Trackwidth Dependence of Transition Jitter

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Abstract—
A simple model that represents the microstructure of magnetic medium as a rectangular tesselation predicts that the mean square jitter is inversely proportional to the trackwidth. We test this prediction using different width heads as well as creating different trackwidths by partially erasing the original track. We also simulate these experiments using a micromagnetic model. Our experimental and simulation results are found to be in agreement with the prediction.

I. Introduction

Increasing the storage density of magnetic recording media requires both shortening the bit length and narrowing the track width. Density limits are set by noise levels and the inevitable loss of signal associated with the reduction of the storage medium per bit. Transition jitter is a major component of medium noise. We show in this paper experimentally and by modeling that as expected [1], the transition jitter associated with permanent microstructural medium irregularities [2], [3], [4] and with relaxation statistics increases with decreasing track width. This finding emphasizes the importance of exploiting the microstructural permanence in adaptive noise compensation [5].

In this paper we investigate the trackwidth dependence of jitter. The observed transition jitter is an average, over the trackwidth, of local deviations of the magnetization reversal from the intended transition center. The local deviations are determined by the downtrack and crosstrack dimensions of the magnetic units constituting the medium.

The medium may be represented by a brickwall model with bricks representing fixed magnetic microstructural units. As shown in Figure 1, transitions are locally recorded at the nearest edge of the underlying magnetic unit. The mean square transition jitter of this model is [6], [7]:

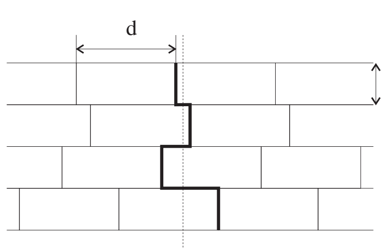

Fig. 1. Brick wall model of medium

$$<\sigma_t^2> \;=\; (\frac{c}{W})(\sigma_s^2) \qquad (1)$$

where (c)/(W) is the number of subtransitions, given a medium with transverse coherence length, c, and trackwidth W. σ_t^2 and σ_s^2 represent the variance of transition and subtransition positions respectively. A detailed derivation of the above is presented in [7].

II. Experiment

Our experiments were performed using a precision spin stand with accurate spatial positioning, a variety of thin film and ferrite heads, and oxide and longitudinal thin film disks. To establish the trackwidth dependence of transition jitter we wrote transitions at 100 preselected locations on the medium. Multiple writes at each location ensured minimization of write uncertainty and 128 read acquisitions provided small read uncertainty. We determined the actual position of the transition by fitting each transition output to a standard transition waveform. The position of maximum cross-correlation of these waveforms is defined as the transition position. The standard transition waveform was obtained by averaging several read averaged transitions written at different locations. Such ensemble averaging minimized both read/write inaccuracy as well as position dependence of the standard transition waveform.

The displacement of the actual position of the transition from its intended position is defined as jitter. For each of the 100 preselected locations mean jitter is computed (from multiple writes at that location). Histograms of these mean jitter values are plotted in Figure 2. The above approach measures jitter relative to the reference trigger which may vary from write to write due to limitations in the instru-

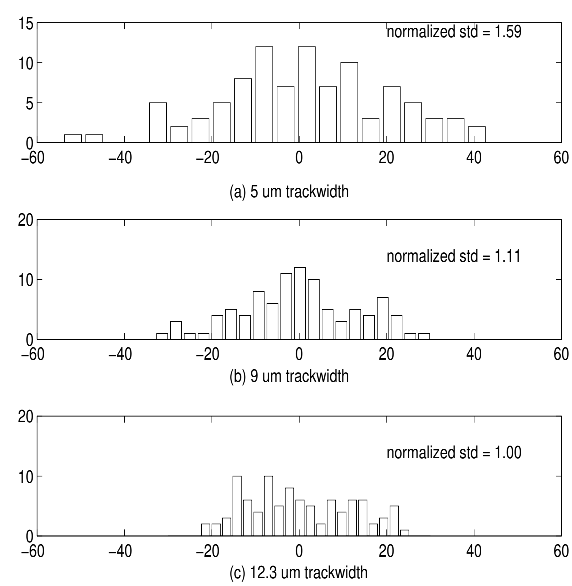

Fig. 2. Histogram plots for trackwidths of 5, 9 and 12.3μm

mentation. To eliminate the effect of a variable reference trigger we employed a center-to-center measurement technique, measuring the distance between two transitions. We wrote 2 consecutive dibits (Figure 3) at randomly selected locations on the medium and determined their position jitter by correlating the first transition(A) and the third transition(B) with a standard transition waveform. The difference between the actual positions of transition(A) and transition(B) gives a measure of the actual distance between them. Jitter is computed as the difference between the actual distance and the intended distance. Presented in Figure 4 are histograms of jitter values.

