AMPEX

MAGNETIC TAPE TRENDS

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RECORDING THEORY AND TECHNIQUES AS APPLIED TO TAPE

PART I - AUDIO

In keeping with the over-all theme and intent of the TRENDS series, the next group of four articles will discuss the basic magnetic recording theory behind audio, video, instrumentation, and computer techniques and factor the exact role of tape into each of these discussions. Although the use and appearance of magnetic tape is known to many, a true understanding of its exact operation is held by few.

We will begin with audio; subsequent issues of TRENDS will be published on video, instrumentation, and computer.

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ACTUAL RECORDING PROCESS

The phenomenon of magnetic recording is possible because of the nature and characteristics of flux leakage in the vicinity of the recording head gap. (Strictly speaking, this is flux fringing and not "leakage".) The flux in the head is established by, and is proportional to the input signal current flowing through the head windings.

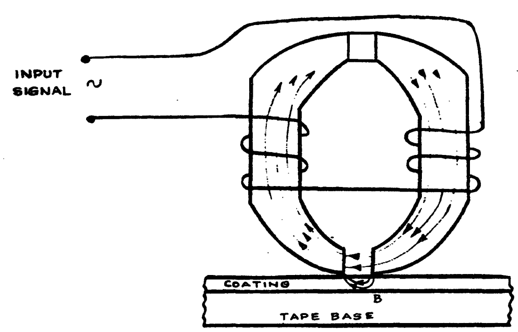

FIGURE 1. RECORD HEAD

The flux leakage penetrates the magnetic coating of the tape as it is pulled past the heads. This penetration sets up a magnetic field within the magnetic coating and causes the individual magnetic domains to assume this pattern, or to line themselves up with the lines of force. Remember, the individual particles do not change their physical orientation

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because they are set permanently in the binder. It is their flux pattern that changes and lines up with influencing field. Longitudinally oriented tape has all particles lined up in the longitudinal direction of the tape. Each individual particle may be considered a separate domain because of its physical size (approximately 8 x 25 microinches), and it maintains a very small magnetic charge at all times. Unrecorded tape consists of many, many domains possessing individual magnetic charges, the net charge of which is virtually zero. This is depicted in Fig. 2.

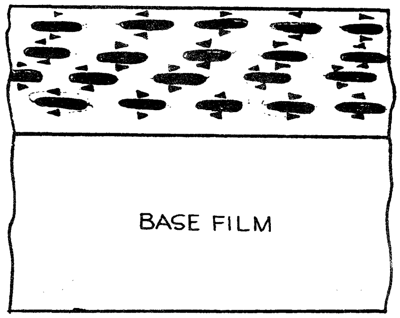

FIGURE 2. NO SIGNAL ON TAPE

Although each domain (particle) has a slight magnetic induction and associated field or flux pattern, the net result of all the domains is essentially a zero magnetic induction. As the tape moves past the head, the flux leakage pattern from the record gap extends into the region of the domains (Fig. 3) and coerces the domains to increase their magnetic induction to a value proportional to the gap flux pattern.

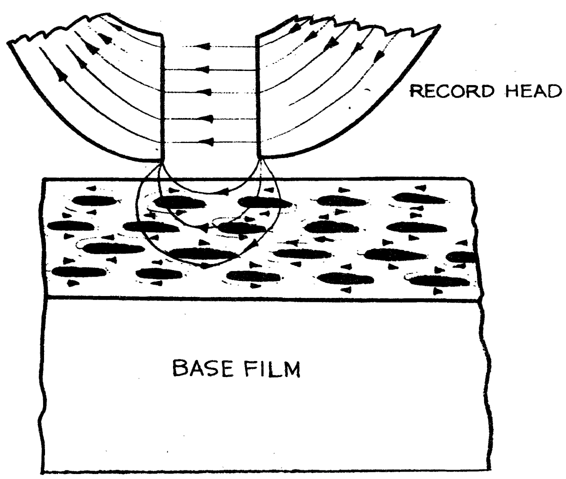

FIGURE 3. RECORD GAP FLUX PATTERN PENETRATING TAPE COATING

Each individual domain (particle) then assumes a given magnetic induction which, when combined with the magnetic inductions of all other particles influenced by the same flux pattern of the head, gives a resultant net magnetic pattern that is proportional to the magnetizing field intensity existing throughout the region of influence of the gap.

