HEAD ALIGNMENT

With Visible Magnetic Tracks

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IT IS REASONABLY OBVIOUS that, in order to obtain optimum results in magnetic recording on tape, it is necessary to align the recording and reproducing head gaps to a certain degree of parallelism. In order that tapes recorded on one machine may be reproduced on another without loss of high frequencies, it is necessary that the gaps be made perpendicular to the edge of the tape. An easy technique has been developed to obtain these alignments which seems to be worth calling to the attention of audio engineers.

The first order approximation for amplitude loss due to skewed gaps is reviewed, and a technique for microscopic examination of the recorded track is described.

Theory of Alignment

Schott[1] first discussed the effect of nonparallel gaps in magnetic recording, although certainly the equivalent situation in photograph recording received prior attention. Imagine a line gap which is within an angle α of being exactly perpendicular to the motion of the tape. It is possible to compute the ratio of the voltage induced in a misaligned head to the voltage induced in a perfectly aligned head. The calculation, given in the appendix, leads to the following result.

$$E_{\alpha_{max}} / E_{0_{max}} = \frac{\sin\beta}{\beta}$$

where $\beta \cong \pi\alpha\, d/\lambda$

The width of the tape is denoted by d and the wavelength on the tape by λ.

From these equations we may predict a decrease in output for a misaligned head which is greater, the greater the gap length d, the greater the angle α and the smaller the wavelength λ. *Fig.* 1 illustrates the effect to be expected for certain practical values of these constants.

Table 1 shows the values from which *Fig.* 1 was plotted.

From a plot such as this, values for other wavelengths and gap lengths may be obtained readily. For instance, the effect of doubling d is the same as doubling α, while doubling λ is equivalent to halving the angle α. *Table II* lists the value of α required to give certain attenuations for various values of d and λ in use today.

If we assume that a given method of slit alignment will assure accuracy of perpendicularity to within an angle of plus or minus δ, the alignment which assures interchangeability of tapes between machines is obviously

TABLE I

	d = 0.1″	λ = .001″
α	Sin β/β	db Loss
2′	.993	.07
4′	.978	.18
10′	.865	1.3
20′	.531	5.5
30′	.141	17
34.5′	0	∞

δ = α′/2 where α′ is the angle for the permissible attenuation. From *Table II* it is seen that δ for 1 db attenuation must be less than 4′ 30″ in cases 1 and 2, less than 3′ 36″ in case 3, and less than 2′ 15″ in case 4. For constancy of reproduction to within 0.5 db, these values of δ are not halved but multiplied by 2/3, since the curve of *Fig.* 1 is not linear.

A method is described in the following section which allows for adjustment of alignment to within a half db in cases 1, 2, and probably 3; to within 1 db in cases 1, 2, and 3, and probably case 4.

Microscopic Technique

Visual examination of the track recorded on magnetic tape may be carried out in a manner analogous to the mapping of magnetic fields by means of iron filings. Using suspensions in ethyl acrylate of Fe_2O_3 particles about 1 micron in diameter, Bitter[2] obtained the first pictures of the domain pattern on a ferromagnetic surface. A similar method has been used before to make the pattern associated with

