Performance Review of Serially Concatenated RSC-RSC Codes using Non-iterative Viterbi Decoding Technique

Navdeep Singh[1], Gagandeep Kaur[2]

[1]*M.tech, Electronics and Communication Engg., Punjabi University Patiala Yadavindra College of Engineering, Talwandi Sabo, Punjab, India, navdeepsingh019@gmail.com*
[2]*Department of Electronics and Communication Engg., Punjabi University Patiala Yadavindra College of Engineering, Talwandi Sabo, Punjab, India,ergagan84@gmail.com*

Abstract—In this paper, review about the performance of RSC-RSC concatenated system in terms of bit error rate (BER) is done using MATLAB software. The RSC-RSC system uses Concatenation of Recursive systematic convolution codes (RSC) as outer and inner codes with the help of interleaver. For decoding of RSC-RSC system, we have used a non-iterative decoding scheme which includes two Viterbi decoders in concatenation with de-interleaver. We show that in the RSC-RSC system BER decreases, as the signal to noise ration increases. We have also investigated the performance of RSC-RSC system for effect of varying data rate using puncturing.

Keywords— Turbo codes; serially concatenated convolutional codes; Recursive systematic convolutional codes; Viterbi decoding; Channel coding.

I. INTRODUCTION

In Digital communication system, channel encoding improves the bits in error rate by added redundancy (additional bits). The primary objective of error-correcting coding is to improving the reliability of communication system. Channel coding is often used in digital communication systems to protect the digital information from noise and interference and reduce the number of bit errors. The history of channel coding, also referred to as forward error correction, In Shannon 1948 article, "A mathematical theory of communication",[1] According to Shannon, it is possible to design codes with any desired small probability of error, whenever the transmission rate is smaller than the capacity of the channel. Unfortunately, Shannon provided no insights on how to actually design these codes.

Until the late 1940s, communication devices were equipped with error detection capabilities only. In 1950 Hamming was the first to propose a single-error correcting code [2], while Golay developed a more efficient scheme able to correct up to three erroneous bits [3]. Both Hamming and Golay codes group blocks of information bits together with parity check bits, the latter being computed using a mathematical combination of the information bits. These types of codes are known as block codes. Popular variations of block codes are the Reed-Muller and the cyclic redundancy codes. Sub- classes of cyclic redundancy codes, such as the Bose-Chaudhuri-Hocquenghem and Reed-Solomon codes, are still used in a wide variety of applications [4].

In 1955, Elias introduced the concept of convolutional coding [5]. The convolutional encoder makes use of shift registers to generate output bits based on the present input bit as well as past inputs.Convolutional codes are one of the powerful and widely used class of codes, These codes are having many applications, that are used in deep-space communications, voiceband modems, wireless standards(such as 802.11) and in satellite communications. The main advantage of convolutional codes over block codes is better error rate performance, owing to the optimal exploitation of soft channel observations by the decoding algorithm. In particular, Viterbi proposed a maximum likelihood sequence estimation algorithm [6] in 1967, while a more efficient but more complex algorithm, based on maximum a-posteriori decoding, was developed by Bahl et al. [7] in 1974. Convolutional coding was initially introduced in standards for satellite communication applications and deep space missions, but

was later also adopted in mobile communication systems.

Concatenation of codes was the next significant step that enabled better performance of codes on communication channels that introduced burst errors. More specifically, Forney showed [8] in 1966, that a concatenated coding system with a powerful outer code can perform reasonably well, when its inner decoder is operated in the high error probability region. In principle, block encoders can be combined with convolutional encoders and interleavers, in parallel or serial schemes.In 1989, Concatenation ofmultiple convolutional codes [9] was introduced, in which Soft Output Viterbi Algorithm (SOVA) are used. However, in 1993, interest shifted back to channel coding, when Berrou, et.al presented turbo codes [10]. Particularly, a turbo encoder is the parallel concatenation of two convolutional codes separated by an interleaver. However, the name "turbo" comes from the similarity in logic between the turbo engine and the iterative decoding process between the two component soft-input soft-output (SiSo) convolutional decoders at the receiver.It shown the performance of Turbo code, in terms of Bit Error Rate (BER), is very close to Shannon's limit.

Shortly after the introduction of the turbo codes, it turned out that serially concatenated RSC codes with a random bit interleaver were equally suitable for iterative decoding [11]. In [12], the authors claim that these codes may have even better performance than the turbo codes. Fig. 1(a) and (b) describe the encoder/decoder of SCCC.

