So You Want An Analog Tape Machine
by Eddie Ciletti

There are two ways to get that analog tape sound. One is to record to analog tape; the other is to simultaneously bounce your digitally recorded to a reel-to-reel tape machine while sending the recorder's output back to your DAW.

Assuming you are using a 3-head deck, the "analog processed" tracks will be delayed by the distance between the record and playback heads as determined by the tape speed. You can easily compensate for this delay by realigning the processed tracks in your DAW. The only 'problem' with this approach is that a tape machine's speed is not as locked as the DAW, so if you want mix digital with analog you may hear a bit if phasing, which is the less exaggerated version of "Flanging."

No Pain, No Gain
No tape recorder that is 20 or more years old can be counted on to be fully functional all the time, no matter how nice it looks. This is why starting with a 2-track stereo machine will be easier and less expensive to maintain and calibrate than a multi-track machine.

There is a remarkable amount of 3rd party support available on the Web, including who are making parts for the most common machines (see the sidebar "Resources"). No matter which track format you choose, the goal is to be able to record with confidence and know that you are getting the best of what analog tape has to offer (unless of course you are *looking* for a "broken" sound).

FORMATS
The first tape machines recording a single track across the full width of ¼-inch tape. Next came stereo – 2-tracks on ¼-inch tape – and that quickly evolved into three and then four tracks on half-inch tape. (Most of the Beatle recordings were made on one-inch four-track tape. A 24-track pro machine uses 2-inch wide tape – that's three tracks per ¼-inch. The semi-pro, narrow-format version squeezes 3 tracks into 1/8-inch of tape! The cassette format is 4 tracks per 1/8-inch of tape, hence the other narrow format options of 8 tracks on ¼-inch and 16 tracks

on ½-inch tape. See **Figure-1** to compare some of the various formats.

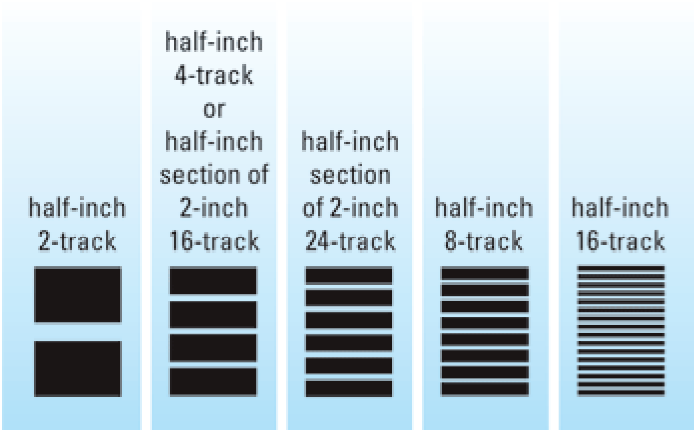

Figure-1: Tape formats at a glance

Whether semi-pro or professional, tape machines seem affordable until maintenance and parts are factored in. You could easily buy a 24 track for under $3k, but each of the three heads may cost in excess of $1500 to replace! Hence the need to learn to DIY as much as possible.

The essential ‘accessories’ for any tape machine include a service manual, a head demagnetizer, a dedicated set of non-magnetic tools and a test tape for playback calibration. A service manual will help you do the simple stuff, whether you’re a geek or not. (Some manuals are actually a treasure trove of information.) At minimum, you’ll need to know how to remove the head assembly so it can be shipped out for evaluation, restoration, and alignment.

Check Your Heads

Heads are *the* wear item on a tape machine, and like brake drums on your car, they need to be resurfaced, contoured, and polished (known as *lapping*) to maintain optimum performance. I can’t emphasize enough that heads in good condition can minimize the more finicky aspects of tape-head alignment.

To do any work in the head area, you will most likely need a hex key set. The recorder's country of origin will determine whether the tools are SAE (USA) or metric (everywhere else). You’ll also want #1 and #2 Philips screwdrivers, preferably in new condition, made from an extra-durable alloy. Screws that are tight will require downward pressure so that the driver does not slip out and damage the screw head or the driver tip.

