Stereo Scene

By Ralph Hodges

TAPE BIAS AND EQUALIZATION

I RECEIVED a crestfallen note from a reader in Illinois recently. He was upset because his tape deck (an older model) lacked the bias and equalization switches that have proliferated over the past couple of years. Therefore, he felt, he wouldn't be able to experiment with the many new types of tape now available—tapes that inspired the switch facilities to begin with.

Fortunately he was wrong. The absence of the switches would mean a certain inconvenience, to be sure, but a tape recorder's *internal* bias and EQ adjustments are still the best way of matching a machine, as closely as possible, to the particular tape being used. I often wonder when I see the legends NORMAL and SPECIAL (or similar nomenclature) on these switches, just what kind of tape is being referred to. Presumably SPECIAL means the so-called low-noise/high-output formulations, but to suggest that all of them, from their numerous different manufacturers, perform identically is being optimistic.

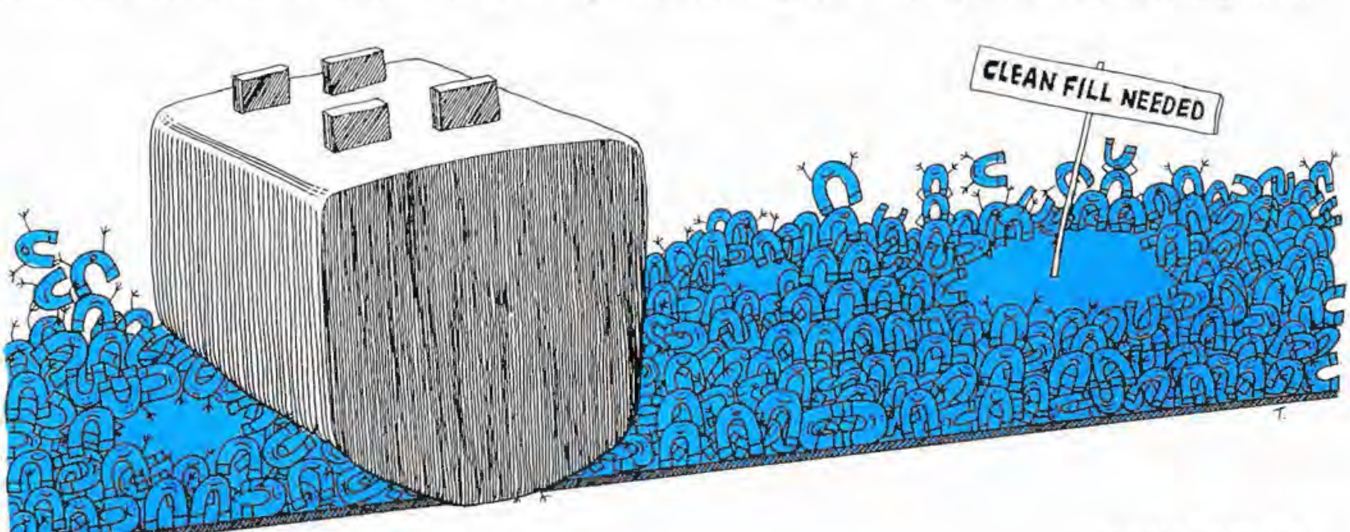
True, chromium-dioxide cassettes tend to be very similar because, with few exceptions, the oxide material all comes from the same source. But the iron oxides applied to open-reel tapes of the low-noise/high-output category are more diverse—so much so that there are evidently tape machines that *can't* be optimally set up for some of them. Not that there are a great many suppliers of such oxides. There aren't! But suppliers do exist in the U.S., Europe, and the Far East, all with products readily available in this country. So far as is possible they are secretive about their manufacturing processes, so differences in oxides and the tapes made with them frequently occur.

Hotter Tapes. Does this mean that when you put a reel of the latest (and "greatest") 1-mil polyester on your machine and casually flip the bias and EQ switches to SPECIAL, you are perhaps not getting the flattest possible frequency response and the lowest noise and distortion. Yes indeed!

The SPECIAL position can only refer to optimum conditions for one particular tape—or at best two or three tapes with highly similar characteristics. For any other tape, it's an approximation, which may or may not be audibly satisfactory. In recognition of this and additional factors, some tape-deck manufacturers still refrain from providing the almost ubiquitous switches. The new $1800 Revox with which I've been amusing myself for the past several weeks, for example, lacks them; but the continuously variable trimmers that can set the bias and EQ much more precisely are accessible (and clearly marked) with the removal of two back panels.

