BASF

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The Inventor's Notebook

**TECHNICAL BULLETIN #3**

# BIAS

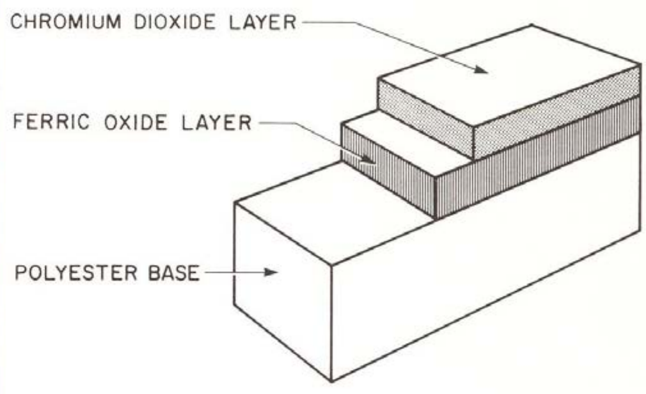
*Terence O'Kelly*

The use of bias in tape recording has become much more widely known as the popularity of cassettes has grown. Bias switches first appeared on cassette decks to provide a bias setting for chromium dioxide tapes when they first appeared in the late 60's. Developments in tape formulation have forced hardware manufacturers to include settings for normal, chrome, ferrochrome, and metal tapes and even, in the most advanced decks, variable bias controls for each type. While bias is widely recognized as important, what it is and what it does are not generally understood.

The benefits provided by the use of a bias signal were discovered by accident in 1940. H .-J. v. Braunmehl and Walter Webe two engineers at AEG, the company that built the first tape recorders in conjunction with BASF, discovered that tapes recorded on a particular machine sounded louder and clearer than ever before. Their examination revealed that the record amplifier in this machine had accidentally gone into oscillation, and this oscillation was aiding the recording process. So they purposely built a high frequency oscillator into the deck to provide a high frequency signal that, when mixed with an audio signal during recording, eliminated a great deal of distortion. This high frequency signal was called the 'bias" signal.

In order to understand how bias helps recording, one must understand the basic recording process. When sound waves strike a microphone, the mic converts the sound waves into electronic signals. These electronic signals are routed through an amplifier, which electronically boosts the signals, to speakers, whose elements vibrate and push air into the same sound waves that struck the microphone. Usually, however, the electronic signals are stored in an intermediate step between mic and amplifier: either as physical grooves in plastic (disc records) or as magnetic prints on tape. The tape is a flexible plastic strip coated with a binder ("glue") that contains trillions of microscopic permanent magnets (about 20 billion per inch; FIG.1). These magnets are needle-shaped particles of iron oxide (rust) or chromium dioxide or tiny strands of pure metal. These needles or strands are suspended in the binder and aligned so that their axes are parallel to the edges of the tape. The positive and negative poles of these tiny magnets have no special arrangement, however, in blank tape. The positiveness and negativeness of the poles is completely random. This randomness means that there is no pattern — and no recorded signal. The poles are arranged into patterns by the signals from the record head that coerce or force the particles to change their magnetic polarity according to the magnetic pattern to be printed. The particles are glued into position and do not physically move; they only change their positive and negative poles.

FIG. 1

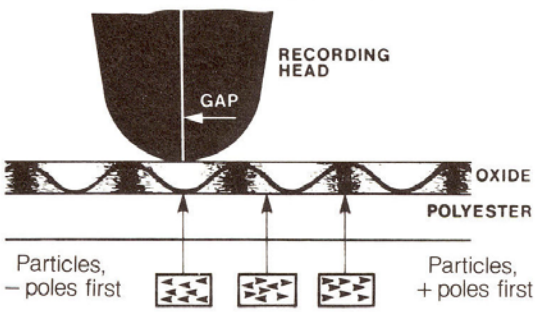



**Ferrichrome tape: two coatings on polyester plastic base.**

The tape recorder is a magnetic printer and reader. The electronic signals sent to it for storage on tape are routed to the record head, which is an electromagnet divided in halves separated by a gap. The signals try to pass from one half of the head to the other; when the tape bridges the gap (FIG.2), the signals cause the head to"print" a magnetic pattern on the tape by magnetically arranging the poles of the particles in a fashion analogous ("analogue recording"*) to the frequency of the electronic audio signal: low or bass frequencies are printed as an arrangement of positive poles together and, a little later on the tape, a group of negative poles together.