Know what a pinch roller costs, where to get one, and have a spare. Reel table clamps (for 10.5-inch reels) are becoming scarce, especially for machines like the Tascam MS-16. When the manufacturer cannot supply what you need, eBay is a good place to begin your search.

Basic Maintenance
It's important to have a good visual view of the head area. This is especially true considering the amount of oxide old tapes can shed. For best viewing, the deck should be horizontal. Place a piece of white paper in front of the head stack to reduce glare, so that the entire area is as visible as **Figure-2**. Clean the heads with an alcohol-dampened cotton swab, using 99 percent (anhydrous) isopropyl or denatured alcohol. Do not use rubbing alcohol, which is 30 percent water.

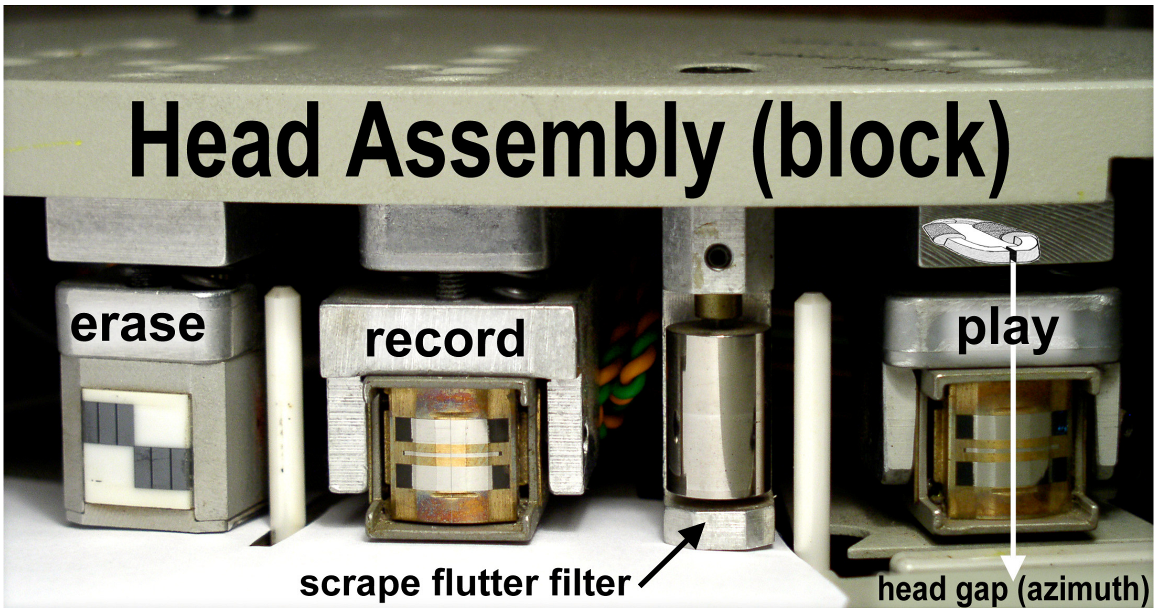

Figure-2: Stereo 'headstack'

Note that pinch rollers can turn gummy due to many factors, not the least of which is age. Whether they are real rubber or synthetic, the pinch - and other rubber-clad rollers such as the tachometer - will react to chemicals in the tape as well as from various cleaning fluids. For this reason I recommend cleaning all "rubber" immediately after a recording project is completed - not when starting one - so that the tape chemicals will not having a chance to be absorbed by, and do damage to, the material. This will make the cleaning process easier, require less chemicals and minimize the aging process.

Because it is likely that you will be buying a new pinch roller, the manufacturer will recommend (and I suggest that you purchase) their product-specific cleaner. For example, Athan's *Pink* cleaning solution is water based, while MDI's *Head, Red & Roll* cleaner (from Precision Motor Works) is a more volatile, quickly evaporating elixir. Both are equally effective at cleaning their respective rubber products and, if applied vice versa, will most likely do no damage. If there is any doubt, consult the manufacturer.

To clean original rubber parts, start with a cloth dampened (not soaked) with a water-based product such as Windex, Fantastik, or Formula 409 (which also works well on ceramic capstan shafts). Wipe a second or third time with a water-dampened cloth to remove any residual dirt and soap. Do not allow liquid to go down into the capstan shaft, or the bearing and motor will be damaged. Avoid using consumer-grade rubber cleaners.