How did these better, "hotter" tapes come about? In general, they started to appear with the high-fidelity boom of the late sixties. The object was to provide tape with better frequency response, less noise and lower distortion. Simplistically put, the reason tape has distortion is that magnetic materials do not really behave linearly, and can be made to do so only with the exercise of considerable ingenuity, and even then with serious limitations. The reason tape has noise (the familiar tape hiss, as well as other noises) is that its surface (the oxide coating) is composed of ground-up bits of magnetic material, and hence is not magnetically or physically smooth. And the reason it doesn't have infinite (for audio purposes) frequency response is that it can't hold onto the very short wavelengths of extremely high frequencies. These closely spaced magnetic poles are neutralized through a number of mechanisms, either right at the moment of recording or later, with the passage of time and use.

Hence, tape manufacturers began a multi-pronged attack on the problems of tape, particularly those of oxide coatings. They worked to make oxides magnetically tougher (higher coercivity), so that they'd be less inclined to relapse from any magnetic state they had been put into. They strove to get the separate oxide particles more uniform in shape and size, and to pack them more densely and smoothly on the tape. The result was tapes with better high-frequency response (in other



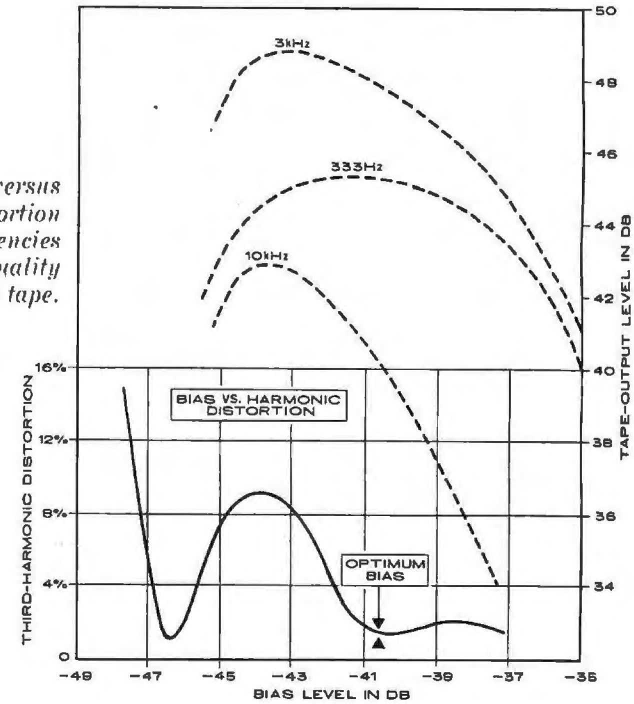
words, hotter), less noise, and higher potential output (since they had a greater concentration of magnetic material per unit area). The result also was tapes that had to be used under somewhat different conditions than the prevailing ones if the most was to be gotten out of them.

Bias. Everyone talks about bias but few seem to truly know anything about it. Bias was discovered long ago in tape's antiquity, when it was learned that the application of a rather strong dc field along with the recording signal served to reduce the distortion of tape and increase its sensitivity. In due time the dc was replaced with ac of very high (ultrasonic) frequency, since the dc bias produced objectionable tape noise. After that, developments in bias were sporadic and concentrated on making it higher in frequency (the Revox's bias oscillator puts out above 1.5 Mhz), less distorted (for instance, an asymmetric bias suggests a dc component, and therefore more noise), and more accurately positioned relative to the point where the recording signal is applied to the tape (the cross-field head technique, for example).

There's still no general agreement as to what these innovations achieved. However, it's unmistakable that bias, pure and simple, does reduce distortion and greatly increase the tape's sensitivity to the recording signal. And at least we can say, with technical accuracy, that it does so by putting the tape into a high state of flux, apparently making it more malleable. Imagine yourself with a stout steel I-beam, intending to sculpt it into a graceful curve for exhibition at some art show. After fruitless efforts with a sledgehammer you resort to a pile driver, which kinks and tortures the metal, and which is difficult to modulate in the intensity of its blows. Finally, it occurs to you to heat the metal almost to the molten state. Then you can approach (in your asbestos suit) and mold it effortlessly into the shape you desire.

This is a very rough analogy, but to carry it a little further, the hotter tapes generally require somewhat more heat (more bias) to achieve "optimum" malleability, and they can usually profit from a stronger molding force (a stronger recording signal). And the hotter a tape gets, the more bias and recording signal it's likely to need, which means readjustment of the tape machine.

Fig. 1. Bias versus harmonic distortion at three frequencies for a high-quality iron-oxide tape.



Bias and Equalization. Recording equalization (EQ) is merely a high-frequency level adjustment, and it is provided in most tape machines simply to complement the *playback* equalization (which should be fixed to conform to the standard NAB characteristics) and to touch up any frequency-response aberrations that things such as the bias adjustment might produce.

To illustrate: the bias signal can partially erase a tape even as it's helping to record it. (In fact, the bias oscillator also drives the erase head—with a much stronger signal.) This erasing potential is first exhibited at the high frequencies. If achieving the desired bias results in a moderate droop at the top end of the frequency response, EQ may then be able to flatten things out, with some cost in signal-to-noise ratio.

