THEORY OF PHASE DISTORTION IN MAGNETIC TAPE RECORDING

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ABSTRACT

The locus of recording when using IRIG standard bias methods is deduced from data on phase distortion presented by the author at ITC 1972. Contrary to popular opinion recording does not occur at the trailing edge of the record gap. At the maximum depth of recording it takes place near the center of the record gap, and in the surface layers next the record head approximately one half the record gap length past the trailing edge of the record gap.

INTRODUCTION

It is known that phase distortion occurs when a tape recorded and equalized for one direction of travel is reproduced with the direction of travel reversed. Unique equalization in phase is required for each direction of travel. It was shown (Ref. 1) that this distortion is a property of the recording method, independent of record/reproduce electronics. The phenomenon can be explained as variable phase as one progresses into the emulsion i.e. magnetization is not constant in a plane normal to the velocity vector as Wallace (Ref. 2) assumed. Wallace's theory, however, is adaptable to the problem, and, using the experimental data from Ref. 1, the locus of constant phase can be approximately constructed.

ANALYSIS

The reproduce geometry is shown in Fig. 1. The model is essentially that used by Wallace, except that recording is assumed to occur on the locus described by y = f(x), rather than in a plane normal to the velocity vector. Signal voltage is:

$$E(k) = E(0)\,\epsilon^{-ks}\int_0^d \epsilon^{-k(x-jy)}\,d(kx) \qquad (1)$$

where : k = wave number = 2π/wavelength
s = separation between the reproduce head and the recorded medium
d = depth of the recorded medium
x = depth in the recorded medium
E(0) = a constant (voltage).

The modifier of eq. (1), outside the integral, has no effect on the phase of E(k), and is eliminated in the following discussion.

An exact solution of eq. (1) for f(x) when the experimental data is the phase of E(k) as a function of wave number, is extremely difficult, and perhaps unnecessary. Using the approximations:

$$\left.\begin{aligned} \epsilon^{-kx} &\simeq 1 - kx, \quad kd \ll 1 \\ y &\simeq ax, \quad kd \gg 1 \end{aligned}\right\} \qquad (2)$$

and defining the following quantities:

$$\left.\begin{aligned} \bar{x} &= \int_0^d x f(x)dx \Big/ \int_0^d f(x)dx \\ \bar{f}(x) &= (1/d)\int_0^d f(x)dx \end{aligned}\right\} \qquad (2)$$

we find that the equivalent displacement on tape X(k)= Ø(k)/k, where Ø(k) is the phase angle, is:

$$\left.\begin{aligned} X(k) &= -\bar{f}(x)\,(2\bar{x} - d)\,k/2, \quad kd \ll 1 \\ X(k) &= (1/k)\tan^{-1}a - \bar{f}(x), \quad kd \gg 1 \end{aligned}\right\} \qquad (3)$$

If we assume the simplest structure for f(x), $y = ax$, $0 \le x \le d$:

$$\left.\begin{aligned} X(k) &= -(kd/6)(ad/2), \quad kd \ll 1 \\ X(k) &\fallingdotseq (1/k)\tan^{-1}a - ad/2, \quad kd \gg 1 \end{aligned}\right\} \qquad (4)$$

DISCUSSION AND EXPERIMENT

Experimental data from Ref. 1 is shown in Fig. 2, together with the fit for a = 2/3 and a depth of recording of 135 microinches. From other experimental data (Ref. 3) a depth of recording of 120 microinches was obtained for an 85 microinch. Tecord gap. Considering the approximations which have been made and the experimental error in the measurement of phase in Ref. 1, the agreement is excellent. The locus of recording is shown in Fig. 3.

Since phase is variable in a plane normal to the velocity vector an amplitude loss occurs. This loss is in addition to the loss due to separation described by Wallace. The loss has been calculated as a function of kd, and is shown in Fig. 4. For an IRIG WB2 recorder with an 85 microinch record gap , kd at the upper band edge is about 12. The loss factor is then approximately 1.5 dB in the upper octave of the pass band, and tapers to essentially 0 at 3% of the upper band edge.

It is noted that the results obtained apply strictly to an IRIG WB2 system, recording with standard bias, using horizontally oriented particle tape.

