2D VISUALIZATION IN MAGNETIC RECORDING

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I. INTRODUCTION

The quality of magnetic recording can be fully assessed from 2D distributions of the recorded read-back signal and noise (media and sensor). These signal and noise maps can be generated using digital signal processing and correlation analysis. Fast 2D mapping modules were developed that allow visualization of pole footprints, arbitrary data patterns, single-bit writing, and encroachment of the writer field onto adjacent tracks. These tests were integrated into a production test environment. Recently, we introduced the new SPAM (Switching Probability Averaging Measurement) method, which can detect the switching of media grains with unprecedented sensitivity (better than 1 out of 1000 grains). This 2D technique provides an experimental method for quantitative assessment of magnetic fields coming from the writer of read-write heads.

II. METHODOLOGY

The digital Guzik tester used for the measurements allows acquisition of high-resolution waveforms (up to 20 GS/s) synchronized with sector gates and synchronous write operation. However, read and write gates exhibit significant timing jitter (typically 10 ns RMS). In order to align traces captured in different cross-track locations, we used band-erased AC media noise waveforms as a reference in each data sector. This allows cross-correlation to a reference media location as long as the adjacent cross-track acquisitions are within the reader sensitivity window (typically < 15 nm). In order to avoid error accumulation during cross-track alignment, we used a least-squares offset reconstruction based on multiple adjacent signals. Alignment and averaging waveforms using multiple disk revolutions allowed accurate time-domain separation of media and sensor noise waveforms.

In order to analyze signal and noise statistics, we used correlation detection of data pattern periods in multiple data sectors. Synchronous averaging allowed high-resolution 2D imaging of the read-back signal. After the 2D average signal is calculated, the residual noise power is accumulated over multiple data periods, resulting in a 2D RMS noise distribution. In order to minimize effects of media velocity variations, the analysis window was limited to several microseconds immediately following the alignment area. Using optimized parallel data processing, we calculated the 2D average signal and RMS noise distributions of 100 cross-track locations and 10K data periods in 10 seconds, which makes these tests feasible for a production environment.

Using synchronous writing, the detailed 2D maps of adjacent- and cross-track interference (ATI/XTI) can be obtained. We developed a media noise cross-correlation technique (SPAM), which compares location-dependent waveforms before and after write operations. The cross-correlation method detects individual grain/cluster reversals of the recording medium, gaining about 3 orders of sensitivity over integral noise detection. The SPAM mapping test outputs high resolution images of logarithmic grain switching probability, allowing sensitive quantitative evaluation of ATI/XTI as well as the locations of write head structure causing erasure. High sensitivity to single grain switching allows extension of the SPAM method for media evaluation, such as thermal decay, media cluster size, HAMR erasure effects etc.

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III. RESULTS

Examples of read-back signal and RMS noise maps are shown in Fig.1. One full period of a pattern having transition bursts of 6T to 1T density shows distributions of cross-track amplitude, asymmetry and transition curvature. These parameters are automatically extracted from the images and reported as part of the production sequence. The RMS noise map shows the recording density dependence on media saturation (DC noise), jitter (transition noise) and track edge noise flip/flop structure caused by read sensor biasing. Small polarity dependent 45 degrees tilted structures on AC noise background indicate XTI erasure (domain wall activity).

Figure 2 illustrates a typical SPAM logarithmic switching probability map. Erasure “hot spots” are generated by magnetic transitions (center track). Cross-track switching probability graph (center) and ABS view of write head image (left) demonstrate that hot spots correspond to side shield boundaries (strong erasure with about one out of 10 grains reversed) and lower probability overhang erasure (about 1 out of 100 grains reversal) features. Overhang domains are mainly excited by lower frequency transitions.

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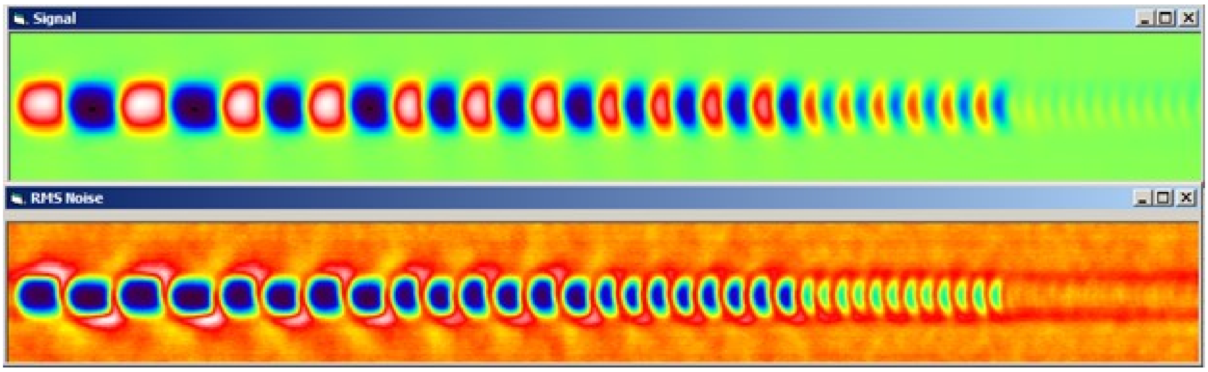

Fig. 1 Pseudo-color maps of 250*1500 nm area. Read-back signal (top) and RMS noise (bottom) of pattern consisting of 1T to 6T transition bursts recorded on AC band-erased media. Measurement time: 10 s.

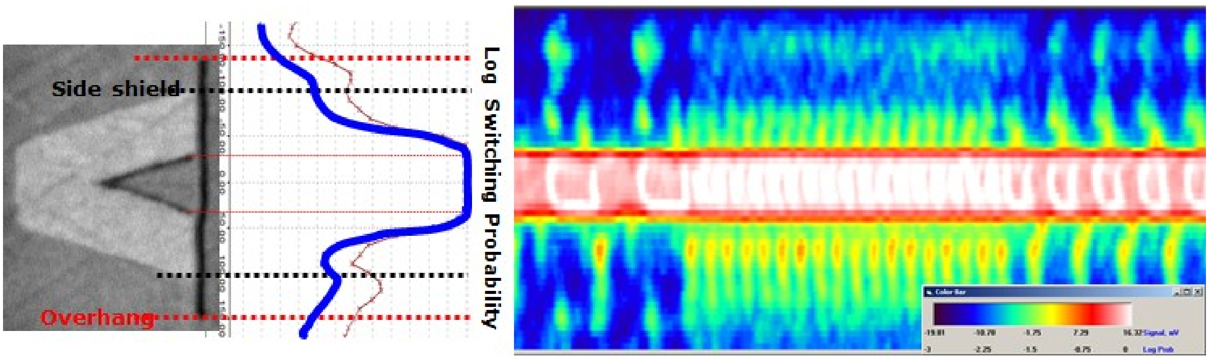

Fig. 2. 2D SPAM logarithmic switching probability map of 300*1000 nm area (right), cross-track integral graph (center) and ABS view of write head (left). Measurement time: 1 min.