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Performance Analysis of Serially Concatenated Convolutional Codes using Different Generator Polynomial and Constraint Length

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Abstract: *In this paper, the bit error rates (BER) in serially concatenated convolutional codes (SCCC) system by using binary phase-shift keying (BPSK) modulation in additive white Gaussian noise (AWGN) channel with Viterbi algorithm decoder is analyse. The bit error rate (BER) performances of RSC-RSC (Recursive systematic convolution) concatenated system is analyse by using the MATLAB software. The RSC-RSC system uses the serially Concatenation system as outer and inner codes with the help of interleaver. For decoding of serially concatenated RSC-RSC system, a non-iterative Viterbi decoding scheme with two Viterbi decoders in concatenation through a de-interleaver. This paper investigated the effect of variation of constraint length and generator polynomials on serially concatenated RSC-RSC convolutional codes system. Simulation results shows that slightly modified Serially Concatenated Convolutional Code (SCCC) schemes provide significant improved performance of the RSC encoder in the error floor region in terms of much lower bit error rate (BER). The proposed non-iterative Viterbi decoding algorithm reduces the bit error rate (BER) with increase of Generator polynomial with constraint length.*

Keywords: *AWGN channel; Channel coding; Recursive systematic convolutional codes; Serially concatenated convolutional codes; Turbo codes; Viterbi decoding algorithm.*

1. INTRODUCTION

In Digital communication system, the channel encoding improves the bit error rate of the system by added redundancy (additional bits) in system. The main objective of the error-correcting coding is to improving the reliability of communication system. Here, Channel coding is frequently used in digital communication system to protect the digital information from noise and

The history of channel coding, also referred to as the forward error correction. In Shannon article, "A mathematical theory of communication",[1] According to the Shannon, it is possible to design codes with any required small probability of error, when the transmission rate is smaller than the channel capacity. But, Shannon provided no in this article on how to actually design these codes.

Until the late 1940s, communication devices were capable with error detection capabilities only. In 1950 [2] Hamming was the first to suggested a single -error correcting code, as 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 the block codes. The traditional 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].

The concept of convolutional coding was introducing by Elias [5]. In which the convolutional encoder makes use of shift registers to generate output bits based on the present input bit as well as past inputs, therefore Convolutional codes are one of the powerful and widely used class of codes, These type of codes are having many applications, likes deep-space communications, voice band 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, due to the optimal exploitation of soft channel observations by the decoding algorithm. In particular, Viterbi proposed a maximum likelihood sequence estimation algorithm in [6], while a more efficient but more complex algorithm, based on maximum a-posterior decoding, was developed by Bahl et al. [7].

The convolutional codes was the next significant step that gives the better performance of codes on communication channels, but these types of codes introduced the burst errors. But Forney [8] showed that a concatenated coding system with a powerful outer code can perform practically very well, but its inner decoder not perform very well, its gives the high error probability. The interleaver overcome the problem of high error probability. In which, block encoders can be combined with convolutional encoders and interleavers, in parallel or serial schemes. In [9], Concatenation of multiple convolutional codes was introduced, with Soft Output Viterbi Algorithm (SOVA). On the other hand, in 1993[10], Berrou *et al.* presented turbo codes interest shifted back to channel coding. Turbo code is a parallel concatenation convolutional codes (PCCC) of two recursive systematic convolutional (RSC) codes separated by an interleaver. This error correcting code, despite its fairly simple structure is able to transmit information across the channel with arbitrarily low (approaching zero) bit error rate. Therefore, in terms of Bit Error Rate (BER) the performance of Turbo code is very close to Shannon's limit. After that turbo codes, it turned out that serially concatenated RSC codes with a random bit interleaver were equally suitable for iterative decoding [11]. In 1998 [12] the Benedetto claim that these codes may have even better performance than the turbo codes. Serially concatenated convolutional codes encoder and decoder described in Fig. 1 and Fig. 2.

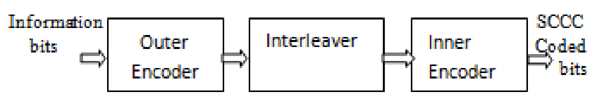

Fig. 1: Structure of the SCCC encoder.