CONCLUSIONS

A locus of recording has been found which fits available experimental data. From this locus it is possible to predict phase equalization required as a function of the length of the record gap. IRIG 106-80 standardized this gap at 85 ±20 microinches. The tolerance permits distortion in amplitude of ±5dB, and phase distortion of ±1 radian over the recorder passband. Discussions with head manufacturers reveals the tolerance might be reduced to 5 microinches at negligible cost. It would then be practical to use bias to adjust standard depth of recording and standard separation. This would allow the use of standard phase and amplitude equalizers, and eliminate a bothersome set of adjustments seldom made in practice because of the time and skill involved, and so a constant source of irritation in the exchange of tapes. Recorders are being designed with track densities of 1000 per inch, for which individual track equalization is patently unthinkable.

References

1. Hedeman, W.R.,Jr., Phase Distortion in Mag. Tape Recording, Proc. ITC, 1972
2. Wallace, R.L., Reproduction of Magnetically Recorded Signals, BSTJ, Oct. 1951
3. Hedeman, W.R.,Jr., and Law,E.L., Particulate Noise Power Spectrum of a Magnetic Tape Recorder/Reproducer, Proc. ITC, 1981.

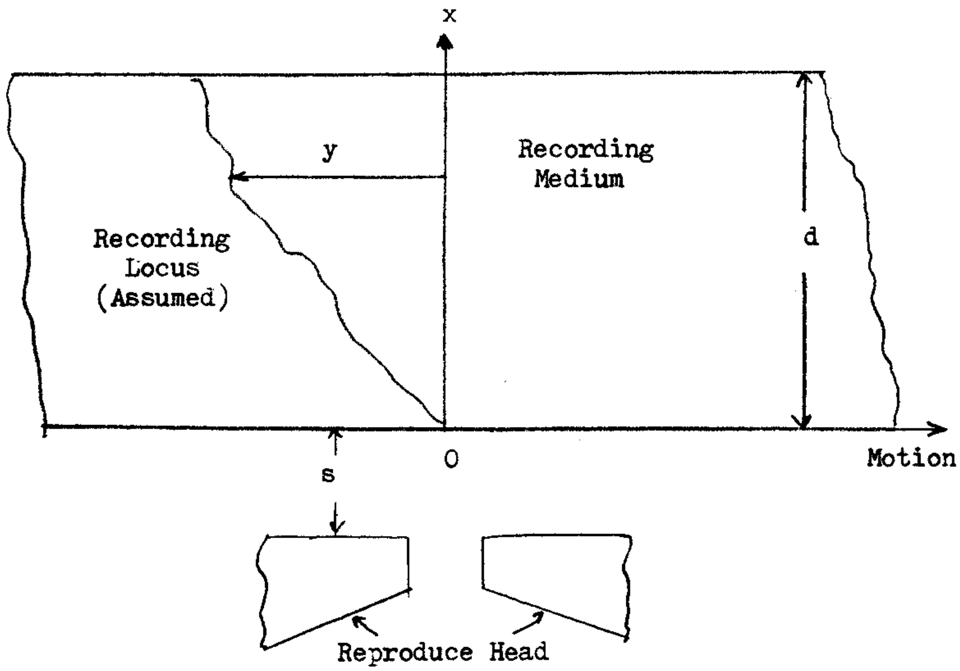

Fig. 1. Reproduce Geometry

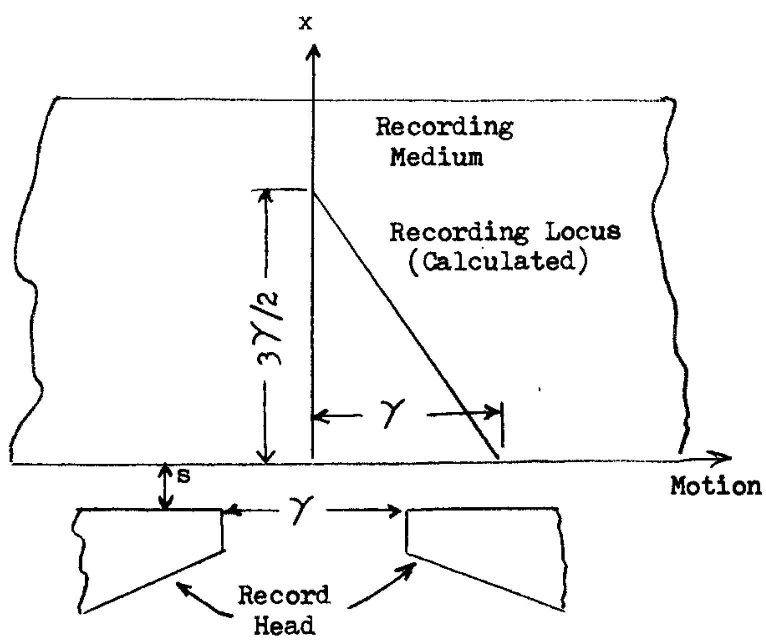

Fig-3. Recording Geometry
(Calculated from data)

