International Journal of Control and Automation
Vol.6, No.5 (2013), pp.385-392
http://dx.doi.org/10.14257/ijca.2013.6.5.33

Performance of Channel Coding Schemes with Interleaver under Impulsive Noise Channel

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Abstract

The concatenated codes or the convolutional codes which are often adopted in the communication systems are originally designed to overcome the random independent noise. As such, the performance is severely degraded over the bursty impulsive noise channels. In this paper we compare the bit error rate (BER) performance of the various different channel coding schemes with interleaver over the bursty impulsive noise channels. In particular, we focus on the existence of the bit level and/or the byte level interleavers and show from the extensive simulations that the performance can be different depending on the existence of the interleaver. From our simulations we can see that the concatenated codes with the byte interleaver between the inner and outer codes and the bit interleaver after the inner code gives the best performance among them. For the schemes which include the bit level interleaver, we also observe the interleaving gain versus the interleaver span so that it can be a good guideline to design the communication systems with the concatenated codes.

Keywords: *Bit interleaver, byte interleaver, concatenated code, impulsive noise*

1. Introduction

The channel coding has been widely used in communication systems to overcome the additive white Gaussian noise (AWGN) channel, which is designed to increase the reliability by adding the redundancy. The block code and convolutional code are the two major elements of channel coding. Since the convolutional code shows excellent performance over the AWGN channel, it is often adopted in communication systems.

The concatenated codes have been favorite in various applications since it was developed by Forney in 1966 [1]. In particular, the concatenated codes, with a convolutional code as the inner code and a Reed-Solomon (RS) code as the outer code, are applied in deep-space communication, which show better performance with acceptable complexity than only a convolutional code case [2]. In this concatenated coding systems, the data stream out of Viterbi decoder enters the RS decoder directly. In this case, if the Viterbi decoder selects the incorrect trellis path, the burst errors can be occurred. If the burst error occurs and the lengths of burst errors exceed the error correction capability of the outer codes, the burst errors are not avoidable [3].

On the other hand, the interleaver is often adopted between the inner encoder and the outer encoder of concatenated codes to increase the reliability. This is one of the most popular concatenated coding systems to improve the error correction capabilities remarkably [4].

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ISSN: 2005-4297 IJCA

Since byte interleaver spreads the bytes over several RS encoded symbols, it is typically located between the inner and outer code. However, concatenated codes with byte interleaver cannot be the solution to the system under the impulsive noise environment [5-6]. The impulsive noise can be a main reason to degrade the link performance considerably with decoding errors through the successive time slots. Under the impulsive noise environment, it results in similar performance whether or not concatenated coding system employs byte interleaver since Viterbi decoder is likely to produce much longer decoding errors and it hinders RS decoder in correcting rightly even if the byte deinterleaver shuffles the corrupted symbols.

Instead of using byte interleaver, bit-level interleaver can be utilized after the inner code to mitigate the effect of the impulsive noise and to improve the system performance. In this paper, we compare the performance using various channel coding schemes over the impulsive noise. Specifically, we investigate the BER performances of 1) convolution code only, 2) concatenated code only, 3) concatenated code with the byte interleaver located between the inner code and the outer code, 4) the concatenated code with the bit interleaver located after the inner code, and 5) the concatenated code with the byte interleaver between the inner and outer codes and the bit interleaver after the the inner code without any structure modification.

The remainder of this paper is organized as follows. In the next section the system and noise models under consideration are introduced. In the following section, we present the numerical results are discussed. Finally, the concluding remarks are followed.

2. System Model

The block diagram of the communication systems that we consider is shown in Figure 1. We consider five different channel coding schemes to compare the performance over the impulsive noise. For simplicity, we use the abbreviations to mention the different channel coding schemes as described in Table 1.