Figure-3: Tape head Demagnetizer

Demagnetize

There is only one head demagnetizer to own, the Annis Han-D-Mag (see **Figure-3**). A demagnetizer with a switch is dangerous and should be discarded or re-purposed to the school science lab. Note that powering a demagnetizer up or down in close proximity to recorders and tapes can do more damage than residual magnetism from the recording process could ever do. If the test / exercise below does not yield results, do not demagnetize your recorder without help from someone experienced in tape-machine maintenance.

All tools should be tested and demagnetized before coming in contact with the heads. If a screwdriver can pick up a razor blade, one or the other is magnetized. (The residual magnetism on the heads is far less and can only be measured with a very sensitive magnetometer.) Plug in the demagnetizer at least three feet away from tools, tapes, and machines, then practice by slowly moving the demagnetizer toward the screwdriver and then slowly away. Do the same with the razor blade and then confirm that the screwdriver can no longer pick up the blade.

Before demagnetizing the heads, the tape machine must be powered down or you'll risk damaging a preamp. Power up the demagnetizer away from the machine, then slowly position it toward the erase head, moving up and down to cover the top and bottom tracks. While maintaining the up and down motion, slowly move the demagnetizer away from one head and toward the next. Also demagnetize the surrounding components—guides and lifters—although these are not typically made of magnetic material.

Check Your Parts

Using a tape machine requires a certain amount of electromechanical awareness. Each component in the recording and playback process—from the iron particles in the tape, to the preamp required by the playback head—contribute noise. For this reason, all tape machines boost treble during record and use an inverse equalization curve when playing back. The standard curves are AES, NAB, and IEC (formerly CCIR).

While some machines have ALL of these options, others have none. You need to know this before buying a test tape. For example, all semi-pro machines are typically fixed for IEC EQ. Pro machines running at 15IPS can be either NAB or IEC and at 30IPS, AES is the standard EQ curve. EQ adjustments compensate for tape, electronic and mechanical variations. The most obvious compatibility issue is a tape recorded on one machine and played on another, but even when a tape "lives" on a single machine, the performance can vary with temperature throughout the day.

ROLLING?

Considering the cost of a test tape, do not attempt a playback calibration until you are sure the machine is operating properly. Here are a few DIY tips to determine whether a machine is in good working order.

Thread up a non-critical tape - one that doesn't need to be baked (see BAKING sidebar) making sure the tape is wound snugly around the reel hub before pressing Play. Careless threading can stretch tape, as well as bend or brake guides, tension arms and rollers.

Before it will do anything, the machine must "recognize" the tape's presence either by using a mechanical arm and a switch or an optical sensor. Some machines have mechanical brakes, while others use an electronic system.

Press Play and pay close attention to how the tape passes through the guides, over the heads, and around the capstan on its way to the take-up reel. There should be minimal up and down tape movement and no tape-edge curling at the guides. (Use reels that are not bent or warped so the tape edge doesn't scrape on the flange. Some manufacturers, such as Otari, provided reel table shims to compensate for reel thickness or poorly adjusted reel table height.

Several mechanical issues can affect and exaggerate tape path problems. The issues are uneven tension on either side of the capstan, how "square" the capstan and other rollers are relative to the deck plate (the surface of the machine), or that a pinch roller has lost its shape. (Shimming the capstan or adjusting anything other than head azimuth is not for the squeamish or impatient.)

Any of these can cause the tape to skew up or down and, when things are really bad, the tape will curl and migrate out of the guides. Consult the manual for tension measuring tools, techniques, and procedures. Fortunately, part of the head lapping process includes a full mechanical alignment of the head assembly.

Quick Record Confirmation. All machines have a mid-band, 1 kHz playback and record level adjustment. Typically, narrow-format machines offer a minimal adjustment range for high-frequency record EQ. Do not use bias to manipulate the record EQ because its purpose is to minimize distortion.

