VLBA ACQUISITION MEMO #241

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To: VLBA Data Acquisition Group

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Subject: Revised model for VLBA head efficiency

The head efficiency model of Acquisition Memo #152 assumed a frequency independent permeability. Recent concern over the performance of production headstacks has prompted a more detailed study. Figure 1 shows the magnetic circuit of a single head. All stray reluctance, including that from mutual coupling being lumped in a single reluctance. The series reluctance of the pole pieces is computed using the conduction analog (see Acquisition Memo #237) and the values of permeability indicated. A pole piece trim of 38 µm below the apex is assumed. The table in Figure 1 gives values inductance and head efficiency for various values of depth of gap, gap length and permeability. Also computed is the current for which a field of 3000 Gauss (240 KA/m) will be produced across the gap. This is the field value at which the observed impedance of a gap bar (with single wire threaded through the winding window) drops by 5% as illustrated in Figure 2. The gap bar model of Acquisition Memo #237 was used for this calculation. The "saturation" currents are computed for comparison with measurements made by adding a D.C. current source to the impedance probe and observing the impedance change with bias current.

Table 1 gives the measured parameters of heads in several headstacks for comparison with the model. The inductance of the recent "D" series of headstacks are best fit with gap length of 0.25 µm (measured from the gap null - see Acquisition Memo #152) and a permeability of about 300 independent of frequency. Measurements of permeability on unprocessed gap bars (see Acquisition Memo #237) confirm the frequency dependent permeability given on the data sheets. The loss of permeability increase at low frequencies may be the result of strains imparted to the tip plate during head manufacture (this suggestion comes from Dan Soo of Metrum). At frequencies above 2 MHz there is also a decrease in efficiency (see notes 2 and 3) which is probably a combination of a drop in permeability and an increase in loss tangent.

The computed and measured values of Isat are in quite good agreement. Also the record efficiency estimated from the current at which a recording is barely made (presumably when the gap field reaches the tape coercivity) is about 50%. However, attempts to verify the playback efficiency (which should equal the record efficiency) are very difficult to calibrate but suggest an efficiency of less than 50%. For example, calculated playback voltage (using Bertram's equation 59) is 100 μV at 1 MHz when

48 turns
efficiency 50%
record depth 0.3 microns (see Acquisition Memo #184)
38 μm track width
λ = 4 microns
spacing 0.15 microns (see Acquisition Memo #184)
tape speed 4 m/s
tape magnetization 1000G

compared with a measured playback voltage of 66 μV. This result suggests that the playback efficiency is around 30%, but parameters like the record depth are quite uncertain.

Efforts are now underway to try and understand the playback efficiency and the major contributions to variations between heads. Head playback performance is not always correlated with inductance suggesting that some heads have gaps which are shunted with magnetic material. Saturation curves of head inductance vs bias current (like that of Figure 3) sometimes exhibit variation at very low bias currents and hysteresis. Magnetic shunts, such as produced by gap smear, have little effect on record as they tend to saturate, they "open" up. If magnetic shunting is not a problem the efficiency should be correlated with variations in the series reluctance of the ferrite, which in turn, should be correlated with inductance. The correlation can be improved by measuring the difference in inductance with and without a saturating bias as this removes variations in leakage reluctance. This correlation for head E09 is shown in Figure 4 along with a model curve. The head model along with inductance measurements look very promising as a tool for understanding head performance. At present, this simple model neglects

a) Reluctance in the fluxor (see Acquisition Memo #152).
b) Reluctance in junction of fluxor and tip plate (thought to be very small).
c) Inductance from the magnetic field around the windings.

The model makes the following simplifying assumptions

a) Lumps all flux leakage into one reluctance.
b) Neglects the changes in flux distribution in the ferrite due to leakage and skin depth effects.