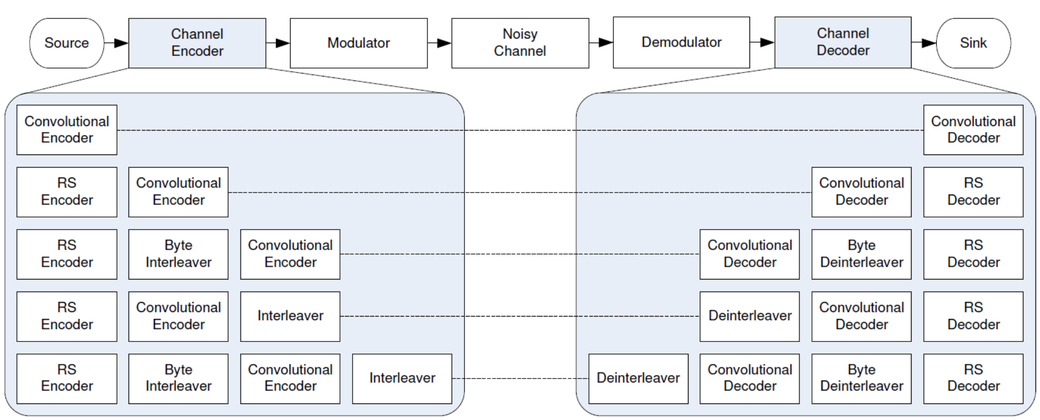

Figure 1. Block diagram of the system model

We adopt the RS code with a rate of 239/255, and the Berlekamp algorithm is used for decoding of the RS code [7]. We make use of the (7, 1/2) convolutional code which is binary non-systematic and generated by octal generators (133,171). The convolutional code with a rate of 3/4 is obtained by puncturing. At the receiver, soft-decision Viterbi decoder is employed as the decoder of the convolutional code. Between the RS code and the convolutional code, the byte interleaver can be added since the byte interleaver does not spread the burst errors out of the Viterbi decoder to multiple RS symbols. The bit interleaver can be also used to divide the burst error into the multiple of random errors, which is inserted after the convolutional code. The block interleaver with two parameters, depth D and span S is adopted as the bit interleaver. The structure of the bit interleaver is illustrated in Figure 2.

Table 1. Channel coding schemes

Channel Coding Schemes	Abbreviation
Conv. coding	C
RS coding + Conv. coding	RC
RS coding + Byte interleaver + Conv. coding	RBC
RS coding + Conv. coding + bit Interleaver	RCI
RS coding + Byte interleaver + Conv. coding+ bit Iinterleaver	RBCI

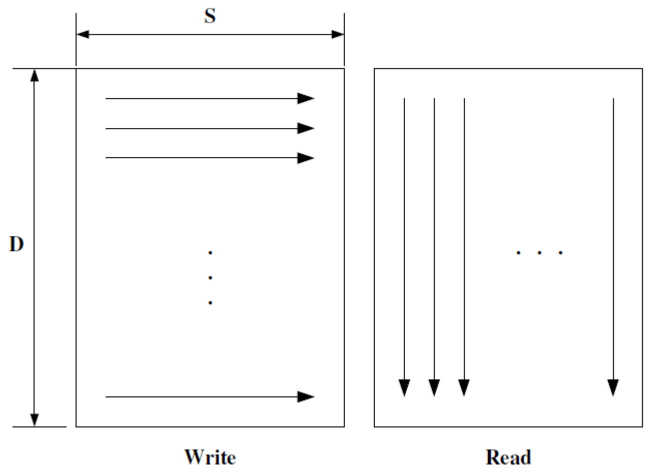

Figure 2. Structure of the bit interleaver

Also we assume the noise model, which consists of AWGN and the impulsive noise as in [8]. In this paper, we fix the arrival rate of the impulsive noise without any loss of generality since the purpose of this paper is to compare the error correction ability of systems with different channel coding schemes.

3. Numerical Results

For BER performance simulation, the Binary Phase Shift Keying (BPSK) modulated signals are assumed. BER performance simulation is first carried out over AWGN only channel. The bit interleaver is assumed to be 255×32. The BER performance over AWGN channel is presented in Figure 3. It is apparent that the performance of concatenated coding system is superior to that of the single channel coding system. Compared to the 1/2 convolutional code only, the concatenated codes provide about 1 dB gain at BER of 10^{-5}. Note that the concatenated codes show the same performance regardless of the existence or position of interleaver.