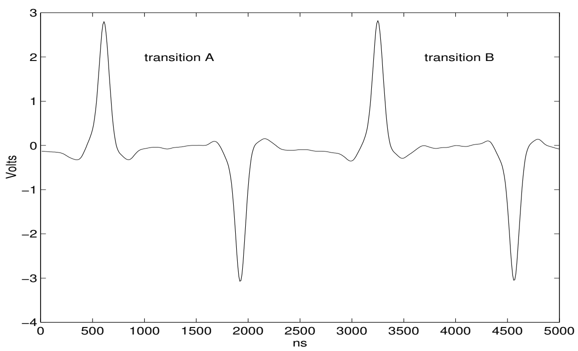

Fig. 3. Consecutive dibits for center to center measurements

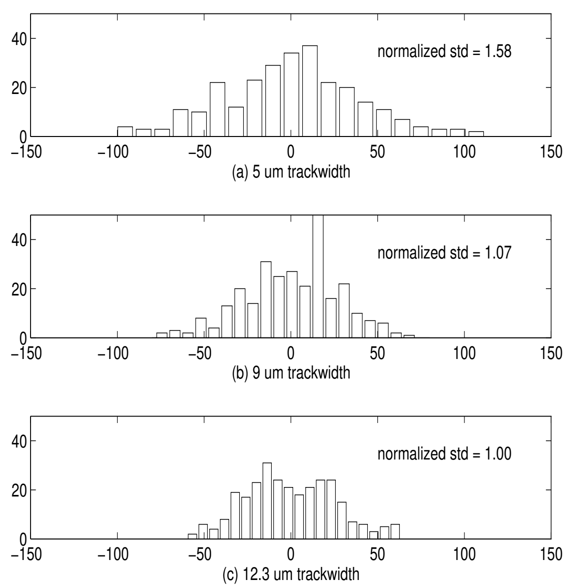

Fig. 4. Histogram plots for trackwidths of 5, 9 and 12.3μm using center to center measurements

We repeated this experiment with heads of the same trackwidth and number of turns but with different structural parameters (e.g. pole thickness). We found that the standard deviation of jitter was unaffected by these parameters; no systematic error, such as amplitude effects, were seen. We also used a single head (thereby keeping flying height, gap width and pole thickness identical from one run to another) to create tracks of different widths by partially erasing a track to various widths (Figure 5). Position jitter was determined as before by correlating transition A and transition B with a standard transition waveform. Figure 6 are histogram plots for different trackwidths. In order to achieve the accurate placement of the transitions it was imperative to maintain control over tracking and downtrack timing. Accurate timing was maintained by phase locking an oscillator to a signal on the disk. We measured thermal variations every 10 minutes, over the span of the experiment. Using the permanent physical microstructure of the underlying medium we infer thermal drifts to be less than 5% of the read trackwidth.

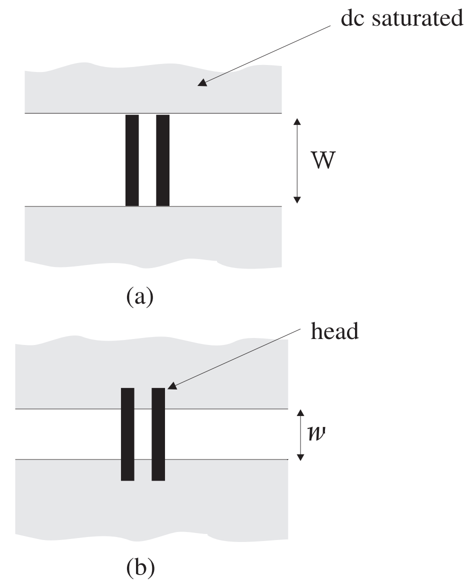

Fig. 5. (a) Original Trackwidth W (b) Partially erased trackwidth $w (w < W)$

III. Results and Discussion

To augment our recording tests we simulated these experiments using a Voronoi tesselation medium (Figure 7). From the histogram plots for each trackwidth we obtain a mean square value for transition jitter. Equation (1) predicts that ratios of mean square values plotted against the ratios of corresponding trackwidths on a log scale follow a slope of -1/2. A modification of equation (1) predicts more rapid increase of jitter with decreasing trackwidth for partially erased tracks. To account for side writing, edge effects, and erased medium noise we assume the effective trackwidth to be linearly proportional to the signal amplitude and plot in Figure 8 mean square ratios vs. corresponding effective trackwidth ratios (base trackwidth = 12.3μm) for experimental data. It is found that experimental and simulated results [8] closely follow theoretical predictions, supporting the proposed model of transition jitter.

