2D Modulation Code Together with Multi-track Reading Technique in Staggered BPMR Systems

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Abstract

To reduce a track width for increasing the areal density (AD) in magnetic recording system, it provides an unpleasant appearance of inter-track interference (ITI). One way, the effect of severe ITI may be mitigated is through the use of coding schemes. In this paper, we propose a rate 5/6 two-dimension (2D) modulation code performed together with the multi-track reading scheme in staggered island bit-patterned media recording (BPMR) systems to salve the severe 2D interference which comprises of the new method encoding/decoding scheme and the new technique is partial-response maximum likelihood (PRML) detection. The PRML technique is based on the channel model by oversampling technique. Simulation results indicate that the proposed coding scheme is better than the conventional system, especially at high AD.

Keywords: Bit-patterned media recording (BPMR), 2D interference, 2D Modulation code, Partial-response maximum likelihood.

1. Introduction

The inter-track interference (ITI) effect of the high areal density (AD) in magnetic recording system is the main problem that can grievously degrade overall system performance [1,2]. To cope this situation; therefore, there are several research works were proposed to mitigate this effect using the coding schemes [3,4]. The previous work [4], we mitigate ITI effect by using the multi-track reading scheme with single reader in BPMR systems which employs the partial-response maximum-likelihood (PRML) detection. The multi-track reading scheme with single reader was proposed in [5]; however, it was investigated it performance in the continuous recording media.

In this work, we present a mitigating 5/6 modulation coding scheme performs together with multi-track reading technique (MRT) to combat the severe two-dimensional (2D) interference. Here, the MRT uses only one reader to read the two data tracks, simultaneously. Our coding scheme will properly rearrange the input data sequence into 2-track recorded sequences based on codewords in a look-up table before recording data onto a staggered bit island magnetic medium.

This coding scheme can guarantee that the BPMR readback signal that obtain from the MRT will not be corrupted by the severe 2D interference. That means the overall system performance can be also developed. Furthermore, we also apply the Euclidean distance concept [6] in the decoding process to verify that the received data can be decoded accordingly.

2. Channel Model

The channel model of the staggered BPMR system with the proposed encoding/decoding schemes is considered in this paper can be shown in Fig. 1. We consider the staggered alignment of hexagonal shape which there is a diameter of 12 nm and a bit period, T_x, of 16.0 and 14.5 nm corresponding to the ADs of 2.5 and 3.0 Tb/in^2. A random binary input sequence $a_k \in \{\pm 1\}$ is encoded by the proposed encoder to obtain two data tracks $\{x_{k,l}, x_{k,l+1}\}$, where $x_{k,l} \in \{\pm 1\}$, before recording data onto the medium. At the receiver, the readback signal is generated from 2D convolution between the media magnetization and readhead sensitivity function response [7]. Then, we apply the PRML [4] and the over-sampling techniques together for detecting data after reading. After, a readback sequence is equalized by a 1D equalizer [8] to obtain an equalized data sequence, $s_{k,l}$, and is then fed to 1D Viterbi detector (VD) to produce the estimated recorded data sequence, $\hat{x}_{k,l}$. This data sequence will be separated to two sequences before passing them to our proposed decoder to estimated input data sequence, $\hat{a}_k$.

3. Encoding and Decoding Schemes

We have investigated the lowest amplitude data patterns [4] which we found that the most of them appear when the desired bit is opposite to their neighbor bits, i.e., $[x_{k,l}, x_{k,l+1}, x_{k+1,l}]$, it can be either $[1, -1, 1]$ or $[-1, 1, -1]$. Therefore, it is defined as forbidden patterns, which are always not allowed to record. We have used this condition to define and search the all possible proper data patterns. Then, we select the best 32 data patterns from 64 data patterns to be as our codeword.

In this paper; the new encoding method maps 5 input bits in the matrix form of 1-by-5 bits, i.e., $\mathbf{a} \equiv [a_k, a_{k+1},$

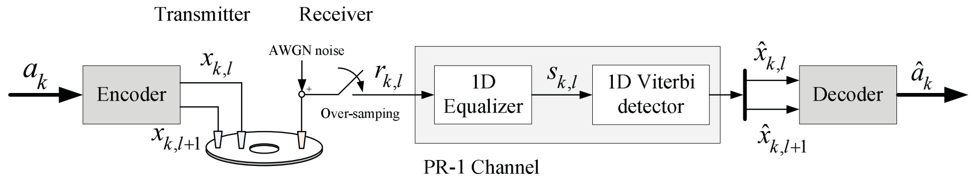

Fig. 1: Block diagram of single-head/two-track reading systems with the proposed a rate-5/6 2D modulation encoding and decoding schemes.