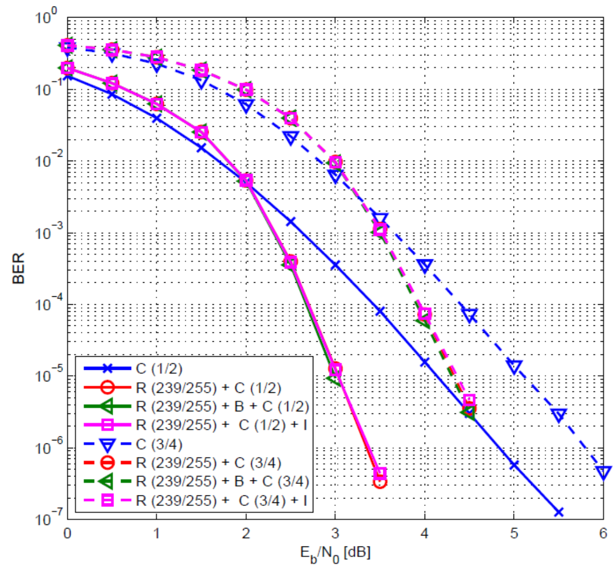

Figure 3. BER performance over the AWGN channel

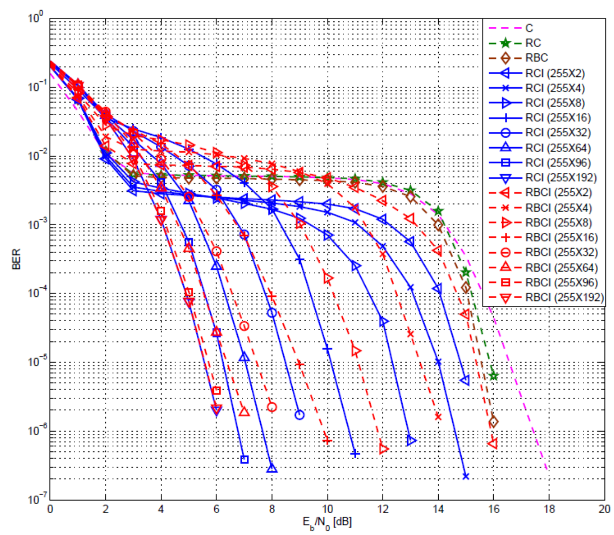

Figure 4. BER performance over the impulsive noise channel

Simulation results for the impulsive channel are summarized in Figure 4. It is shown that the curves of C, RC, and RBC are similar. This is because the received signals are corrupted by the impulsive noise resulting in a burst of error at the Viterbi decoder output. If the burst-error-length exceeds the error correction capability of the outer RS code, a burst of error is occurred even though we utilize the concatenated coding system such as RC and RBC. Due to this reason, we can find the error floor at between BER $= 10^{-2}$ and 10^{-3}. The curves of C, RC, and RBC start to fall at relatively high E_b/N_0, which implies that the impulsive noise components are not regarded as the dominant sources of corruption anymore at high E_b/N_0.

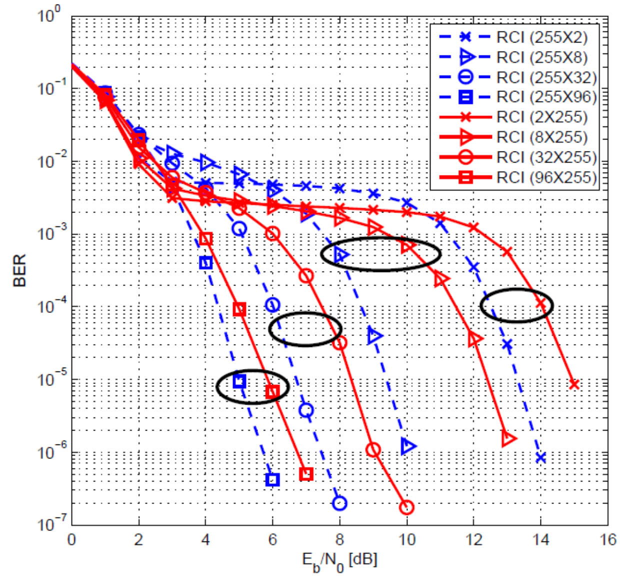

Figure 5. Performance of RCI: solid lines for fixed depth and dash lines for fixed span, respectively