Transition jitter measurements by Huang:1994:GTT *et al.* [9] are also consistent with expectation and show increasing jitter with decreasing trackwidth.

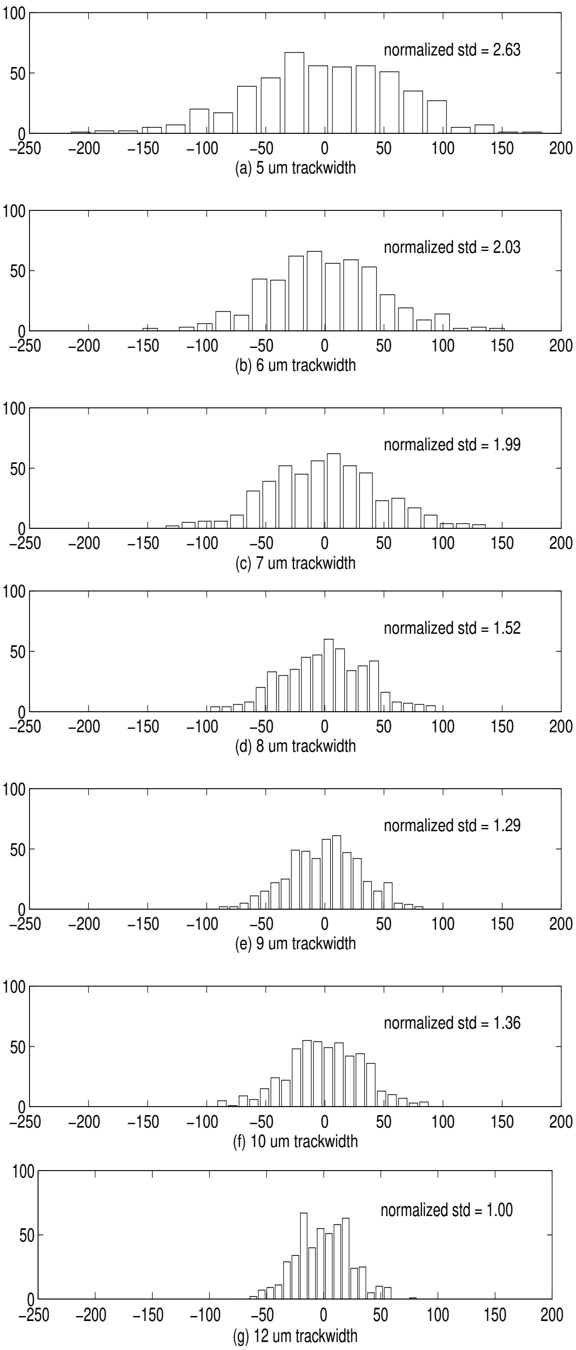

Fig. 6. Histogram plots for partially erased tracks with width w = 5,6,7,8,9 and 10μm. Original track = 12.3μm

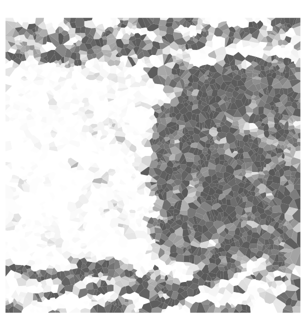

Fig. 7. An isolated transition in a partially erased track using a Voronoi tesselation medium

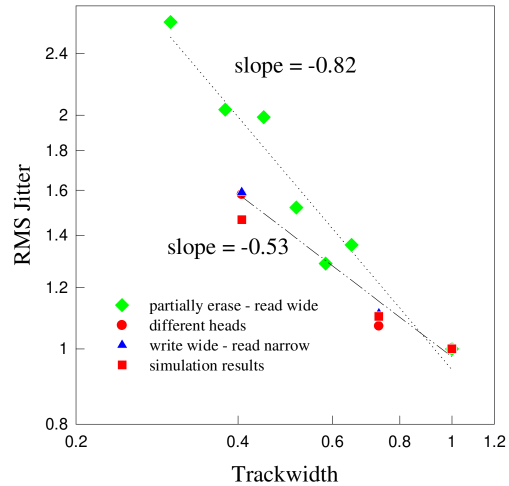

Fig. 8. RMS jitter as a function of trackwidth

IV. Conclusions

We have shown that transition jitter increases with decreasing trackwidths and validated our theoretical predictions with experimental results. These results provide valuable input to real time pre-compensation schemes which aim at improving SNR and recording densities by using the repeatability of medium induced effects.

V. Acknowledgment

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