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A Channel Coding Scheme with Enhanced Synchronization Capability

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Abstract

A new decoding algorithm that modifies error searching soft decision method is presented. The proposed algorithm improves the decoding error performance caused by repeated searching. It is shown that the simplicity inherent in the hard decision decoding is still maintained. This paper proposes an error correcting binary channel code which promotes symbol transition. This scheme exploits the error correcting capability of the preparatory code. It is demonstrated that the proposed code combine good symbol transition property with their own error correcting capability.

Keywords: ***C****hannel coding, Error correcting codes*

1. Introduction

The channel coding schemes of digital communication systems ensure that bits transmitted over the channel are received correctly despite the effects of interference of various types and origins. While a code word is transmitted over a noisy channel, some are received in error. The decoder must therefore identify the unreliable variables.

Soft decision decoding improves the reliability of the coding systems by using more information than that of hard decision decoding. The generalized minimum distance (GMD) decoding [1] generates a number of candidate code words. To reduce the probability of decoding failures, some improved versions [2-4] of soft decision decoding algorithms have been proposed. These algorithms, however, do not have much excellence in error rate and decoding complexity.

In this paper, we present a simple decoding algorithm that modifies error searching soft decision method. A new candidate code words region is searched to distinguish the variables belonging to the unsatisfied constraints.

The demand for efficient and reliable digital data transmission systems has been accelerated. One of the problems in high speed data transmission system is the occurrence of errors. The problem of how to control these errors is one of basic importance.

We propose an error correcting code that bounds the length of stretches of repeated bits during which the signal does not change. The stretches of repeated bits are called runs. If the runs are too long, clock recovery is difficult.

An 6-ary (2, 4) code [5] has been developed to achieve high coding density. Some improved versions [6-8] of coding and decoding schemes have been proposed. These schemes, however, do not have much excellence in error probability and symbol transition property.

In this paper, we present an error correcting binary channel code which expedites symbol transition. In our method, a new code words region is searched to distinguish the variables belonging to the unsatisfied constraints.

2. Error Correcting Binary Code

The use of error correction coding is effective because it permits us to detect and correct errors in transmission. Coding accomplishes its purpose through the deliberate introduction of redundancy into messages.

S. A. Abdulhak, *et al.*, [9] attempted to simultaneously mix the user experience with the system development lifecycle to show the effectiveness of the application from usability perspectives and user experience, we build an application using three different development environments, namely, IBM DB2, Visual Basic, and MS Excel.

M. E. Khan [10] proposed approaches to white box testing technique for finding errors. He described one of the main software testing technique that is white box testing. He also described briefly the working process of white box testing technique and some of its most frequently used techniques that are control flow testing, data flow testing, branch testing, basis path testing and loop testing.

X. Xiao, *et al.*, [11] estimated the error rate in an apache web server system. They focused on the relationship between the error rate which is one of the representative reliability measures in Apache web servers and the system parameters which reflect on the web server's system performance, and develop a probability model to describe it.

S. Lee *et al.*, [12] proposed side information update method of error correction decoder for distributed video coding. This method improves the quality of side information. The side information values are updated using both the values of quantization index and its quantization interval. Side information update method reduces the amount of parities transmitted to decode quantization index.

H. Park, *et al.*, [13] proposed the method that enhance accuracy of pitch detection system, through SNR compensation using time-domain SNR estimator with continuous voice signal. And they proved the performance of the detector, in drawing pitch contour of variable SNR signals.

Coding has the advantage that it allows us to increase the rate at which information may be transmitted over a channel while maintaining a fixed error rate.

Coded digital messages contain redundant symbols. These symbols are used to accentuate the uniqueness of each message. They are chosen so as to make it very unlikely that channel disturbance will corrupt enough of the symbols in a message to destroy its uniqueness.

Let $\mathbf{u}$ be a binary information vector. The vector $\mathbf{u}$ corresponds to information polynomial $u(x)$. The operation + between binary numbers denotes modulo-2 addition. We encode $u(x)$ by preparatory code as follows. The generator polynomial of preparatory code is $g(x)$. From dividing $x^8u(x)$ by $g(x)$, we get the quotient $t(x)$ and the remainder $v(x)$, *i.e.,*

$$x^8u(x) = t(x)g(x) + v(x)\,. \tag{1}$$

The remainder $v(x)$, whose degree is 7 or less, is parity check polynomial. The resulting preparatory code polynomial is

$$p(x) = v(x) + x^8u(x)\,, \tag{2}$$

whose degree is 14 or less. The polynomial $p(x)$ corresponds to preparatory code word vector $\mathbf{p}$. From $p(x)$, we obtain

$$z(x) = x[p(x) + x^7] + [p(1) + 1]. \tag{3}$$

The polynomial $p(x)$ corresponds to (16, 7) code word vector $\mathbf{p}$. The following definitions are given

When a code word is transmitted over a noisy channel, it may be corrupted by noise. At the channel output, the received vector may not be the same as the code word. The decoder recovers the transmitted code word from knowledge of the received vector. The decoder first tests whether or not the received vector is a code word. If the received vector is divisible by the generator polynomial $g(x)$, the received vector is a code word. This can be accomplished simply by calculating the syndrome of the received vector.

