VLBA ACQUISITION MEMO #207

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27 June 1990

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SUBJECT: Measurements of record spacing loss and a simple numerical model to evaluate the effect of demagnetization fields

Introduction

There are several motivations for trying to understand the headcurves of VLBA Acquisition Memo #184:

1] To predict the improvement in short wavelength response we might expect from a shorter gap length;

2] To check for the effect of added head to tape spacing which might exist during record due to imperfect head contours or flying at high tape speeds;

3] To better understand the fundamental limits of short wavelength response.

Record models

While the playback theory is quite straight forward, the record process is very complex owing to the interaction fields or "demagnetization" fields between magnetic particles. If there were no interaction fields and the individual magnetic particles behaved as perfect magnetic "switches", then during record all particles would have their state determined by the head field contour whose value equals the particle coercivity. In this model the particle states would be set by the trailing contour and there would be a sharp, but curved, boundary between magnetic transition states as illustrated in Figure 1. The curvature of the magnetization state boundary will introduce some phase shift in the playback signal which depends on the distance of the particles from the surface. This alone produces an effective transition length for a magnetic layer of finite thickness. When fit to an arctangent the magnetization variation with distance in the direction of tape travel is

$$M(x)-(\frac{2}{\pi})\tan^{-1}(x/a)$$

where $a = \delta/10$

and $\delta =$ record depth (set by field strength contours that equals the coercivity)

This result was obtained by computer simulation using the Karlquist head field approximation. The simulation also showed that for this purely geometric effect there is little dependence on the gap length or head to tape separation at least for

gap length $\langle \delta$

and head tape separation d $\langle \delta$

The inclusion of demagnetization fields increases the transition width.

Bertram(1) gives

$$a - \frac{DMr}{2\pi H_c}$$

where $D =$ medium thickness or record depth (whichever is smaller)

$M_r =$ remnant magnetization

$H_c =$ coercivity

while a computer model by Miles and Middleton(2) gives

$$a - \frac{DMr}{10H_c}$$

[A more complete theoretical expression for the transition length given by Middleton is used later.]

These expressions give the dependence of the transition length of longitudinally oriented media as a function of record depth, saturation remanence and coercivity. The detailed dependence on head field is not given except that the record depth D will depend on the head field. For example, the magnetic field of a head with gap length G decays from a maximum in the gap to half this value at a distance

$$D_{50} = G/2$$

so that a smaller record depth will be more easily maintained by a record head with a short gap since the field gradient is higher. This suggests that a short gap length will be advantageous for recording wavelengths short enough to be limited by demagnetization.

Record spacing loss

The measurement of the dependence of the short wavelength response on the distance of the media from the gap during record tells us something about the dependence of transition length of the record magnetic field strength and gradient. Bertram(3) has shown that loss to be

$$\approx -44 \text{ dB/wavelength}$$

for moderately large separations ≈ 0.25 μm,

and for standard high density media with

$$\frac{Mr}{H_c} - 3$$

We have measured the record loss as a function of head to tape separation (using Sony D1K tape) and observe much lower values in the range -10 to -30 dB/wavelength. This was accomplished by using a thick tape (see VLBA Acquisition Memo #170) to "spoil" the head contour and produce a spacing between the tape and the head gap. The spacing was then estimated by measuring the loss in signal for 1 micron wavelength recording made with perfect contact. Another recording was then made with the known separation and its playback level measured. The head was then recontoured for perfect contact and the recordings made with various spacings played back to measure the record spacing loss. Measurements were made with both the optimum record current (at 1 micron wavelength) for zero head to tape spacing and an elevated record current to reoptimize with non-zero spacings. The record loss results for these two cases were not sufficiently different to justify plotting the results separately. The results of these measurements are plotted in Figure 2 and show that the record spacing loss tends to increase with spacing. While the measured record loss is not as great as that measured by Bertram our results are for relatively small head to tape separations and hence are not inconsistent with previous results.

