BER and Latency Analysis of RS-RSC Concatenated Codes with QPSK Technique for AWGN Channel

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ABSTRACT
In this paper, the analysis of performance of serially concatenated codes constituted by Reed-Solomon (RS) and Recursive Systematic Convolutional (RSC) codes in term of bit error rate (BER) and latency over Binary phase shift key (BPSK) and Quadrature phase shift key (QPSK) modulation technique using MATLAB software is performed. This model of serially concatenated codes uses RS as outer encoder and RSC as inner encoder. The MATLAB simulation results shows that the performance of RS-RSC concatenated codes in term of BER is better with QPSK modulation over AWGN channel. The effect of variation of code rate is also analyzed. It is found that QPSK outperforms BPSK in RS-RSC concatenated code in terms of BER.

Keywords
BER; QPSK;BPSK;AWGN; MATLAB; RS-RSC.

1. INTRODUCTION
Digital communication systems play a significant role in military, government and our daily life. To communicate means transfer of information from one place to another place. During transmission errors are occurred in the received data due to channel noise, interference, distortion, attenuation and wireless multipath fading etc. So to recover original data that was transmitted by transmitter, there is need of retransmission of data. To overcome this problem of retransmission of data error correcting codes are used. According to Shannon's theorem by proper encoding of the information, error caused by noisy channel or storage medium can be reduced to any desired level if the data transmission rate rb, from source encoder is smaller than the channel capacity C. but if the data rate rb > C, it is not possible to design a code that can attain small error probability [1]. Aim of error correcting codes is to improve the original data at the receiver as reliable. This is done by adding extra bits in the transmitted sequence. These extra bits are called parity bits and they do not carry any information. Based on this redundancy receiver can detect and correct errors introduced by the channel.

In first category of error correcting codes are BCH codes, hamming codes, cyclic codes and Reed Solomon codes. One of the most interesting of these codes is Reed Solomon code used today for both detection and correction. Reed-Solomon codes are block-based error correcting codes which were proposed in 1960. It is vulnerable to the random errors but strong to burst errors. These codes are non-binary BCH codes. Reed-Solomon code can work on symbols rather than individual bits. Reed-Solomon code is specified as RS (n,k) with s-bit symbols. This means that the encoder takes k data symbols of s bits each and adds parity symbols to make an n symbol codeword. There are n-k parity symbols of s bits each. A Reed-Solomon decoder can correct up to t symbols that contain errors in a codeword, where 2t = n-k. For decoding of RS codes Berlekamp-Massey decoding is used.

Second category of error correcting codes is convolutional codes. The difference between convolutional code and block code is that Convolutional code has memory (tree code) and the linear block code is without memory (block code).

Convolutional codes are extensively used for real time error correction. Convolutional coding is done by combining the fixed number of input bits. The input bits are stored in fixed length shift register and they are combined with help of mod-2 adder. Convolutional encoders are effectively digital filters and therefore contain three basic elements: multipliers, storage and adders. If the information bit is not directly present in the output sequence, the code is said to be a nonsystematic code (NSC). A convolutional code can be made systematic without affecting its minimum distance properties by feeding back one of the outputs to the input. Such a code is called a Recursive Systematic Convolutional (RSC) code.

The third category is the recently developed concatenated codes. Forney in 1966 first gave the proposal of concatenated codes [2]. According to Forney, concatenation is a way of building long codes from the shorter ones. Concatenation was implemented with Soft Output Viterbi Algorithm (SOVA) and Concatenation of multiple convolutional codes was introduced in 1989. There are two types of concatenated codes: Parallel Concatenated Codes (PCCC) and Serially Concatenated Code (SCCC). Convolutional codes suffered the problem of burst errors and RS codes suffered from problem of random error. To compensate this problem, concatenated codes are used. By concatenating two different codes we can get the effect of improving the total bit error rate [6].

2. RELATED WORK
In 1993 Berrou et.al introduced simple iterative decoding technique based on Maximum A Posterior algorithm with Soft-In Soft-Out. From simulation results it was shown that in terms of BER the performance of turbo codes, is very close to Shannon's limit [4].

In 1996, the concatenation of convolutional codes was investigated in which Serially Concatenated Convolutional Code (SCCC) was introduced and it was shown that SCCC has better performance than PCCC [5].

