VLBA ACQUISITION MEMO #245

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

February 25 1991

Telephone: 508-692-4764
Fax: 617-981-0590

To: VLBA Data Acquisition Group

From: Alan E.E. Rogers

Subject: Efficiency variations in VLBA headstacks

VLBA headstacks show considerable variation in efficiency between heads within a stack. The variation of performance is found to be correlated with inductance (see Acquisition Memo #241). This is interpreted as a variation of series reluctance in the pole arms. Now further evidence has been found to pinpoint the exact cause of the variation of effective permeability of the pole arms. The single crystal ferrite is a material whose permeability is a function of the bulk strain (a property of magnetostrictive materials - see Saito, IEEE Trans. Mag. Vol 26, page 2942, Nov. 1990, also Dan Soo private communication) and the coefficient can be estimated by mechanically loading a headstack. Figure 1 shows where the load was applied to the front of the head. Treating the head pole arms as a bridge beam, as shown in Figure 1, the maximum strain is given by

$$S = 3WL/(4\ Y\ a^2\ b) \quad \text{(from beam theory)}$$

where W = load

Y = Young's modulus 2×10^7 psi

where L = Length of the beam (~38 μm)

a = Thickness of the beam (~57 μm)

b = Width of the beam (~38 μm)

For a load of 20 grams (0.04 lb) the maximum strain is approximately 3×10^{-4} and the effective permeability is seen to drop by a factor of 2. A separate calculation was made to show that the supporting epoxy which surrounds the sides of the pole arms doesn't add much to the stiffness of the ferrite "bridge" as the ratio of elastic moduli is large (Y ferrite/Y epoxy >30). Measurements on a gapped bar in the bridge set-up shown in Figure 1 gave a 5% effective permeability change for a strain of 3.5×10^{-5}. No sensitivity was observed to bending about the thicker dimension, presumably because bending in this direction imparts no strain to the gap line since it is along the neutral line. Also the sensitivity of permeability to strain is likely to depend on the direction of strain and it was not possible to strain the gap bar in the same direction as in the headstack. The gapped bars also show a strain bias so that reversing the direction of the strain initially increases the permeability.

Most of the heads examined in headstack D82 appear to be strained in such a manner that applying a negative force to the head tip increases the inductance (improving the efficiency). The equivalent of a negative force can be obtained by pushing on the outer edges of the head as illustrated in figure 1. Also the heads can be thermally tuned. Heating the front of the headstack improves the efficiency. D82 has a temperature coefficient for ambient changes (presumably owing to differential expansion) of about 0.3% inductance increase per °C.

The questions raised by discovery of strain sensitivity in the inductance of the heads are:

1] Can poor heads be improved by annealing during manufacture, or even perhaps after manufacture by some method that doesn't damage the epoxy?

2] Can the strain imposed during manufacture be reduced?

3] Do we need to test the gapped bars for strain sensitivity? (A quick look at an old headstack with Matsushita gapped bars shows a similar sensitivity.)

The numerical values given in this memo are only approximate and indicate only the order of magnitude of the observed effects.

<u>Added note on theory:</u>

If the strain dependence is related to magnetostriction λ then the magnetoelastic coupling constant B can be derived from equation 10.34 page 183 of Kittel's "Introduction to Solid State Physics", so that

$$B = 3\,\lambda\,Y \qquad \text{(where } Y = \text{Young's modulus)}$$

and magnetoelastic energy is

$$B\,e = 3\,\lambda\,Y\,e \qquad \text{(where } e = \text{strain)}$$

An estimate of the order of magnitude strain at which the magnetic properties will be significantly affected might be given by equating the magnetoelastic energy to the magnetic energy so that

$$e \sim (1/2)\,B^2/\,(3\,\lambda\,Y\,\mu)$$

$$\sim 2 \times 10^{-4}$$

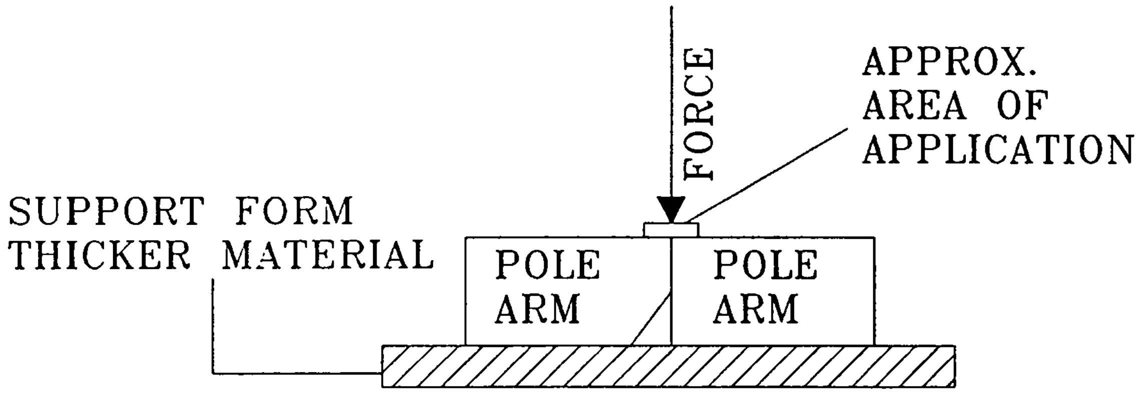
for $B = 4000$ G

$\lambda = 10^{-5}$ (approx. saturation magnetostriction for single crystal ferrite)

