# All about tape recorder bias

*Modern biasing techniques continue to improve audio fidelity*

by **NORMAN H. CROWHURST**

THE FACT THAT TAPE SPEEDS AND CORRESPONDING FIDELITY achieved by off-the-shelf equipment today would have been considered impossible a decade or so ago testifies that changes have been occurring in both tape and tape recording. The variety of changes has led to some confusion, and sometimes to failure to achieve expected performance. To clarify the whole situation, let's examine the purpose and needs of high-frequency bias.

### Original need for high-frequency bias

Every text on tape recording explains this. Without high-frequency bias, the waveform recorded was highly distorted because of the inherent nonlinearity of magnetic materials. The initial effect of high-frequency bias, before considering all the other factors, is twofold:

1. It saturates the tape at high frequency and virtually "demagnetizes" the material, leaving the instantaneous value of the audio waveform virtually free of this nonlinear distortion (Fig. 1).
2. It enables a wider recording gap to be used than would be possible without this high-frequency bias. This achieves deeper penetration of the magnetization into the tape, particularly at high frequencies where gap dimensions are important (Fig. 2).

### Kinds of tape

In the early days, it was pretty remarkable that we could put a ferrous oxide onto a plastic base that would take magnetization at all. In those days, control of molecular size and the magnetic properties of the material was a long way off. By today's standards, the product was crude, although this was not easy to see, because magnetic properties and molecular size are not visible to the naked eye or even under any ordinary microscope.

In tnis article, we'll not get into chemistry and methods of preparing and applying magnetic material to tape. That's a specialist's job, and it's enough that we can go out and buy a whole variety of tapes. But modern techniques permit the production of material with smaller molecular structure, enabling more miniscule "magnets" to be formed on the tape. Also, magnetic properties have been changed, so "better" magnets can be made.

The quality of a magnetic material is reflected in its hysteresis loop, which is what happens as it passes through a whole cycle of magnetization. Three properties are of importance in any magnetic application: saturation density, remanence and coercivity. These are illustrated in Fig. 3.

These quantities are all relative, and vary from material to material. But taking the sequence relative to the parameters of one particular material, as magnetization is applied, the magnetism induced in the material responds slowly at first (region A). Then it rises much more rapidly (region B), until it reaches saturation (region C).

When this magnetization is removed, much of the magnetism remains (point D), and the amount remaining is known as the *remanence* of the material. At first sight, this would appear to be what gets left on the tape when making a recording—or the maximum level, at least. But this ignores the fact that the tape must leave the magnetizing head and transfer this magnetism to a playback head before it can be considered to have done its job.

This means that, unless this remanence is accompanied by another property called *coercivity*, it won't do much good. So modern tapes are rated on their coercivity. Note that coercivity is also related to the magnetization that has to be applied in the first place to reach saturation. The steep rise (region B) approaching saturation is not reached until the magnetizing force approaching the material's coercivity is neared.

So improvements in magnetic material have advanced through coercivity changes, while at the same time diminishing molecular size, so smaller magnets can be formed that will hold their magnetization through playback. Saturation density and remanence have both been increased somewhat, but coercivity and molecular size have been the important changes.

Early materials had what today would be called low coercivity. In turn, this meant that a lower bias current would push them to saturation. It also meant they were more subject to precise values of bias current.

At lower frequencies (up to, say, 1000 Hz) increasing bias current reduced distortion up to a point of diminishing returns. Actually, the loss that occurs with too much bias current at these audio frequencies is a loss of output, rather than an increase in distortion. But at higher frequencies the