FIG. 2

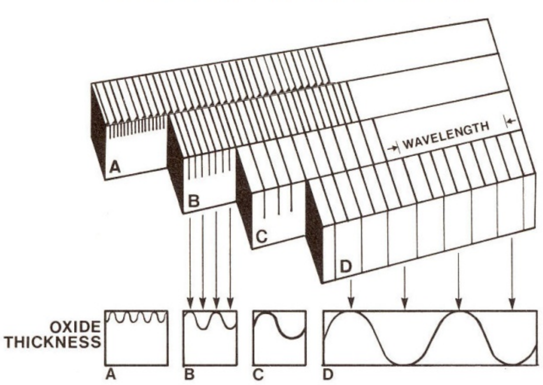
MAGNETIC PRINTING




As frequencies of the electronic signal go higher into the treble region, the distance between the group of positive poles and negative poles becomes closer. Loudness depends on how deeply into the magnetic coating the arrangement penetrates and how many magnets it affects: the deeper it goes and the more magnets arranged, the louder the signal (FIG.3).

FIG. 3

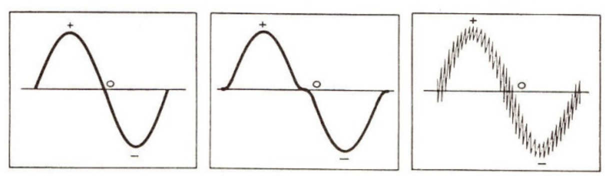
WAVELENGTH ON OXIDE COATING




Playback of recorded signals works in reverse. The magnetic prints from the tape moving past the playback head create an electronic signal in the head, and this signal is amplified and sent to speakers to return as audible sound waves.

The entire record/playback system works amazingly well in that recorded sounds do sound very much like the original sound waves that struck the microphone. There are imperfections in the system, however. The signals sent to the tape head can be represented pictorially as combinations of sine waves. When the cycle passes from a strong positive excursion to a strong negative excursion (or negative to positive) (FIG.4A), it crosses a zero point. When the head is magnetically aligning the poles into patterns, this zero point produces distortion in the head and on the tape because both the head and the tape particles must be driven hard enough magnetically to avoid this distortion. (FIG.4B) The process is somewhat like trying to ride a bicycle at 1/4 m.p.h. — the bike will wobble or "distort." Unless the bike, the head, and the tape are driven hard enough to work properly, they will distort.

FIG. 4

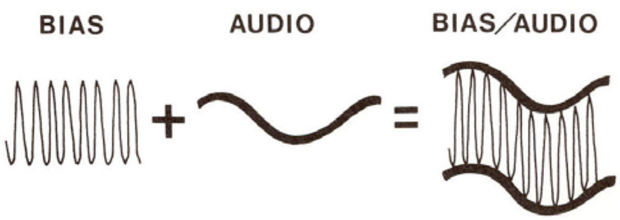



The addition of a bias signal significantly reduces distortion. Bias is merely a high frequency signal (generally five times higher in frequency than the highest signal to be recorded and much higher than anyone could hear; if the deck can record out to 1 5kHz, the bias frequency should be at least 75kHz) mixed with the audio signal (FIG.5) so that, when the audio signal reaches the zero point, the high frequency bias signal is still driving the head and the tape. The bias signal is a pure sine wave; but since it has many more cycles per second, there is always a strong element of bias present to magnetically influence the tape particles when the audio waveform is at a very weak point or even zero. (FIG.4C) The high frequency bias signal is used only during recording to get the prints on the tape properly. Once they are on the tape, bias is not needed. Cassette decks for playback only, such as those used in car stereos, do not have a bias oscillator.