As this particular group of domains leaves the influence of the record gap flux, each domain "remembers" or continues to hold the magnetic flux pattern corresponding to the last remaining record gap flux line exerting an influence.

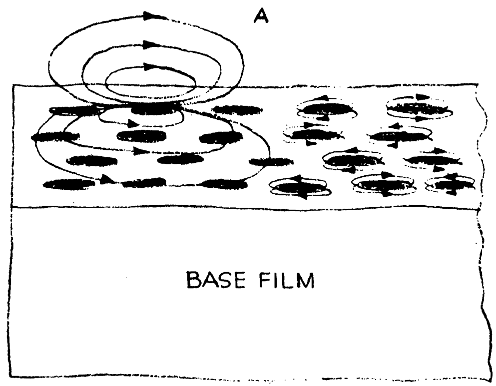

FIGURE 4. RESULTANT FLUX PATTERN OF RECORDED SIGNAL

The net pattern retained by the system of domains (oxide particles) will have a magnitude and direction that is a function of the magnetizing field that existed at the instant the tape left the region of influence of the record gap. This explains why the trailing edge of the record gap is the most effective region in the recording process.

* * *

PLAYBACK

Playback is essentially the reverse of recording. The recorded tape has a magnetic field that extends above the surface of the tape (point A, Fig. 4) as a result of the net magnetism retained by the domains (particles). As the tape is transported past the playback head, this field enters the gap and sets up a magnetic induction inside the head that generates a voltage in the head windings proportional to the rate of change of flux (magnetic induction).

To sum up, the input signal is fed into the record head windings as a current. This fluctuating current creates a varying magnetic induction inside the head (point A, Fig. 1). As these flux lines "jump" the gap, a certain portion of them leak out and set up the flux leakage (fringing) pattern (point B, Fig. 1). As the tape is transported past the heads and through this field, a magnetic field is induced in the tape. In playback, the tape with its external field is pulled across the heads and the magnetic field fills the gap and induces flux in the head which in turn creates a voltage in the playback head windings.

From the previous discussion on the recording process, it is obvious that a quality tape must have high quality magnetic oxide that is properly processed and dispersed uniformly in the binder system to give satisfactory performance. This is simply one parameter of many that must be carefully controlled to produce quality tape. To understand the other areas where constituent variables have a marked effect on performance, let's briefly look into biasing techniques.

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BIAS

Recording on magnetic tape was impractical until proper biasing techniques were developed. Magnetic tape must be biased for the same reason that vacuum tubes are biased because of non-linearity performance characteristics. The transfer characteristics of magnetic tape are shown in Fig. 5.

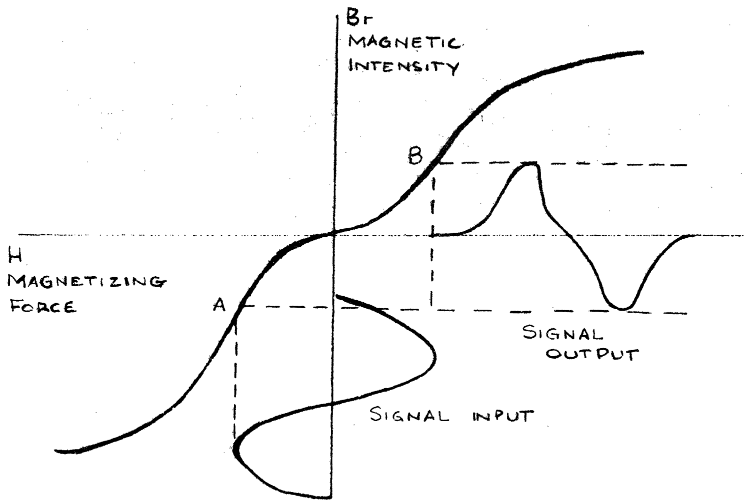

FIGURE 5. TRANSFER CHARACTERISTIC WITHOUT BIAS

The input signal contains excessive distortion on playback (signal output) because the tape is being operated over non-linear portions of its "BH" curve (points A to B in Fig. 5).

The output fidelity may be increased substantially by limiting the operation to a more linear portion of the "BH" curve (points C to D in Fig. 6). This may be accomplished by adding DC bias.