The important thing to realize about the EQ adjustment is that it *follows* the bias adjustment, and is in a sense subsidiary to it. Bias is not a fix-it for what you can't or prefer not to achieve with EQ. Certainly you can bring up the high-frequency response of a recording by reducing the bias, but you will also affect distortion and noise, as well as fail to make the most efficient use of the tape. The bias must be correct to begin with; then you can try to effect any repairs needed on frequency response with the EQ.

Setting the Bias. Figure 1 (Memorex MRX_2 curves) shows the way a varying bias affects the sensitivity and distortion of a particular iron-oxide tape. The top of the figure gives the output levels obtained for recording signals of constant strength at three different frequencies. The solid curve near the bottom indicates total harmonic distortion for the 333-Hz signal. (Odd-order harmonic distortion is characteristic of tape, which means that distortion at the lower frequencies is of greatest concern. Any distortion products generated with the 10-kHz signal would all be at 30 kHz or above, and therefore inaudible.) The first thing that happens as bias increases is a precipitous drop in distortion. Then the output of the tape begins to climb—at the higher frequencies first—and so does distortion. Sensitivity nears a maximum at 333 Hz, as distortion meanwhile declines again, along with the tape's output at the higher frequencies. Ultimately an "optimum" bias point is achieved at just over −41 dB.

In this example, optimum bias occurs at a point very close to the conditions for highest output and lowest distortion at 333 Hz, but that is perhaps more by accident than design. There are other factors to consider, noise being an especially important one. Because a magnetic field obeys an inverse-square law, even a slight variation in distance between the recording-head gap and the tape can significantly affect the field strength impinging on it. And the word "slight" includes the minute surface roughness of a tape, with tiny troughs and bumps that pull and push the tape toward and away from the head face. Referring again to Figure 1, you'll note that optimum bias closely corresponds to the broad peak in the tape's sensitivity at 333 Hz. Small changes in bias strength (as would be caused by tape-surface roughness) will therefore not affect the tape's output much at that frequency. But the 10-kHz curve's slope is quite steep at that bias value, meaning that small bias changes will produce much larger changes in output.

This is the mechanism—or one of them—responsible for drop-outs: momentary signal losses caused by tape-oxide irregularities (Fig. 2). If the tape's surface is consistently irregular and bias is not set at optimum, these drop-outs (or drops up and down) may become the steady susurrus known as modulation noise. The amplitude of the signal on the tape is then being constantly modulated by the tape's oxide-coating aberrations. Naturally, various other interesting types of distortion are also involved.

Drop-out and modulation effects are not as noticeable at 10 kHz as they are at 333 Hz, which is one good reason for biasing near the point where lower-frequency sensitivity changes least with bias. Another is that maximum low-frequency sensitivity implies that the bias field is penetrating down through the full thickness of the tape's oxide coating. (I should say that *particular* tape's oxide coating, since thicknesses vary.) Much low-frequency energy is recorded deep within the oxide layer, provided bias is also present at that depth to facilitate the process. If it is, then the full potential of the tape can theoretically be realized.

For the foregoing two reasons, optimum bias for a tape is not likely to be many decibels away from the value that yields greatest sensitivity at lower frequencies. But with that bit of wisdom, the hard-and-fast rules end. Unless you have a better-equipped lab and a fuller understanding of all the considerations involved than most, you're not going to be able to deduce much more than this about how to bias a tape properly on your own.

What are your other recourses? The tape machine's manufacturer is the first one. His service manual will give the procedure for biasing to the tape he recommends. Usually this involves recording a high-frequency tone, monitoring the playback-head output, and raising the bias to where the output peaks and then beyond, until output falls perhaps 3 or 4 dB (whatever is specified) from its maximum. Note that this is essentially a process of adjusting to a benchmark. Presumably the manufacturer has considered *all* the relevant factors in advance, chosen the best bias for the combination of his machine and his selected tape, and then provided an easy way to home in on it. He doesn't mean to imply (I trust) that a 3-dB or so falling off at 10 kHz results in optimum bias for *any* tape.

The machine's manufacturer may also have some idea of how to bias for other tapes you want to try. But if he doesn't, there's always the manufacturer of the tape himself. Unfortunately, unless you can make some sort of contact with the tape company's engineering staff, the information you get may not be particularly helpful. You might receive reams of literature on why the tape is superior without learning a bit about how to exploit its superiority. Its bias requirements could be identical to those of the tape you have been using, but you might never know. Furthermore, there are factors involving the machine itself. The way the bias field impinges on the tape depends on the configuration of the record head (or the cross-field head, if the machine has one). So another element of confusion is added to the mix.

