Optimization and Emulation Analysis on Sampling Model of Servo Burst

Signal in Read/ Write Channel of Magnetic Storage

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Abstract. In order to calculate the servo position error signal (PES) in the servo system, it is necessary to make high precision sampling and FFT calculation for the burst signal. Most designer s adopt 6bits ADC converter in the read write channel servo system of hard drive controller chip 88i6310 to cost down, and both servo system and signal system share the sampling circuit. Because of the quantitative noise disturbing during the sampling process, it is not enough to use 6bits ADC converter for the serve burst signal, and significant error exist for t he burst signal with the FFT calculation. This paper analyzed the existing servo over-sampling model via quantitative error model firstly, and provided the enhanced servo system sampling model. The simulation shows that, the enhanced solution reduces the average quantitative error from 0. 38 LSB to 0.14LSB, and improves the resolution of ADC converter from 7.5 bits to 8.8 bits.

Keywords: Magnetic Recording, Read/Write channel, Servo signal, Resampling signal, Data storage

1. Introduction

With the fast development of information technology, the demand to high capability data storage and high speed data transmission is hugely increased, and the recording density and transmission speed are also growing fast. Read/write channel is the important part of information storage system as figure 1, the data produced by PC or downloaded from internet goes into the read/write channel through adapter and controller and then be recorded in the storage medium through the signal conversion device (magnetic head or optical head), we call this as the write data process. The inverse process is read the data [1, 2], to read the information in the storage medium through the signal conversion device (read the wave form), and change into pulse sequence through read/write channel, and then the mixed sequence with data and clock pulse will be recovered into the original state by decoding of controller, and finally input into the master or network server through I/O port, so the user can use it. The high-efficient and reasonable read-write channel design not only can increase the recording density but also can increase transmission speed of data efficiently.

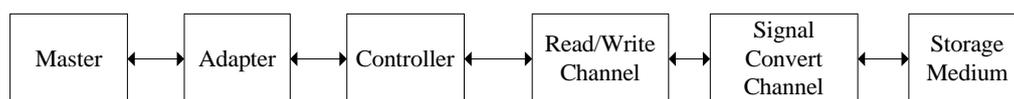| Master	Adapter	Controller	Read/Write Channel	Signal Convert Channel	Storage Medium

Fig. 1. Data Channel

The traditional longitudinal recording medium is challenged by gradually increasing record density. Firstly, the higher density is accompanied with the shorter record wave and the stronger degaussing field of record position, which result in the instability of record of signal. In order to increase the density of record and enhance of the reliability of high-density information, traditionally, we decrease the degaussing field by

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increasing the coercive force Hc of medium, and reducing magnetic layer (reduce the Mrt). Secondly, now the density and transmission speed is high, the precision and stability of sampling clock makes the channel sampling difficult, so it is necessary to improve the current sampling models. The sampling circuit composited by ADC adapter and recovery circuit of servo clock are two parts of servo system clock. In the servo system, it needs the high-precision sampling for servo burst signal and calculate by FFT, in order to calculate the position error signal (PES). But from the literature, now most of companies not only adopt 6bit ADC adapter in the read-write channel servo system just as Marvel 88i6310controller chipset, but also servo system and data signal are sharing the same sampling circuit. Because it will produce the quantization noise while sampling, the 6bit resolution ADC adapter is not enough for servo burst signal, and it will introduce big error by burst signal after FFT calculations. So we have to solve this problem efficiently by studying the new servo system sampling model, and improve the FFT calculation efficiently.

2. Over sampling model of channel servo burst signal

Over sampling is based on the following assumption: general quantization noise power (variance) of one ADC equals to square of least significant digit (LSB) of adapter and then divide by 2, namely general quantization noise power $\sigma^2 = $ (LSB value) / 12. We also assume that the quantization noise value is real and random for over sampling, so this means quantization noise has a smooth frequency spectrum in the range of frequency.For example Marvell88i6310 controller chipset use the ADC converter in data channel to sample and quantize the burst signal, and then the digit burst signal will be added through the adder and stored to the register as the position error signal.

