A 2D-Interference Mitigation with a Multitrack Recorded-Bit Patterning Scheme for Bit Patterned Media Recording

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Abstract

The two-dimensional (2D) interference, consisting of the inter-symbol interference (ISI) and the inter-track interference (ITI), is a crucial problem in bit patterned media recording (BPMR) systems. Because the severity of 2D interference at the detected bit depends on its surrounding bits, we propose a simple multitrack recorded-bit patterning (M-RBP) scheme to combat the 2D interference effect, which requires no redundant bits at the expense of increased buffer memory. Specifically, we circularly shift each data track to find the best data pattern based on the accumulated weight before recording. Compared to the recorded-bit patterning (RBP) scheme proposed in [1] under same areal density, the M-RBP scheme performs better than the RBP scheme and the system without coding.

Keywords: BPMR, multitrack recorded-bit patterning (M-RBP), position jitter noise, recording-bit patterning

1. Introduction

To achieve high recording densities in BPMR, the spacing between data bit islands in both the along-track and the across-track directions must be reduced, thus increasing the 2D interference, which can degrade the overall system performance significantly. There are many 2D coding schemes have recently been proposed [2-3] to cope with the 2D interference. However, these 2D coding schemes had a drawback that the redundant bits decrease the recording area.

Therefore, this paper proposes the M-RBP scheme without redundant bit (i.e., a code rate of 1) to combat the 2D interference at the expense of increased buffer memory. Specifically, a data sequence of each track is rotated until the best data pattern is obtained based on a look-up table, where the best data pattern is defined as the data pattern with the maximum accumulated weight, which causes the lowest effect of the 2D interference in the readback signal of the detected bit.

2. Channel Model

Fig.1 illustrates the BPMR system based on [4] with the M-RBP scheme. A binary input sequence $a_k \in \{\pm 1\}$ with bit period T_x is split into five tracks, and is sent to the M-RBP transmitter block. The readback signal from the k^{th} data bit on the l^{th} track can be expressed as

$$r_{l,k} = \sum_n \sum_m h_{m,n} x_{l-m,k-n} + n_{l,k} = x_{l,k} \otimes h_{l,k} + n_{l,k}, \quad (1)$$

where $x_{l,k}$'s are the recorded bits, $h_{m,n}$'s are the 2D channel response coefficients [4], n and m represent the indices of the bit islands in the along-track and the across-track directions, respectively, $\otimes$ is the 2D convolution operator, and $n_{l,k}$ is an additive white Gaussian noise (AWGN) with zero mean and variance σ^2. Note that the position jitter noise is modeled as a truncated Gaussian probability distribution function with zero mean and σ_j^2, where σ_j is specified as percentage of the bit period T_x.

Then, the readback data sequence $r_{l,k}$ is equalized by a 2D equalizer and fed to the 2D Viterbi detector to determine the most likely input sequence [4]. Finally, the M-RBP receiver block is used to rearrange the data sequence with an aid of the buffer memory. Specifically, the data sequence in each track will be shifted back to its original position according to the number of shifting times stored in the buffer memory that is obtained from the M-RBP transmitter block.

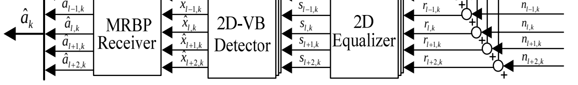

Fig. 1 A BPMR channel model with the M-RBP scheme.

3. Proposed Scheme

To explain the proposed MRBP scheme, we firstly define a window of a 3-by-3 array that covers 9 bits. Within this 3-by-3 window, we define the weight to describe the severity level of the 2D interference. We found that the value of the weight can be either positive or negative, depending on whether the 2D interference is constructive or destructive. Accordingly, the weight of the i^{th} data pattern denoted as W_i is defined as

$$W_i = \begin{cases} Y_i - Y_s, & Y_i > 0 \text{ and } Y_s > 0 \\ |Y_i| - Y_s, & Y_i < 0 \text{ and } Y_s > 0 \\ -\left(Y_i + |Y_s|\right), & Y_i > 0 \text{ and } Y_s < 0 \\ -\left(|Y_i| + Y_s\right), & Y_i < 0 \text{ and } Y_s < 0 \end{cases}, \qquad (2)$$

where Y_i and Y_s are the peak amplitude of the readback signal obtaining from the i^{th} data pattern and the single bit case [1], respectively. Based on (2), we obtain 512 weights for all possible data patterns.