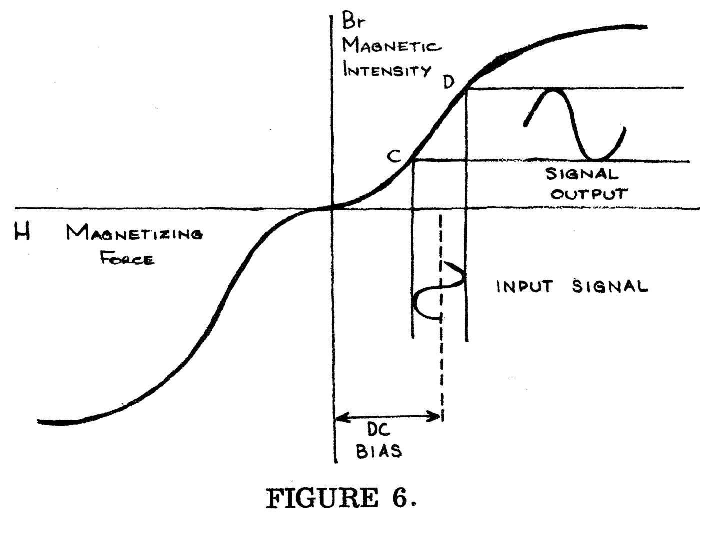

FIGURE 6.

The input signal is now operating above and below (i.e., superimposed on the DC level) the pre-set bias instead of operating above and below the zero bias level as in Fig. 5.

Many inexpensive tape recorders use DC bias. The main disadvantage is the noise and distortion introduced by this method of biasing. Proper AC biasing will limit operation to the more linear portions of the BH curve without introducing excessive noise or distortion. This operation is shown graphically in Fig. 7.

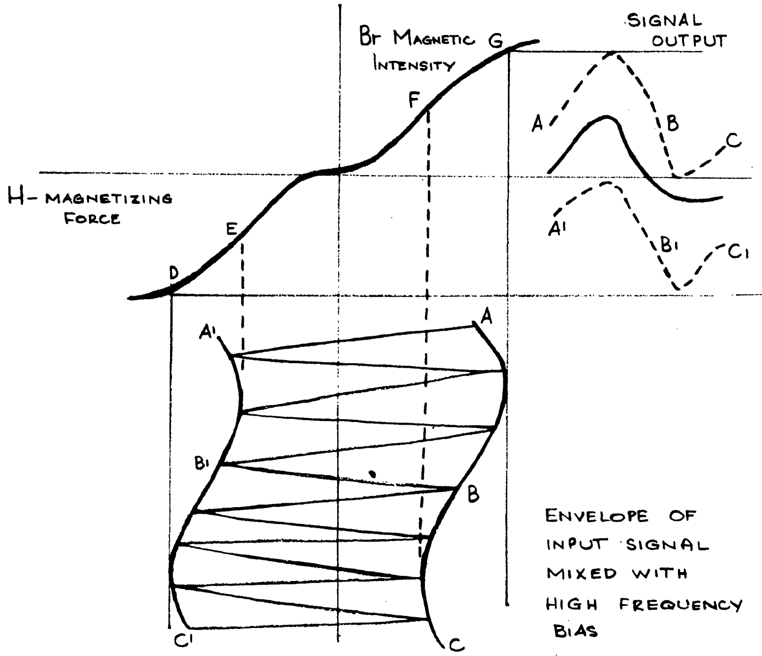

FIGURE 7.

AC bias is a high frequency (usually four to five times the maximum signal frequency to be recorded) and generally has a greater amplitude. The resulting envelope as seen in Fig. 7 now utilizes the more linear portions of the B-H curve, D-E, and F-G. This method of biasing is most efficient and enables the full utilization of the linear portions of the B-H curve without introducing excess noise or undue distortion. All quality audio recorders use AC biasing.

Once again we see that premium tape must contain only the highest quality elements to deliver proper performance.

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GENERAL

Obviously the previous discussion has merely touched the surface of the magnetic recording phenomenon and details have been omitted. The main purpose, however, was to provide a little background to assist in understanding the role that magnetic tape plays in the process.

