The Story of AME (Ampex Master Equalization): An Informal History

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0 Introduction

Ampex Master Equalization (AME) was introduced around 1958 with the special variants of the 351 electronics supplied with Ampex 300-3 and 300-4 mastering recorders. AME was designed to reduce tape hiss on playback of magnetic recordings.

1 Background

Ampex machines were designed to use 3M 111-A tape all the way from the model 200 up to the model MR-70. Incredible as it may seem today, 111-A was *the* standard recording tape from 1948 to 1965. 111-A tape was always almost supernaturally uniform. Over these years its response varied less than 0.25 dB year-to-year and 0.5 dB over nearly twenty years. For this reason alone, it remained the professional standard many years after it ceased to be the best recording tape available.

From a user standpoint, the problem with magnetic recording was tape hiss. As vinyl LP records improved, a point was reached where tape hiss was noticeable above the disc noise. This problem was the inspiration for the Dolby Type A noise reduction system (resulting in the formation of Dolby Laboratories in 1965). Some very expensive solutions to the tape noise problem were adopted by some record companies—most notably, the use of 35mm magnetic film. Film base was stiffer than magnetic tape base and thus could accommodate a much thicker magnetic coating. This allowed a significantly higher signal level to be recorded, and while this solved the noise problem, it required equipment that was not only more complex and expensive but the 35mm magnetic film was also very expensive.

2 Attempts to reduce tape hiss using wider tape formats

In the early1960s at Ampex, we developed an experimental recorder we called the model 330. This used one-inch wide tape for three tracks. The tape itself was custom-made with a very heavy oxide and only provided 20 minutes of recording time on a 14-inch reel. This machine actually achieved an honest 80 dB signal-to-noise ratio—at least for the first few plays of the tape. But the oxide shed was so bad that after even just one pass through the head assembly there was debris everywhere. As the oxide was lost, the signal-to-noise ratio diminished[1].

Additionally, the model 330 suffered from the same problem as 35mm film—the cost of the media and the fact that the machine had to be continuously cleaned. At one point we even considered building a vacuum cleaner system into the head assembly. This would not have gone over well in an audio recording studio!

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[1] This machine, which Bob Langevin and I built, turned up in the estate of José Iturbi a few years ago. The performance of the machine was sufficiently good that the recordings he made with it were completely suitable for transfer to release on Compact Disc.

3 The AME curve emerges as a practical way to reduce tape hiss

By the late 1950s, a more practical way to improve apparent signal-to-noise ratio with conventional mastering recorders was already available. This was the Ampex Master Equalization (AME) curve. It was introduced in 1958 with the special variants of the 351 electronics supplied with Ampex 300-3 and 300-4 mastering recorders.

AME was described in a JAES paper by Jay McKnight (see http://mrltapes.com/mcknight_sn-problems-and-a-new-eq.pdf) which was based on research undertaken at Bell Telephone Laboratories in the 1930s (published as Steinberg, "The Stereophonic Sound Film System—Pre- and Post-Equalization of Compandor Systems" SMPE Journal Vol 37, 1941-10 pp 366...379, available for download via the AESHC website).

Using various 15 ips master recordings, Jay built a device that used vacuum diodes to store peak sound-pressure levels[2] in 1/12-octave bands. At the time, he concluded that, based on the sound-pressure distribution in music, it would be safe to boost the recording level in the midrange. Then, on playback, this boosted range could be dipped down and in the process the tape noise would be taken down as well. The range in question was a rather broad one centered around 3 kHz, where the ear is most sensitive. (See http://mrltapes.com/mcknight_peak-energy.pdf.)

While AME seemed an excellent idea when first introduced, two problems diminished its usefulness within a few short years. One problem was changing musical taste; the other the perceived difficulty adjusting AME-equipped recorders in the field.

Classical music generally has a very predictable sound-pressure spectrum. AME worked quite well for these recordings and provided an apparent noise reduction of about 6 dB. But as AME-equipped recorders found their way into recording studios and other venues, most of our customers were no longer recording classical music. Instead, they were using the machines for pop recording, which with its predominance of drums and edgy guitars had high sound pressure in the very frequency range where AME was boosting the record level. This drove the tape into saturation very easily—and this sounded terrible.

The other problem was the perceived difficulty of aligning the machine (which was invariably a multitrack Ampex 300-3 or 300-4). Back in those vacuum-tube days, such machines required more maintenance (increased reliability was one of the main things that "sold" solid-state). Customers found adjusting the AME equalizer difficult and had trouble matching the recording boost with the playback dip to get smooth overall response. All in all, our customers did not find AME to be a practical solution, and I believe that very few recordings were made using it.

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[2] At the time (and in the cited publication), these peak levels were characterized as "peak energy" but this device actually measured peak-power levels, not energy (energy is the time-integral of the power); this correction provided by Jay McKnight in an e-mail to the author on 2021 Sept 18.

The nonstandard recording-level problem and how it hindered progress in noise-reduction

Since I am rambling along here at length I would like to say a word about the Ampex Operating Level[3]. It must be remembered that in the 40s, 50s, 60s and early 70s, we did not actually know how the recording process for magnetic tape worked. We had to treat it as a "black box" and just put in circuitry that made the results come out right. It was not until the middle 70s that Neal Bertram (of the Ampex Research Department) actually worked out in detail the recording process. Jay has recently posted Neal's papers, along with what purports to be a simplified explanation of the rather advanced mathematics involved, on the AESHC website.

In particular, in the 1950s and 60s, we did not know how to measure the absolute flux on magnetic tape. Jay spent a large amount of effort on this problem. More recently, he summarized this in a paper now available at http://mrltapes.com/mcknight_tape-flux-measurement-revisited.pdf.

Notwithstanding the lack of absolute flux measurements, there was still a critical need for a reference standard for recording levels. This was produced by the Ampex Standard Tape Laboratory as follows:

A roll of 3M 111-A tape was carefully burnished by having the tape rub against itself — a procedure used for all alignment tapes and, later, all tapes. Then the ultrasonic bias level was very carefully peaked at a 15-mil wavelength (1 kHz at 15 ips). Finally, a 400 Hz tone was recorded on the tape and the level was increased until the THD reached one percent. This level was designated *Ampex Operating Level*. This precious roll of tape was carefully stored in a temperature-controlled room, and small pieces of it were used periodically to check the calibration of the Standard Tape Laboratory level. Later on, when it became possible to actually measure the magnetic flux on tape, this fluxivity was found to be 185 nWb/m. It was further found that the method used to produce the reference tape in previous years produced very stable results over a number of years.

Nowadays, with improved tape, the standard fluxivity reference level has gone substantially higher than 185 nWb/m.

Now it turns out that with 3M 111-A tape, a tone recorded at Ampex Standard Level and adjusted to read 0 VU is about 10 dB below tape saturation; that is to say tape saturation occurs at about +10 VU. The AME equalization curve consumes about 6 dB of this 10 dB leaving only 4 dB of headroom. As you might imagine, this was totally inadequate for pop music (which in actual practice, was typically over-recorded, without careful attention to tape saturation).

Thus came and went AME.

5 Acknowledgements

Thank you to Jay McKnight, who reviewed this history and recalled important details. And thanks to David Dintenfass for editing this paper.

[3] "*Ampex Operating Level* is technically incorrect because levels are measured in decibels. But that's what they [Ampex] called it, and we can't change that," explained Jay McKnight in an e-mail to the author on 2021 Sept 18.