The resolution of position error signal of burst signal is decided by the quantization error of sampling. The average of quantization error is:

$$E_{ave} = \sum ek \Big/ n \tag{1}$$

In the formula, "n" means the point of sampling, "ek" means the quantization error of burst signal. When the sampling clock is asynchronous, the quantization error of each sampling point are distributed between -0. 3LSB and + 0. 3LSB. Relative to quantization error of each sampling, it can reduce the average value of quantization error by asynchronously sampling the burst signal[1,3-5].

The average quantization error changes while the amplitude and sampling time change. It is necessary to change these changes for the valid quantization errors. And the valid resolution is calculated as:

$$y = x - \log_2 EQ \tag{2}$$

"Eq" means the range of change of average quantization error, and "x" is the bit number of ADC converter.

In order to obtain the valid quantization error, the amplitude and sampling error of burst signal can be calculated by simulation. Table 1 contains the simulation conditions, and Figure2 is the average quantization error for burst signal sampling. The valid resolution can be calculated by Formula (2).
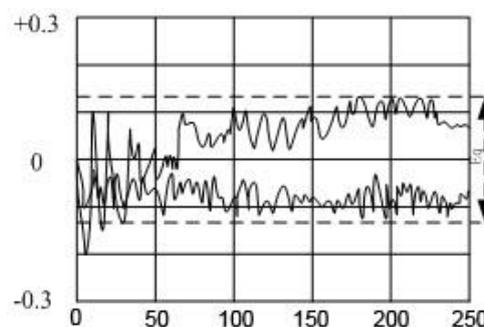

Fig. 2. Range of change of average quantization error

Table 1. Simulation conditions

ADC	6bits ,250[mVopd] full range
burst signal figure	sine wave
burst signal figure	3T pattern(100100…)
Sampling phase	$0\sim 2\pi$
Signal amplitude	25~ 250[mVopd]

3. Problems in over sampling of servo burst signal

To increase the sampling points can distribute the quantization error uniformly and reduce the range of average quantization error. Figure 3 shows the relationship between sampling points and resolution. It can be seen that although the sampling points continue increasing, the valid resolution gets saturated at 7.5 bits.
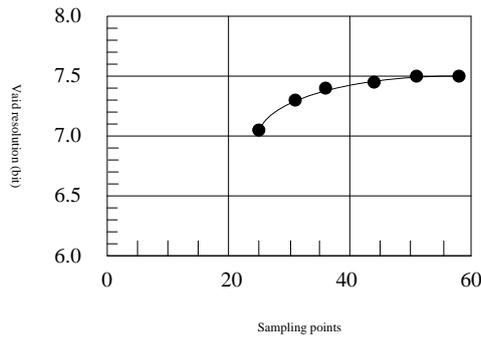

Fig. 3. Sampling frequency and valid resolution simulation

4. Model of over sampling of servo burst signal of improved channel

Figure4 shows the schematic diagram of improved burst signal sampling compared with the traditional solution,the new solution has the following improvements.

1) Append a level of wave form rectifier between analog filter and ADC converter. Before sampling of burst signal, let the burst signal pass through the rectifier to change from [- V, + V] into [0, + V], while the data signal and servo signal don't pass through the rectifier. The switching of signal is realized by recognizing the identifier of servo address. When sampling for the burst signal, the dynamic range of ADC converter reduces to a half, it means the burst signal has been improved by 1 bit compared to other signals.

