JOSEF DORNER

From 15 MilliMaxwell to 1,200 NanoWebers

Need an explanation? Here's a look at the evolution of fluxivity and level standards.

AN EYE-CATCHING HEADLINE to attract or confuse the reader? Well, certainly not the latter, because one is often confused enough when trying to understand the data printed on the specification sheets accompanying many tape recorders. We find distortion performance and signal-to-noise ratios referred to 185, 200, 250, or even 370 nWb/m. In some cases, flux values as high as 1,000 and even 1,040 nWb/m are mentioned, while Europeans use such odd values as 320 and 514 nWb/m for reference fluxivity. Where do all these different values come from? Maybe some light can be shed on this matter by looking back into the history of magnetic recording.

A STANDARD IS CREATED

Let's go back about 30 years, to a time when Geman technicians were already talking about a standard tape flux, well before their cohorts on the other side of the Atlantic were. Their definition read something like this: "...for the purpose of program exchange, a reference value for remanent tape magnetization has to be established. When using general purpose tapes, this level shall be approximately 6 dB below maximum output level. *(In reality, the span was only 4 dB at that time—author).* Fortissimo passages shall modulate the tape up to that reference level. This is of importance for the purpose of program exchange. Only in applications where program exchange is not a criterion, modulation up to 3 percent of third-harmonic distortion may be tolerated; this is in order to achieve a higher signal-to-noise ratio and better utilization of the tape. For class 38 (15 ips) the reference level is set to 200 milliMaxwell and for class 19 (7.5 ips) to 160 milliMaxwell." (Draft for DIN 45 513).[1] Remember this dates back to 1955!

In America, all that was known at that time, as far as a recording standard was concerned, was the calibration tape made by a well-known manufacturer of magnetic tape recording equipment (Ampex) with a reference level recorded on it, which was named the "Operating Level." That Operating Level was used to calibrate the VU-meter to obtain a 0 VU deflection. By digging a little deeper, one was able to learn that this Operating Level

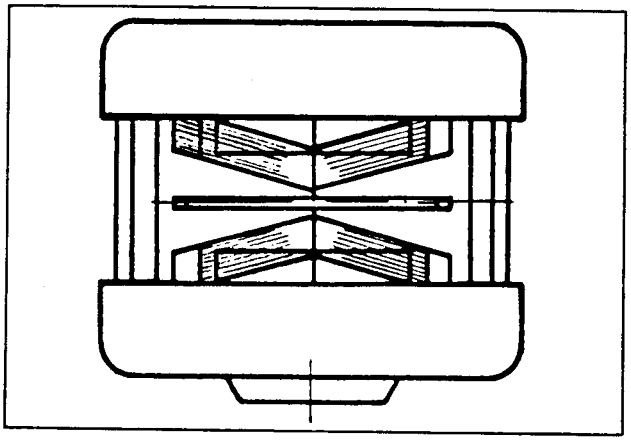

Figure 1. Butterfly Head.

corresponded to 1 percent of third-harmonic distortion on the then most widely used (general purpose) recording tape in the USA.

MOL AND THE VU METER

At this point it may be of interest to note that this general purpose tape produced 3 percent of third-harmonic distortion when it was modulated to a point some 6 dB above Operating Level. Many a studio (particularly some European studios)—where the VU-meter started to make its appearance in the early '60s—may have been misled by this fact to think that a VU-meter has to be operated with a 6 dB lead. By 1966, however, the Deutsche Industrie Normen (DIN) had already recognized that this was not quite correct, because it is stated in the explanatory note accompanying DIN 45 406 that "....on average the lead required is about 8 dB (8 VU). Deviations from this average by ±5 dB, however, are not exceptional."

If one compares this with the old RETMA TR 105 B standard (1951) for Audio Facilities for Broadcasting Systems, one can read the following in section V.2.a: "If a VU-meter is incorporated, it shall remain as normally connected, and its multiplier shall remain set for a signal which is 10 dB below standard output level" (Standard output level is +18 dBm).

Can one not conclude from this that signal peaks, as recorded on tape, produced flux values up to some 8 to 10 dB beyond the 1 percent distortion level, in other words, far in excess of the 3 percent distortion point? Yes, because in 1965 the NAB standard for reel-to-reel recordings has the following to say in a footnote to section 2.04, which relates to the standard reference program level: "It is well established that at least 10 dB margin is required between the sine wave load handling capacity of a system and the level of program material as measured by a standard volume indicator." The NAB standard reference level is described in section 2.03 with a footnote which reads as follows: "The recording was made...at an output level 8 dB below that which produces 3 percent third-harmonic distortion." (This is not contradictory to the above statement because it simply defines a level of tape magnetization which is to serve as a reference.) So, where do we go from here?

