USER AREAL DENSITY OPTIMIZATION FOR CONVENTIONAL AND 2D DETECTORS/DECODERS

[1]Kheong Sann CHAN, [2]Ashish JAMES, [2]Sari SHAFIDAH, [1,4]Susanto RAHARDJA
[3]Jinlu SHEN, [3]Krishnamoorthy SIVAKUMAR, [3]Benjamin J. BELZER

[1]Nanjing Institute of Technology, Nanjing, China, kheongsann@ieee.org.

[2]Data Storage Institute, (ASTAR), Singapore, jamesa@dsi.a-star.edu.sg.

[3]Washington State University, Pullman, WA, USA, (jshen,siva,belzer)@eecs.wsu.edu

[4]Northwestern Polytechnic University, Xi'an, China, susantorahardja@ieee.org.

I. INTRODUCTION

Advances in the magnetic recording channel have the potential to detect and decode the stored data at lower SNRs, higher channel areal densities (CAD), lower code rates (R) and lower bit aspect ratios (BAR) than conventionally used in today's systems. The magnetic recording channel today optimizes at parameters in the vicinity of $R = 0.85$, $\mathrm{BAR} = 3$, $\mathrm{BL} = 12.5\mathrm{nm}$, $\mathrm{TP} = 38\mathrm{nm}$, but it has been suggested in [1] that as the industry moves to shingled recording and starts using heads with multiple readers, the density could optimize at lower BAR's and code rates, and at a higher CADs. In the current work, we use the grain-flipping probability (GFP) model developed in [2], [3] together with conventional and advanced recording channels to determine the optimized user areal density (UAD) that can be delivered to the customer using conventional and advanced 2D detectors and decoders.

II. GFP DATA GENERATION MODEL

In this work, the GFP model is used to generate mass waveforms at various CADs, UADs, code rates (R) and BARs. In this study, we attempt to maximize the UAD over R and BAR. The metric that is observed is the frame error rate (FER) of the coded channel as a function of the UAD. The GFP model is trained from micromagnetic simulations. In this work, we started with a micromagnetic parameter set similar to that in [1] in which the target density is 4Tbpsi, but it was agreed that we would scale them down by $\sqrt{2}$ to a target density of 2Tbpsi, which is more appropriate given the state of today's head and media technology. The head and media parameters used in the micromagnetic simulations are shown below in Fig. 1.

Parameter		Value	Parameter	Value
Grain density	(Tgpsi)	11.4	σ_{gs}	20%
Grain boundary	(nm)	1.4		
K_u	(J/m^3)	450e3	σ_{Ku}	5%
M_s	(A/m)	750e3	σ_{Ms}	0%
H_k	(kOe)	12	σ_{Hk}	5%
exchange	(erg/cm^2)	2.5		
A_x	(J/m)	5.6e-12	σ_{Ax}	3%
e_z		0°	σ_{ez}	3°
media thickness	(nm)	14.1	HMS (nm)	5.6

Parameter	Symbol	Value	Parameter	Symbol	Value
Main Pole trailing width	MPTW	70nm	Side shield gap	SSG	14nm
Main Pole height	MPH	130nm	Trailing shield gap	TSG	14nm
Main Pole angle	MPA	75°	Head Media spacing	HMS	5.6nm
Interlayer thickness	ILt	1.4nm	Media thickness	Mt	14nm

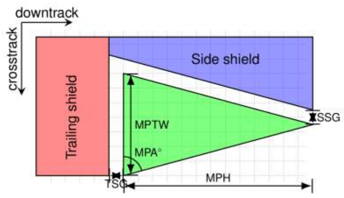

Fig. 1. Media parameters for the micromagnetic simulations are shown on the left, while the head parameters are on the right.

The micromagnetic simulations are used to characterize a GFP look-up table (LUT) which is then used to generate signals for simulations using conventional 1D LDPC coded channels and the FER is measured. The UADs, code rates and BAR's are the independent variables in our simulations. The UAD was varied from 1.35 to 2.2 Tbpsi in steps of 0.05, the code rate R was varied from 0.5 to 0.95 in steps of 0.05 while the BAR was varied from 1.0 to 3.1 in steps of 0.3. Results with the conventional 1D channel at representative BAR's are shown in Fig. 2 below.

Corresponding Author
E-mail:kheongsann@ieee.org
tel: +65-67149088

Work funded in part by ASTC.

