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Noise characterization of perpendicular magnetic media using autocorrelation method

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Abstract

Frequency-domain analysis using the measured noise spectrum has usually been used for medium noise analysis. However, with this method it is impossible to observe where the noise occurs and how the reproduced waveform behaves. On the other hand, time-domain analysis using the autocorrelation function enables the spatial distribution of noise to be visualized. Recently, the transition position jitter and the transition width fluctuation have been recognized as noise sources in perpendicular magnetic recording. In this paper, some of these noise sources of actual readback waveforms were estimated by using autocorrelation method. The result of this work was that the noise in perpendicular magnetic recording could be visualized and power ratio of several noise sources was calculated. And it was confirmed that the jitter is the most dominant noise source.

Keywords: Perpendicular magnetic recording; Noise autocorrelation

1. Introduction

Medium noise is one of the crucial factors which limit high areal density in perpendicular magnetic recording. We have studied about medium noise by using frequency-domain analysis such as noise spectrum analysis. The frequency-domain analysis using the noise spectrum has usually been used for the measurement of reproduced noise. This is the analyzing method which used the Parseval's theorem. While there is a merit that the amount of a noise can be measured easily, there is also a demerit that a non-stationary noise cannot observe how it has been generated. Then, we paid attention to the technique of the noise analysis by autocorrelation.

The previous literature suggested that the medium noise was mainly caused by jitter noise at transition [1]. Besides the jitter noise, noise caused by transition width fluctuations and the one caused by domain reversals are generated from a medium. It is reported that two former increase with magnetization transition becomes dominant at the time of high-density recording. There is also system noise such as noise caused by head and electrical noise, which does not depend

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on a medium recording layer. If autocorrelation method is used, it can visually observe where the above noises generate in bit length. In this report, the relationships between the different sources of noise and the autocorrelation were clarified using a simulation waveform, and further, in the noise analysis of a survey waveform by autocorrelation method, since estimation of a readback waveform parameter was also performed.

2. Autocorrelation method

The noise autocorrelation is commonly defined as the inverse Fourier transform of the spectrum. However, in order to be applicable to the non-stationary noise, more general definition is used, that is,

$$R_N(t_1, t_2) \equiv \overline{N(t_1)N(t_2)},$$

where the bar means ensemble average and t_1 and t_2 are two time-points. The value of the autocorrelation from this definition formula is obtained by the following procedure [2]:

1. Obtain m observed waveforms (the noise is included) for bit length; denote the ith recorded waveform by $X_i(t)$.
2. Find the average $S(t) = \overline{X_i(t)} = 1/m \sum_{i=1}^{m} X_i(t)$; this is made into an ideal signal which has no noise.
3. For each X_i, find the noise $N_i(t) = X_i(t) - S(t)$.
4. Calculate noise autocorrelation about each observed waveform and average them.
$$R_N(t_1, t_2) = \frac{1}{m} \sum_{i=1}^{m} N_i(t_1)N_i(t_2)$$

Fig. 1 shows the noise autocorrelation of a longitudinal thin film medium. The write track width and read track width are 300 and 200 nm, respectively. There are two pairs of positive and negative peaks as shown in Ref. [2]. This autocorrelation pattern indicates the transition jitter corresponding to the readback pulse of longitudinal recording.

In perpendicular magnetic recording, the jitter noise and the transition width fluctuation noise are typical. Figs. 2 and 3 show the autocorrelation profile of jitter noise and noise caused by transition width fluctuation, respectively. These autocorrelations show that jitter noise has conical shape and noise caused by transition width fluctuations has dipulse shape. The difference comes from the shape of the readback pulse.

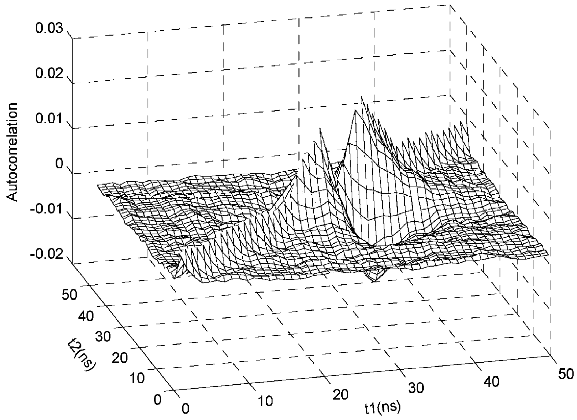

Fig. 1. Noise autocorrelation measured in an actual R/W system (longitudinal).

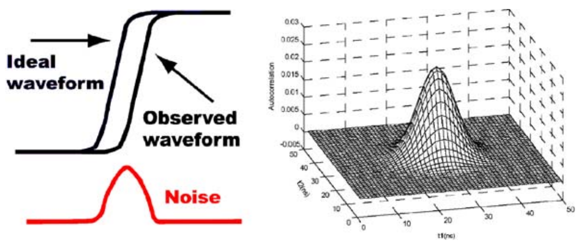

Fig. 2. Autocorrelation of jitter noise. Even if a transition position shifts to which direction, conical profile is always convex upward.

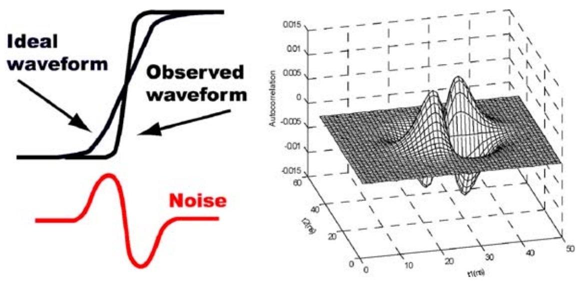

Fig. 3. Autocorrelation of noise due to fluctuations in the transition width. The profile is always a twin cone shape along the $t_1 = t_2$ line.