Minimum-Noise Test. Through the good offices of the Boston Audio Society's newsletter, I recently became aware of a bias-adjusting procedure being used by dbx. It involves adjusting for minimum drop-out and modulation noise and forgetting about everything else. The rationale for this, I suppose, is that improvements in tape have rendered even distortion and frequency-response problems minor in comparison with tape noise. Also, according to dbx, the results achieved through this process typically differ only slightly from what you get with other bias-adjusting schemes.

The dbx approach goes like this. Start recording a 30-Hz steady tone on the tape and use appropriate filters to roll off the playback head's output below 400 Hz and above 4,000. Then just listen. The 30-Hz tone will be removed by the filter setup, so that all you will hear is noise—drop-out noise, which sounds like dull popcorn detonations, and hiss, which sounds more or less like the usual tape malady. Reportedly, by altering the bias, you should be able to locate a fairly precise point that minimizes both these noises. And that is optimum bias.

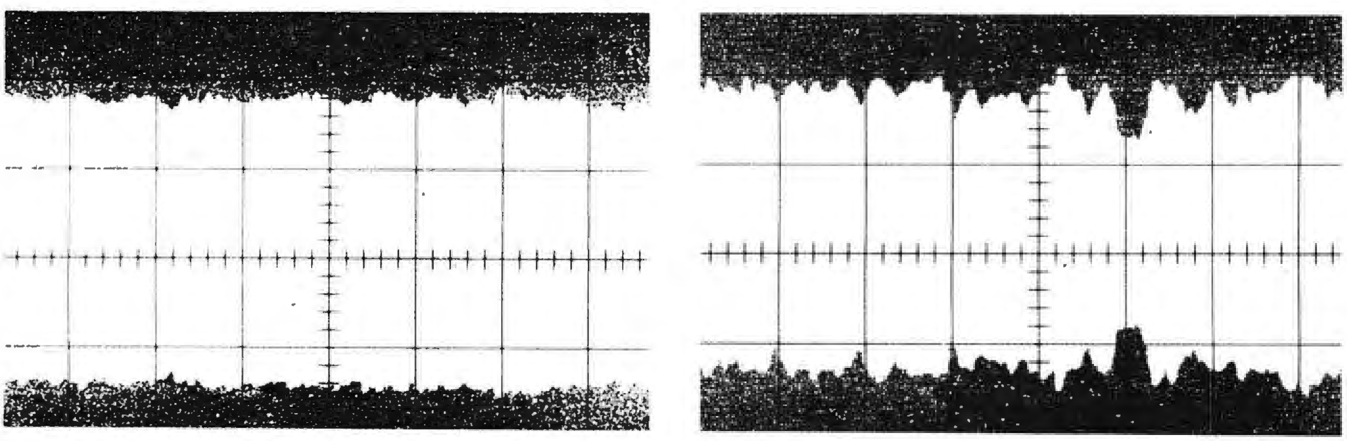


Fig. 2. Oscilloscope photo at left shows playback of a high frequency signal from tape with proper bias. At right is playback of same tape with improper bias. Momentary signal losses can be seen.

As soon as I could, I tried this technique on the Revox A700, starting with the 15-ips speed, since dbx advises that slower speeds are much more problematic with this test. I didn't know what recording level to use for the 30-Hz tone, so I opted for one that made the distortion and modulation effects of the tone (quite audible at low bias settings, even though the tone itself wasn't) effectively disappear at higher bias settings. Then to business, which proved even more difficult than I had expected. One of the problems was that drop-out noises are discrete and random in their occurrence, so that, as I manipulated the bias trimmer, I couldn't be sure if I had minimized them or just found a momentary quiet patch on the tape. Another was that the hiss I heard was composed both of tape and tape-machine noise, and noise from subsequent electronics in the chain (rather high gain settings were necessary for the test). Focussing in on the difference was exasperating.

At last I decided on a setting and, wonder of wonders, it turned out to be just a hair above Revox's recommended adjustment, which is essentially what dbx predicted. However, I'm not at all sure I could repeat it reliably. And when I tried the test at 7½ ips, I was utterly boggled. Even with electrostatic headphones, any decisive clues as to where the trimmer belonged simply eluded me. Perhaps my difficulties lay with the filters, which didn't precisely conform to dbx's specification. I can't say for sure until I try the test again.

Where does this leave us? For obvious reasons, I tend to favor the dbx technique whenever it proves workable. Barring that, you could try to compile the best information from tape and equipment manufacturers and attempt some kind of seat-of-the-pants interpolation. Of course, there's nothing wrong with taking a shot in the dark, aiming at the best compromise between frequency response (adjusted subsequently by EQ) and signal-to-noise ratio, for example. The point is to get results that satisfy your own special requirements, whether you be picky or easy-going. Do not, however, be over-hasty in blaming any new, highly touted tapes when their performance seems to fall short of your standards. It might just be that your machine and its recording environment fall short of *their* standards. ◈