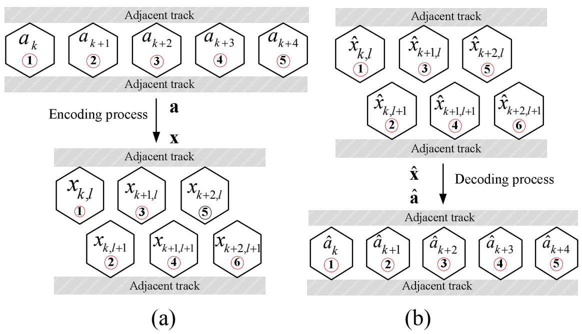

Fig. 2: The proposed (a) encoding and (b) decoding schemes, which encode 1-by-5 input bits to be a 6-bit codeword in the form of matrix 2-by-3 bits and decode 6 estimated recorded bits to be the 1-by-5 estimated input bits, respectively.

a_{k+2}, a_{k+3}, a_{k+4}] to be a 6-bit codeword, $\mathbf{x}$, in matrix form of 2-by-3 bits (or a codeword), which composes of the first 2 bits of input data that kept in the first column [$x_{k,l}$, $x_{k,l+1}$], the second column [$x_{k+1,l}$, $x_{k+1,l+1}$] will be used to store the middle 2 input bits, and the last column [$x_{k+2,l}$, $x_{k+2,l+1}$] stores the last input and redundant bits as shown in Fig. 2(a). This method is a base line in encoding scheme and the rest of patterns are mapped along codeword.

For the decoding process, the 6 estimated recorded bits, $\hat{\mathbf{x}}$, will be rearranged to be the 5 estimated input bits, $\hat{\mathbf{a}}$, as shown in Fig. 2(b). The estimated 2-track recorded bit is decoded by means of a modulation decoder; we apply the Euclidean distance. Furthermore, these encoding and decoding schemes not only easily perform but also yield a better performance.

4. Simulation Results

We compare the BER performance between the MRT system for both with and without coding technique [4] and the conventional system, which denoted as "Coded system AD 3.0 Tb/in^2", "Uncoded system AD 2.5 Tb/in^2 [4]", and "Conventional system AD 2.5 Tb/in^2", respectively. Note that the one reader reads the data from one data track, both of its adjacent tracks are also the random bits. In this paper, the SNR is defined as SNR = $10\log_{10}(1/R\sigma^2)$ in dB, where R is code rate, i.e., R = 0.833.Therefore, with the reason of fair comparison, we have compared their BER performance in the same user density (UD), which is defined as UD = AD×R.

Fig. 3 shows that the proposed coding scheme is slightly better than the uncoded MTR system and superior to the conventional system. The proposed system can provide the performance gain for about 0.5 dB over the uncoded system at BER = 10^{-4} and UD of 2.5 Tb/in^2. The reason may be because the data position identification in the codeword can lead to obtain more accuracy in the decoding process.

5. Conclusion

This paper proposes the new encoding and decoding schemes of a rate 5/6 2D modulation code for staggered BPMR systems. This proposed 2D modulation code is designed base on the multi-track reading technique (MRT) that use only one readhead reads the two desired tracks, simultaneously. The good data patterns that provide the highest readback signal will be defined as the codewords. Then, the over-sampling is employed to obtain the data samples of the readback signal. The results indicate that the system performance can be significantly improved when the proposed coding scheme is adopted for single-head/two-track reading in staggered BPMR systems, especially when the AD is high.

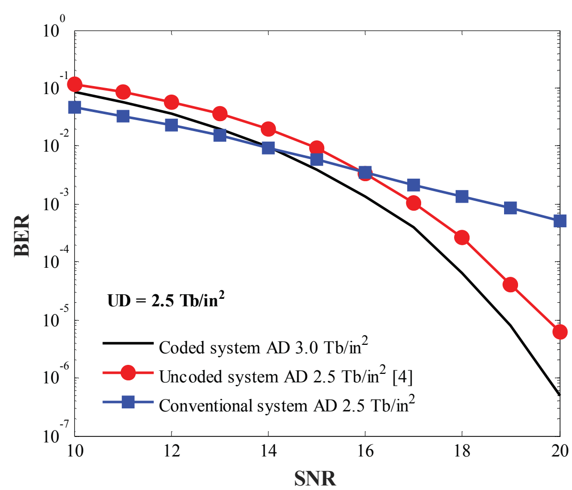

Fig. 3: BER performance comparison of the conventional system, the uncoded system [4], and the proposed coded system at the ADs of 2.5, 2.5, and 3.0 Tb/in^2, respectively, i.e., All of three systems are considered at the same user density at 2.5 Tb/in^2.

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