DISSECTING MEASURED JITTER IN HAMR: SEPARATION OF WRITTEN-IN AND REMANENCE CONTRIBUTIONS

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I. INTROCUCTION

The linear density capability of magnetic hard disk drives is limited by transition jitter in the read-back waveform, j_{exp}. Though measured jitter originates from imperfections of the written pattern as characterized by written-in jitter jw, it is also sensitively affected by the spatial resolution of the reader. Conventional interpretations of j_{exp} take only the finite *cross-track resolution of the reader* into account and predict $j_{exp} = j_w/\sqrt{n}$, where n is the number of grains / micro-tracks within the effective reader width [1, 2]. They also assume that i) the random distribution of the location and size of magnetic grains, and ii) the ratio of the switching field distribution and the gradient of the effective write field are the only two sources for measured jitter [2]. Heat assisted magnetic recording (HAMR) is developed to extend the linear density capability of conventional perpendicular recording on the promise that it can reduce both these sources of jitter simultaneously. The thermo-magnetic writing process of HAMR not only allows for media comprising much smaller grains but also yields much larger effective write field gradients [3].

In a previous study [4] we have shown that the *finite reader resolution along the down track direction*, σ_R, causes measured jitter to depend on the degree of media saturation, as quantified by the noise-to-signal ratio in the center of long bits, NSR_{REM}. From this, that we proposed to describe measured jitter via

$$j_{exp} = \sqrt{j_{GS}^2 + j_{SFD}^2 + j_{REM}^2} \quad , \tag{1}$$

where the magnitude of the remanence dependent pseudo-jitter, j_{REM}, is given by

$$j_{REM} = NSR_{REM} \cdot \left(\frac{dS}{dx}\Big|_{x0} \right)^{-1} = NSR_{REM} \cdot \sqrt{\frac{\pi}{2}} \cdot \sigma_R \tag{2}$$

The presence of j_{REM} and the importance of eq. 1 for correct data interpretations have been confirmed by two independent studies [5, 6].

II. JITTER AND HEAD FIELD RISE TIMES

When measuring jitter as function of write current (write field), linear disk velocity and overshoot amplitude (head field rise time), we found a strong increase of jitter with increasing rise time and disk velocity that became more pronounced at low write fields and could not be explained in terms of eq. (2). We suggested [4], that the discrepancy between measurement and expectation could be explained via the competition between write-bubble- and disk-velocity, that can cause write fields at transitions to be significantly smaller than the ones governing media saturation in the center of long bits. This suggestion implied general validity of eq. (2) if NSR_{REM} is understood as a measure of the media saturation in the vicinity of transitions. Here, we test this conjecture via a new data analysis scheme that allows separation of written-in and pseudo-jitter.

III. SEPARATION OF WRITTEN-IN AND PSEUDO JITTER

All noise, including jitter, refers to differences between observed and expected behavior. Most studies, including ours, use averaging of measured periodic signals, shifted by multiples of the period length, to obtain noise-free waveforms representing the expectation. However, the averaged waveform often differs from the ideal waveform one would expect for a noise free system. For the example of a square wave that is subject to written-in jitter and read with a reader of down-track resolution σ_R, the width of the error

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function describing the transitions of the averaged waveform is given by $\sigma_{ave} = \sqrt{\sigma_R^2 + j_w^2}$ instead of σ_R as expected for the ideal waveform. Only when all equivalent transitions are aligned to one particular but arbitrarily chosen transition before averaging, will the width of the averaged waveform at this transition be $\sigma_{align} = \sigma_R$. However, the width of all other transitions becomes even larger $\sigma_{anti} = \sqrt{\sigma_{ave}^2 + j_{exp}^2}$. We will show, that simultaneous analyses of signals, noise and jitter obtained via ordinary averaging as well as averaging after alignment to a single transition allow the separation of written-in and pseudo-jitter. Exemplary data and results of such analyses are shown in Figures 1 a) and 1 b), respectively.

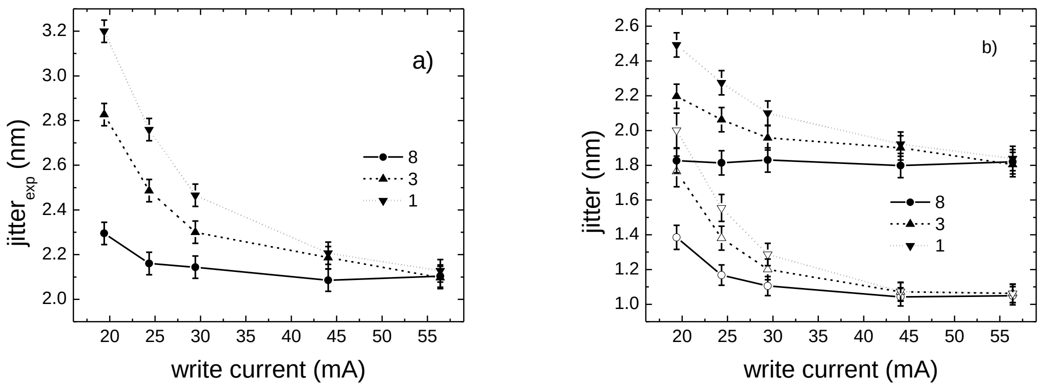

Fig. 1 a) Variations of jitter with write current as measured at linear disk velocity of 16.6 m/s for three different overshoot amplitude amplitudes given in the legend. b) Corresponding variations of $j_w/\sqrt{n}$ (solid symbols), and of j_{REM} (open symbols).

To our big surprise, we find that the increase of measured jitter is not only due to an increase of j_{REM}, but also due to an increase of j_w. This finding triggered us to perform additional simulations which revealed the presence of thermal-fluctuation induced jitter, j_{th}, the magnitude of which increases with the product of disk velocity and head field rise time. Thus, analyses of jitter measured in HAMR should consider four different contributions

$$j_{exp} = \sqrt{j_{GS}^2 + j_{SFD}^2 + j_{REM}^2 + j_{th}^2} \quad . \tag{3}$$

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