ASYNCHRONOUS JOINT TRACK EQUALIZER FOR ARRAY READER BASED INTERLACED MAGNETIC RECORDING

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I. INTRODUCTION

Interlaced magnetic recording (IMR) shows potential to achieve high areal density capability (ADC) by pre-fixing the recording orders as interlaced and differentiating the write configurations such as linear densities [1]. The interlaced approach can be combined with other advanced recording technologies for extra ADC gain and heat assisted interlaced magnetic recording (HIMR) has shown a tangible ADC gain based on spin-stand tests with extra controls of the laser spot [2]. On the read channel perspective of IMR, inter-track interference (ITI) may limit its ADC performance by the track density push, particularly for the bottom double-sided squeezed tracks. The ITI cancellation (ITIC) scheme can be customized for IMR by enforcing effective synchronizations of neighboring tracks, which provides extra ADC gains by subtracting the ITI signal based on the estimated side track data [3]. Due to the extra read overheads to retrieve side track data, the ITIC can be applicable as a retry feature, which is applied only for the sectors of which 1st reads fail to converge. In order to fully leverage the gain of interlaced recording, on-the-fly ITI mitigation is needed and array reader based IMR (ARIMR) is introduced in this study, where the joint multi-track equalizer implicitly suppresses the ITI in the equalized output.

II. ASYNCHRONOUS JOINT TRACK EQUALIZER FOR ARIMR

For on-the-fly ITI mitigation in ARIMR, and asynchronous joint track equalization scheme is proposed for implicit ITI mitigation among the linear density differentiated tracks. The read channel of ARIMR with 2 read sensors is illustrated in Fig. 1, where joint 2 track equalizer (J2TE) effectively synchronizes the oversampled waveforms to make up the linear density difference from the neighboring track. The equalizers J2TE-B and -T for the bottom and top tracks respectively can be trained in least square sense,

$$\{\mathbf{g}_{b,b}, \mathbf{g}_{b,t}\} = \arg\min (\underline{\mathbf{y}}_b - \mathbf{g}_{b,b} * \mathbf{x}_{b,1\mathrm{x}} - \mathbf{g}_{b,t} * \mathbf{x}_{t,(1/\gamma)\mathrm{x}})^2 \qquad (1)$$

$$\{\mathbf{g}_{t,b}, \mathbf{g}_{t,t}\} = \arg\min (\underline{\mathbf{y}}_t - \mathbf{g}_{t,b} * \mathbf{x}_{b,\gamma\mathrm{x}} - \mathbf{g}_{t,t} * \mathbf{x}_{t,1\mathrm{x}})^2 \qquad (2)$$

where $\underline{\mathbf{y}}_b$ and $\underline{\mathbf{y}}_t$ are ideally equalized outputs for each track respectively. Note that the analog frontend (AFE) and loops are first processed based on the bottom track readback $\mathbf{r}_b$ for J2TE-B, and down-sampled by a factor of γ by interpolation (ITP) for J2TE-T. Note that only the ITI from the other reader side can be implicitly mitigated for 2 reader ARIMR and 3 or more readers are needed for on-the-fly ITI mitigation from both sides. In addition, for jointly reading two-tracks with an array reader of 2 read sensors, cross-track separation (CTS) between two sensors should be near its track-pitch (TP) for the target bit-error-rate (BER) performance in both tracks. However, CTS ξ varies with the skew angle θ due to the down-track separation (DTS) ζ as below [4], $\xi(\theta) = \xi(0)\cos(\theta) - \zeta(0)\sin(\theta)$, where $\xi(0)$ and $\zeta(0)$ are zero-skew DTS and CTS respectively, given for the array reader. Therefore, the J2TE for the ARIMR need to take into account performance margin against the inevitable CTS variation, for example $0.69 \le \xi(\theta) \le 1.24$ TP for -16 to 16-degree skew with $\xi(0) = \zeta(0) = 1$ TP.

For numerical evaluation of the ARIMR, the micro-pixelated magnetic (MPM) channel model [1] is employed and BER performance of J2TE is investigated for the array reader of two sensors with CTS of 1.0 and 0.8 TP. The track and linear densities are scanned to find the operable pair of the densities jointly satisfying the squeeze-to-death and off-track capability margins for bottom and top tracks, respectively [5]. The rate of top over bottom linear densities is set to $\gamma = 0.8$ and corresponding write track widths are configured with double elliptical writer foot-prints, which are set to (long, short) diameter pairs of (72, 16) and (48, 24) nm for bottom and top respectively. In order to illustrate the implicit ITI effect with J2TE, the normalized cross-correlations along the down-track direction are plotted for J2TE $\mathbf{y}_b$ and conventional single track equalized (S1TE) $\mathbf{y}'_b$ with ideal bottom $\underline{\mathbf{y}}_b$, next $\underline{\mathbf{y}}_t$, and previous $\underline{\mathbf{y}}_{t-1}$ signals, respectively. Track density is set to 605 kilo track per inch (kTPI) and linear density is set to 2,500 and 2,000 kilo bit per inch (kBPI), where T_b and T_t are corresponding