(a)

(b)
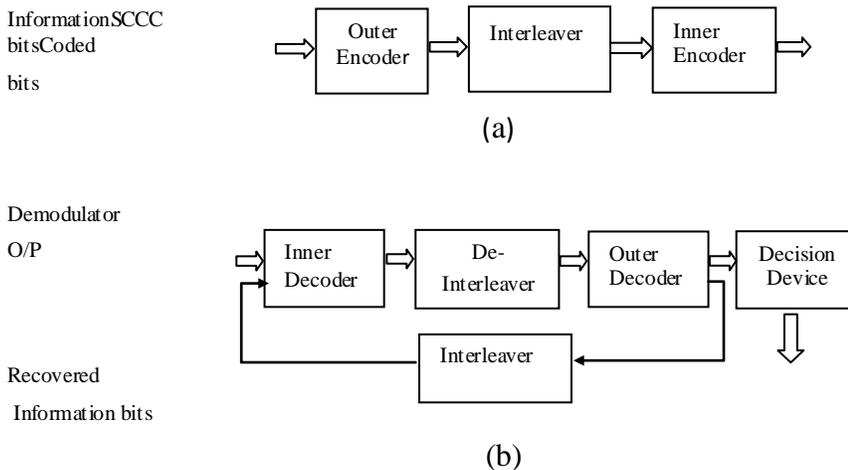
Figure 1. Structure of SCCC encoder and decoder. (a) SCCC encoder structure (b) SCCC decoder structure.

The iterative decoding yield a remarkable increase in performance than a single iteration decoding and in some cases approximates the theoretical limit. Through iterative decoding scheme, performance in terms of BER is enhanced, but at the expense of complexity of the system.

However, the convolutional codes suffered from the problem of burst errors [13] and Reed Solomon codes suffered from problem of random errors [14]. To compensate this problem, a new concatenated scheme was proposed in which a concatenation of a Reed-Solomon (RS) code and a Recursive systematic convolutional code (RSC) codes was used & it was shown that RS-RSC concatenated codes have good performance than RSC itself [15]. For SCCC codes, simple concatenated Viterbi decoding was proposed with certain drawbacks [16].

In recently research a solution was provided that, RSC-RSC serially concatenated convolutional code with non-iterative concatenated Viterbi decoding was implemented and it shown that RSC-RSC system has better BER performance than RS-RSC concatenated code [17].

In this paper, we compare the BER performance of serially concatenated RSC-RSC code using non-iterative concatenated Viterbi decoding [17]. In Modern communication system, a low bit error rate,

signal-to-noise ratio is very important parameter. The rest of the paper is organized as follows. In section II, system structure of concatenation scheme is presented. The simulation results and its discussion are given in section III. Finally, the section IV concludes the paper rate, signal-to-noise ratio are very important parameter. The rest of the paper is organized as follows. In section II, system structure of concatenation scheme is presented. The simulation results and its discussion are given in section III. Finally, the section IV concludes the paper.

II. SYSTEM STRUCTURE

In this section, structure of the simulated system with simulation parameter is described.

The basic scheme of two serially concatenated block codes [11] is shown in Fig. 2.
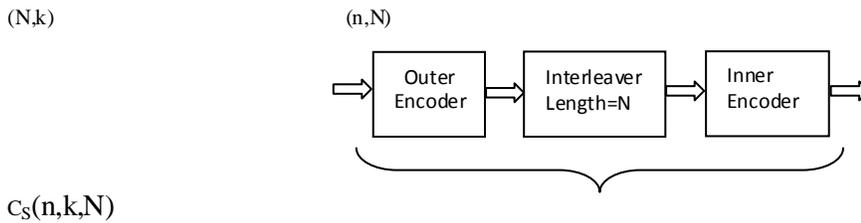
Figure 2. Serially concatenated (n,k,N) block code.

It is composed of two cascaded CCs, the outer (N,k) code C_o with rate $R_o^c =k/N$ and the inner (n,N) code C_i with rate $R_i^c=N/n$, linked by an interleaver of length N. The overall Serially concatenated block code is then an (n,k) code, and we will refer to it as the (n,k,N) code C_s, including also the interleaver length.

A.   RSC-RSC system:

A serially concatenated RSC-RSC code is concatenated of two recursive systematic convolutional encoder (i.e, outer encoder and inner encoder) through an interleaver in between them. Because convolutional encoder improves only random error, so we have used an interleaver in serially concatenation between outer encoder and inner encoder which provides solution to improve the brust error correction.

