Transition Shifts Due to Applied Head Fields

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Abstract — We investigate the effect of applied dc head fields on existing written transitions and demonstrate transition displacement due to those fields. In addition to experimental results, we model our experiments and conclude that the transition shifts may be explained by the asymmetrical change in the magnetization caused by the applied field.

I. INTRODUCTION

The application of stray head fields over or close to existing written tracks can deteriorate the data pattern by reducing transition amplitude. We examine the effects of applied head fields by investigating position shifts caused by these fields. The goal is to produce a description of the nature of the shifts and to provide possible explanations for observed phenomena. We experimentally apply increasing dc fields to written transitions and simulate the experiments using micromagnetic modeling to provide further insight into our observations.

II. EXPERIMENT

Experiments were performed on our spin stand using a ferrite head (10 μm track width) and two thin film (5 and 9 μm track width) inductive heads on commercial longitudinal thin-film disks of three different coercivities (950, 1350, and 1950 Oe). Our recording system uses a phase-locked loop which provides accurate triggering for writing and reading. Read averaging is used for all waveform acquisitions to eliminate electronics noise.

In our experiments we write dibits with enough separation between the positive and negative transitions so that they can be considered isolated. The dibit is then subjected to monotonically increasing dc head fields. After the application of each dc field, the dibit waveforms are read and digitized. Fig. 1 shows the original dibit (dotted) recorded with the 9 μm thin-film head on the 1350 Oe disk. The other waveforms portray the same dibit as it is perturbed by the dc fields applied with increasing head currents. Figs. 2a and 2b schematically show the magnetization pattern corresponding to the original dibit.

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Fig. 1. Original dibit (dotted) overwritten with negative dc fields. Define directions pointing to the right as positive and to the left as negative for both magnetization and applied dc field. Fig. 2a shows the case of a positive applied dc field; Fig. 2b corresponds to a negative applied field.

Fig. 1 demonstrates a reduction in amplitude, which is to be expected since we are effectively performing overwrite (albeit with relatively weak fields). We also note a shift in the position of the two transitions which increases monotonically with the erase field. We look for the reason why directly overwriting a transition causes a peakshift.

III. MICROMAGNETIC SIMULATION

We simulate the overwrite experiment using a micromagnetic model[1]. Related simulations have been per-
formed but by recording transitions with increasing head fields. The two effects of amplitude reduction and transition shift were observed in that case, and attributed to the change in the magnetization slope at the transition and the shrinking of the recording bubble, respectively, during the write process[2]. Our thin film medium is modeled by Voronoi tessellation. Write and reproduce modeling uses a Karlvist head model. This modeling allows for direct observation of the magnetization in addition to readback waveforms.

IV. RESULTS AND DISCUSSION

Figs. 3a and 3b show the shift of positive and negative transitions corresponding to the recording schemes in Figs. 2a and 2b. These results were obtained with the 10 μm ferrite head on the 1350 Oe disk. This combination demonstrates the transition shift effect very clearly, possibly because of the ferrite head's domain stability as compared to the domains of the thin-film heads. Results from using both the thin-film heads were qualitatively similar to those of the ferrite head.

Fig. 3. Dibit shift under positive and negative applied fields.

Concentrating on Figs. 2a and 3a, we see that the negative and positive transitions shift in a way that enlarges the magnetization region that is of the same direction as the applied field (positive). The same phenomenon was observed for partial erasure of magnetization patterns with static dc fields[3]. In Figs. 2b and 3b, where negative fields are applied, the negative magnetization region expands as shown by the positive transition shifting to the left (negative shift) and the negative transition shifting to the right (positive shift). For all head/disk combinations we obtained the same qualitative shifts. We note that the magnetization adjacent to the track, whether it was positively or negatively saturated, or in a demagnetized state, was not a factor in these results. We compared the shifts for the three different disks we used. Fig. 4 displays the saturation plots for the disks, using the ferrite head. We obtain plots similar to Fig. 3 by recording a dibit at the saturation current and applying increasing overwrite currents close to the first knee of the saturation plot. On average, the shift observed on the lowest coercivity disk was about 20% less than that observed in the two higher coercivity disks. The amount of the shift for the latter two was roughly the same. It remains to be examined whether coercivity is a primary reason for the shift increase between the 950 Oe disk and the other two disks.