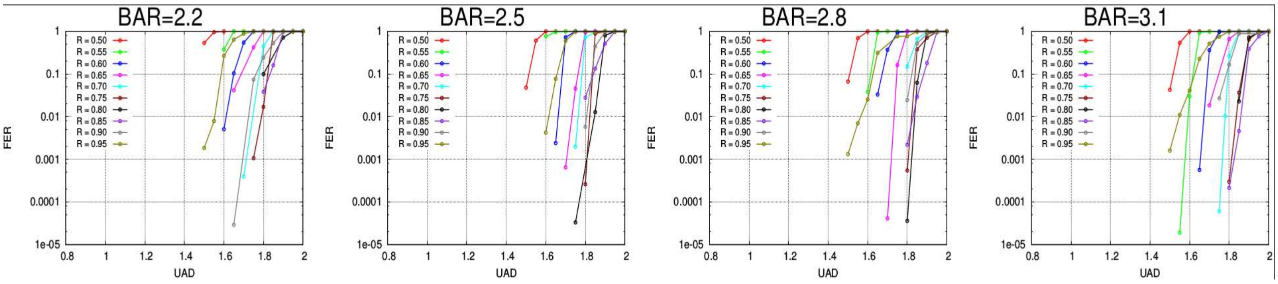

Fig. 2. FER vs UAD at different BARs and code rates.

The results from Fig. 2 show that for a conventional channel, the performance improves up to BAR=3.1 and an optimum code rate of 0.8 to 0.85 is observed at this BAR, with an achieved UAD of around 1.8 Tbpsi. It is noted here that the head/media are spec'd at 2Tbpsi. These results match closely with the HDD system parameters today.

III. 2D SIGNAL PROCESSING AND CODING SYSTEM

The system shown in Fig. *3* employs a three-input one-output 2D MMSE linear equalizer of size 3×15, for estimation of the coded data bits on the central track. This setup assumes a read head capable of simultaneously reading three tracks. The MMSE equalizer reshapes the channel to an 8+16D 1D PR target on the central track; processing three rows at a time enables equalization of the ITI from the outer two tracks. The equalizer output flows into a two-state 1D BCJR detector that uses the PR target to compute branch labels. The BCJR exchanges LLRs with an irregular repeat-accumulate (IRA) LDPC decoder to minimize the user BER. The main innovation is the use of three tracks to estimate the central track, within a relatively low-complexity system architecture.

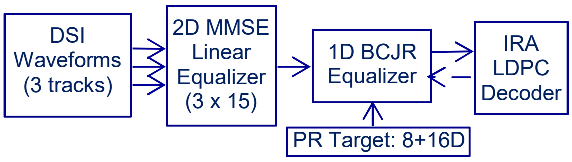

Fig. 3. 3-input / 1output MMSE/BCJR turbo detector

IV. SIMULATION RESULTS

Fig. 4 presents BER vs. user bits per grain for the system shown in Fig. 3. For a fixed BL of 11 nm, the best result of 2.289 Tbpsi is achieved at 21 nm track pitch (1.91 BAR). This is somewhat higher than the best results for the baseline one-track system in Fig. 2, which achieves 1.80 Tbpsi; the improvement is due to processing three tracks at once.

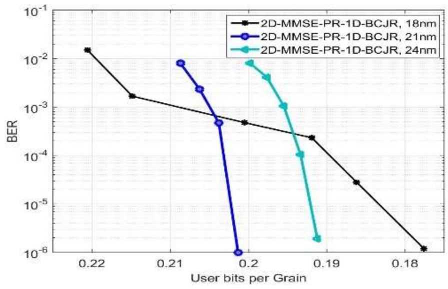

Fig. 4. Simulation results for the system in Fig. 3

REFERENCES

1) J. Barry, B. Vasic, M. Khatami, M. Bahrami, Y. Nakamura, Y. Okamoto, Y. Kanai, "Optimization of bit geometry and multireader geometry for TDMR", *IEEE Trans Magn.* Vol 52, No 2, Feb 2016.
2) K. S. Chan et al., "Channel Models and Detectors for Two-dimensional Magnetic Recording," *IEEE Trans. on Magn.*, vol. 46, no. 3, pp. 804–811, Mar. 2010.
3) K. S. Chan et al., "Comparison of Signals from Micromagnetic Simulations, GFP Model, and an HDD Readback," *IEEE Trans. on Magn.*, vol. 51, no. 11, pp. 1-4, Nov. 2015.
4) M. Mehrnoush, B. Belzer, K. Sivakumar, and R. Wood, "Signal Processing for Two Dimensional Magnetic Recording Using Voronoi Model Averaged Statistics," in *Proc. Conf. on Inform. Sci. and Syst.*, March 2015, pp. 1–6.
5) R. M. Todd, E. Jiang, R. Galbraith, J. R. Cruz, and R. W. Wood, "Two-dimensional Voronoi-based Model and Detection for Shingled Magnetic Recording," *IEEE Trans. on Magn.*, vol. 48, no. 11, pp. 4594–4597, Nov. 2012.