The consequences of the shorter gap length in recent headstacks (D45,48,49, and E09) all have gap length approximately 0.25 microns) are as follows:

On the plus side:

1] A better short wavelength response (compared with 0.33 micron gap) having the gap null further out

at 33,000 bpi (λ = 1.54 microns) + 0.4 dB
at 56,000 bpi (λ = 0.91 microns) + 1.0 dB

On the minus side:

1] Lower efficiency (effects only playback if head is well saturated during record).

for depth of gap 38 microns - 1.2 dB
for depth of gap 19 microns - 0.6 dB

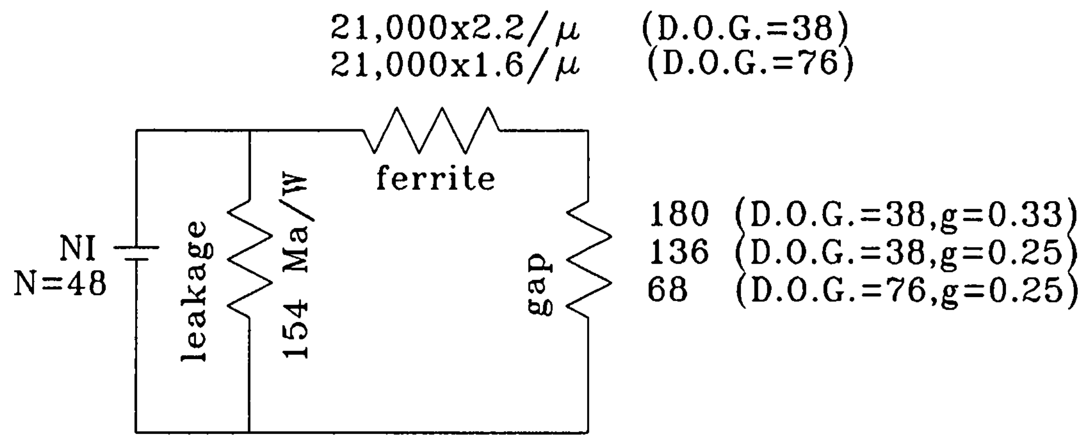
For those heads which have poor performance owing to a high series reluctance (as in head E09) the shorter gap could decrease efficiency by up to 0.25/0.33 = -2.4 dB.

2] Smaller record depth owing to head saturation (effects only long wavelengths). At a distance into the tape from the gap equal to the gap length the field has dropped by a factor of about 3 and for a given tape the maximum obtainable record depth is proportional to the gap length.

0.25/0.33 = - 2.4 dB

3] A higher record current is required to overcome lower efficiency and lower currents for which saturation starts.

Since the negatives outweigh the positives it would seem advantageous to try and ensure that the gap bars have the nominal 0.33 micron gap length.



g=0.25 μm, μ= 300			
D.O.G. μm	inductance μH	effic. %	Isat ma
0	15	100	1.25
38	23	47	2.66
76	28	37	3.38

g=0.25 μm, μ=600			
D.O.G. μm	inductance μH	effic. %	Isat ma
0	15	100	1.25
38	26	64	1.95
76	33	55	2.27

g=0.33 μm, μ=300			
D.O.G. μm	inductance μH	effic. %	Isat ma
0	15	100	1.65
38	22	54	3.06
76	26	44	3.75

g=0.33 μm, μ=600			
D.O.G. μm	inductance μH	effic. %	Isat ma
0	15	100	1.65
38	24	70	2.36
76	31	54	2.66

Notes: 1] Leakage reluctance from inductance of headstack with 0 depth of gap (worn out head.)

2] Factors of 2.2 and 1.6 are from conduction analog meas.