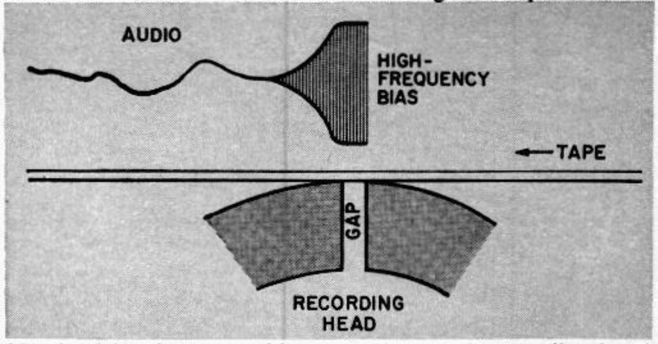



**Fig. 1—High frequency bias,** superimposed on audio signal, "demagnetizes" tape to instantaneous audio waveform value.

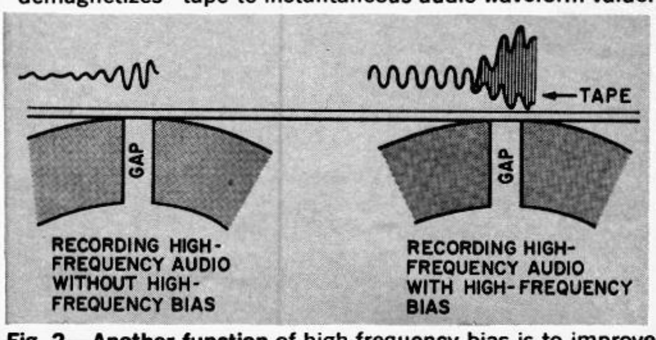
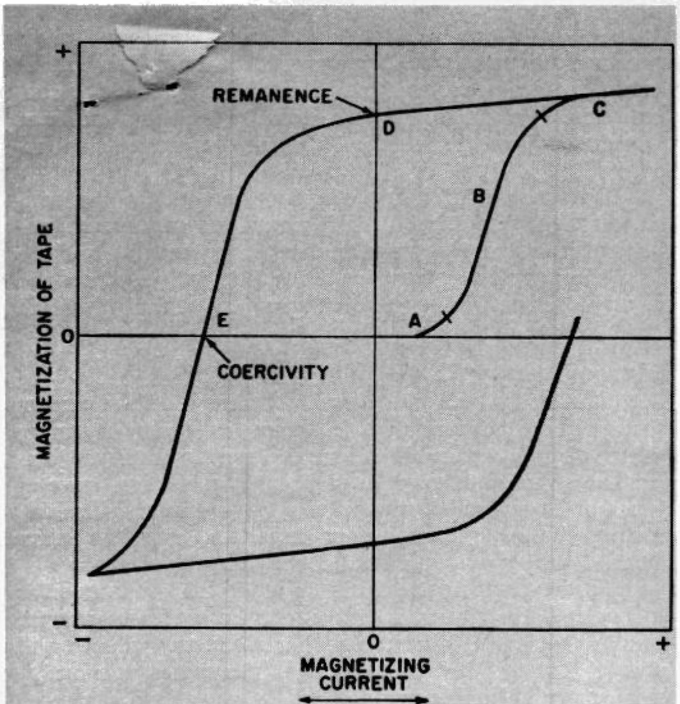



**Fig. 2—Another function** of high-frequency bias is to improve high-frequency response, even with a wider recording gap.



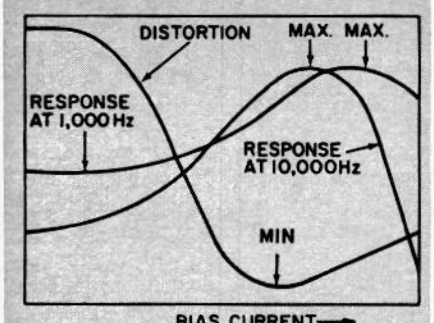




**Fig. 3—Opening** magnetizing cycle shows essential features of a magnetic substance in a hysteresis loop.

**Fig. 4—Optimum** bias for low mid-range distortion is inconsistent with good high-frequency response in low-coercivity tape.

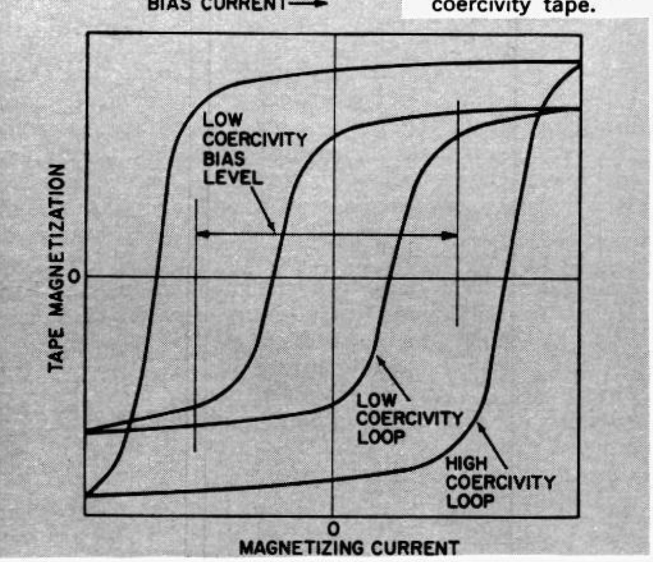



**Fig. 5—Hysteresis loops** of low- and high-coercivity tapes, showing the different bias levels needed for magnetization.

