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ANALYSIS OF DC NOISE IN THIN FILM MEDIA

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I. Introduction

Thin film magnetic media utilized in high performance disk drives are comprised of fine grains. The granular structure gives rise to a stationary or DC noise in addition to transition noise. In particular, it is the variation in the mix of magnetic grains and non-magnetic intergranular spacing in regions along the recording track that causes a broadband stationary noise.

Historically, in contrast to magnetic tape, DC noise has been widely considered to be insignificant in comparison to transition noise and consequently the design of media has focused on shrinking the average grain size to minimize the negative influence of transition noise on system performance. For ultra high density applications (i.e. beyond 100 Gbit/sq.in.), the DC noise may increase relative to the transition noise since electron microscopy suggests that as the grain diameters are decreased, the intergrain boundary may not decrease in proportion [1].

To study this phenomenon, we built a numerical model of granular media which permits control of grain size variance σ_A, orientation distributions $F(\theta)$ and packing fraction p . Using this model, we determined by Monte Carlo simulation the DC noise 2-D spatial correlation function $R(x,y)$ for a range of media parameters (σ_A, $F(\theta)$, p). Of particular interest is the area under the correlation function which gives a measure of the noise spectral density near DC, the component remaining after filtering with the head response function. The total power at DC may be written in terms of the area under the normalized correlation function [2]

$$TP_{DC} = W_r M_g^2 A_{corr} p(\overline{\cos^2\theta} - p\overline{\cos\theta}^2) \int_{-\infty}^{\infty} dx' H^2(x').$$

II. Granular Medium Modeling

A Monte Carlo simulation was used to create 2-dimensional realizations of thin-film magnetic media by quantizing a large sample with square grids of pixel area chosen sufficiently small to make the quantization error negligible. A cellular automaton (CA) was used to simulate grain growth. This involves initializing an empty array with random seed locations and growing the seeds by iteratively applying an update rule to every empty pixel. In general it is difficult to achieve circular growth from a CA on a square grid. We obtained satisfactory results by alternating between 2 rules:

1. if any 4-neighbor of a pixel is magnetic and there are no other grains within a radius δ then that pixel becomes part of the grain.

2. if any 8-neighbor of a pixel is magnetic and there are no other grains within a radius δ then that pixel becomes part of the grain.

The rules are shown graphically in Fig. 1. Alternating between these rules will grow an isolated seed into an octagonal grain. A sample section of media with normalized grain area standard deviation $\sigma_A/\bar{A} = 0.4$ and packing fraction $p = 0.7$ is shown in Fig. 2. The advantages of using a CA to simulate the grain growth are that the simulation time increases only linearly with the number of grains simulated and the grain boundary width is easily controlled.

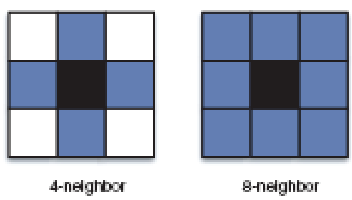


Fig. 1. A pixel has (a) four 4-neighbors and (b) eight 8-neighbors. A cellular automata growth rule corresponds to applying an OR operation to a set of neighbors to determine if a pixel should be magnetic.

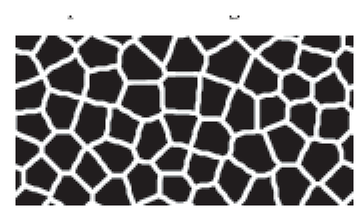
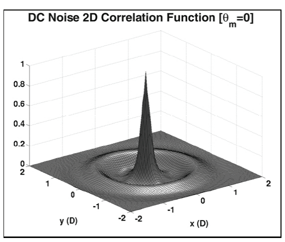


Fig. 2. A perfectly oriented media realization.

To control the packing fraction, the grain boundary was set to a constant width δ. Each seed location was generated from 2 random numbers (x_i, y_i) where x_i is uniformly distributed along the track and y_i is uniformly distributed across the track width. To control the grain area variance, (x_i , y_i) was repeatedly generated until its minimum distance to all previously generated seeds exceeded a given number.

III. Results

The statistics of the DC noise were estimated for $\sigma_A/\bar{A} = 0.4$ and $p = 0.7$. The spatial correlation function is shown in Fig. 3(a) for perfectly oriented media, where the correlation function decreases to near 0 at a radial distance equal to the intergranular spacing. We see a slight increase in the correlation function at a distance equal to the average grain diameter, an artifact that becomes more pronounced as the grain size variance is tightened and the grains becomes more regularly aligned. The main lobe of the correlation function broadens as the media is allowed to become more randomly oriented (Fig. 3(b)) causing a significant increase in the area under the correlation function and hence the total power near DC. The radial cross-sections of the correlation function is plotted for a range of grain orientation distributions in Fig. 4.



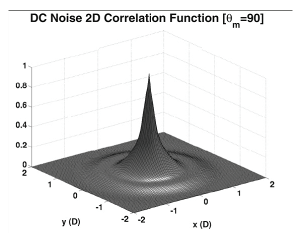


Fig. 3. Spatial correlation function cross section for Θ_M = 0, 52, 65, 90 .

In Fig. 5, the DC noise power relative to the transition noise power (in dB) is plotted for media with grain orientations uniformly distributed on [-Θ_M ,Θ_M] for 5 values of ΘM .

The average grain diameter was fixed at 7 nm and the intergranular spacing varied from 0.5 nm to 2 nm. The squareness ratio (SR) is shown in the figure for the values Θ_M = 0, 52, 65, 90 which are characteristic of very well oriented longitudinal media, current moderately oriented product media, and unoriented media with typical intergranular interactions, respectively. It can be seen from the plot that if the grain orientation is not tightly controlled, then even at modest intergranular spacing the DC noise power can exceed that of the transition noise.

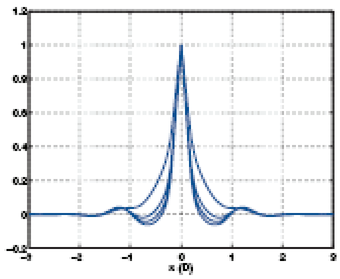


Fig. 4. Spatial correlation function cross section for Θ*M* = 0, 52, 65, 90

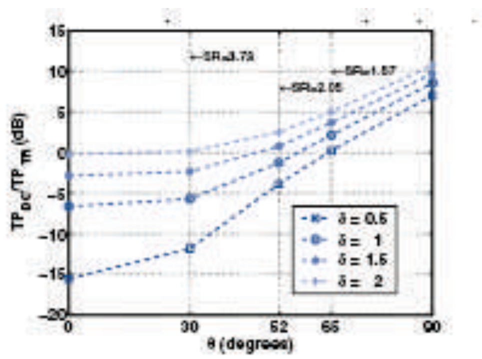


Fig. 5. DC noise power compared to transition noise power.

References

[1] J. Wittig, MMM-INTERMAG Conference proceedings, Anaheim, CA, January 2004.

[2] H. N. Bertram, M. Marrow, J. Ohno, and J.K. Wolf, “Analysis of DC noise on thin film media,” MMM-INTERMAG Conference proceedings, Anaheim, CA, January 2004.