THEORETICAL LIMITS OF MICROWAVE ASSISTED MAGNETIC RECORDING (MAMR) EFFECTIVE FIELD GRADIENT

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Microwave Assisted Magnetization Reversal (MAMR) is a phenomenon where RF frequency field is applied to magnetic material and by resonantly exciting large angle precessions succeeds in lowering its coercivity. There was a wealth of publications that offered a reasonably accurate theoretical prediction of the coercivity reduction expected from such an effect[1], for a uniform linearly or circularly polarized RF field with a constant amplitude and frequency. Most modern implementations of MAMR system however rely on using an STO (Spin Torque Oscillator) for the purpose of field generation, which produces a highly non-uniform field, and which is further combined with non-uniform low frequency or essentially DC field, generated by a magnetic write pole. It is possible to extend the theoretical treatment to such scenario[2], however with the emphasis on estimating the parameters enabling the maximum possible reduction of coercivity. The question arises whether this approach can realistically predict the optimal performance of a real system. The areal density is going to be determined by the best linear achievable for the selected track density, which is usually determined by the STO width. The gating factor is a jitter parameter, if this parameter exceeds about 15% of the total bit length, there is a substantial probability of an event where on both sides of the "bit" the transitions will be shifted by thrice the value of standard deviation, and therefore the bit will disappear altogether. At this point, the number of errors is bound to be very considerable. In zeroth order approximation, the jitter value, a, depends (Eq.1) on the media grain diameter D, write width W, dynamic gradient smearing and timing jitter, together represented as velocity of the media ϑ multiplied by time constant τ, switching field distribution SFD, and the effective gradient of the writer's field along the downtrack direction dH/dx, with what we assume to be a constant c.

$$a \sim \vartheta\tau + \sqrt{\frac{D}{W}}\sqrt{cD^2 + \left(\frac{SFD}{dH/dx}\right)^2} \quad (1)$$

When *a* is measured in nanometers, the peak linear density (in kilobits per inch) will then be close to:

$$KBPI = 25400\frac{0.15}{a} \quad (2)$$

For the maximum media anisotropy that can be written with a MAMR system, we previously deduced the following formula (Eq.3), under typical assumptions of a single spin model[2]:

$$H_k \approx H_{SW} + 5.8H_{RF}\left|\cos\Delta a\right| \quad (3),$$

where H_{SW} is the amplitude of low frequency or DC Stoner-Wolfarth effective field, and Δa is the difference between the angle at which the RF field is applied and the optimal value, which depends on the value of the H_{SW} angle. In case of three dimensional (with x and yz plane components[2]) STO generated RF field:

$$\mathbf{H}_{RF} = \mathrm{Re}\left(e^{-i2\pi\omega t}\cdot\left(\hat{y}H_{yz}\sin a - \hat{z}H_{yz}\cos a \pm i\hat{x}H_x\right)\right) \quad (4),$$

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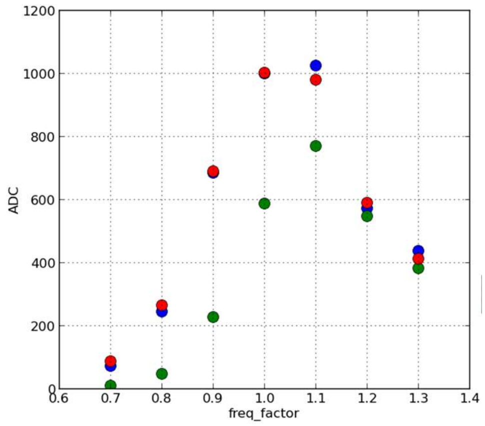
this can be further extended to yield the following equations for the maximum writeable anisotropy and corresponding optimal (maximum) operating frequency[2], where H_z is the component of DC field parallel to the anisotropy:

$$H_k \approx H_{SW} + \left|5.8\left(H_{yz}\left|\cos\Delta a\right| \pm 0.8H_x\right)\right| \quad (5)$$

$$\omega = 0.72\gamma(H_k - H_z) \quad (6).$$



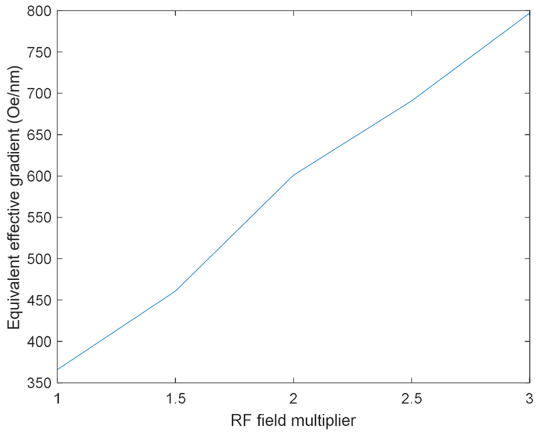


Figure 1. Modeled areal density for a single layer media with three writer designs, and equivalent effective field gradient versus the amplitude of the RF field generated by the STO.

The question is then whether these values actually define the optimal performance point of a real system, which includes non-uniform DC and STO fields. We performed an ADC estimation by modeling three writer designs (Fig. 1), with different gaps between the write pole and the trailing shield (determining the gradient of the DC field), and different write pole width. In each case we optimized the frequency, measuring the latter as a ration to the value provided by the (Eq.6) for the anisotropy value of (Eq.5). In our second run, we attempt to estimate the value of the effective gradient produced by the system, in a method similar to the one published[3] previously. We start by modeling an artificial conventional writer design with a constant gradient of the effective field, thus allowing us to produce a jitter number as a function of gradient. Then, we model a number of MAMR cases, including the one with relatively uniform DC field (i.e. very wide write gap), and the STO RF field multiplied by an arbitrary parameter. This allows us to consider the relationship between the RF field generated and the effective gradient (Fig. 2). Considering a single spin predicted the effective gradient of the order of 1500 Oe/nm for the multiplier of 1, one can see the value with a more realistic media to be just about 15% of the theoretical maximum. The difference can be shown to be driven by the modification of (Eq.1) that needs to be adopted to account for the MAMR physics. The effectiveness of conversion of the RF field to the effective gradient can then be manipulated by the MAMR system design.

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