While the tape is stopped, set the machine to monitor input and apply a 1 kHz sine wave, either directly from an oscillator or through a mixer, preferably to all channels at once. (Be sure to disable any built-in or external noise reduction.) At some point, the oscillator's level must be precisely known and set (don't strive for perfection yet). For the moment, make adjustments until the meters read *roughly* 0 VU.

Assuming the deck has three-heads, simultaneous playback during record is possible. Most narrow-format multi-tracks have only erase and record heads, and so monitoring from tape is not possible without first recording and then rewinding. This makes any part of the record alignment procedure a bit tedious and very time consuming.

Put the machine into record and toggle between input and reproduction (playback) to confirm that all switches and relays are reliable. If the meters are not steady, the problem may be electronic - dirty switches and relays - or mechanical (funky tape, poor tape path). Continuing to toggle between modes is an "exercise" that may self-clean the switch or relay contacts (short term). The alternative is to clean the contacts (if possible) or replace the parts.

NOTE: Mechanical VU meters may also be part of the problem, especially if the previous owner loved to bury them in the red. There is a "more transparent" way to get more saturation without slamming the meters, it's called "elevated level" and it's achieved by calibrating the playback tape to something less than 0VU, then increasing the internal record level adjustment to compensate.

FUN KEY

Switch the oscillator to 40 Hz. (This frequency will help you find room nodes - places where the bass builds up or disappears - although headphone monitoring might be more appropriate for this next series of tests.) A 40 Hz tone is great for finding funky pots, switches and relays *PLUS* "tape rocks," the latter being a sign of damaged or used tape, magnetized heads, or bias-oscillator distortion. (Why they're called "rocks" will immediately be obvious.)

One other potential noise source is the scrape flutter **filter (see Figure-2, aka the Head Assembly picture)**, a roller located between the record and playback heads designed to support the tape so it behaves less like a guitar sting. You can easily test it by applying a little bit of finger pressure. If the noise stops, the roller should be removed, disassembled, and lubricated with analog watch oil.

Record 100 Hz, 1 kHz, and 10 kHz tones, flipping between input and repro (playback during record). The tones should be steady, even if not perfectly aligned at 0 VU. If not, check the tape for up and down wandering or curling in the guides, then apply a little "drag" to the supply reel with finger. If that helps, try to localize the problem by gently applying finger pressure to the tape on ether side of the record and then the play head. If the signal level increases or becomes more stable, there may be tension or mechanical alignment issues. The heads may also be worn, in which case they can often be re-lapped.

BIAS is a high-frequency signal that is applied to the erase head and mixed in with the audio signal on its way to the record head. Without bias, only the audio signal's peaks would magnetize and be captured by the magnetic tape particles, resulting in a very distorted recording. With bias, the particles are magnetized and oriented to capture the full dynamic range of the source material.