3] Isat is current for 3000 Gauss in gap

Figure 1. Magnetic model of head

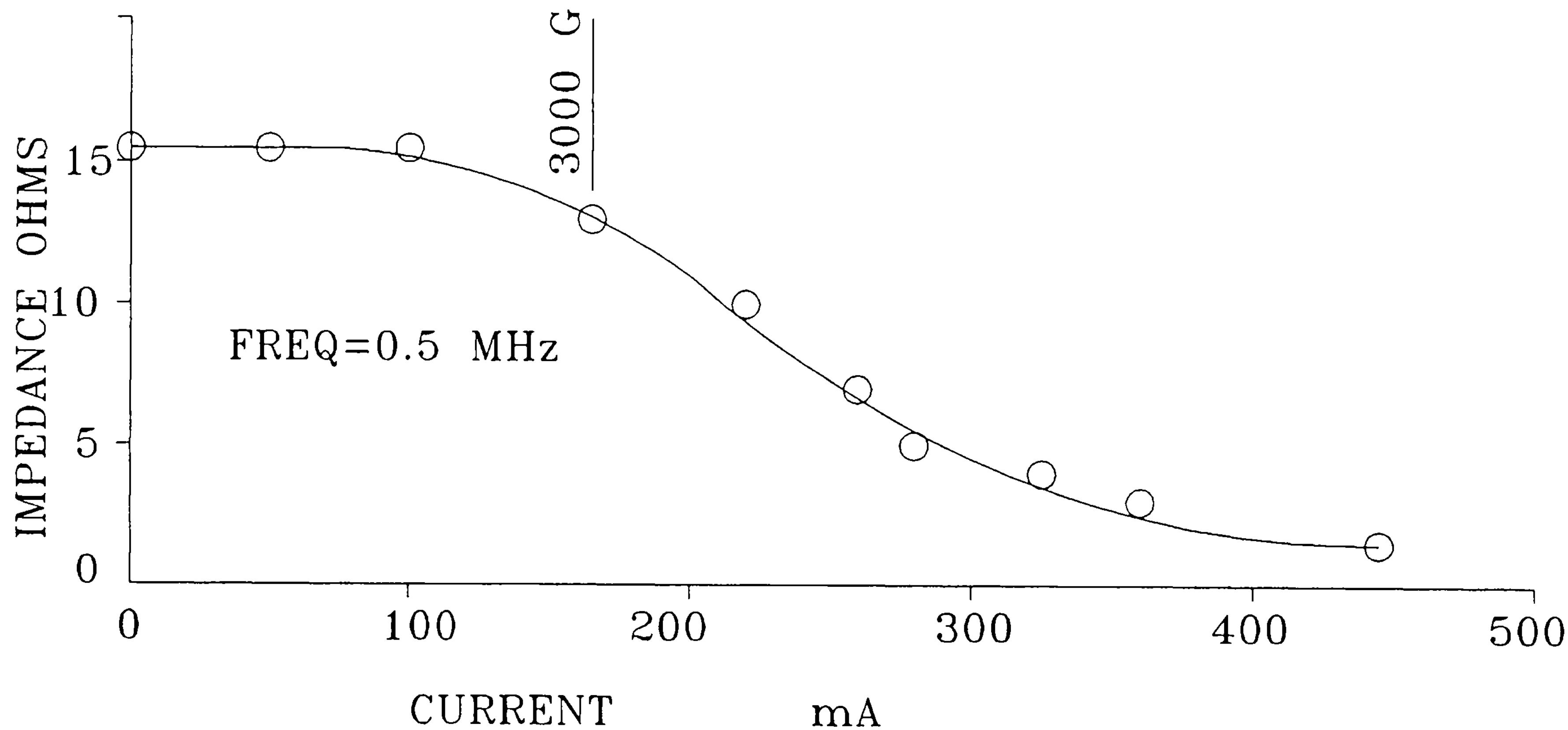


Figure 2. Saturation curve of ferrite bar

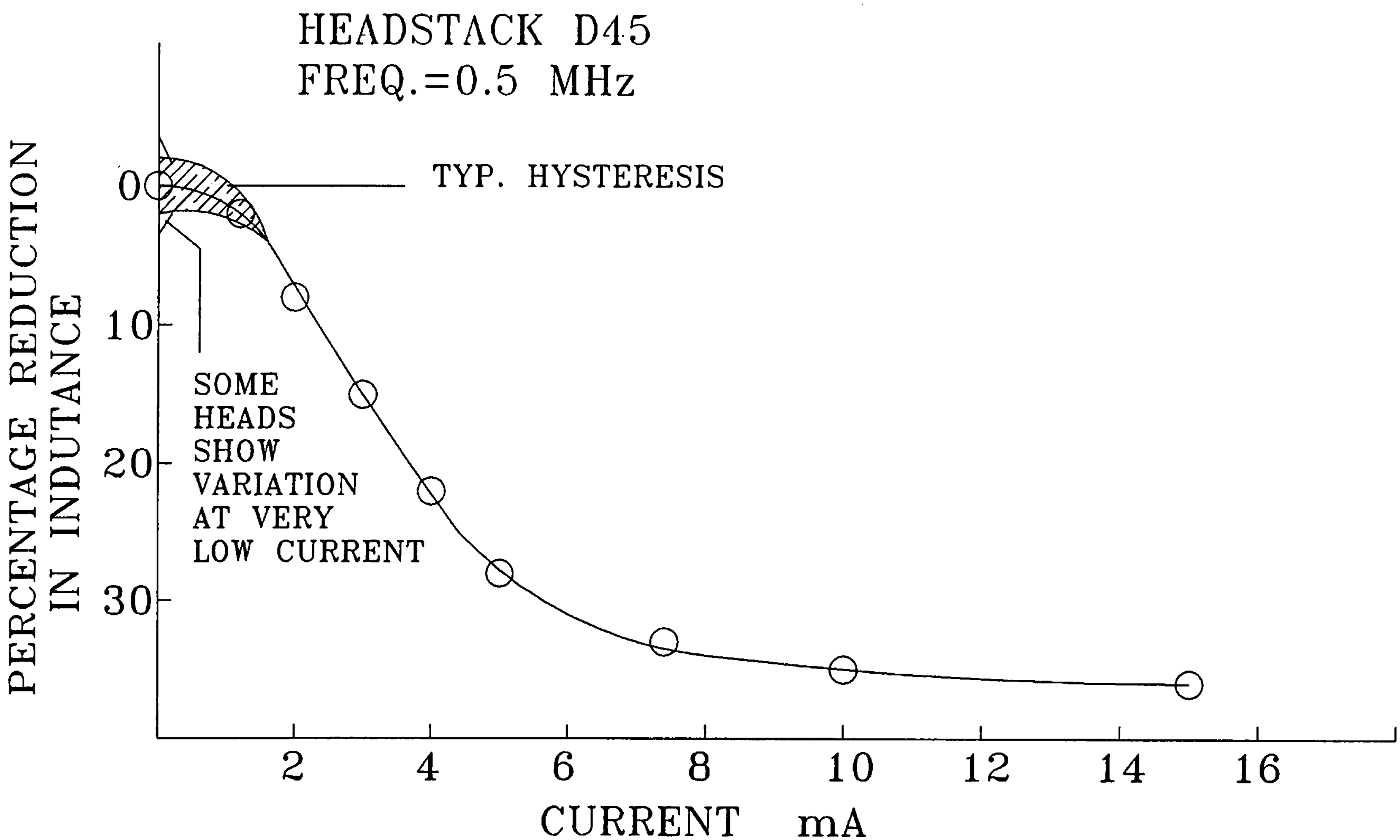


Figure 3. Saturation of head inductance

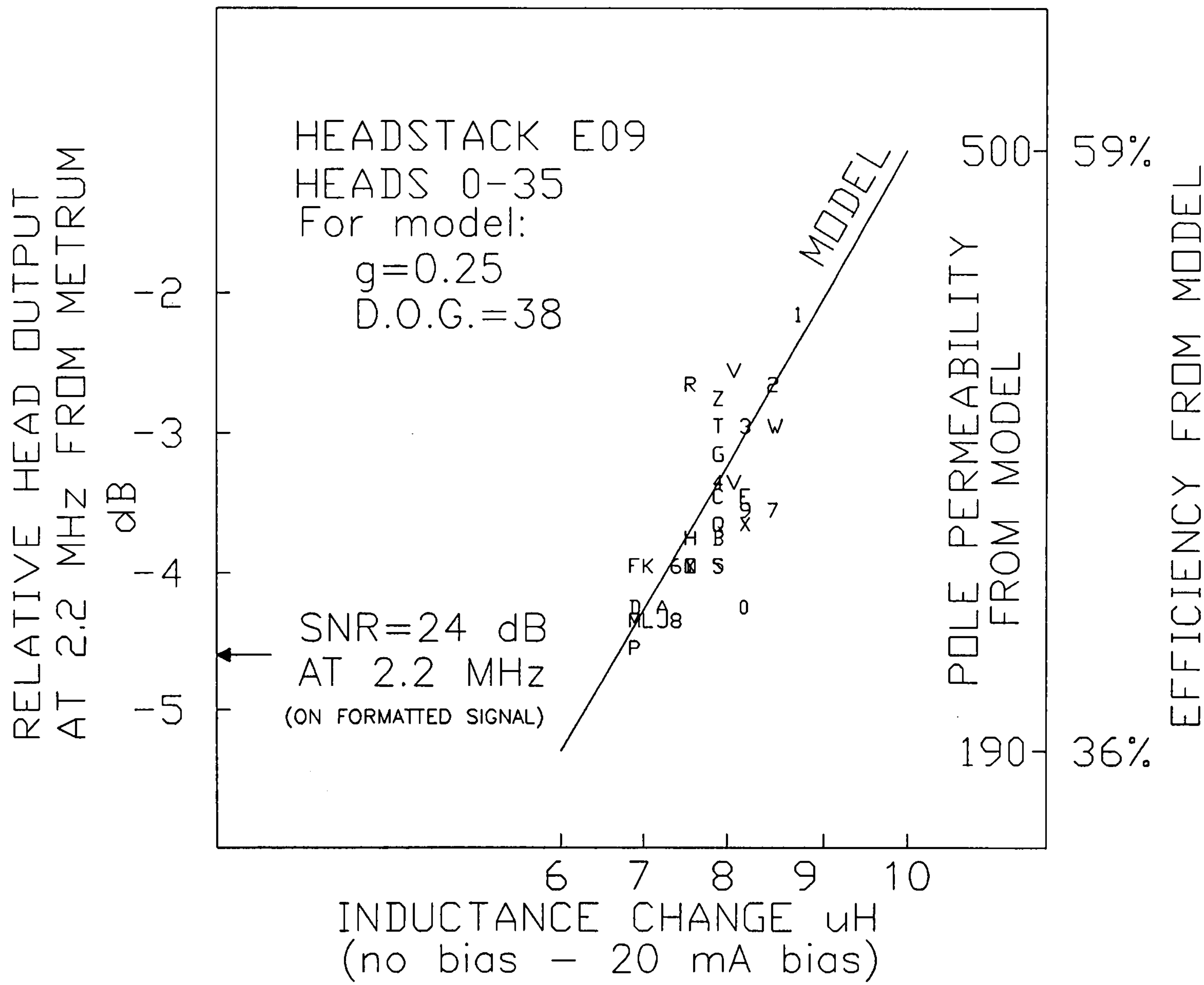


Figure 4. Correlation of head output vs inductance change

Definitions: TIP = type of gapped bar; M=Matshita,H0=Hitachi early
H1=Hitachi -1,H2=Hitachi -2
Lf = inductance at depth of gap DG
Lw = inductance of worn out head
Isat = current bias which reduces ind. by 5% at 5 MHz
gap = gap length from gap null

HEAD	TIP	Lf	DG	Lw	Isat	gap	NOTES
B21	H0	26		16			
D45	H1	23	38		2.4	0.25	1,2,3
D48	H1	22	38		2.5	0.25	
D49	H1		38			0.25	
E09	H2	24	38			0.26	1,3
C25	H0	24	55		3.0		
C32	H0	20	37		4.0		
B27	H0	25				0.33	

Notes: 1] Inductance showed <5% var. 0.5 - 2 MHz
2] 2,3,4,5 mA p-p at 2,4,8,12 MHz required to barely record D1K with head D45
3] Isat was observed to increase by 30% at 8 MHz

Table Measured head data