Different tapes need different amounts of bias signal depending on the coercivity of the tape. Coercivity is a measure of the magnetic force needed to coerce or force a particle to switch its magnetic poles for the

FIG. 5

BIAS

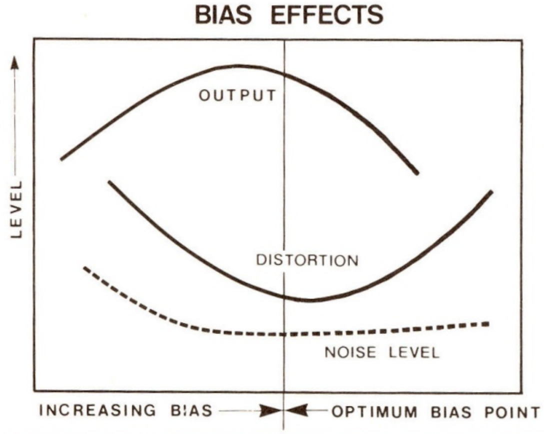



prints. The more coercive a tape, the harder it is to magnetize and the more bias it needs to get the particles to react without distortion. (Increasing bias does not raise its frequency — only its amplitude or strength or ‘loudness” if it could be heard; the frequency stays the same.)

The more difficult it is to magnetize a tape, the more difficult it is to demagnetize it. This difficulty becomes an advantage for high frequency response. Figure 1 shows the different print patterns for different audio frequencies. As the audio signals become higher in frequency, the prints of positive and negative patterns become narrower and closer together and more in danger of erasing each other as the positive prints cancel negative prints. The two ways to preserve the prints would be to separate them farther by speeding up the tape (the open-reel solution) or making the tape more coercive and more difficult for the prints to erase themselves. The chromium dioxide and metal tapes are harder to magnetize and, therefore, have better high frequency response than normal tapes. It is also for this reason that they need more bias than normal tapes in order to be properly magnetized and to minimize distortion.

FIG 6.

BIAS EFFECTS

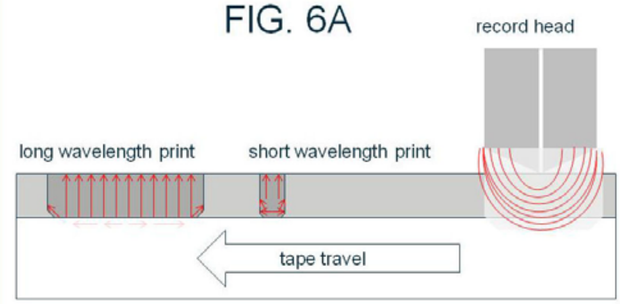



The application of bias to a particular tape can be critical because bias affects not only distortion but output as well. As the bias is increased, the output at a frequency of 315 Hz gradually increases and the distortion decreases. (FIG.6).

The output at a high frequency of 10kHz, for example, will be much more radically affected by changes in bias. Too little bias will increase overall distortion and exaggerate high frequency output because the bias current is not deeply penetrating the tape coating and is favoring the particles nearest the surface of the tape coating — those particles that are responsible for the high frequencies (see FIG.2). Increasing bias beyond the “optimum” point will both reduce overall distortion to a degree and reduce high frequency output because the increased bias moves the high frequency prints too deeply into the magnetic coating to be retrieved on playback. Too much bias will begin to increase overall distortion.

FIG 6A below shows how bias level has such an effect on high frequency response. The reduction in high frequency output with excessive bias levels is due to a combination of particle self-erasure and spacing loss.

FIG. 6A




Spacing loss is a reduction of output due to the thickness of the tape. Magnetic output from short wavelengths is more effective closer to the surface of the tape because the short wavelength patterns deeper in the coating change the direction of their magnetic patterns as they leave the recording area of the record head. Although this is also true for long wavelengths, there is a much greater area of “correctly aligned” flux with the wider and deeper magnetic patterns that long wavelengths produce than the narrow bands that short wavelengths produce. The changed flux patterns deep in the coating tend to cancel each other out until they get closer to the surface.  Decreasing the bias during recording brings more short wavelength magnetic energy closer to the surface and reduces short wavelength loss due to self-erasure, but the bias reduction also reduces the penetration into the coating and results in lower output/higher distortion from the long wavelengths because less pigment is properly magnetized. Increasing bias magnetizes more pigment, up to a point, but also drives the short wavelength prints deeper into the coating and increases self-erasure with a reduction in high frequency output.