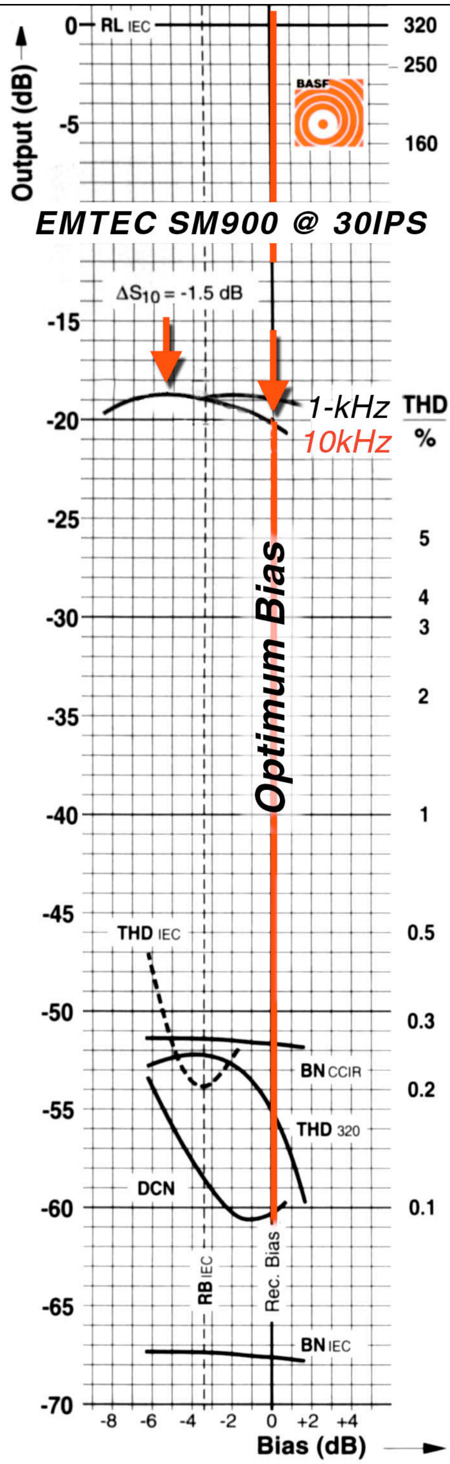

Figure-4: How Bias affects sensitivity at various frequencies, distortion and noise.

BIAS optimizes the tape's sensitivity and minimizes distortion at mid frequencies and below (**see Figure-3**). The optimum bias setting for minimum distortion reduces high frequency sensitivity by a few dB, hence the term "overbias." The recommended amount of over-bias, and the high frequency is used for this adjustment, is machine- and speed-specific, and correlates to the size of the record-head gap (**see Figure-5)**.

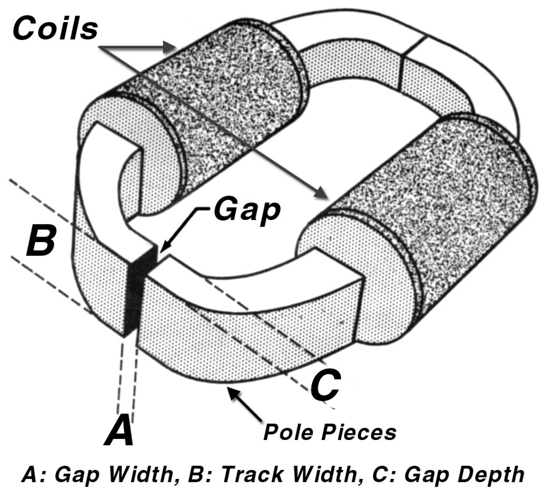

Figure-5: 3D view of key tape head parts

Bias may be adjusted via potentiometer (pot), a variable capacitor or through digital controls. Adjustment location varies with make and model. The earliest tape machines had separate cards for Repro / Sync, Record / Input and Bias / Erase adjustments. Later (and semi pro) machines put all of the adjustments on one card. Access to the adjustments is via doors on pro machines and removable panels on semi-pro machines. Acquire and consult the manual for more details.

TO SET BIAS
Set the machine to Input, apply a 10 kHz sine wave for 15 ips (or 20 kHz for 30 ips), so that the Input Level is 3dB below 0VU. Enter Record and monitor Repro while adjusting the bias control until the signal reaches the maximum level. If the meter pegs, then lower the audio oscillator's output level.

Once the maximum is found, further increase the bias by turning the bias level control clockwise until the signal is reduced by the specified amount as indicated in the manual. For example, is the recommended overbias at 15IPS is 3dB, then continue to increase the bias past he peak until the 10kHz level drops by 3dB. If recording at 30IPS, you may use 20khz and the same amount of overbias OR use 10kHz and overbias by half (1.5dB). Consult a professional if the information on adjusting the bias on your machine is missing from the manual or out of date relative to current tape availability.

Azimuth
Once the recorder is proven safe and functional, it is time to address the routine aspects of tape machine maintenance. The azimuth is perfect when the record and playback heads are perpendicular to the tape and parallel to each other. That’s hard to see with the naked eye, but there are several ways to check it.

Send pink noise from your workstation's multi-function generator to all of your tape machine's channels. Put the machine into record and monitor playback while listening to all channels summed to mono. The noise should sound bright and clear with no swishing. However, if it sounds swishy, then the heads are not in precisely lined up. By applying a wee bit of thumb pressure to the tape, on either side of the heads, you can non-destructively manipulate the azimuth enough to exaggerate this effect.