B.   Simulation Model:

The simulation model of RSC-RSC concatenated system is shown in Figure 3. In this setup, RSC-RSC system is implemented with two RSC encoder of feed forward polynomial of [133 171] and feedback polynomial of [133], with constraint length of 7. Their base code rate is 1/2 each and punctured code rates are 1/2, 2/3, 3/4. For decoding of RSC-RSC, two Viterbi algorithm decoders in serially concatenated with de-interleavers are used. The effect of signal-to-noise ratio on bit-error rate is observed. Table 1 describes the simulation parameters used in simulation model.
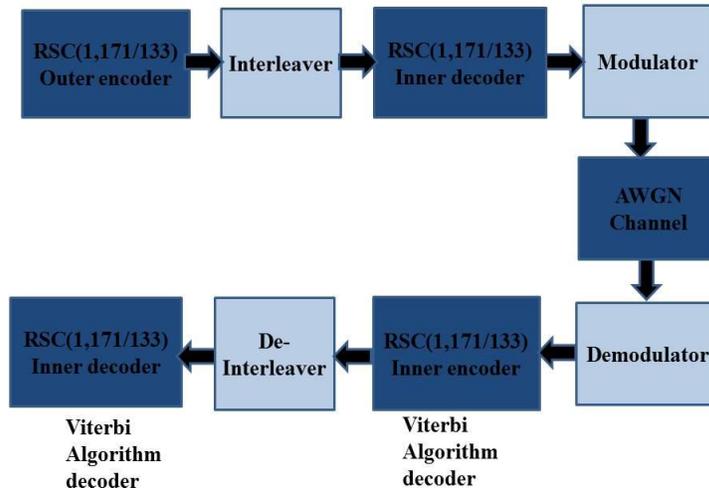
Figure 3. Simulation Model for RSC-RSC system [17]

Table 1. Simulation Parameters of RSC-RSC System [17]

Outer Encoder	Inner Encoder
RSC (1,171/133)	RSC (1,171/133)
Constraint length = 7	Constraint length= 7
Base code rate = 1/2	Base code rate = 1/2
Punctured code rate = 1/2, 2/3	Punctured code rate = 1/2, 2/3, 3/4
Viterbi Algorithm (hard-decision) Depth=140	Viterbi Algorithm (hard-decision) Depth=140
Helical interleaver	
BPSK modulation	
AWGN channel	

III. RESULTS & DISCUSSION

The serially concatenated RSC-RSC system is described in section II is implemented using MATLAB (R2012a) and BER is observed for different values of E_b/N_o (signal-to-noise ratio).

A. RSC-RSC concatenated system:

After simulation using MATLAB (R2012a) software results observation have been obtained as shown in Figure 4 and noted down in Table 2. It shows that for RSC 1/2–RSC 1/2 system, BER value of 0 at E_b/N_o of 1 dB. It is quite better than other three code rate, where BER is quite high at same value of E_b/N_o i.e. 1 dB.
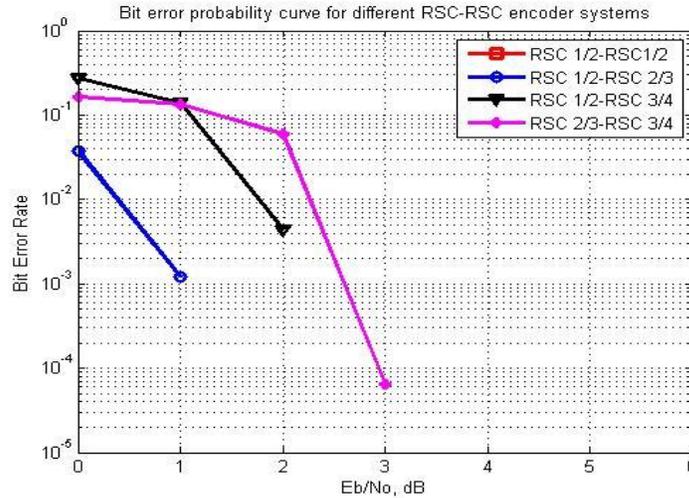
Figure 4. BER probability analysis for RSC-RSC system

Table 2. BER v/s Signal-to-noise ratio for RSC-RSC system

Coding scheme	Signal to noise ratio (Eb/No)				
	0 dB	1 dB	2 dB	3 dB	4 dB
RSC 1/2- RSC 1/2	0	0	0	0	0
RSC 1/2 -RSC 2/3	$10^{-1.4}$	$10^{-2.9}$	0	0	0
RSC 1/2 -RSC 3/4	$10^{-0.5}$	$10^{-0.8}$	$10^{-2.3}$	0	0
RSC 2/3- RSC 3/4	$10^{-0.7}$	$10^{-0.8}$	$10^{-1.2}$	$10^{-4.3}$	0

IV. CONCLUSION

In this paper we have simulated and reviewed the BER performance of serially concatenated RSC-RSC code using non-iterative Viterbi decoding. The purpose of the simulation is to analyse the performance of serially concatenated RSC-RSC system. The simulation results shows clearly that the performance of serially concatenated RSC-RSC system is decrease as increasing the overall code rate i.e. low value BER occur at low overall code rate.

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