A Simple Baseline Popping Detection and Correction for Perpendicular Magnetic Recording Channels

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Abstract

In high-density perpendicular magnetic recording (PMR) channels, the read head has a great impact on the quality of the readback signal. In general, the instable read head causes an additive voltage transient in the readback signal known as baseline popping (BLP), which can significantly degrade the overall performance of hard disk drives. This paper proposes a simple method to detect and correct the BLP based on a least-squares fitting technique. Results indicate that the proposed method performs better than the conventional one.

Keywords: baseline popping, detection and correction, perpendicular magnetic recording.

1. Introduction

Currently, the magneto-resistive head is used to read and write data for perpendicular magnetic recording (PMR) channels. At high recording densities, the stability of the read head is one of the crucial factors to maintain satisfactory performance. Practically, the head instability causes many problems, such as BLP, spiking noise, writer induced instability, permanent magnet reversal instability, and random telegraph noise [1-2]. Thus, this paper focuses on how to detect and correct the BLP-affected readback signal in PMR channels.

2. Channel

The PMR channel model with the BLP effect is shown in Fig. 1, where $H(D) = \sum_k h_k D^k = 1 + 2D + D^2$ is a PR2 channel [8], h_k is the k-th channel coefficient, and D is a unit delay operator. A data input sequence $a_k \in \{\pm 1\}$ with bit period T passes through the PR2 channel. The BLP-affected readback signal, $p(t)$, can be written as

$$p(t) = \sum_k r_k s(t - kT) + n(t) + u(t) \qquad (1)$$

where $r_k = a_k * h_k \in \{0, \pm 2, \pm 4\}$ is a noiseless channel output, $*$ is a convolution operator, $s(t) = \sin(\pi t/T)/(\pi t/T)$ is an ideal zero-excess bandwidth Nyquist pulse, $n(t)$ is the additive white Gaussian noise with two-sided power spectral density $N_0/2$, and $u(t)$ is the BLP signal defined in [3].

At the receiver side, the readback signal $p(t)$ is filtered by an ideal lowpass filter, whose impulse response is $s(t)/T$ to eliminate the out-of-band noise, and is then sampled at time kT, assuming perfect synchronization. The sampled output y_k is fed to the BLP detection and correction block to alleviate the BLP effect. Then, a sequence z_k is sent to Viterbi detector to determine the most likely input data sequence a_k.

3. BLP Detection and Correction Methods

3.1 Conventional Method

In the conventional BLP detection and correction method, the BLP-affected readback signal y_k is fed to an averaging filter with a window length of L bits to obtain a sequence q_k, and is then sent to a threshold detector to determine the presence of BLP. Basically, the BLP is detected if $q_k > m_1$, where $m_1 > 0$ is a threshold value.

After the BLP is detected, the BLP detection operation is disable, and the BLP correction operation is activated for a duration of T_f bits so as to mitigate the BLP effect. Therefore, the corrected readback signal is given by $z_k = y_k - q_k$ when BLP is present, whereas $z_k = y_k$ when BLP is absent. Finally, the sequence z_k is fed to the Viterbi detector for data detection.

3.2 Proposed Method

To improve the performance of the conventional method, we propose a simple BLP detection and correction method. Specifically, to detect the BLP location, we first adjust the amplitude of the readback samples $\{y_k\}$ according to

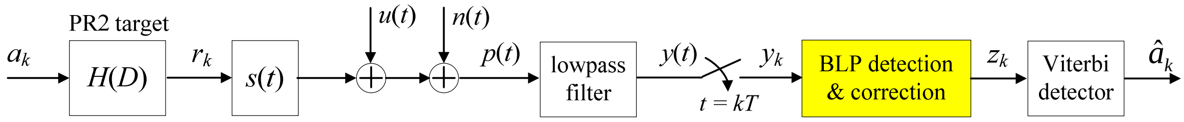

Fig. 1 A perpendicular magnetic recording channel model with a baseline popping detection and correction.

$$d_k = \begin{cases} \sum_k |h_k|, & y_k < \sum_k |h_k| \\ y_k, & \text{else} \end{cases}, \quad (2)$$

where $\sum_k|h_k|$ is the peak amplitude of the normal readback signal. Next, the adjusted sequence d_k is sent to an averaging filter with a window length of L bits to obtain an averaged sequence q_k. Then, the sequence q_k is fed to a threshold detector with the threshold values of m_2 and m_3 to determine the BLP location. Specifically, the starting point of the BLP event is detected if $q_k > m_2$ and $y_k > m_3$ for n consecutive samples so as to make it more robust to a false alarm, whereas the ending point of the BLP event is detected if $q_j < m_4$, where $j > k$.

The information about the starting and the ending points will determine the location of the BLP signal. The bits $\{y_k\}$ from the starting point to the ending point are used to estimate the BLP signal, w_k, based on a least-squares (LS) fitting technique [4], where the BLP signal during a decay time is exponentially decay [3]. Because the rise time of the BLP signal is very short, we then ignore to estimate it. Consequently, the corrected readback signal, z_k, is given by

$$z_k = \begin{cases} y_k - w_k, & \text{if BLP is present} \\ y_k, & \text{if BLP is absent} \end{cases}. \quad (3)$$

4. Numerical Result

In simulation, we define the energy per bit-to-noise power ratio (E_b/N_0) as $E_b/N_0 = 10\log_{10}(E_c/2\sigma^2)$ in dB, where E_c is an energy of the PR2 channel. We consider the case where every one 4096-bit data sector is corrupted by on BLP event. The BLP signal has the amplitude at the starting point and the ending point of $0.5\sum_k|h_k|$ and $0.4\sum_k|h_k|$, respectively, with the duration of 500 bits [3]. For PR2 channel, the conventional BLP detection and correction method employs $L = 251$ and $m_1 = 1.14$, while the proposed method uses $L = 101$, $m_2 = 4.12$, $m_3 = 4.5$, $m_4 = 4.015$, and $n = 3$ [3].

Fig. 2 shows the bit-error rate (BER) performance for each method. Clearly, the system without BLP, denoted as "Without BLP" effect is the best. However, when the system faces with the BLP effect, the performance of the system without the BLP detection and correction method is unacceptable, denoted as "with BLP." In addition, it is apparent that the proposed method referred to as "Proposed" performs better than the conventional one denoted as "Conventional."

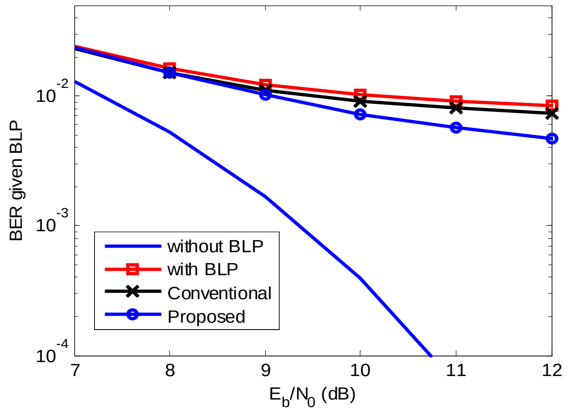

Fig. 2 BER performance.

5. Conclusion

This paper proposes a simple BLP detection and correction method to suppress the BLP effect for perpendicular magnetic recording channels. Simulation results showed that the proposed method yields better performance than the conventional one in terms of BER. Also, we found that the window length of the averaging filter used in the proposed method can be smaller than that used in the conventional one, while still retaining a good performance.

References

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