Keep in mind that we have not yet calibrated the playback, but have been testing other aspects of the machine's performance in order to determine where the bodies are buried. If you've gotten this far then both the machine and your dedicated self are certifiable - that is, safe to play your precious alignment tape. You should now remove all tapes from the area, power down the machine and demagnetize.

Playback Alignment
The remaining user-variable before calibrating the machine is to choose the playback reference level. As tape, heads, and electronics have evolved, so too has the ability to record at higher levels, lowering the noise floor in the process. You don’t have to peg the meters to record loud—they’re expensive to replace. Simply pick an operating level based on the capabilities of your machine and the brand of tape you plan to use on it.

The reference level is specified in nanowebers per meter—185 nW/m was an early popular standard. (A nanoweber is the quantity used to express the magnitude of magnetic flux.) The standard or reference level has changed over the years as tape formulations have improved (by having greater headroom and lower noise). Just as 0VU is a reference (and not the lack of signal) so too is 250nW/m.

Elevated Levels generally increment in 3 dB steps. The level on tape will be referred to as “+x over y” where "+x" refers to the number of dB over the reference level "y." (+3 dB over 185 nWb/m is 250 nWb/m) To avoid confusion, always know and state the reference level: don’t just say "+6."

NOTE: On narrow-format machines, level calibration should be done according to the manufacturer’s specification (using the modern equivalent tape formulation and not a higher output variety). Internal noise reduction reduces the need to hit the tape harder.

Test tapes typically have a 1 kHz tone for checking playback level and a 10 kHz tone for checking high-frequency playback level. (1kHz is in the middle of the audio spectrum and least affected by most anomalies.) Low-frequency response is typically adjusted *after* recording a tone sweep from 250 Hz down to 20 Hz. Because test tapes are recorded full-track mono, do not adjust to the prerecorded low-frequency tones unless they have been "compensated for multi-track reproduction." (Full track tapes will show exaggerated low frequency response when played on a multi-channel machine.)

PLAYBACK AZIMUTH
8kHz and 16 kHz tones are provided for coarse and fine azimuth. This adjustment optimizes the head's high-frequency response and compatibility with other machines. While adjusting azimuth, note any level discrepancies that may exist between 8 and 16 kHz. (10kHz is used to set Playback EQ, the two frequencies on either side can use them to evaluate and ballpark the HF response. See **Figure-6** for the typical adjustment location.)

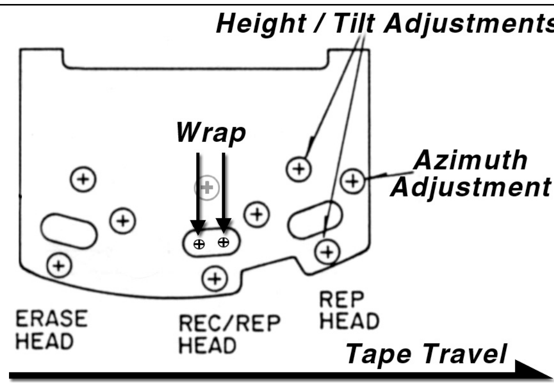

Figure-6: Mechanical adjustment locations on the top of the head block

The playback azimuth adjustment is tricky because the wavelengths of 8 kHz and 16 kHz are so small. (This is why I suggested using pink noise during the record test.) The easiest, most accurate way to adjust Record and Playback head azimuth is by mixing all tracks from the test tape to mono (for Sync and Repro, respectively). The alternative is to route two neighboring tracks to either an oscilloscope or mixer (summing to mono) while monitoring on a VU meter. (Each individual signal should read -6 VU and sum to 0 VU. The false positive will be ever so slightly less.)

Record Alignment

Once the bias is correctly set, the record level can now be adjusted. Set the machine to monitor Input, then apply a 1 kHz tone at the machine's reference level (+4dBu or -10 dBV as required by either XLR or RCA connectors, respectively. This translates to -18dB Full Scale in the digital domain.)

Some machines have an Input Calibrate adjustment that may interact with the Record Level calibration. Enter Record, switch to Repro and adjust record level for 0VU. Check Input and tweak Input Cal if necessary. Once satisfied, set the oscillator for 10kHz, confirm the input is still 0VU, then monitor repro while tweaking he Record EQ adjustment.