THE AMERICAN REFERENCE FLUX

Fortunately, John McKnight in the United States seemed to have been bothered by this lack of a precise value for recorded tape flux. As a consequence, he investigated this situation and prepared his findings for publication in the *Journal of the Audio Engineering Society.*[2] A reference flux of 100 nWb/m is mentioned or suggested in that investigation, and one reads for the first time 210 nWb/m for the earlier discussed Operating Level and 165 nWb/m for the NAB Standard Reference Level. Later on, these values were downward corrected slightly, and from a 1972 data sheet of a manufacturer of calibration tapes, one can read 185 nWb/m for the Operating Level and 150 nWb/m for the NAB Reference Level.

At this point, we should pause to take a closer look at the units of measurement.

UNITS OF MEASUREMENT

NanoWeber-per-meter is the value of fluxivity that would be measured if the tape was 1 meter (or approximately 39⅜ inches wide. Reducing this to a more realistic width, namely 1mm (or 39 mil), the unit became pico-Weber-per-millimeter, which was 0.1 milliMaxwell per millimeter in the days before the ST units came into force. In the case of the NAB Reference Level, the result is 15 mM/mm, which explains one of the values mentioned in the title of this article.

Since we are already doing some calculations, let's look at the previously mentioned German reference of 200 milliMaxwell for ¼-inch tape. If we divide that figure by the metric equivalent of ¼ inch, which is 6.25mm (tapes today are 6.3mm wide), then we get the figure of 32 mM/mm. Converting this to nanoWebers, we arrive at the standard 320 nWb/m.

It may be worth mentioning at this point that in a comparison of U.S. and European levels one must be aware of the fact that the ANSI S 4.6 method of measuring remanent flux yields a value which is lower by 0.8 dB, as compared with a measurement performed in accordance with DIN 45 520. In practice, this means that when comparing calibration tapes of U.S. and European origin, the U.S. tape will yield a higher signal level because what is 200 nWb/m in the U.S. would measure 220 nWb/m in Europe. (This also explains the previously cited downward correction from 165 to 150 nWb/m.)

STEREO-MONO COMPATIBILITY

After this digression into levels and their history, let's continue on. Magnetic oxides were improved over the years, making higher levels of magnetization possible without adversely affecting distortion performance. This made it feasible to raise the operating level (0 VU) to 250 nWb/m for the so-called High Output tapes. In Europe (more precisely in Germany), the advent of stereo made those exacting engineers reach for their slide rules, because stereo/mono level compatibility was their goal. Music productions were already recorded in stereo, yet broadcasts were still in mono. Such a stereo recording, when played back on a full track head, did not produce the same signal level as that which resulted when playing a mono recording; there was some unused, unmagnetized "land" between the stereo tracks, and left and right signals were not adding up ~~correctly~~ algebraically. One can live with reduced cross-talk performance in stereo, so the tracks were widened until they were spaced only 0.75mm apart, making each track 2.75mm wide. As a result of this, the core sections of the head spread out at an angle to accommodate the windings. With this, the Butterfly Head was born (see FIGURE 1).

The tape's width was utilized to a possible maximum, but stereo/mono level compatibility was still not reached. A few quick calculations and one can see that a stereo recording has to be modulated to 514 nWb/m in order to produce the same signal level as that which is obtained from a 320 nWb/m mono recording when playing the stereo tape on a monophonic reproducer.

Total flux, mono on ¼-inch (6.25mm) tape:

$$320\ \text{nWb/m} \times 6.25 = 2000\ \text{nWb/m}$$

Stereo played on full track head:

$$\sqrt{(514\ \text{nWb/m} \times 2.75)^2 + (514 \times 2.75)^2} = 1999\ \text{nW/m}$$

The goal was reached: The fader on the mixing desk did not have to be moved, regardless of whether mono or stereo recordings were played! At the time it was a bit strange, perhaps, to see blank tape appearing on the market which was labelled "stereo," though this simply meant that such a tape could be modulated to the higher stereo level without any increase in distortion.