We have also developed a computer model to illustrate the qualitative effects of:

1] Increased demagnetization (M/H)

2] Record current dependence (which effects the record depth)

3] Record spacing dependence

4] Record head gap length

The model consists of a 3-D array of particles with two states of magnetization (+1 = in direction of tape motion, -1 = in opposite direction) whose state can be switched if the component of magnetic field in the direction of motion from both the head and other particles (demagnetization field) exceeds the coercivity H_c. The interaction field is calculated on the assumption that each particle produces a dipole field

$$(3\,(\bar{\mu}\,.\,\hat{r})\,\hat{r} - \bar{\mu})\,/\,(4\,\pi\,r^3)$$

where $\bar{\mu} = \pm Mr l^3 \hat{r}_x$

$\mathbf{r}$ = vector from nearby grain to particle which state is being determined

$\hat{r}$ = unit vector in the direction of $\mathbf{r}$

$r = |\mathbf{r}|$

H_c = coercivity

$\hat{r}_x$ = direction of tape motion

Mr = magnetization

l = distance between particles

This is basically the method of Miles and Middleton with the following changes

1] Extended from 2-D to 3-D.

2] Assumes each particle takes on only 2 magnetic states.

3] A Karlquist head field is used.

4] The head field is moved along the tape and at x = 0 and its direction switched to simulate a transition being recorded.

The general trends seen in Figure 3 are:

1] The particle transition length (fitted with an arctangent) increases with increased particle interaction.

2] There is a small increase of transition length with head to tape spacing under the constraint that the record field is increased with the spacing to maintain a constant record depth.

3] There is little if any increase in transition length with record gap length - under the constraints of maintaining a constant field at the surface of the tape and a constant record depth.

In trying to understand 3] we note that the gradient of magnetic field in the x direction (along the tape) is not reduced with a large gap. Jeffers(4) has measured the relative record performance of heads with gap length from 0.25μm to 1.9μm always played back with the same 0.25μm reproduce head and measures a gap length dependence of about

6 dB/wavelength

as inferred from data in his Figure 4.

Jeffers' measurements might be consistent with a lack of gap length dependence in our model when account is taken of the variation of record depth with the various heads used by Jeffers.

The model results in Figure 3 were compared with an analytic expression given by Middleton (5) as follows:

$$a--D/4+[(D/4)^2+(1/\pi)(B/H)D(D/2+d)]^{1/2}$$

where

$(B/H) = 1220$ Gauss/830 Oersted $= 1.5$ (for Sony D1K tape)

The Middleton expression gives

$a = 0.09\ \mu m$

for

$D = 0.3\ \mu m$

$B/H = 1.5$

$d = \phi$

it also gives a record loss (from the dependence of a on d) of -20 dB/λ

for

$d = 0.05\ \mu m$.

Both the analytic expression of Middleton and our computer model give a value for the transition length which is smaller than the 0.15 μm derived from the headcurve (see VLBA Acquisition Memo #184). This suggests that our present single crystal manganese-zinc ferrite head may suffer from a dead layer of about 0.05 μm. This is further incentive to pursue metal-in-gap (MIG) heads for smaller dead layer and the ability to drive higher coercivity tapes.

References

1] Bertram, Proc. IEEE, Nov 86, pp 1494.
2] Miles and Middleton, IEEE, Trans on Mag., vol 26, Jun 90, pp 204.
3] Bertram, IEEE, Trans on Mag., No. 6, Nov 82, pp 1206.
4] Jeffers, Proc. IEEE, Nov 86, pp 1540.
5] Middleton, Chapter 2, Vol. 1., (Page 62, Equation 2.52), of Magnetic Recording by Mee and Daniel, McGraw-Hill, 1987.

