SERVO PREDICTION AND HIGH POSITION UPDATE RATE TO SUPPORT 10 TERABIT/SQ-IN PATTERNED MEDIA TECHNOLOGY

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ABSTRACT

To achieve 10 Terabit/in² magnetic recording density, the bit aspect ratio (BAR) is estimated to be ≤ 4 indicating track density of 1.6 to 3.2 MTPI. This is going to place tremendous challenges to servo-mechanical. In this paper, a projection of the required servo sampling rate and bandwidth to achieve 1.6 MTPI is conducted. A method using the preamble field of the data channel is proposed to detect the position error as well as the timing information to increase the sampling rate without increasing overhead. Dual stage control design with a conventional VCM actuator and slider-based MEMS actuator is also preformed to achieve 9 kHz servo bandwidth.

1. INTRODUCTION

The achievable density for perpendicular recording is soon going to reach the limit of 0.75-1 Terabit/in², due to superparamagnetic effects [1]. With a new target to achieve 10 Terabit/sq-inch areal density by INSIC, more advanced or novel combination of technologies are required. One of the possible solutions is bit patterned media (BPM) where a regular array of islands of magnetic media is fabricated over the entire disk surface combined with energy assisted writing technology.

Fig. 1 Servo and data sector layout on disk media.

Embedded servo technology is widely adopted in the disk drive industry. To achieve high servo bandwidth, the sampling rate needs to be at least ten times greater than the open-loop servo bandwidth to minimize the loss of phase margin [2]. However, the rate at which the servo controller reads the PES measurements is proportional to

the disk spinning speed and the number of servo burst sectors on the disk surface. If the spinning speed of the disk is increased, it will result in increased mechanical disturbance from spindle motor, such as non-repeatable run out (NRRO) error and other noise issues. Increasing the number of servo sectors will in turn reduce the amount of storage space which is undesirable.

2. DATA SECTOR POSITION DETECTION

In HDD, there is usually a preamble at the start of each data sector as shown in Fig. 1. Based on the bit layout format, the position of the read head during reading the user data sector can be detected from the preamble/synchronization field at each data sector. Using the multi-row per track concept for bit patterned media [3], position error can be detected by magnetizing the alternate sub-tracks in the following manner as shown in Fig. 2. In this way, there is no increase of overhead, the demands for narrower read/write head fabrication, feature sizes requirement can be relaxed, as well as having a higher data recording rate. As the data sector is based on constant density, where there will be variable number of data sectors per track. An extrapolator is used to synchronize the data PES obtained from different interval and provide a fixed interval PES to the digital controller.

Fig. 2 Modified magnetization of the preamble field and its corresponding readback waveform at track centre.

The read head is assumed to be wider and cover two sub-tracks data. When the read head is positioned at the track centre, the positive and negative half of the acquired waveform is ideally the same. If the read head is slightly off-track towards N-1, the amplitude of Burst A will be

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larger than that of Burst B, and vice versa. Thus the position error can be detected as follows and shown in Fig. 3.

$$PES(z) = \frac{X_A(z) - X_B(z)}{X_A(z) + X_B(z)} \quad (1)$$

Fig. 3 Simulated cross track profile of PES and QPES from Burst A and Burst B ("I": Based on amplitude detection, "P": Based on averaging detection).

2. SERVO PREDICTION

Conventional single-stage VCM (Voice Coil Motor) servo system is not able to achieve servo bandwidth as high as 9 kHz, as the primary resonance of VCM actuator is at around 5-8 kHz and has limited the achievable bandwidth. The dual-stage servo systems using VCM actuator and a slider-based MEMS (Micro Electro Mechanical System) microactuator are good candidate for achieving high bandwidth [4], as it has no significant resonance mode up to 100 kHz except one resonance at around 1.5-2 kHz due to its flexural pivot.

Fig. 4 Frequency responses of the VCM actuator and the microactuator.

In this paper, the sampling frequency is assumed to be increased by 4 times to 105.6 kHz by making use of the additional PES information from user data preamble. Parallel dual stage control configuration controller is adopted and designed. The VCM actuator is subjected to the input and output disturbances and measurement noise, obtained from a 3.5" 7200rpm drive [5]. It can be seen from Fig. 4 that the dual-stage system achieves the open-loop bandwidth of 9 kHz, with the phase margin of 40 degrees and gain margin of 8 dB. Compared to the

single-stage servo, the achievable servo bandwidth has been greatly increased using dual-stage servo.

As shown in Fig. 5, the 1σ value of PES for single-stage servo is 4.57nm, which is equivalent to the track density of 185kTPI, while the achievable track density for dual-stage servo is approximately 500kTPI with the 1σ value of PES being 1.7nm.

Fig. 5 Power spectra linear density of PES with their cumulative sum.

5. CONCLUSION

The proposed layout of the user data preamble provides additional information of the position error. Thus the PES sampling rate can be increased without additional overhead. A dual-stage microactuator controller is designed with the increased sampling rate of 105.6 kHz. The servo bandwidth of 9 kHz is obtained, increasing the achievable track density to 500 kTPI. To achieve 10 Terabit/in² areal density, track density need to be at least 1.6 MTPI. Thus, simply by increasing the sampling frequency and servo bandwidth using dual-stage servo is not sufficient. Further reduction in the vibration and novel design of the mechanical structure like Helium-filled HDD may be required and explored thoroughly to realize the 10 Terabit/in² target.

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