In 2010 K. Byun et al. presented a paper in which Performance comparison of Reed Solomon (RS) code with non- systematic convolutional (NSC) and recursive systematic convolutional (RSC) codes. In this work a new solution was proposed to the problem of random errors in Reed-Solomon encoders and to the problem of burst errors in Convolutional encoders, where a concatenation of a Reed-Solomon (RS) code and a Recursive systematic convolutional code (RSC) codes was used and it was shown that RS-RSC concatenated codes have good performance than NSC, RSC & RS-NSC.Aim of this paper is to improve the bit error rate performance of serially concatenated codes and also compared the performance of RS-RSC concatenated codes with NSC, RSC &RS-NSC [6].

In 2013 S.V. Reddy et al. introduced that the design of Convolutional codes basically encoders which are very important for extremely low error probabilities used at high data rates of wireless communication applications. For the basic design of the codes can be developed based on constraint length and code rate. As the constraint length was increasing the parallel implementation had to be used for high data rates and feasibility with less delay [8].

3. SIMULATION SETUP

In this section the simulation setup along with RS-RSC simulation model and its simulation parameter.

3.1 RS-RSC serially concatenated code

In this simulation setup RS and RSC codes are concatenated in which it uses RS as outer code and RSC as inner code. At the transmitted site, encoding is provided by two different encoders. In which outer encoder takes the input data sequence and it performs the encoding operation on input data. The output of RS encoder is used as input of inner encoder. After receiving the input RSC encoder performs the encoding operation. Encoding is done by adding extra bits. These extra bits do not carry any information. These bits are called the redundant bits. The resulting coded sequence is then modulated. In this work BPSK and QPSK modulation techniques are used. For transmission AWGN channel is used. On receiver end, the received bits are demodulated and decoded by Viterbi decoding and Berlekamp-Massey decoding. The simulation parameters used in this simulation model are described in Table 1.

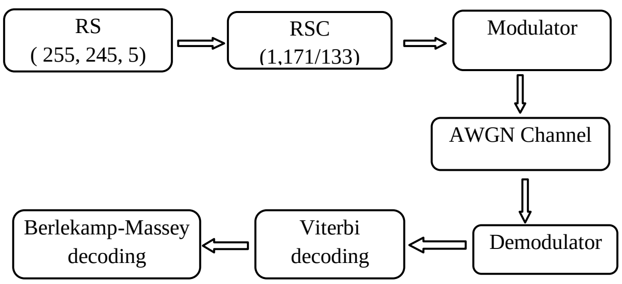

Fig 1: RS-RSC Concatenated System

Table 1. Simulation parameters for RS-RSC system

Outer encoder	Inner encoder
Reed-Solomon (255,245) over GF (28) Reed-Solomon (255,223) over GF (28) Reed-Solomon (185,223) over GF (28)	RSC (1,171/133)
	Constraint length (k) = 7
5-symbol error- correcting code	Base code rate = ½
	Punctured code rate = 2/3, 3/4, 5/6

Berlekamp-Massey decoding	Viterbi decoding (hard-decision)
Modulation = BPSK/ QPSK	Modulation = BPSK/ QPSK
Code termination- truncation	Code termination- truncation

4. RESULTS AND DISCUSSIONS

The RS-RSC concatenated system described in section III is simulated using MATLAB software and bit error rate is observed for different values of signal to noise ratio [Eb/No]. The latency of RS-RSC system using BPSK and QPSK modulation techniques is also observed.Further code rate of RS-RSC system is changed to analyze the effect of different code rate on performance of RS-RSCconcatenated system in terms of BER.

4.1 BER analysis of RS-RSC system for BPSK and QPSK

RS-RSC concatenated system performance is analyzed using two modulation techniques. First RS-RSC system uses BPSK modulation technique and second RS-RSC system uses QPSK modulation technique. We use (255,245) RS code and RSC mother code rate is ½. After simulation there are different BER values at different values of Eb/No. Fig 2 shows that RS-RSC with QPSK modulation technique has improvement in BER as compared to RS-RSC with BPSK modulation technique.