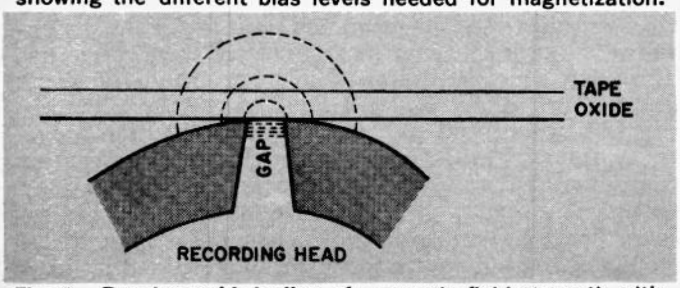



**Fig. 6—Due to rapid decline** of magnetic field strength with distance, the magnetizing field may not penetrate oxide layer.

loss of output begins at a much lower bias current.

At the bias frequency and tape speed, combined with the gap dimensions, several periods of bias oscillation occur while the tape is passing the gap. Recording occurs as the tape leaves the gap. At upper audio frequencies to be recorded, loss would occur in the absence of high-frequency bias because gap width is commensurate with the audio wavelength being recorded.

Thus at the higher audio frequencies, the frequency being recorded begins to behave in a manner similar to the bias magnetization. Because of this, too much bias current reduces the "headroom" for recording these upper audio frequencies.

So it happens, with low-coercivity tapes, that optimum bias for reducing distortion at mid-range frequencies does not coincide with optimum bias for achieving high-frequency response (Fig. 4). As good quality is usually defined in terms of both low distortion *and* good high-frequency response, a compromise bias setting was usually chosen such that neither distortion nor high-frequency response suffered too much.

Then, came high-coercivity tapes. Larger bias currents are needed to saturate them and to utilize the higher coercivity. For a first-time recording, the quality may be as good as with low-coercivity tapes, but unless bias current or erase current is raised from the value that suits the low-coercivity tapes, it will be impossible to reuse high-coercivity tapes because they will not fully erase.

This is shown by comparing the properties of the two kinds of tape (Fig. 5). A bias current that will easily saturate a low-coercivity tape does not even approach saturation in the high-coercivity tape. Conversely, if a head is set to saturate high-coercivity tape, it will considerably oversaturate low-coercivity tape if it should ever be used on the same recorder, resulting in considerable loss of performance.

This means that any good recorder should be adjusted to work with a specific tape or type of tape (similar types from different manufacturers could be used) and then always used with that type. This applies particularly to recording. Playback is not so critical. In fact, once the recording is made, it can be played back on any recorder equipped for playing the particular track configuration impressed on the tape.

Using finer playback heads merely insures that a better rendition of what is on the tape is retrieved. The limitation

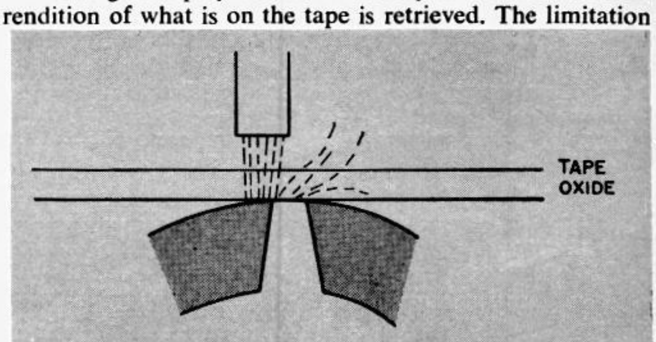



**Fig. 7—Addition of a "back pole"** can change shape of magnetic field through tape in vicinity of head, aiding penetration.

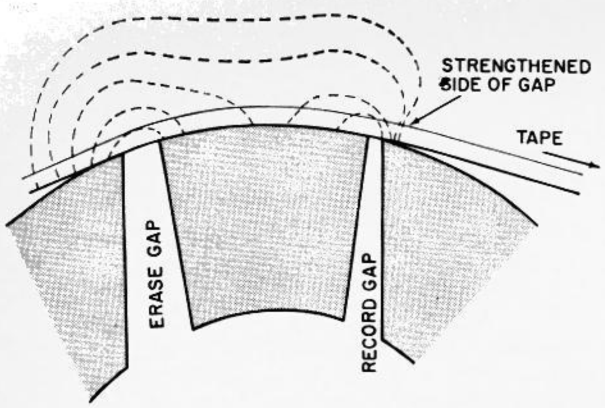



**Fig. 8—Single assembly** combining erase and record heads boosts field near record gap just as extra crossfield pole does.

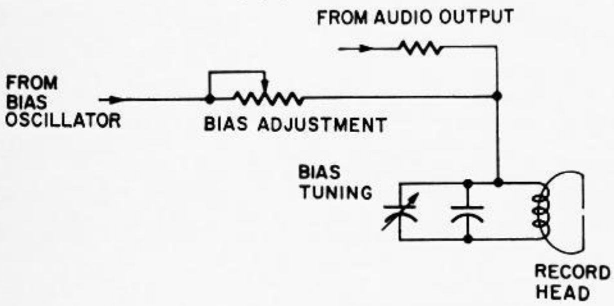



**Fig. 9—Typical setup** for high-frequency bias adjustment. Head bias current is first maximized, then set for tape type.

is the quality of recording on the tape, which comes back to the recording end.