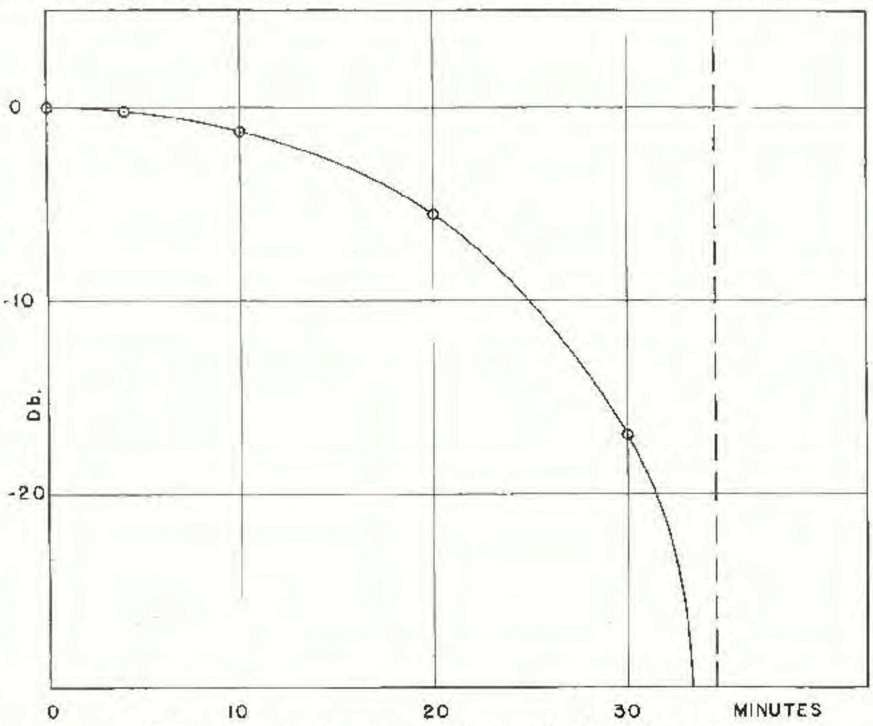

Fig. 1. Db loss versus α in minutes of Arc. d = 0.1 inch, λ = 0.001 inch.

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[1]Z. Techn. Physik 17, 275 (1936).

[2]F. Bitter, Physical Review 41, 507 (1932)

the track on magnetic tape visible. The process consists simply of covering the surface of a magnetic tape recorded to saturation with an oil suspension of Carbonyl Iron particles. There appears, almost at once, a series of straight lines at right angles to the length of the tape which is visible to the naked eye. Photomicrographs of typical patterns are shown in *Fig.* 2. Wavelengths as short as 0.001 inches have been examined where the alternating poles are one-half mil apart.

The materials used for producing a visible pattern of the recorded signal on magnetic tape vary. Black magnetic oxide of iron, gamma ferric oxide, or iron powder may be used. These should be very fine particles, 3 microns or less, and dispersed in a liquid which does not evaporate readily and which has a sufficiently high viscosity to prevent flocculation. Flocculation, to any great extent, interferes with the sharpness of the lines and consequently with the accuracy of the measurements. The powder selected should give as much color contrast as possible with the tape being used. Carbonyl Iron of about 3 microns diameter made by General Aniline Company, Grasselli, New Jersey, having a grey color which reflects light well, has given very satisfactory results when mixed with raw linseed oil or a mineral oil such as "Nujol".

Using this method of making the track visible, the process of alignment of magnetic recording heads is as follows: A saturated signal of one mil wavelength is recorded on the tape. A portion of the tape is covered with the oil suspension of Carbonyl Iron and examined by means of a microscope provided with cross hairs and a rotating stage in order to determine whether or not the lines corresponding to the recorded track are perpendicular to the edge of the tape. Adjustment of the head, recording and microscopic examination of the track are repeated until the track is aligned within the desired angle.

Once the recorded track is correctly oriented, the recording head is obviously aligned. To adjust the reproducing head, a long recording is made at the highest frequency the system is designed to produce. A meter is connected to the output of the system and, using the long recording, the reproducing head is adjusted to give maximum output. From the theory of misalignment, it is apparent that the greatest sensitivity for adjustment is found at the shortest wavelength.