An important point to remember is that virtually all the recording and reproducing is done on the surface of the tape. The thickness of the oxide coating (0.40 mil average) is required solely for low frequencies or long wavelengths. Because all the work is performed right at the tape's surface, the importance of a perfect surface is obvious. Excellent tape-to-head contact must be maintained at all times to insure satisfactory performance. If a tape is pulled away from the head by a nodule or surface imperfection, the signal is affected as follows:

$$\text{Signal loss (db)} = \frac{55d}{\lambda}$$

where: d = tape-to-head separation
λ = wavelength

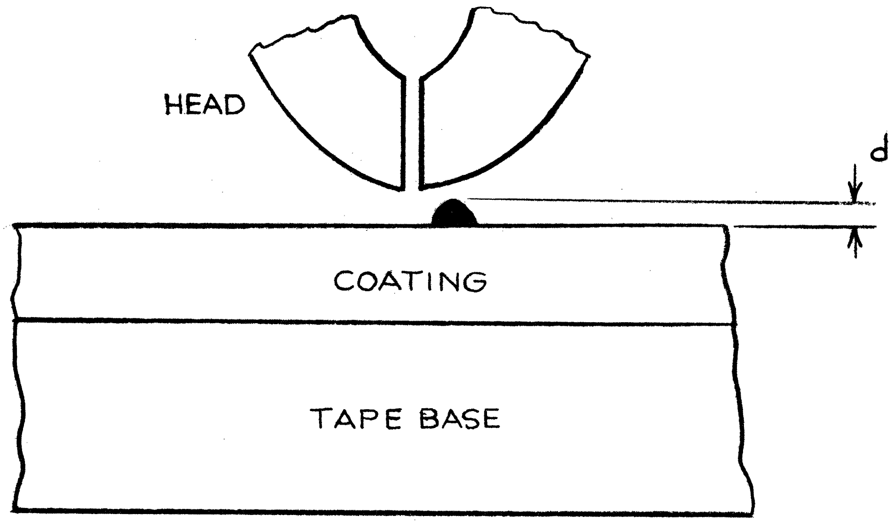

FIGURE 8. SEPARATION LOSS

Example: if freq. = 10 kc
and tape speed = 7.5 ips
then λ = 0.75 mils because, tape speed = freq. x wavelength.

If there is a bump on the tape surface measuring 50 microinches
then

$$\text{signal loss} = \frac{(55)\ (50 \times 10^{-6})}{0.75 \times 10^{-3}} = \underline{\underline{2.75\ \text{db}}}$$

To understand the importance of tape surface uniformity, the previous example illustrated that a 50 microinch irregularity reduced the playback signal almost 3 db. Incidentally, the average size of a particle of cigarette smoke is 25 microinches in diameter!

This explains why some tapes will not deliver their maximum output until after they have been run for ten or twenty passes, and the surface has been "worn in".

Surface characteristics of magnetic tapes are also important in considering head wear. Tape TRENDS No. 6 discussed in detail the relationship between head wear and tape surface.

Because tape is the recording medium, virtually all recording system malfunctions manifest themselves as apparent tape problems. For instance, excess edge shed may be the result of misaligned guides or pressure pads. Poor guiding and skew will show up as tape output variations. Other common machine problems are WOW, FLUTTER, and DRIFT, which are the results of instantaneous tape speed variation. FLUTTER denotes speed variations occurring at frequencies above 10 cps. WOW includes those between 0.5 and 10 cps, and DRIFT covers frequencies below 0.5 cps. For audio applications, obviously FLUTTER and WOW are more important than the sophisticated DRIFT.

A common question is, "I have a high quality audio recorder and since all audio tapes are about the same, what difference does it make whether I use a medium or high quality tape?" The performance of any tape recorder is solely dependent upon the tape used. We have already discussed the importance of tape surfaces. Of equal importance are the additional parameters such as oxide uniformity, coating and dispersion uniformity, binder formulations, quality slitting, and uniform base film. Because there is no industry standard for magnetic tape, it is most difficult and almost impossible to evaluate different tapes by comparing their respective published specifications. Each tape manufacturer offers a wide line of audio tapes from the top of the line, mastering, on down to white box. White box tape is the cheapest tape available. It is factory reject tape, usually downgraded computer tape that is re-slit to 1/4". It has no guaranteed specifications and should be avoided if any degree of performance is desired.

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This edition has dealt primarily with audio, but many concepts were introduced that will be used in later "TRENDS" written for instrumentation, computer, and video.

George F. Armes
3 April 1964