2) The sampling time of burst signal reduces by half, and this will also reduce the change of sampling phase, and the range of quantization error.
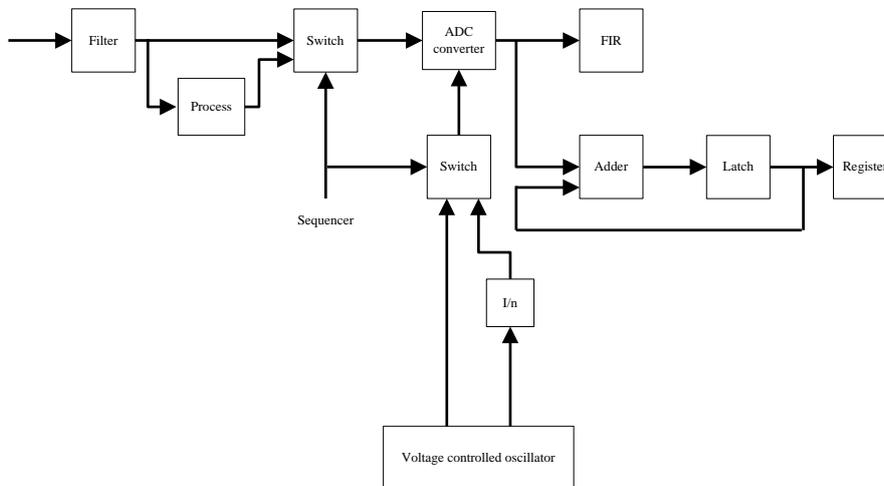

Fig. 4. Frame of improving over sampling

Figure5 shows the sampling curve of new sampling for circuit signal. When ADC converter samples the burst signals, the dynamic range of sampling reduces by half and sampling frequency doubles compared other signal sampling, so the resolution of burst signal are also doubled.
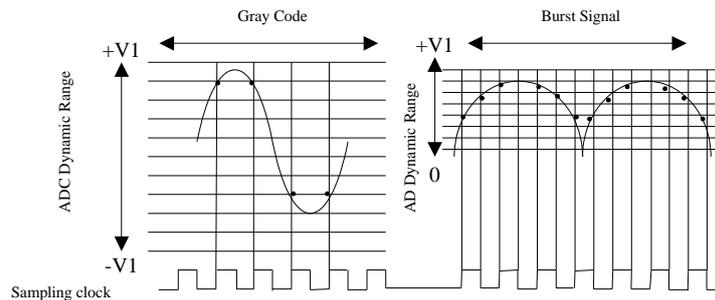

Fig. 5. Comparison of sampling of serve position error signal and other signal

5. Analysis of sampling simulation of burst signal of improved channel

Figure 6 shows the result of quantization error of sampling the burst signal. The amplitude of burst signal is 25mV to 250mV, and sampling phase is $0 \sim 2\pi$. The sampling points of traditional sampling solution is 64, while the new solution is128. The average quantization error of new sampling is 0. 14LSB, but it is 0. 38 LSB for the traditional solution. According to Formula (2) we can calculate that the resolution of ADC converter of new solution reaches 8.8bits.
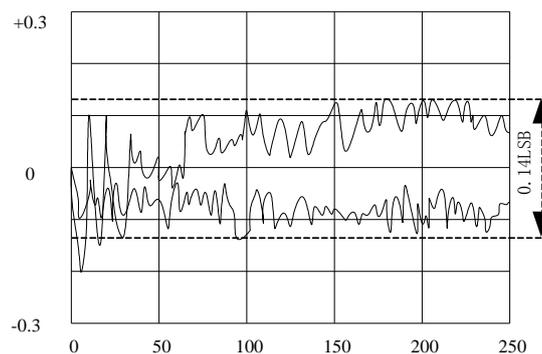

Fig. 6. Range of quantization error of new sampling solution

6. Conclusion

This article is about the quantization noises produced when sampling. For servo burst signal, 6bits ADC converter is not enough to constrain the problem of big error of burst signal after FFT calculation, This paper analyzes the current over sampling model of servo system based on sampling quantization error model, and present the idea of over sampling model of improved servo system. The simulation results show that average quantization error reduces from 0.38 LSB to 0.14 LSB and resolution of ADC converter raises from 7.5bit to 8.8 bit by the improved sampling solution, which prove the efficient and improvement.

7. Acknowledgements

8. References

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