The "optimum" bias point is a compromise between low and high frequency output and minimum distortion. Since high frequency output can be controlled somewhat by the recording equalization, setting bias for a reduction of distortion is generally favored over setting bias for flat frequency response. Those cassette decks with adjustable bias and test tones of 400Hz and 8 or 10 or 15 kHz, however, recommend adjusting bias for equal output at the low and the high frequencies. This procedure sets the bias level for flat frequency response rather than for lowering distortion.

When an erase head removes recorded signals, it is being fed the bias signal alone. The erase head is trying to print positive and negative patterns of an extremely high frequency signal, and the positive negative changes are too rapid for the particles to accept in a definite pattern. The erase head, in effect, "randomizes" the particles and removes almost all magnetic print patterns and the signal. There is a minute amount of bias signal left on misaligned or magnetically "maverick" particles. This signal, known as "bias noise," is audible as an extra amount of hiss added to virgin blank tape when it is recorded or erased with an erase head. A bulk demagnetizer will remove bias noise and reduce any hiss to that of virgin blank tape.

A significant advantage of chromium dioxide as a magnetic particle is that its synthetic nature can assure a more uniform size and more precise particle orientation and alignment in the binder. The bias noise, therefore, is usually at least 2.5dB less than ferric oxide tapes or ferric-cobalt "chrome equivalents" at the 70-microsecond equalization setting.

Bias noise of different tapes can be compared by putting a tape deck in the record mode and recording no signal on the tape. When the tapes are monitored, only the hiss will be heard. The tape hiss of chromium dioxide or ferrochrome tapes will be audibly less than that of any other kind of tape.

* "Analogue" comes from two Greek words loosely meaning "word for word," as in a translation. The adjective is a way of describing information in one understandable way analogous to or similar to the actual way. The description is often applied to the use of a "picture for picture" instead of a "word for word" translation. For example, an analogue clock has hands that make a complete circuit in a minute or in an hour or in half a day, depending on which hand it is. The hands continually go around just as the earth turns completely around on its axis in a day. Analogue recordings "draw" an impression of sound waves in the squiggly groove in vinyl records or as variations of magnetic energy in cassette tape. The vinyl records and tape store these "pictures" of the sound patterns and allow them to be played back. The problem with this system is that the information gets mixed up with the flaws of the medium. A clock hand that does not keep up with the other hands gives inaccurate information. Dust in a record groove causes sounds and noises not meant to be heard. Tape imperfections cause hiss that was not part of the original sound.

Digital recording is a method that avoids these flaws. Digital recording does not try to draw or imitate the information that is being saved. Instead, it converts the information into a mathematical code that ignores the flaws of whatever medium is storing the data. To use an analogy, a canvas painting of a landscape records the landscape with all the "flaws" of canvass and paint texture (those "flaws" that make a painting an inaccurate but artistic impression). If oil is spilled on the painting, it is difficult to restore what was there because the oil becomes part of the record. If, however, someone recorded the landscape with a "paint-by-number" scheme in great detail, the oil would not matter. The oil stain had no numbers assigned to it; so the artist could reproduce the landscape by following the number code exactly. The more numbers involved, the more accurate and detailed the reproduction would be—and every copy would be almost identical to the original.

The word" digital" refers to digits or numbers. It comes from the Latin word *digitus*, or "finger," because everyone learns to count on his or her fingers. We have ten fingers, so our common numbering system is to the base 10 and uses ten digits—0 to 9. The mathematical code used in digital recordings is very intricate and needs computer chips to encode and decode; but computers don't have fingers. They have transistors that recognize only two states: on/off (or "0/1," "change/no change," "+/-," etc.). Computer engineers use the binary numbering system for computers, a numbering system to the base 2 that needs only two numbers, 0 and 1, to construct any value.