The syndrome of the received vector contains the information about the error pattern in the received vector, which will be used for error correction. The syndrome calculation is accomplished by a division circuit which is identical to the encoding circuit at the transmitter.

The detection circuit is just the syndrome calculator with a single additional flip-flop connected to the output of the calculator. If the syndrome is not zero, the flip-flop sets and an error has been detected. Otherwise, the received vector is a code word.

The minimum Hamming distance of preparatory code is 5. The proposed (16, 7) code has additional one more parity check bit z_0. The addition of a parity check bit increases the minimum Hamming distance by 1. The inversion of the bit z_7 does not affect the minimum Hamming distance. Thus, the minimum Hamming distance of the proposed (16, 7) code is 6.

When the information vector $\mathbf{u}$ is $\mathbf{0}$ (zero vector), one's density for zero $\mathbf{a}$ is 1/8. When $\mathbf{u}$ is not $\mathbf{0}$, preparatory code word vector $\mathbf{p}$ has 5 or more ones because the minimum Hamming distance of preparatory code is 5. Then, (16, 7) code word vector $\mathbf{z}$ has 4 ones. Thus, one's minimum density for non-zero $\mathbf{u}$ is 1/4. As a result, one's minimum density of the proposed (16, 7) code is 1/8.

3. Soft Decision Decoding Algorithm

There are two fundamentally different types of decoding methods, hard and soft. A slicer makes a hard decision, doing its best to detect the transmitted symbols. A soft decision decoder starts with the continuous-valued samples of the received signal. The receiver processes these samples directly to detect the decoded bit sequence.

Soft decision decoding is capable of providing better performance, at the expense of implementation complexity, since it makes use of information that the slicer would otherwise throw away.

We use a (n, k, d_{min}) binary linear block code. The hard decision vector is $\mathbf{h}$ and another is confidence information vector $\mathbf{s}$. The decoder uses $\mathbf{h}$ and $\mathbf{s}$ to determine which code word has been transmitted.

The error pattern vector $\mathbf{q}$ for an estimated code word $\mathbf{x}$ is given by $\mathbf{q} = \mathbf{s} \oplus \mathbf{x}$, where $\oplus$ denotes modulo-2 addition. The analog weight of error pattern $\mathbf{q}$ is denoted by $W(\mathbf{q})$. The decoder has to select the code word whose error pattern minimizes the analog weight. When $\mathbf{q} \neq \mathbf{0}$, to examine the second sufficient condition of Optimality, we think the error pattern of any other candidate code word. For linear code, a candidate code word is denoted as $\mathbf{x} \oplus \mathbf{r}$, where $\mathbf{r}$ is another non-zero code word. The error pattern for $\mathbf{q} \oplus \mathbf{r}$ is $\mathbf{h} \oplus \mathbf{x} \oplus \mathbf{r}$ which can be simplified as $\mathbf{q} \oplus \mathbf{r}$ because $\mathbf{h} \oplus \mathbf{x}$ is $\mathbf{q}$.

Starting from a code word $\mathbf{x}$ and its error pattern $\mathbf{q}$, we explore other candidate code words. Let $\mathbf{r}^m$ be a vector whose Hamming weight is integer m. The analog weight of error pattern $\mathbf{q}$ is denoted by $W_H(\mathbf{q})$. We set $r_i = 1$, for all positions i where $e_i = 1$ and least reliable $[m - W_H(\mathbf{q})]$ positions i where $q_i = 0$.

The vector $\mathbf{r}^m$ may not be a code word. So we hard decision decode $\mathbf{r}^m$ to obtain a code word $\mathbf{x}^m$. So we obtain a candidate code word $\mathbf{x} \oplus \mathbf{x}^w$ and its error pattern $\mathbf{q} \oplus \mathbf{x}^w$.