Next, on a 3-head deck, record a bass sweep from 250 Hz down to 20 Hz while monitoring repro. Align the low-frequency EQ until peaks and dips fall on equal sides of 0 VU, then select a low frequency that falls on 0 VU. Print that tone to tape and note it on the tape box. Include the bass sweep at the beginning of the tape if it will be used for a mix master.

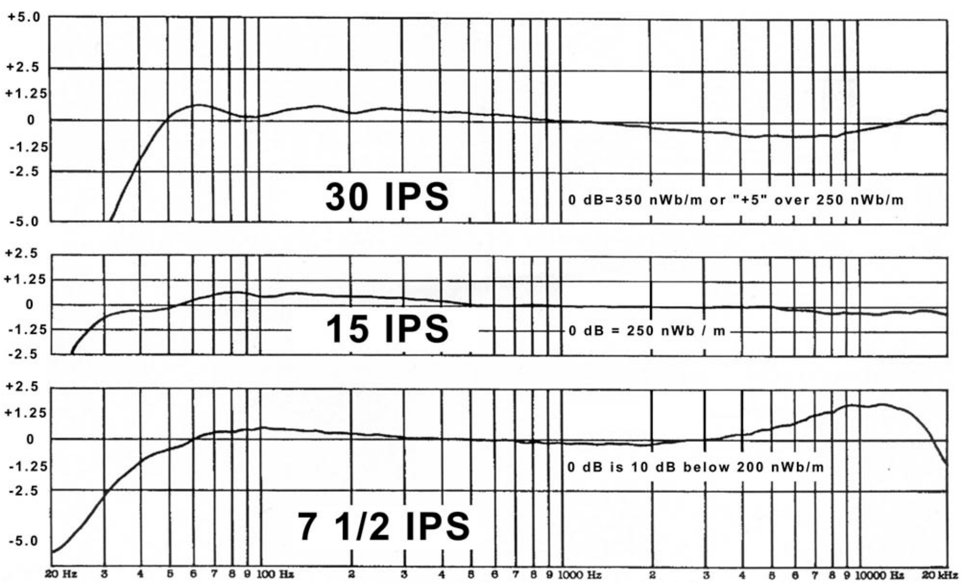

Figure-6: A Studer B-67’s frequency response is different at each of its three speeds. At left are the bass "bumps," all of which are incorrectly adjusted above the 0dB reference.

On a 2-head deck, record the bass sweep then rewind and check playback. Since many narrow format machines have neither a Bass EQ adjustment nor VU meters, all you can do is simply note the frequencies at which there are peaks and dips. Select a low frequency that falls on 0 VU, print that tone to tape, and note it on the tape box. Extreme bumps above 0 VU can case noise reduction mis-tracking, which results in artifacts such as pumping. For ALL machines, having the heads lapped can cure exaggerated bass bumps.

Tape storage: Tail Out

Tapes should be stored as played, which is known as *tail out*. This serves two purposes. As it plays, the tape is packed evenly and smooth so that dust and humidity won't damage the exposed edges.

In addition, louder audio signals will saturate the magnetic particles on the tape, making it easy to magnetize the layers before and after, causing pre- and post-echo. Post-echo is more acceptable and is often masked by the original sound.

Conclusion

Once you've done all the dirty work, it's time to play. For example, record a kick drum while monitoring repro, slowly increasing the record level until you notice saturation. Then, compare the input level - what's being sent ***to*** tape - with what's coming back. (Saturation will affect the observed and perceived levels.) What side of saturation (and sonic nirvana) is your call. Don't forget that, in addition to individual tracks, you can send an entire mix to your "new" analog two track.

SIDEBAR: Baking

The sad reality is that the glue that secures the iron particles to the plastic tape, also known as "The Binder," absorbs moisture over time and eventually becomes more like rubber cement. Tapes with degraded binder will shed their oxide on to stationary surfaces such as heads, guides and lifters.

The good news is that baking the tape at a low temperature (125 degrees F) eliminates the moisture and reactivates the binder. This is done mostly when archiving previously recorded material. It is not recommended for recycling old tape for new projects.

Visit **http://www.tangible-technology.com/tape/baking1.html** for more info.