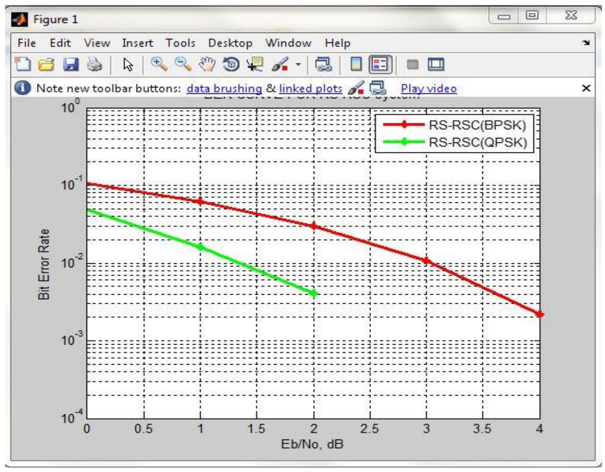

Fig 2: BER analysis for RS-RSC concatenated system

Further, to achieve better BER performance of RS-RSC system with QPSK modulation technique, there different code rates are used. The code rates are changed by the use of puncturing. Puncturing is used to increase or decrease the code rate of the system. In general, puncturing offers a convenient way to change the code rate of the system without increasing hardware complexity. It affects BER and bandwidth of coded system.

4.2 Latency comparison of RS-RSC system with BPSK and QPSK

Latency performance of RS-RSC concatenated system with BPSK and QPSK is performed and it is found that RS-RSC system with QPSK takes more transmission time as compared to RS-RSC system with BPSK.

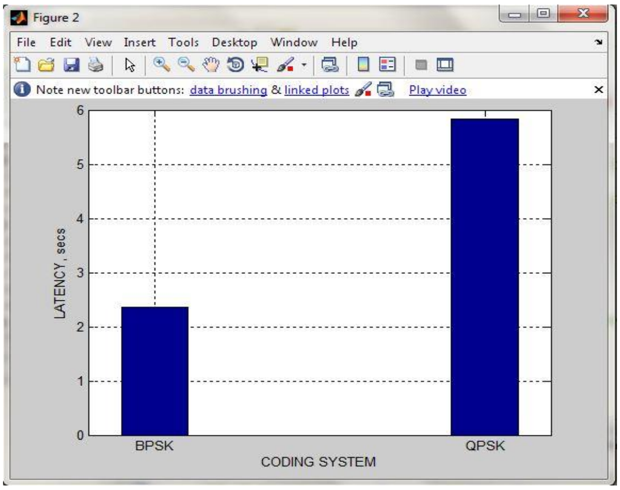

Fig 3: Latency analysis for RS -RSC concatenated system

The simulation result shows in fig. 3 the latency of RS-RSC (BPSK) system is 2.4162 seconds and latency of RS-RSC (QPSK) 5.9210 seconds. Here simulation results observe that the latency of QPSK is higher as compared to BPSK

4.3 RS-RSC system with RS (255,245) code rate

To analyze the performance of RS-RSC system different code rates are used. In this system QPSK modulation technique is used. RS (255,245) code rate in GF (28) is used that has 5 symbol error correcting capability. RSC with mother code rate ½ and 2/3, 3/4, 5/6 are punctured code rates. Fig 4 shows that RS 245/255 -RSC ½ system has better BER performance than other punctured code rate (i.e. 2/3, 3/4, 5/6).