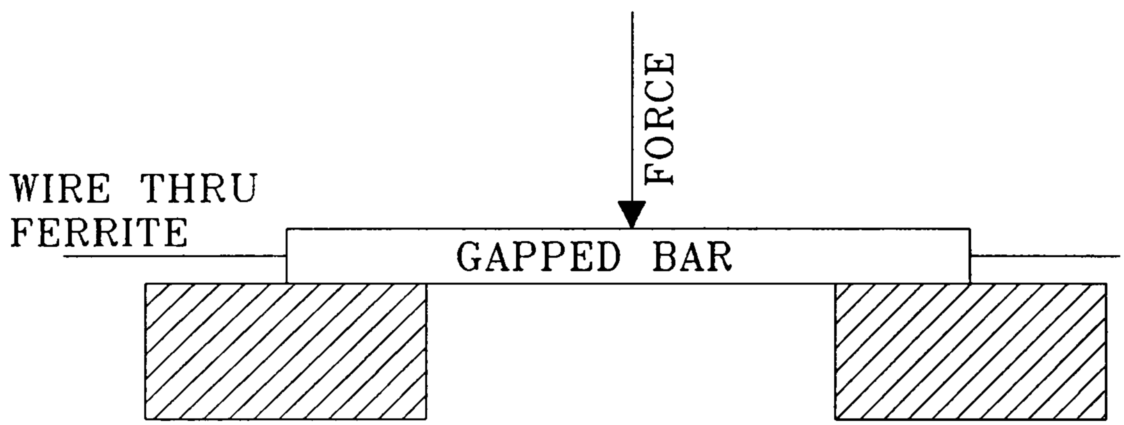
$Y = 1.4 \times 10^{11}\ \mathrm{N/m^2}$

$\mu = 100\,\mu_o$

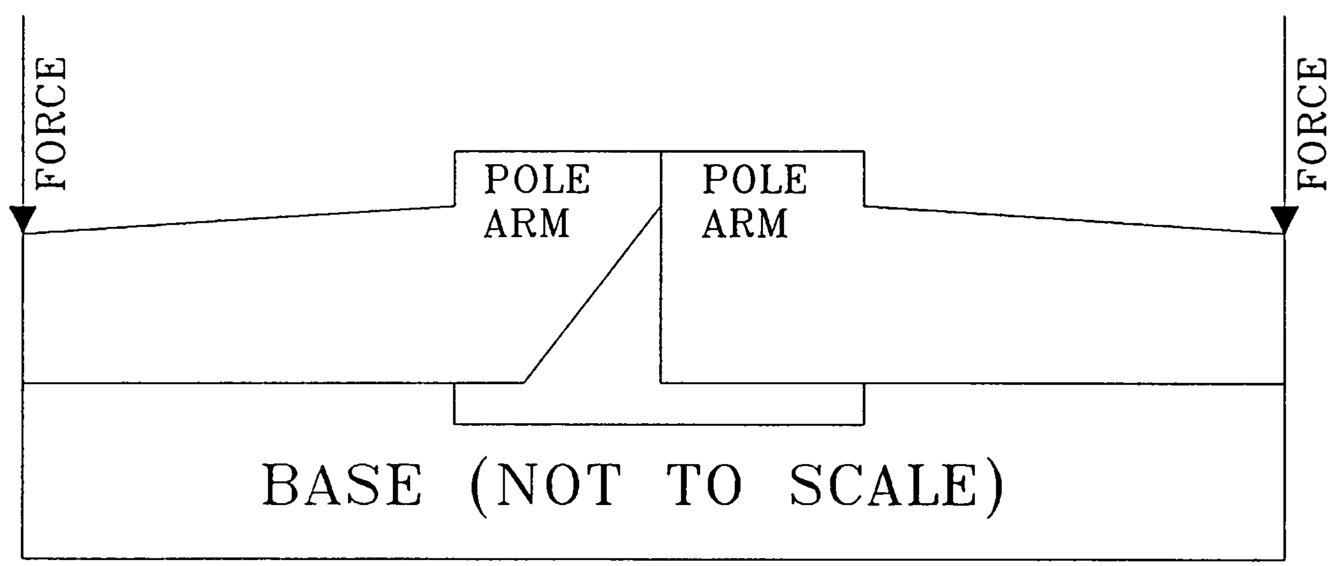
So that the smaller the magnetostriction the larger the strain needed to affect the permeability. I think the above equation is similar to Equation (4) of Saito but I am not sure of the physics.



20 GRAMS PRODUCE A 50% DROP IN EFFECTIVE PERMEABILITY OF THE HEAD



200 GRAMS PRODUCE 5% DROP IN EFFECTIVE PERMEABILITY



300 GRAMS PRODUCES SMALL INCREASE IN PERMEABILITY

FIGURE 1. OBSERVED STRAIN SENSITIVITY