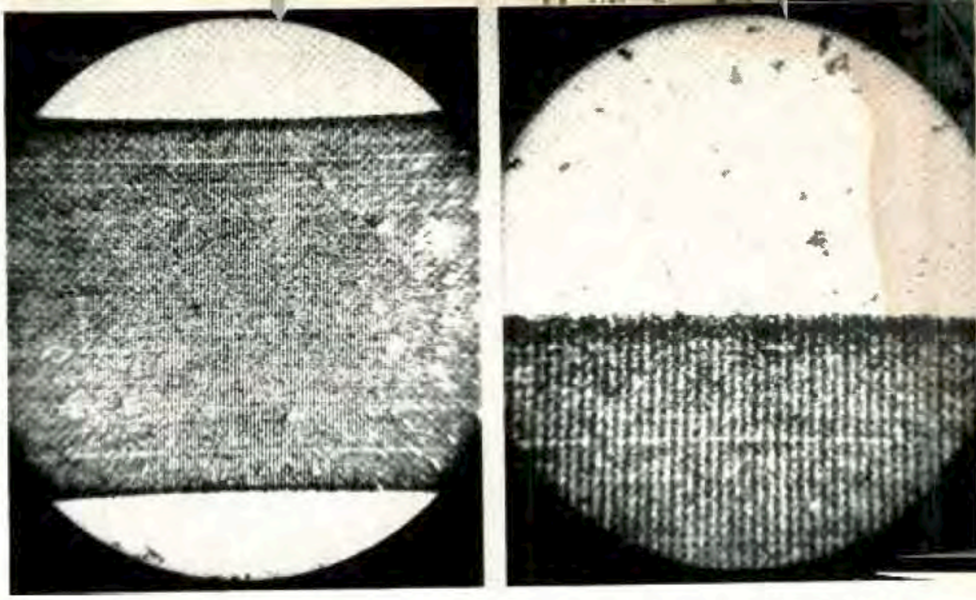

Fig. 2. 0.0023 inch wavelength signal at magnifications of about 20X and 60X.

We were required to align a set of heads which fitted the conditions of Case 1, *Table II*. The microscope used was provided with a carefully centered rotating stage and a vernier attachment graduated to 03′. A 28 mm. objective and a 12.5X eyepiece gave ample magnification. The stage was shifted until the horizontal cross-hair fell on the track edge, then the vertical cross-hair was used to measure the angle of the recorded pole[3].

TABLE II

Case	d	λ	f in cps	V in./sec.	α′ for 1 db att.	α′ for .5 db att.
1	0.1″	.001″	7500	7½″	09′	06′
2	0.2	.002	9000	18″	09′	06′
3	0.25	.002	15000	30″	07′ 12″	04′ 48″
4	0.25	.00125	12000	15″	4′ 30″	3′ 06″

If pains are taken to make the length of the tape parallel to one of the motions of the stage, then the stage motion at right angles may be used to follow the track across the tape. The alignment can then be checked by observing the fraction of a track width that the tape is misaligned. Knowing this, the wavelength and width of the track, the angle of misalignment may be computed.

Centering the track edge in the field avoids the "pincushion" effect so apparent in *Figure 2a*. With this equipment it was relatively easy to obtain track perpendicularity to less than 0°03′.

For measuring the angularity of the recorded signal, a magnification of about 30 to 40 times is all that is necessary. A greater magnification than this leaves such a short part of the recorded signal in the field of view that accuracy of measurement is reduced.

The visual examination of the track not only provides a means of aligning tape, but also reveals peculiarities in head construction. In *Fig.* 2 for example, there appear streaks along the length of the recording. Gaps between laminations will show up in such a manner, but will be much more pronounced. In one instance the gap of the record head was made as small as possible by removing the foil. Upon examining the track recorder from this head, it was found that each lam-

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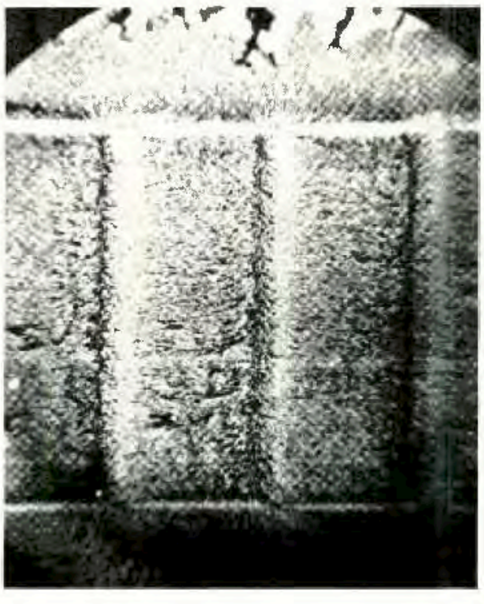
Fig.3. 92 mil wavelength signal, magnified approximately 20 times.