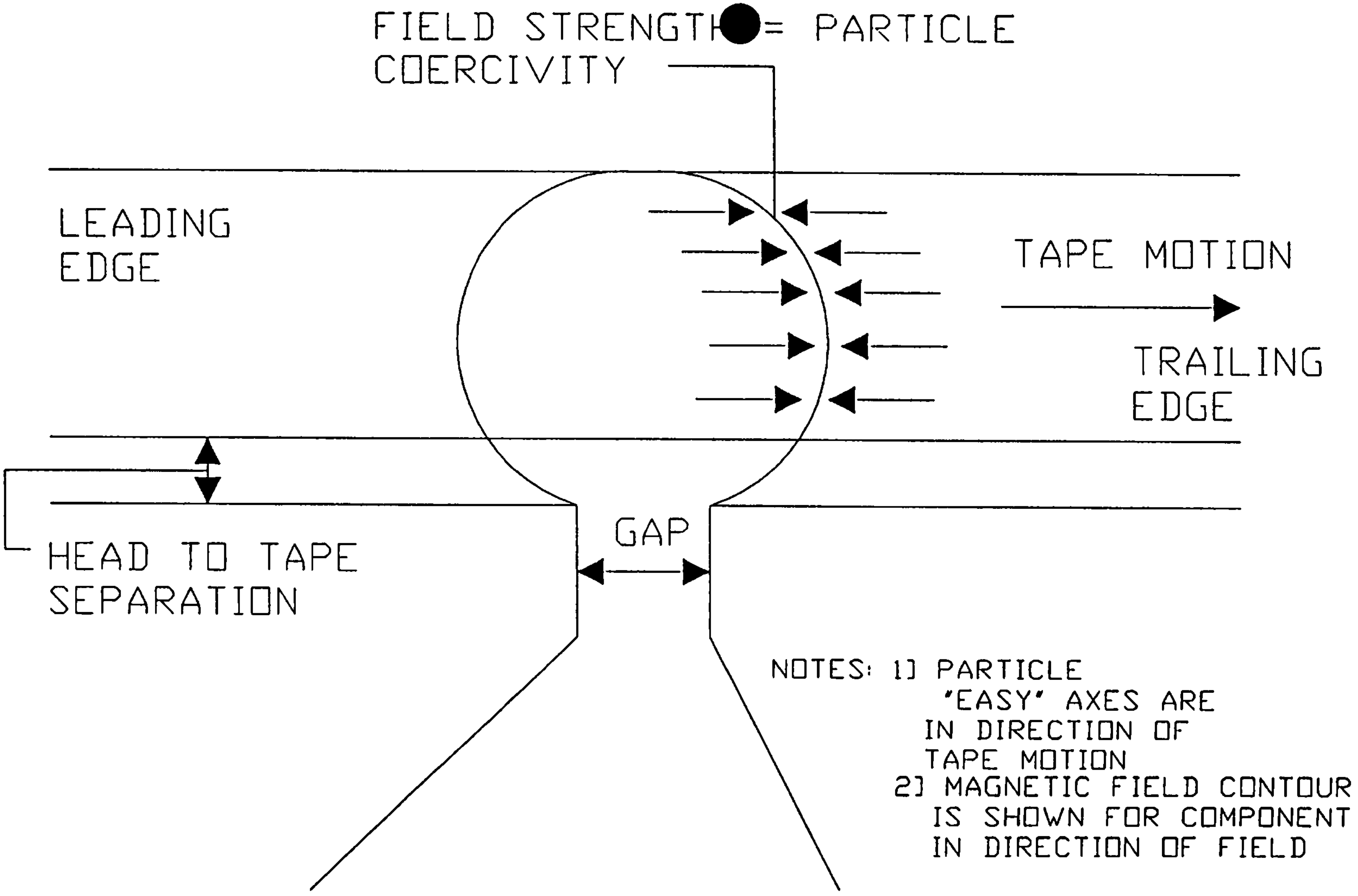


FIG 1 HEAD FIELD AND PARTICLE STATES SHOWN AS HEAD FIELD REVERSES

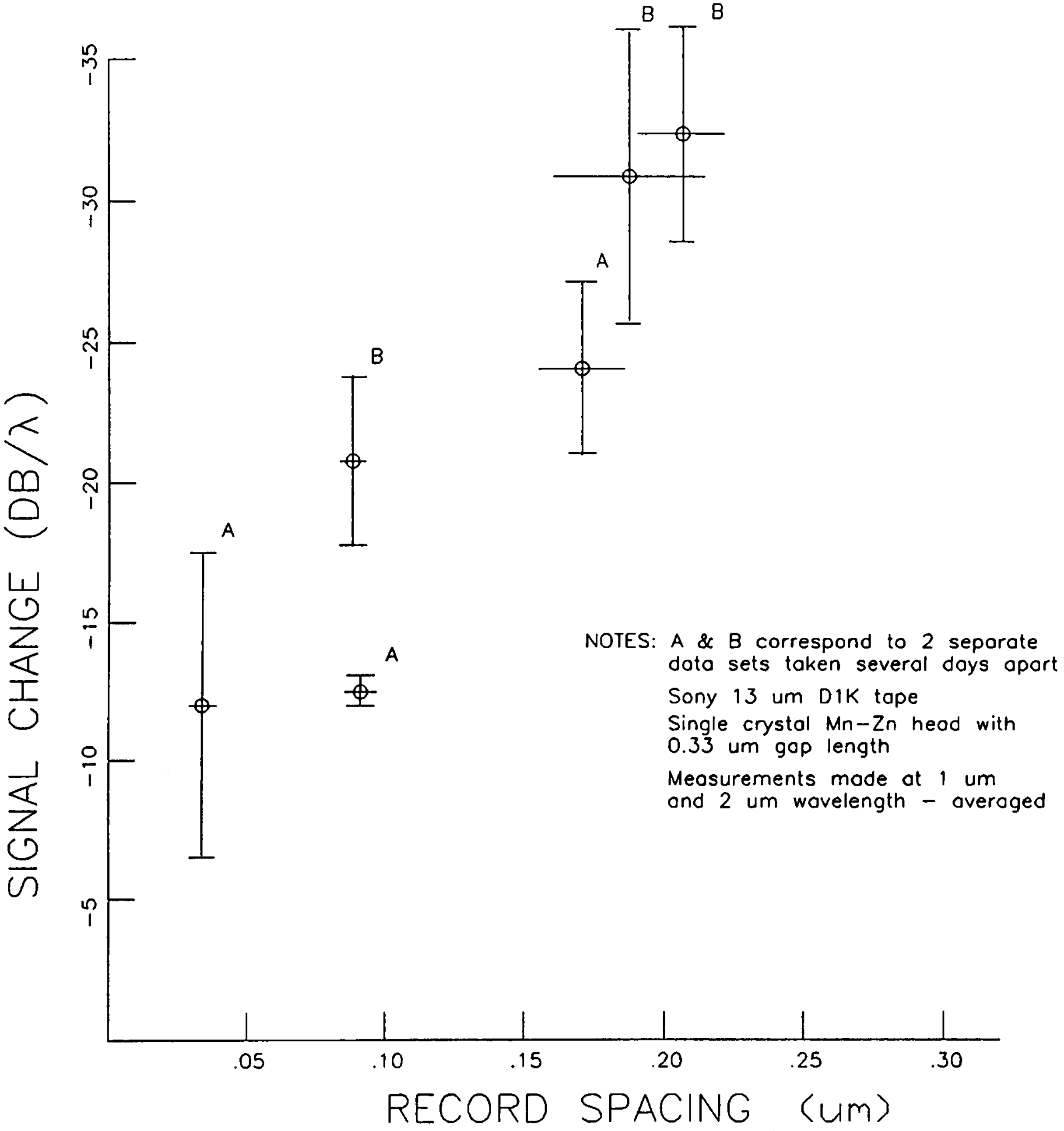