4. Experiment and Result

In this section, we present the performance of the proposed soft decision decoding algorithm and that of bounded distance decoding. The normalized threshold algorithm changes the range of candidate code words according to SNR of the channel. This adaptive change improves the performance. Soft decision decoding improves the reliability of the coding systems by using more information than that of hard decision decoding.

Over the additive white Gaussian noise (AWGN) channel, the extended (128, 99) BCH code with 10 minimum Hamming distance and the extended (128, 85) BCH code with 14 minimum Hamming distance are used. The energy per information bit is E_b, and the single-sided noise spectral density is N_0.

Figure 1 and Figure 2 show the bit error rate of the extended (128, 99) BCH code with 10 minimum Hamming distance and the extended (128, 85) BCH code with 14 minimum Hamming distance, denoted by EBCH (128, 99) and EBCH (128, 85), respectively. For (63, 30) BCH code with 13 minimum Hamming distance, the bit error rate is shown in Figure 3. The constructing criterion is used in the bounded distance decoding and normalized threshold algorithm.

Figure 4 and Figure 5 show the average reduction rate of EBCH (128, 99) and EBCH (128, 85), respectively. The sufficient conditions can be used when at least one candidate code word has been generated. For (63, 30) BCH code, the bit error rate is shown in Figure 6.

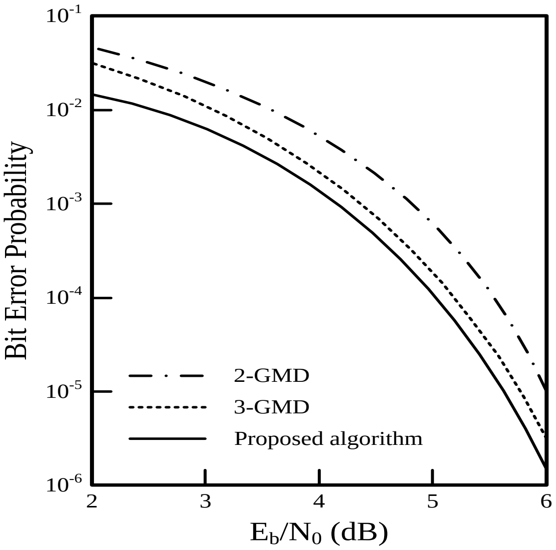

Figure 1. Bit error probability of EBCH (128, 99)

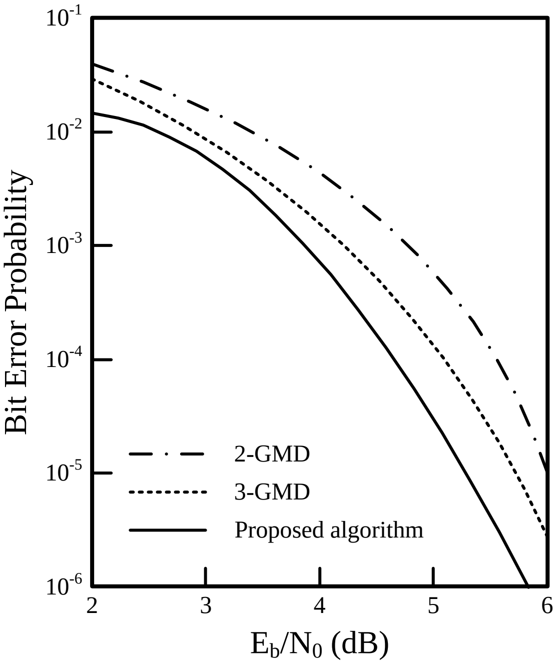

Figure 2. Bit error probability of EBCH (128, 85)

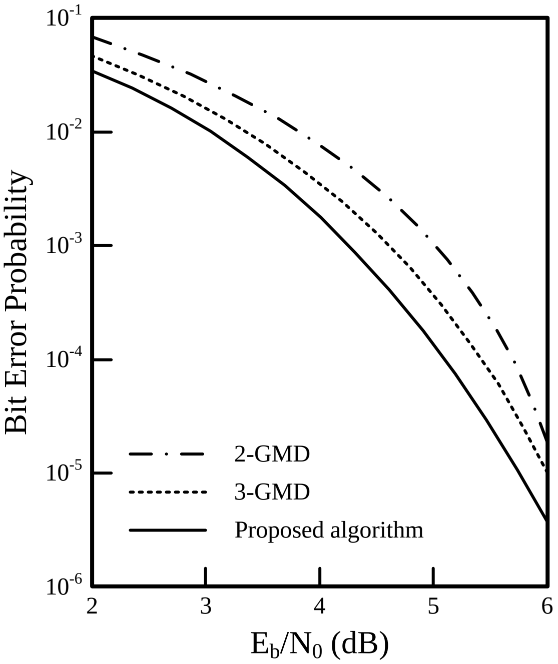

Figure 3. Bit error probability of BCH (63, 30)