Fig. 2 shows the M-RBP process. In the first step, we move the 3-by-3 sliding window (centered at the center track) from the beginning to the end of the track. Note that we compute the weight and accumulate at each time when the window is moved so as to obtain the total weight. Next, we fix the center track and then circularly shift the upper track to the right or the lower track to the left to create all possible 3-track data patterns. For each 3-track data pattern, we perform a similar procedure to compute the total weight. Finally, the number of shifting times used in both the upper and the lower tracks that yields the maximum total weight will be stored in the memory, which will be used to shift the data bits back to their original position in the M-RBP receiver block. Note that the data pattern that gives the maximum total weight will practically cause the lowest effect of the 2D interference in the readback signal.

In the second step, we fix the $(l\text{-}1)^{th}$ and $(l+1)^{th}$ track. Then, the 3-by-3 sliding window will be centered on the $(l\text{-}1)^{th}$ and $(l+1)^{th}$ track. Now, the data sequence on the $(l\text{-}2)^{th}$ and $(l+2)^{th}$ track will be circularly shifted to find the best data pattern. Here, we use a similar process as used in the first step to compute the total weight.

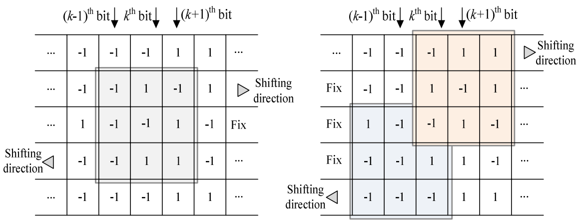

Fig. 2 The proposed M-RBP scheme with the 1st step (left) and the 2nd step (right).

4. Simulation Results

We test the performance of the M-RBP scheme in the BPMR channel shown in Fig. 1 at an areal density of 2.5 Tb/in^2. The signal-to-noise ratio (SNR) is defined as $20\log_{10}(1/\sigma)$ in decibel (dB)), where '1' is assumed to be the peak amplitude of the readback signal. The 2D 3×3 target and the 2D 3×7 equalizer are designed based on an MMSE approach [4] in the presence of position jitter noise at the SNR required to achieve the bit-error rate (BER) of 10^{-4}.

Fig. 3 compares the performance of different schemes by plotting the SNR required to achieve BER = 10^{-4} as a function of position jitter noise amounts. It is clear that the M-RBP scheme performs better than the RBP scheme and the system without coding (denoted as "Normal"), especially when the position jitter noise is large.

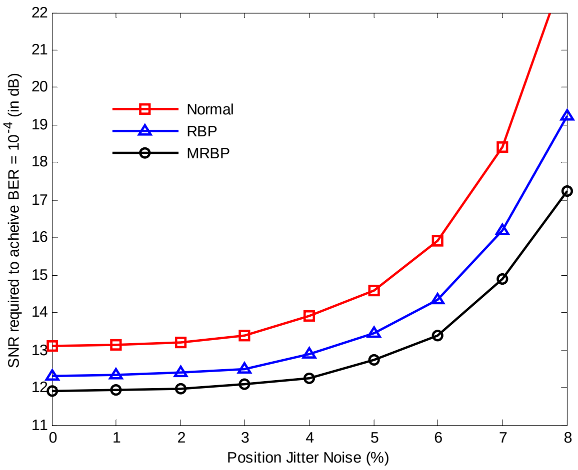

Fig. 3 Performance comparison of different schemes at 2.5 Tb/in^2 with various position jitter noise amounts.

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