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unit bit-lengths. Note that the J2TE residual ITI from next track cross-correlation $\rho(\underline{\mathbf{y}}_b, \underline{\mathbf{y}}_t)$ by red circular dash-dot line is negligible by the implicit ITI mitigation, whereas J2TE ITI from previous track and S1TE from both tracks are still exist. For various track densities, BER performances are evaluated for ARIMR, and bathtub shape profiles are plotted in Fig. 3 and 4 for CTS of 1.0 and 0.8 TP with 529 and 498 kTPI, respectively. For the target BER of -1.5 order, the operable track density satisfying over 10 nm margins for both tracks can be found as 498 for S1TE and 529 for J2TE with CTS of 1.0 TP in Fig. 3. On the other hand, the margins for S1TE are reduced or disappears for CTS of 0.8 TP in Fig. 4, whereas those of J2TE are increased 18.9 and 14.7 nm, respectively for 498 and 529 kTPIs. As illustrated, the proposed J2TE tangibly improves BER of individual tracks, while common off-track capability for 2 tracks is significantly impacted by the CTS. For large CTS variations, multi-read joint equalization for the single track should be employed for ARIMR, which will effectively work as an on-the-fly ITI canceller.

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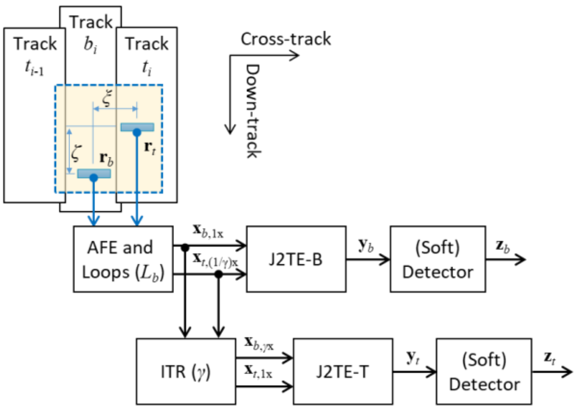

Fig. 1 Illustration of ARIMR for two read sensors.

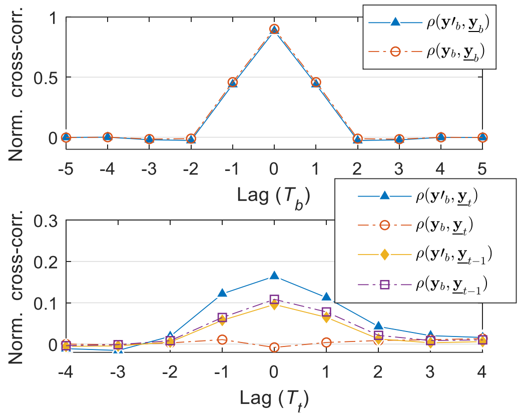

Fig. 2. Correlation of equalized and ideal signals.

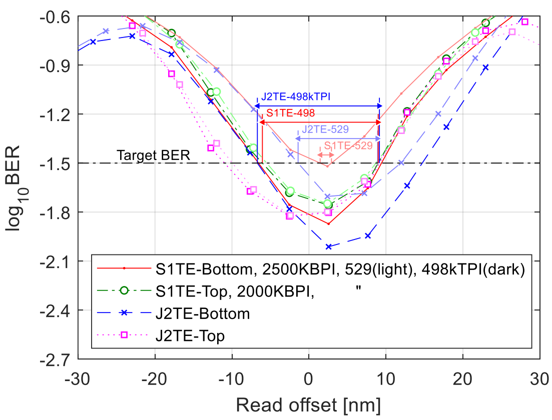

Fig. 3 BER bathtubs of ARIMR for ξ = 1.0 TP.

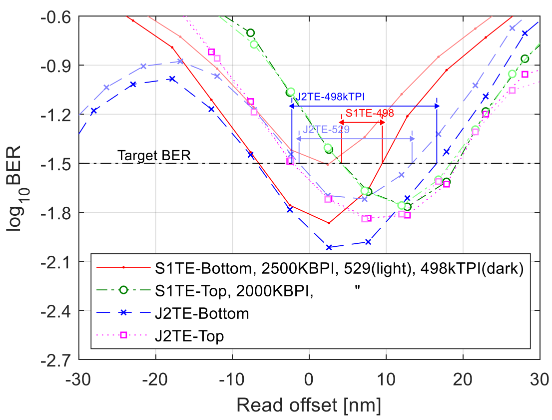

Fig. 4. BER bathtubs of ARIMR for ξ = 0.8 TP.