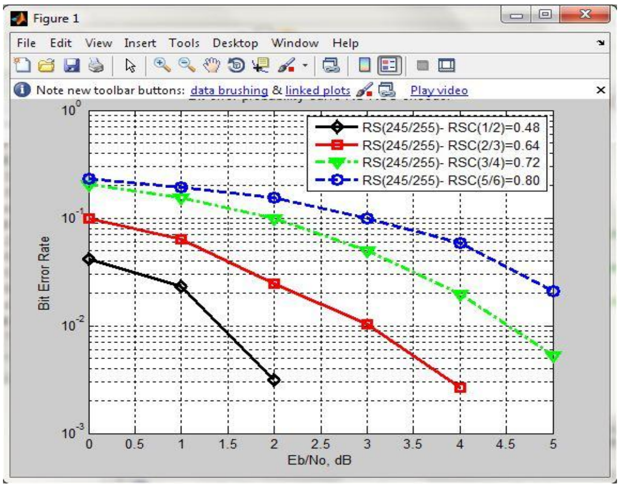

Fig4: RS-RSC system with RS (255,245) code rate

4.4 RS-RSC system with RS (255,223) code rate

In this the RS code rate is (255,233), by using this error correcting capability increased. RSC with ½ base code rate and other punctured code rates are (i.e.2/3, 3/4, 5/6). Fig 5 shows that RS 223/255 -RSC ½ systems has better BER performance than other punctured code rate (i.e. 2/3, 3/4, 5/6) but takes more BW as compared to other punctured code rate.

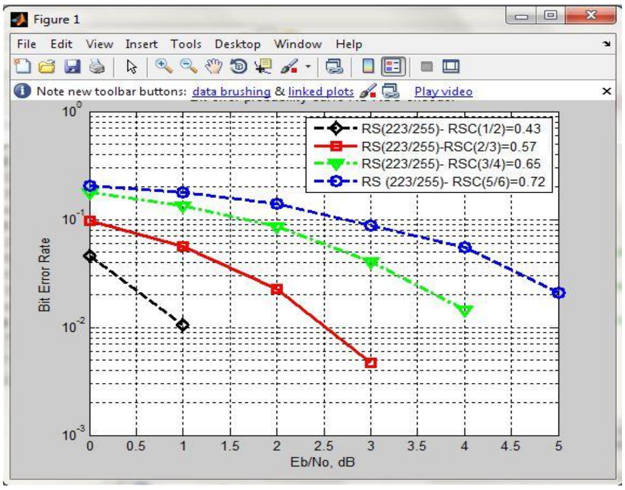

Fig 5: RS-RSC system with RS (255,223) code rate.

4.5 RS-RSC system with RS (255,185) code rate

Further RS code rate is changed. In this system RS (255,185) code rate is used. This code rate increase the error correcting capability of RS-RSC system. RSC with ½ base code rate and other punctured code are 2/3, 3/4, 5/6. Fig 6 shows that RS 185/255 –RSC ½ system has improvement in BER. This BER performance is better than other punctured code rate. It can be seen that as we decreases the code rate the BER performance improves.

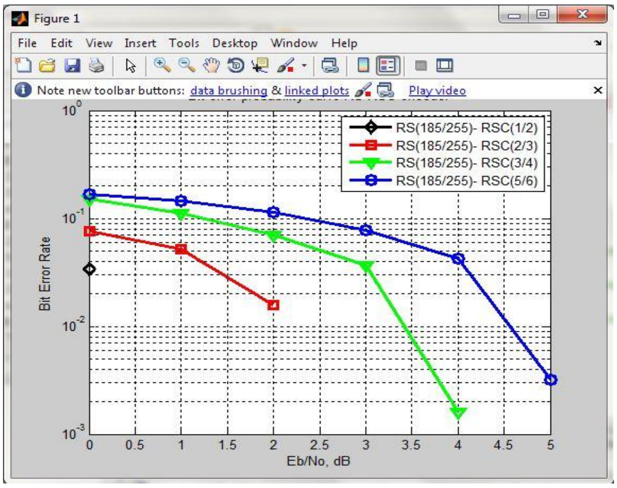

Fig 6: RS-RSC system with RS (255,185) code rate

Simulation result shows that RS (255,185)-RSC (1/2) system gives better BER value 0.0336 at Eb/No of 0dB. This BER value is less than the other values of BER at same point which are achieved by using different code rate. It is observed that increasing the code rate with help of puncturing decreases the redundancy and increases the BER. But it helps in reduction of BW requirement for data.

5. CONCLUSION

In this work particular performance of serially concatenated codes has been investigated. It is observed that RS-RSC system performance with QPSK modulation is better than RS-RSC with BPSK modulation in terms of BER but RS-RSC system with QPSK takes more latency as compared to with BPSK. It is also found that as we decrease the code rate of RS- RSC system the BER performance improves and best result comes. Also QPSK takes less bandwidth as compared to

BPSK. For future work, it is recommended to better technique with high code rate and less BER.

6. ACKNOWLEDGMENT

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