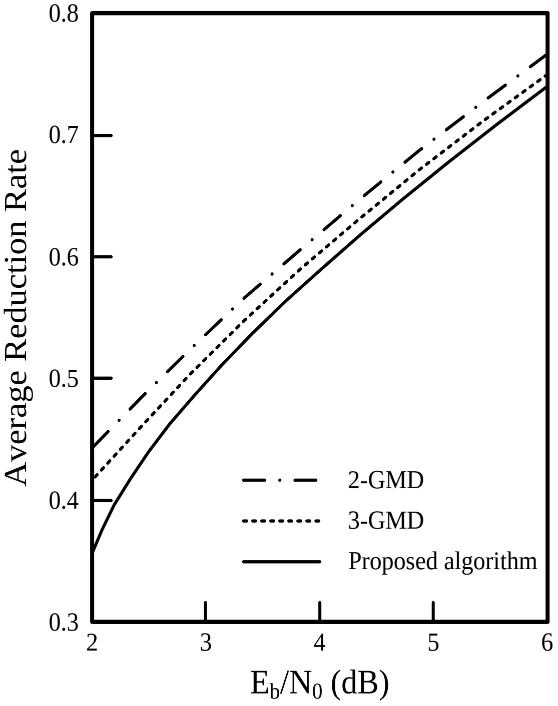

Figure 4. The average reduction rate of EBCH (128, 99)

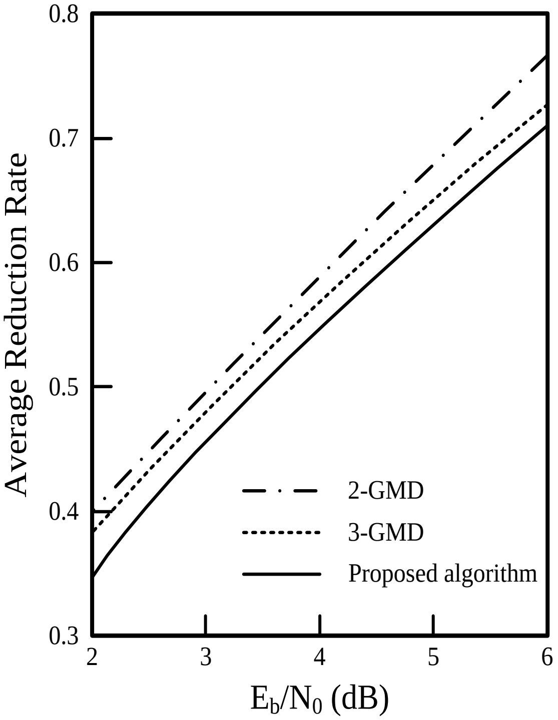

Figure 5. The average reduction rate of EBCH (128, 85)

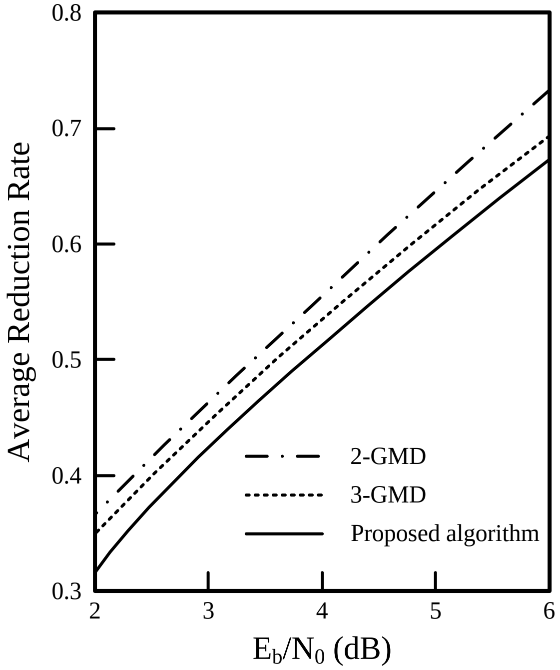

Figure 6. The average reduction rate of BCH (63, 30)

