A Simple Method to Detect and Correct an Insertion/Deletion Error for Bit-Patterned Media Recording

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Abstract

Bit-patterned media recording usually encounters not only the two-dimensional interference but also the insertion and deletion (Ins/Del) error. This Ins/Del error arises from a write synchronization error, which could result in an error burst at data detection process. Thus, this paper proposes a method to suppress the Ins/Del error, which uses the trellis-based detection in conjunction with the Varshamov and Tenengolts code. Simulation results show that the proposed method can help improve the system performance in the presence of Ins/Del errors.

Keywords: Bit-patterned media recording, trellis-based detection, write synchronization error

1. Introduction

Super-paramagnetic limit is a major problem to increase an areal density in conventional magnetic recording [1]. Bit-patterned media recording (BPMR) is a promising technology to avoid the thermal instability of magnetic material, which can increase an areal density (AD) up to 4 Tbit/in^2 [1]. In general, BPMR confronts with the two-dimensional (2D) interference consisting of inter-symbol interference (ISI) and inter-track interference (ITI), which can deteriorate the system performance, especially at high AD. However, the BPMR system also encounters an insertion and deletion (Ins/Del) error, which can cause an error burst at the data recovery process [2]. Generally, the Ins/Del error could result from the write synchronization error, the write timing error, and the location fluctuation of magnetic islands, and so on [2].

Many works have been proposed to deal with the Ins/Del error [3-5]. For example, Seller [3] presented a simple method to detect and correct the Ins/Del error by using a so-called "marker code." Nonetheless, this marker code cannot find the exact location of the inserted or deleted bit. Then, Kuznetsov and Erden [4] proposed to utilize the Varshamov and Tenengolts (VT) code to detect and correct the Ins/Del error; however, this method is sensitive to an additive noise. Koonkarnkhai *et al*. [5] introduced a method to detect the Ins/Del error in BPMR systems based on the trellis structure, which is performed inside the Viterbi detector. Nevertheless, Koonkarnkhai *et al*. [5] did not mention a method to correct this Ins/Del error.

Therefore, this paper proposes a method to handle the Ins/Del error in the BPMR system, which employs the trellis-based detection in conjunction with the VT code. Specifically, we utilize a technique in [5] to detect the Ins/Del error and then use the VT code to correct it.

2. Channel Model

Consider a BPMR channel model with the proposed method to handle the Ins/Del error in Fig. 1. A binary input sequence $a_k \in \{0,1\}$ with bit period T is encoded by a VT code followed by a marker code. Next, a sequence c_k is fed to the Ins/Del channel to include the effect of insertion and deletion error in a system. Then, the readback signal y_k can be given by

$$y_k = d_k * h_k + n_k, \qquad (1)$$

where h_k's are the coefficients of a PR2 channel [5], n_k is an additive white Gaussian noise (AWGN) with zero mean and variance is σ^2.

At a receiver, the readback signal y_k is fed to the Viterbi detector [6] to determine the most likely data sequence, $\hat{b}_k$. Note that the detection of Ins/Del errors will be performed inside the Viterbi detector as proposed in [5], which will output the Ins/Del error location to the VT decoder for correction.

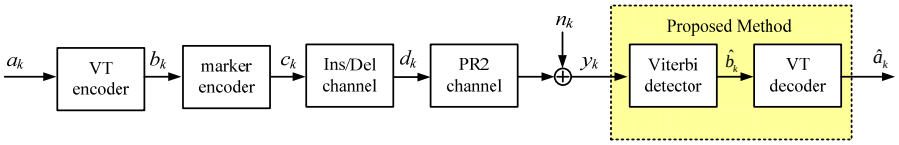

Fig. 1. A BPMR channel model with the proposed method to suppress the Ins/Del error.

3. Proposed Method

This paper proposes a method to detect and correct an insertion/deletion error in a BPMR system. To do so, we encode an input data sequence by a VT code and a marker code.

For Ins/Del error detection, we use a marker code with pattern $\mathbf{M} = [1\ -1\ -1\ -1\ 1]$ inserted every m bits and detect an Ins/Del error inside the Viterbi detector as explained in [5] for a PR2 channel. Specifically, if $\hat{b}_{n+1}^{n+l} = \mathbf{M}$, it means no Ins/Del error in a system, where $\hat{b}_{n+1}^{n+l}$ is a set of decoded bits from time $n+1$ to $n+l$ obtained from the Viterbi detector and $l = 5$ is the length of the marker bits. Then, the insertion error is detected if $\hat{b}_{n+2}^{n+l+1} = \mathbf{M}$, whereas the deletion error is detected if $\hat{b}_{n}^{n+l-1} = \mathbf{M}$.

To correct the Ins/Del error, this paper uses the VT code. The trellis-based Ins/Del detection will output the location of the Ins/Del error to the VT decoder, which can effectively correct one Ins/Del error per codeword [4, 7].

4. Simulation Setup and Result

Consider the BPMR channel model with insertion and deletion error in Fig. 1. The signal-to-noise ratio is defined as $E_b/N_0 = 10\log_{10}(\Sigma_k|h_k|^2/2R\sigma^2)$ in decibel (dB), where E_b is an energy per bit and R is the overall code rate of the system. The insertion or deletion error will occur during the write process with a probability of 0.5, where the location of this error is occurred randomly. The bit-error rate (BER) is computed based on a minimum number of 10000 data sectors and 500 error bits, and call it as "BER given Ins/Del." Here, the proposed method uses a rate-247/255 VT code and a rate-255/260 marker code. Thus, the overall code rate of this system is $R = 0.92$.

Fig. 2 shows the BER performance of different schemes, where the performance of the system without insertion and deletion errors is denoted as "without Ins/del." Without a technique to suppress Ins/Del errors, the system performance is unacceptable, referred to as "with Ins/Del." Clearly, the proposed method performs better than the existing method [3] whose code rate is 0.98.

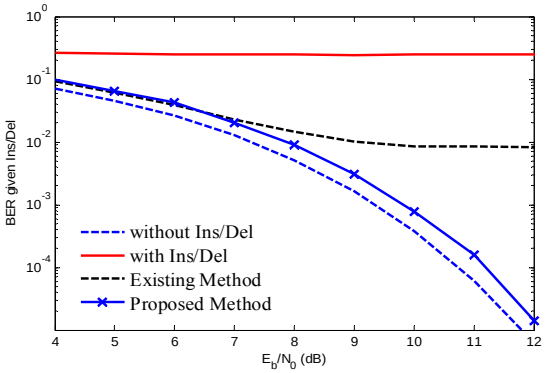

Fig 2. BER performance of different schemes.

5. Conclusion

The Ins/del errors are a major problem in a BPMR system because it can yield an error burst at the data detection process. This paper proposes to use the trellis-based technique in [5] to detect an Ins/Del error and employs the VT code to correct this error. As shown in simulation, the proposed method is superior to the existing one in terms of BER.

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