OPTIMIZATION OF BIT GEOMETRY
AND MULTI-READER GEOMETRY FOR TDMR

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I. OVERVIEW

The move from traditional single-track magnetic recording to TDMR [1][2] with squeezed tracks and multiple readers opens up new design degrees of freedom beyond the track pitch and bit aspect ratio, including the widths, spacing, and crosstrack positions of the readers. In this paper we present a systematic method for determining the combination of multiple-reader geometry, track pitch, and bit-aspect ratio that maximizes the areal density of a TDMR system. The method combines realistic modeling of the medium and write/read processes, advanced signal detection, and information-theoretic tools. The optimal reader geometry was found to use two comparably sized readers (widths of 14.6 nm and 17.7 nm) with significant overlap in the crosstrack direction (centers spaced by 2 nm). The optimal track pitch was 16.1 nm and the optimal bit length was 8.3 nm. At the optimal operating point, the information rate per coded bit is 0.8.

II. QUASI-MICROMAGNETIC CHANNEL MODEL AND MULTI-READER DETECTION

Waveforms are derived from a simulation that uses realistic head fields and a Voronoi medium with Stoner-Wohlfarth switching [2]-[5]. The mean grain-pitch is 6 nm and there are distributions in the anisotropy magnitude and angle. Magnetostatic and exchange interactions are included. The read sensitivity function is obtained by 3D-finite element modeling of a double-shielded magnetoresistive (MR) reader at several widths.

We limit consideration to single-track detectors which separately equalize the readback waveforms before adding; the equalizers and one-dimensional target are jointly optimized using standard techniques, so that subsequent processing can use conventional one-dimensional Viterbi and BCJR detectors. Mutual information rate (MIR) is an information-theoretic bound and useful benchmark for achievable storage densities. In [5], using the BCJR forward recursion, MIR is computed for a one-dimensional white Gaussian noise channel with memory, and is accurately estimated by Monte Carlo methods. To account for the correlation and data-dependent noise in a TDMR system, we use pattern-dependent noise predictive filters in the BCJR algorithm to whiten the noise, and we estimate MIR by assuming the residual noise is Gaussian.

III. RESULTS

We consider a set of five consecutive tracks written in a shingled fashion with independent PRBS sequences of length 40950, with the center track being the track of interest. A total of 900 readback waveforms were generated, as described in Sect. II, with a bit length of 7.3 nm, one for each of six track pitches (from 16.1 nm to 26.1 nm in 2 nm increments), six reader widths (from 70% to 145% of a nominal reader width of 20.8 nm), and 25 reader positions (spanning the center three tracks at one-eighth of a track increments). An additional 100 readback waveforms were generated at a track pitch of 16.1 nm and 70% reader width, one for each of four additional bit lengths (5.3, 6.3, 8.3, and 9.3 nm) and the same 25 reader positions. All readback waveforms were oversampled (perfect synchronization) at two samples per bit. The same amount of electronic ratio thus loses 6 dB per halving of read-width. The power of the added noise was chosen to be 24.6 dB below the peak (constant response) signal level for a centered 100% reader at 22.1 nm track pitch.

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We first assume a bit length of 7.3 nm and optimize all other parameters. We then fix these remaining parameters and optimize bit length. In particular, for 7.3 nm bit length and every pitch and reader geometry, the corresponding pair of readback waveforms was processed according to Sect. II, and both the MIR and BER computed. An exhaustive search over all possible candidate geometries was then performed. A similar exhaustive search was also performed for a single-reader system. Results are shown in Fig. 1, where we plot BER after Viterbi detection versus track pitch. Every parameter of the system (bit geometry, reader geometry, equalizer, and target) is optimized separately for each point in the curves so as to minimize the resulting BER. The two-reader system is seen to offer an 11% increase in areal density over the single-reader system.

In Fig. 2 we plot versus track pitch the optimized areal density as predicted by $(1 - h_2(\text{BER}))/G$, where $h_2(p) = (p)\log_2(p) + (1 - p)\log_2(1 - p)$ and $G$ is the number of grains per written bit. A maximum areal density of 3.6 Tb/in$^2$ (or 0.165 bits/grain) is achieved at a track pitch of 16.1 nm, with reader widths 14.6 nm and 17.7 nm and center spacing 2 nm. The corresponding code rate is 0.67. Compared to an optimized single-reader system, the second reader provides a 10% increase in areal density. Optimizing bit length while keeping the reader geometry and track pitch (16.1 nm) fixed yields a further increase in areal density of 5%, achieved by increasing the bit length from 7.3 nm to 8.3 nm, with a corresponding increase in code rate from 0.67 to 0.8.

REFERENCES