The micromagnetic simulation yields results qualitatively similar to the experiments. The two situations depicted in Figs. 2a and 2b were simulated. The corresponding transition shifts in the simulation were in the same direction as the shifts found experimentally. Fig. 5 shows how a dibit recorded with a 2 μm Karlvist head is affected by the application of a series of negative dc erase fields. The transitions shift the same way as they do in the experiment, although the effect is not as pronounced.

Fig. 4. Saturation plots using the 10 μm ferrite head.

The simulation provides the advantage of being able to examine the state of the medium's magnetization directly instead of inferring it from the readback waveforms as we must with experimental data. Fig. 6 shows the magnetization profiles for the dibit of Fig. 5. The profiles provide a straightforward interpretation of the observations: as

Fig. 5. Simulation of dibit overwritten with negative dc field.

Fig. 6. Magnetization profiles of waveforms in Fig. 5.
the applied current increases, the magnetization profile is reduced in slope. It is also reduced in amplitude, but only on the transition side whose existing magnetization opposes the applied field. Given the slope reduction, it is clear that an asymmetrical magnetization change on only one side of the transition will naturally result in the displacement of the transition center. Fig. 7 illustrates this idea.

We propose a plausibility argument to support the magnetization-change scheme in Fig. 7: Applying and removing a field causes the medium to traverse a curve from its local starting point on the remanence curve. If the field is large enough, the final state differs from the starting point. This hysteretic behavior depends on the initial point and on the sense and strength of the applied field. This effect is most pronounced where the slope of the remanence curve is large, and smaller near that end of the curve where the applied field drives the medium toward saturation. Applying this consideration to the magnetization distribution of the left-hand transition on the bottom of Fig. 2 (schematically pictured in Fig. 7), we expect the applied field to change the magnetization distribution as shown in the figure: remaining largely intact at the left-hand end and reduced as we move away from saturation in the field direction.

The argument is more complicated when the transition’s demagnetizing field is taken into account, but the inference is not changed. When the applied field is parallel to the magnetization, the demagnetizing field reduces the applied field’s effect. Conversely, when the magnetization is antiparallel to the applied field, its demagnetizing field enhances the applied field. Keeping this in mind when considering the magnetization distribution of Fig. 7, we see that the applied field opposes the demagnetizing field to the left of the transition and adds to the demagnetizing field in the right half, accentuating the hysteretic effect described above. The simulations that we have carried out are consistent with this picture, but detailed confirmation, and an explanation of the asymmetry of the shift reported in Figs. 3a and 3b awaits further work.

Figs. 8a and 8b show the magnetization pattern of the thin film medium around the dhib of Fig. 5, before application of any dc fields and after applying the dc field produced by the 0.75mA current in Fig. 5. The positive applied dc field causes the positive magnetization regions to expand, as was also implied by the experimental data.

Besides the insight that it might provide on the mechanism of magnetization redistribution at the presence of applied head fields, the transition shift effect might also prove to be influential in actual recording systems: as data is being overwritten, data patterns cross-track or down-track from the recording location might be affected by those fields.

![Magnetization pattern corresponding to solid and dash-dotted waveforms in Fig. 5.](image)

**V. CONCLUSIONS**

dc fields applied to magnetically recorded transitions cause amplitude loss and shifts. The direction of the shift depends on the direction of the applied field and the transition. Simulation leads us to believe this is an effect of the slope change in the magnetization coupled with the expansion of the magnetization whose direction is aligned with the applied head field. Future work will examine the role of the demagnetizing fields at the transition and their effect on the shift.

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**REFERENCES**