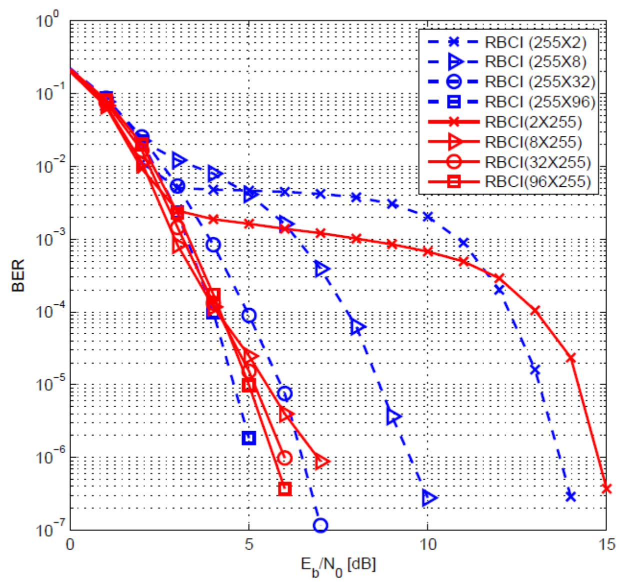

Figure 6. Performance of RBCI: solid lines for fixed depth and dash lines for fixed span, respectively

The bit interleaver for RCI and RBCI divides the burst error into the multiple short-length errors. It reduces the decoding error of the Viterbi decoder, and RS decoder corrects more errors since the number of symbol errors can be decreased up to the error correction capability of the RS decoder with higher probability. Therefore, it is obvious that RCI and RBCI show better performances compared to the systems without bit interleaver. For the same reason, the BER performance becomes better as the span of bit interleaver increases. In Figure 4, we also recognize that the performance of RBCI is better than of RCI in case that the size of the bit interleaver is fixed. However, as the span of the interleaver increases, the performance of RCI approaches to that of RBCI with the same size of the bit interleaver.

In Figures 5 and 6, we see the performances for varying interleaver depth as well as the interleaver span. Simulations are first carried out for the fixed interleaver depth while the interleaver span is varying. In the second simulations as the interleaver depth is varying and the interleaver span is set to 255 in order to compare the effect of the size of the span and the depth, respectively. Under the same product of interleaver span (S) and the interleaver depth (D), the performance is better when S is bigger for RCI. On the other hand, in the case of the performance of RBCI, the performance with varying the interleaver depth is much better than with varying the interleaver span. Moreover, the performance is saturated rapidly according to the interleaver depth. The performance of RBCI using the interleaver with a size of 8×255 already approaches to the performance of RBCI using the interleaver with a size of 255×96.

From the results, we can see that the performance improvement can be obtained with RBCI with the modest depth of the bit interleaver. Moreover, we can use the results in the system design, for example, if the latency is more important criterion than the performance, RCI can be a more proper candidate as the channel coding scheme to decrease the time delay due to the absence of the byte interleaver. On the other hand, if the performance improvement against the impulsive noise is a more essential issue, RBCI can be chosen as the channel coding scheme.

4. Conclusion

In this paper, we presented the performance comparisons of various channel coding schemes under the impulsive noise. Numerical results show that the concatenated codes with bit interleaver outperform the other schemes over the impulsive noise channel. We can see that, by only increasing the span of interleaver, the considerable reliability can be obtained. Moreover, the performance improvement can be achieved by using RBCI with the modest depth. Our study can be utilized as a guideline selecting the proper error correcting codes of the communication systems over the impulsive noise channel. In other words, from our results, we can choose the concatenated codes with acceptable performance according to the system criterion such as the latency or the performance.

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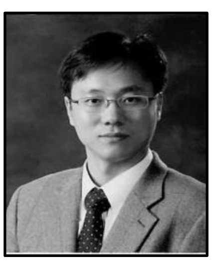

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