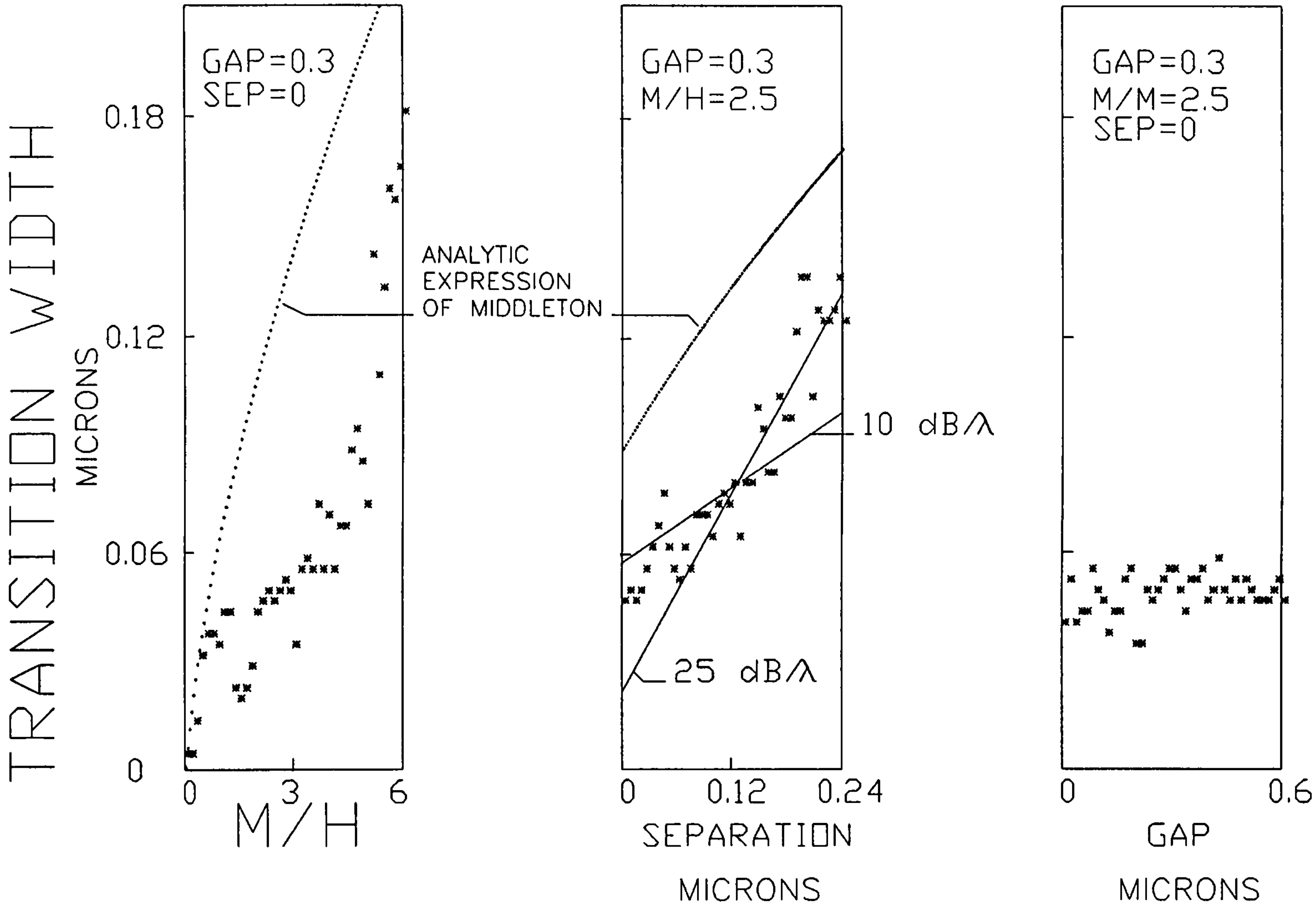


Figure 2. Measurements of record spacing loss



RECORD DEPTH = 0.3 MICRONS
PARTICLE SEPARATION = 0.06 MICRONS
PARTICLE ARRAY SIZE 20x10x5
INTERACTIONS CALCULATED FOR PARTICLES
UP TO 2 CELLS APART = 5x5x5 −1 =124 PARTICLES

FIGURE 3 TRANSITION WIDTH FROM MODEL