**Cross-field heads**

The quality and intensity of signal on the tape is a function, not only of the input signal into the tape, but of how far into the oxide layer the signal extends. Although the oxide layer is quite thin, it does have finite thickness. Particularly at the high-frequency end, this thickness is an important factor.

Fig. 6 shows the magnetic field in the proximity of a recording gap. It gets rapidly weaker with distance from the gap, which is shown tremendously magnified. So, unless the field is very strong, especially with high-coercivity tape, magnetization may not extend even all the way through the oxide layer. Thus the effect is weakened by a magnetic "short-circuiting effect" of the unmagnetized portion behind the magnetized portion.

To achieve penetration, the important part of the field is the high-frequency bias. If an extra pole is put behind the tape (Fig. 7), the field in the proximity of one pole is strengthened, while the other is correspondingly weakened. The important effect—the part used to effect an improvement—is where the field strength is increased by the crossfield pole.

While the basic concept of an extra head behind the tape is fairly simple, its application could get quite involved: getting the extra head accurately positioned laterally across the tape to coincide correctly with track positions, and longitudinally along the tape so the field takes the correct shape—which cannot be seen, of course.

The tracks are only hundredths of an inch wide, the oxide is only fractions of a thousandth of an inch thick, and the gap width has similar dimensions. So accurate positioning of a head behind the tape requires extremely precise engineering, along with facility for inserting and removing the tape that will not disturb this accuracy.

So a further improvement (Fig. 8) achieves the same purpose by combining the record and erase head in such a way that a leakage field from the erase gap passes through the tape and returns to the record-head gap vicinity in the same way that a crossfield pole would produce. This puts all the engineering problems into a single, fixed block of construction. The needed precision can be built in, and head adjustment is no more critical than in the conventional recorder.

Use of crossfield magnetization does reduce the criticalness of bias adjustment. This means that a recorder, adjusted for optimum performance with one tape, will not be so seriously below optimum performance with another tape as would be the case where ordinary instead of crossfield heads are used.

**Bias adjustments**

The foregoing nas discussed adjustment of bias current for optimum performance in general terms. One more thing is important in all cases: The waveform of the bias oscillator should be good, as close to a perfect sine wave as possible. If the oscillator waveform departs from sinusoidal, it transfers its onlinearity, or departure from sine-wave form, to the program signal recorded.

So the first thing to do in checking bias adjustment is to be sure the waveform is good, whatever the current. Tuning the head inductance with a shunt capacitance will always improve it, as well as get more bias current by using more efficient coupling. But the waveform generated by the oscillator should be good before this improvement is added. It is not sufficient to rely on this method of improvement.

Having made this adjustment, the next step is to adjust the actual bias current to achieve optimum performance with the tape being used (Fig. 9). The method of making this adjustment will vary, according to the recorder facilities. A recorder that has full playback facilities, head and electronics, in addition to the record facilities can use the playback to monitor recording as the adjustments are made.

A recorder which uses the same electronics and/or head for playback as for record must employ a different, somewhat more protracted method of adjustment, but the end objective is the same. In the first, the adjustment is made while watching the playback monitor directly for the desired indication. In the second, a succession of adjustments are made, carefully noting the settings and using voice announcements on the tape to identify them. Then the tape is played back to determine the results. If necessary, a further series is tried, until the optimum is achieved.

Some manufacturers specify a way of adjusting the bias current in terms of output level at a specified high frequency, such as to adjust for a maximum output, then back off by a quarter turn on the adjusting screw, or by so many mA on the bias current reading.

This is a method of approximating ideal overall performance based on setting for maximum high-frequency response, and then modifying it to improve distortion properties.

If you want to actually measure distortion, as well as high-frequency response, you'll need to find a way of making this kind of measurement on tape, which is not so easy as measuring distortion in amplifiers. Fluctuation in level, not large enough to matter, due to variation in tape characteristics along the tape, or fluctuation in speed, insufficient to be significant as flutter or wow, can invalidate conventional distortion measurements that use highly sensitive frequency-selective circuits to eliminate the fundamental.

A method of measurement that is not sensitive to these fluctuations but will detect the forms of distortion sought must be used. The CCIF form of intermodulation distortion measurement detects only second-harmonic distortion. But by using the same basic method, with different test frequencies, the method can be adapted to finding the forms of distortion that are important here, and measuring them independently of small fluctutations in speed or amplitude. These we will describe in a future article. **R-E**