraint length polynomial the polynomial of constraint length 6 can be used to reduce the computation efforts of decoder which further reduces the complexity of the system. From the graphical results shown in Fig. 4.1 it is depicted that beyond 2dB Es/No all the selected polynomials provide much reliable transmission as they give negligible or near zero BER.

IV. CONCLUSION

The performance of convolutional codes depends on various parameters like code rate, constraint length, and generator polynomials. The performance of a digital communication system, in terms of BER, is improved as the constraint length increases, though at the cost of increasing system complexity. In this paper, the impact of generator polynomial is analyzed on the performance of the system for different constraint length codes. For the constraint length 3 and 4 the most suitable generator polynomials turn out to be 3[7,5] and 4[13,17] in terms of lower BER. Further, it is concluded that inappropriate selection of generator polynomial may result in poorer results even at higher constraint length resulting in increased complexity as well. Appropriate generator polynomial selection at lower constraint length may result in comparable or even better BER thereby resulting in better performance and lower complexity of the system.

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