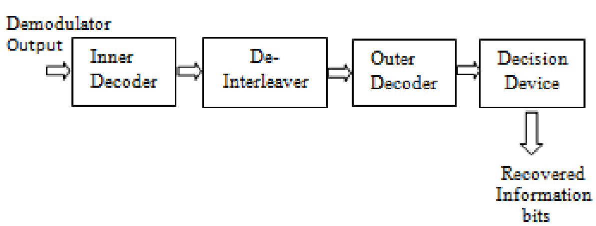

Fig. 2: Structure of the SCCC decoder.

However, the burst errors [13] occurred in convolutional codes and random errors [14] occurred in Reed Solomon codes. To solve this problem, a new concatenated system was proposed. In this type concatenated system a Reed-Solomon (RS) code and Recursive systematic convolutional code (RSC) codes was used and it was shown that RS-RSC concatenated codes have good performance as compared to RSC itself [15]. For SCCC codes, there some drawback of simple concatenated Viterbi decoding system[16].

In recently 2013 [17], Manish provided a solution 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 other RS-RSC concatenated code.

Aim of this paper is to improve the BER in serially concatenated convolutional codes. This paper analysis the BER performance of serially concatenated RSC-RSC code using non-iterative concatenated Viterbi decoding. It find out what's the effect of Generator Polynomials and the Constraint lengths on the BER in serially concatenated convolutional RSC-RSC codes system. In Modern communication system, the bit error rate and signal-to-noise ratio is the very important parameter. This paper also compared its performance with serially concatenated RSC-RSC system [17].

The rest of the paper is prepared as follows. In section II, serially concatenated convolutional codes system structure scheme is presented. In section III the simulation results and its discussion are given in this section. Finally, the section IV concludes the paper.

2. SYSTEM STRUCTURE

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

In the basic scheme of serially concatenated block codes [18] is shown in Fig. 3.

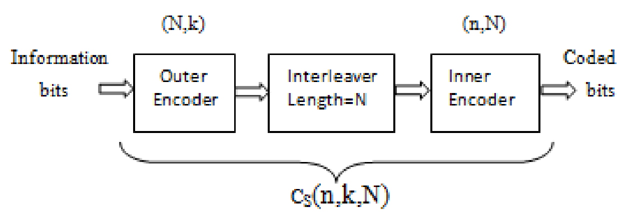

Fig. 3: Serially concatenated (n, k, N) block code.

It is composed of two serially concatenated convolutional codes, 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 convolutional code is then an (n, k) code, and it will refer to as the (n, k, N) code C_s, including also the interleaver length [18].

Serially concatenated RSC-RSC System

A serially concatenated RSC-RSC code system is obtained with the help of two recursive systematic convolutional encoder (i.e. outer encoder and inner encoder). These two RSC-RSC encoder are concatenated through an interleaver in between them. The random errors and brust errors are solved by this type serially concatenated RSC-RSC system. As this type code have different behaviour in the terms of error-correcting codes, so they try to give a lot of benefits in bit error rates performances.

Serially concatenated RSC-RSC system with different Generator Polynomial and Constraint length.

A Generator Polynomial describes the connections between the shift registers and modulo-2 adders in the convolutional encoder system. Build a binary number representation by placing a 1 in each connection line from shift feed into the adder and 0 elsewhere. Convert this binary representation into an octal representation by paring of three consecutive bits, paring starting from the rightmost bit. If the number of bits is not a multiple of three, then place zero bits at the left end as necessary.

In convolutional code, the Constraint length *K* is defined as the number of shifts over which a single message bit can influence the encoder output.

Simulation Setup

In this setup, simulation model is designed as shown in Fig. 4. In which serially concatenated convolutional RSC-RSC encoders and decoders system is implemented with a non-iterative concatenated Viterbi decoding scheme. In which different RSC-RSC generator polynomial values with different constraint length are used. Table 3 describes the simulation parameters which is used in simulation model.

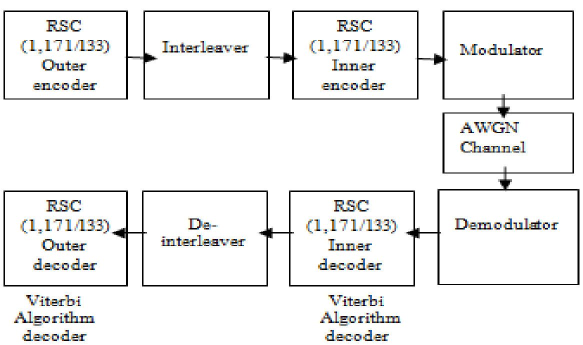

Fig. 4: Simulation setup for RSC-RSC system.