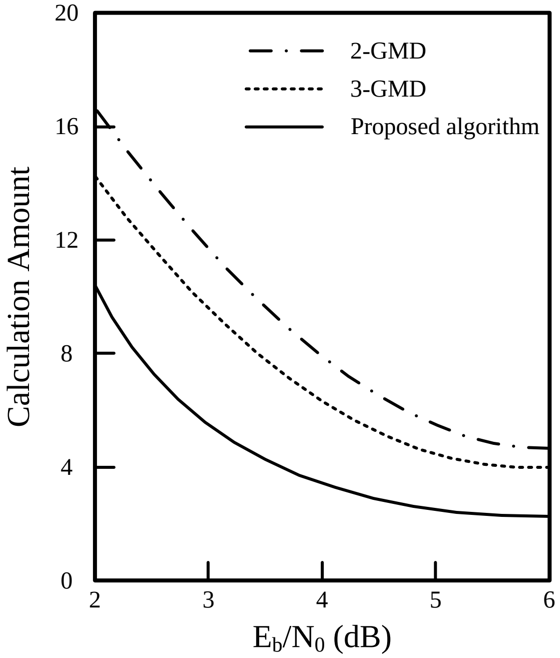

Figure 7. The calculation amount of EBCH (128, 99)

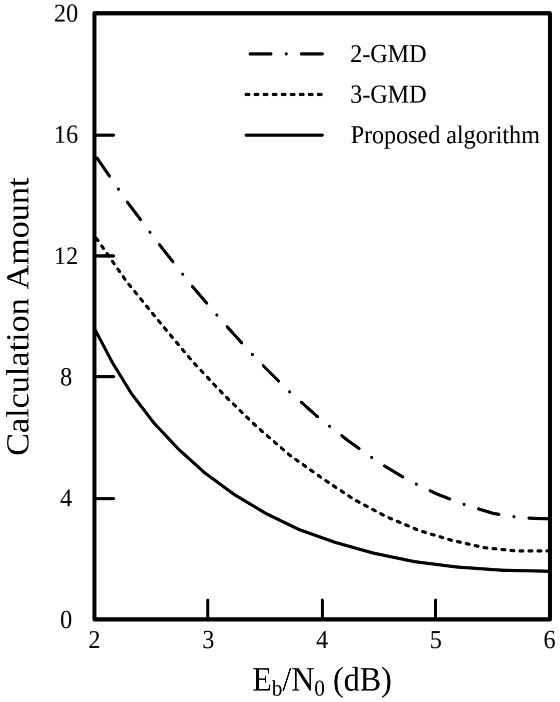

Figure 8. The calculation amount of EBCH (128, 85)

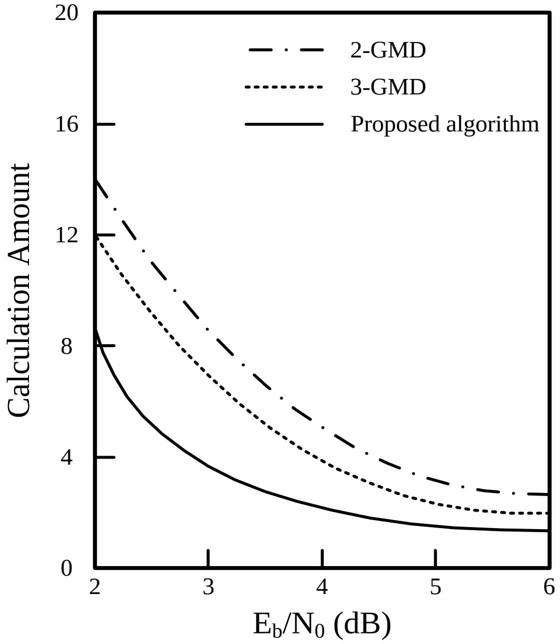

Figure 9. The calculation amount of BCH (63, 30)

The normalized threshold algorithm attains lower block error probability than bounded distance decoding. The effect of the normalized threshold algorithm is confirmed. Decoding complexity is proportional to the number of hard decision decodings. Thus, the number can be used as index of decoding complexity. The proposed algorithm much more rapidly reduces the decoding complexity. Figure 7, Figure 8 and Figure 9 are the experimental results.

5. Conclusion

We present a simple decoding algorithm that modifies error searching soft decision method. A new candidate code words region is searched to distinguish the variables belonging to the unsatisfied constraints. The proposed algorithm improves the decoding error performance caused by repeated searching. We show that the simplicity inherent in the hard decision decoding is still maintained.

In this paper, we present an error correcting binary channel code which expedites symbol transition. The use of error correction coding is effective because it permits us to detect and correct errors in transmission. Coding accomplishes its purpose through the deliberate introduction of redundancy into messages. It is demonstrated that the proposed code combine good symbol transition property with their own error correcting capability.

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