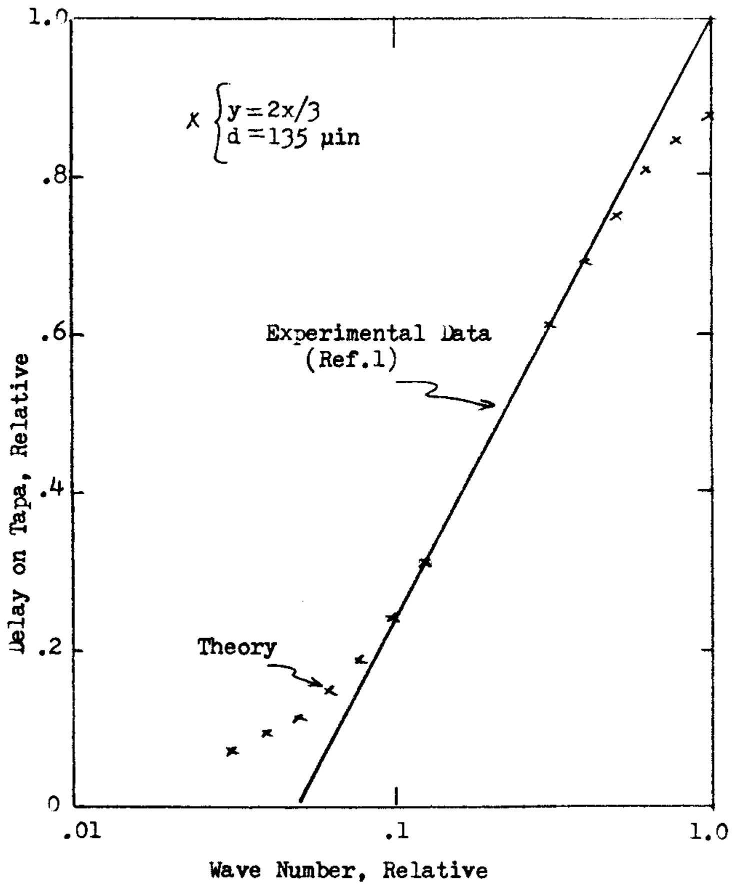

Fig. 2. Experimental Data from Ref.1, and Comparison with Theory

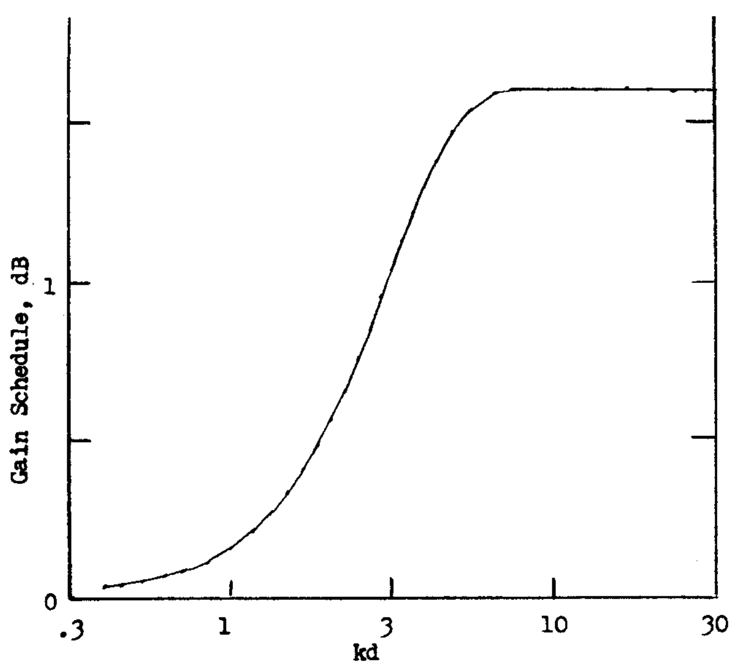

Fig. 4. Post Emphasis Schedule for the Phase Function