In Table 2, described the different Generator Polynomial with Constraint length. Constraint length is also significant parameter for serially concatenated convolutional RSC-RSC code system. Therefore different Generator polynomial with different Constraint length are used.

Table 2: Different Generator Polynomial with Constraint Length

Constraint Length	Generator Polynomial
K=3	RSC (1, 7/5)
K=4	RSC (1, 17/15)
K=5	RSC (1, 35/23)
K=7	RSC (1, 171/133)
K=8	RSC (1, 371/247)

Table 3: Simulation Parameters of RSC-RSC System

Outer Encoder	Inner Encoder
RSC (1, 7/5), (1, 17/15), (1, 35/23), (1, 171/133), (1, 371/247)	RSC (1, 7/5), (1, 17/15), (1, 35/23), (1, 171/133), (1, 371/247)
Constraint length = 3, 4, 5, 7, 8	Constraint length = 3, 4, 5, 7, 8
Base code rate = 1/2	Base code rate = 1/2
Punctured code rate = 2/3	Punctured code rate = 2/3
Viterbi Algorithm (hard-decision) Depth= 140	Viterbi Algorithm (hard-decision) Depth= 140
Interleaver–Helical scan	
Modulation-BPSK	
Channel-AWGN	

3. RESULTS AND DISCUSSION

In section II, described the systems which is implemented using MATLAB and observed the bit error rate (BER) at different values of signal-to-noise ratio (E_b/N_0).

B. Serially concatenated RSC-RSC system with different Generator Polynomial and Constraint length.

The performance of serially concatenated RSC-RSC system are evaluated by the using simulation model shown in Fig. 4. Simulation parameters for this system are described in Table 3.

After simulation using MATLAB software, its results are obtained that are shown in Fig. 5 and its resulted values are shown in Table 5. It shows that the BER decreases as increases Generator Polynomial with respect to Constraint length. Its results are obtained is quite better than other schemes of error correcting codes.

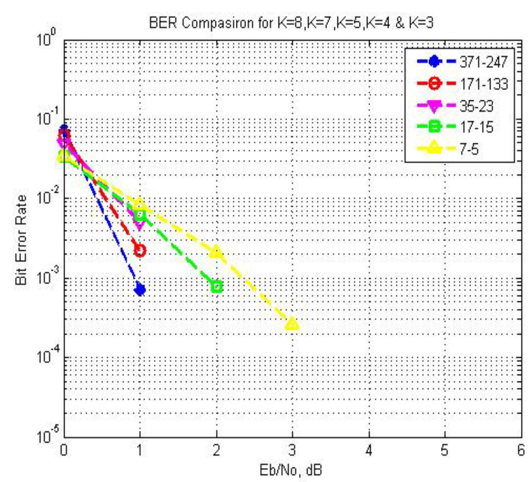

Fig. 5. BER probability analysis for serially concatenated RSC-RSC system with

Table 4: Ber versus signal-to-noise ratio for rsc-rsc system with different generatpr polynomial and constraint length

Generator Polynomial with Constraint length	Signal to noise ratio (Eb/N0)					
	0 dB	1 dB	2 dB	3 dB	4 dB	
(1,7/5), K=3	10-1.47	10-2.09	10-2.69	10-3.59	0	
(1,17/15), K=4	10-1.47	10-2.2	10-3.11	0	0	
(1,35/23), K=5	10-1.31	10-2.3	0	0	0	
(1,171/133),K=7	10-1.21	10-2.66	0	0	0	
(1,371/247),K=8	10-1.14	10-3.15	0	0	0	

4. CONCLUSION

The purpose of the simulation is to confirm the outperformation of the serially concatenation of RSC-RSC convolutional system, with the use of non-iterative viterbi decoding algorithm scheme. The simulation has investigated that RSC-RSC serially concatenated convolutional code system gives the better BER performance i.e. BER decreases as increases Generator Polynomial with respect to Constraint length. Hence RSC-RSC serially concatenated system has significant of Generator polynomial.

In this paper, assumption mode are use of Helical scan interleaver, BPSK modulation, AWGN channel and Hard-decision decoding. For a future work, the author plans to work could be researched for various other types of the same elements and the major improvement could be the use of Soft-decision decoding with non-iterative concatenated technique.

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