[3]Instruments such as the Gaentner Coordinate Comparator, which may be adjusted to a smaller angle, 01′, might also be used. Some limitation on the method is imposed by slight imperfections along the edge of the tape and by lack of definition of the track.

side service organizations equipped to do so.

As in allied electrical sciences, it is reasonable to expect that minimum performance standards and accepted measurement techniques eventually will be forthcoming in the motion-picture field. Until then, however, the logical course for the television station staffs is to maintain their sound-film projectors obtainable through repeated checks, using procedures similar to those outlined.

REFERENCES

1. RMA Standard #TR-105-A Sept. 15, 1947
2. 16-mm & 35-mm Test Films (a publ.) by Motion Picture Research Council and Society of Motion Picture Engineers, 342 Madison Avenue, New York City
3. F. Durst and E. J. Shortt: "Characteristics of Film Reproducer Systems," J. SMPE (Feb., 1939) p. 169
4. Research Council Basic Sound Committee: "Discussion of Magnetic Recording," J. SMPE (Jan., 1947) pp. 52-53
5. Standard Electrical Characteristics for Theatre Sound Systems, (a technical publ.) by Motion Picture Research Council. April 20, 1948

Magnetic Recording Head

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ination was acting individually so that there were as many tracks as there were laminations. Offset laminations also show up in a striking manner. Some notion of the fringing effect at the edge of the gap may be obtained by looking at long wavelengths. There is shown in Fig. 3 a 92 mil wavelength track where fringing is in evidence. It should be noted that in order to obtain clear tracks, a fairly strong signal must be recorded on the tape.

In conclusion, the authors wish to express their thanks to the management of Minnesota Mining & Manufacturing Company for permission to publish this material.

Appendix—Theory of Alignment

Schott's attack on the effect of nonparallel gaps in magnetic recording is essentially as follows:

For simplicity, assume a line gap and further suppose the flux intercepted by the reproducing head to be the sum of the induction in the tape under each increment of the gap length.

Let a tape whose length lies in the y direction be recorded with an induction B varying sinusoidally such that

$$dE = C \sin \frac{2\pi y}{\lambda} dx; \quad \text{for } \frac{-d}{2} \leq x \leq +\frac{d}{2}$$

which expresses the fact that the induction is uniform from —d/2 to +

d/2 in the X direction. Let the reproducing gap make an angle α with the X-axis. Any element dX of the gap will, therefore contribute to the flux pickup in the head an amount

$$d\theta_\alpha = C \sin \frac{2\pi}{\lambda}(y - X \tan\alpha)\, dX$$

where

$$\frac{2\pi X \tan\alpha}{\lambda}$$

represents the phase angle of the flux at X resulting from misalignment.

The total flux pickup is then given by

$$\theta_\alpha = C \int_{-d/2}^{+d/2} \sin \frac{2\pi}{\lambda}(y - X \tan\alpha)\, dX$$

or

$$\theta_\alpha = Cd \frac{\sin\beta}{\beta} \frac{\sin 2\pi Y}{\lambda}$$

where

$$\beta = \pi d \tan\alpha / \lambda \qquad (1)$$

Substituting $y = Vt$, where V is the constant tape velocity and t is time, we may calculate the voltage developed in n turns of the pickup winding.

$$E_\alpha = -n \frac{d\theta_\alpha}{dt} = C'd \cdot \frac{2\pi V}{\lambda} \frac{\sin\beta}{\beta} \cos \frac{2\pi Vt}{\lambda}$$

The peak value of $E\alpha$ occurs when

$$\cos \frac{2\pi Vt}{\lambda} = 1$$

or

$$E_{\alpha_{max}} = C'd \frac{2\pi V}{\lambda} \frac{\sin\beta}{\beta}$$

For a perfectly aligned gap

$$\alpha = 0,\ \beta = 0 \quad \text{and} \quad E_{0_{max}} = C'd \frac{2\pi V}{\lambda}$$

or the fractional decrease in voltage may be written as:

$$E_{\alpha_{max}} / E_{0_{max}} = \frac{\sin\beta}{\beta} \qquad (2)$$

For small values of α

$$\alpha: \quad \beta \cong \pi\alpha\, d/\lambda \qquad (3)$$