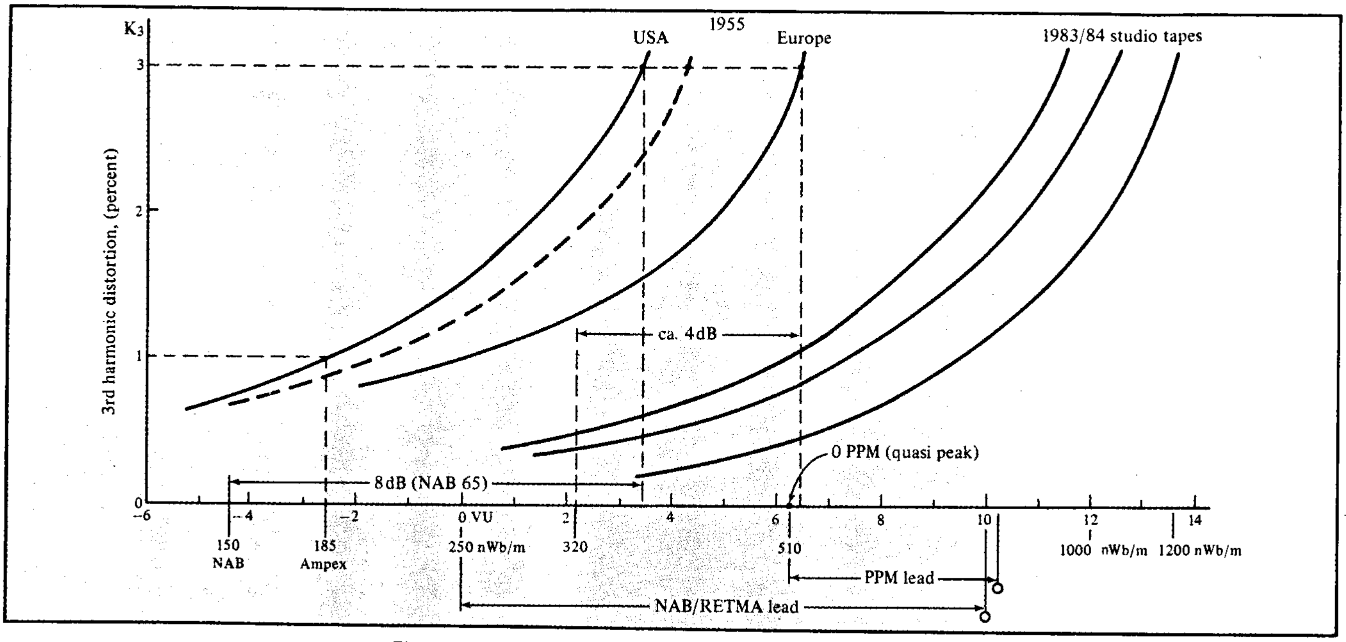

Figure 2. Maximum Output Level (MOL) performance of magnetic recording tapes at 15 ips. O = Theoretical peak flux values when aligning VU meter or PPM as described in text. The dashed line (1955) represents the performance of the old U.S. tape if flux values were measured in accordance with DIN.

Stereo/mono compatibility—which is not of much interest anymore—is thus explained, but what about universal compatibility of recorded levels in general?

VU VS. PPM AND PEAK FLUXIVITY

In America the VU-meter is still favored while in Europe the peak program meter (PPM) is predominant. The performance characteristics of the latter are described and specified in IEC 280-10 and in DIN 45 506. It is a quick-acting meter, and because of this, it is also called a "quasi peak-reading meter." However, as suggested by the word *quasi*, it is not a true peak-indicating device. A closer examination of its characteristic behavior suggests that short modulation peaks may overshoot by 1 to 4 dB.[3]

A graphic presentation (FIGURE 2) of the maximum output level performance (MOL) of various tapes, including the most modern oxides, shows how tape performance has improved over the years. The point of maximum modulation, which is universally considered to be the level at which the third-harmonic distortion content measures 3 percent,[4] has shifted gradually to higher flux values, with 1,200 nWb/m being reached by at least one state-of-the-art tape. This explains the second figure in the title. Quite a wide range from the NAB reference of 150 nWb/m via the high-output operating reference to the German DIN levels for mono and for stereo, up to the MOL which is possible today.

Attempts to establish references of even figures have been repeatedly made. For example, there is the EIA standard RS-400/1972 containing a reference to CCIR 79-1/1966 at which time the value of 100 nWb/m was recommended, and in more recent times, one finds 400 nWb/m mentioned in a newer EIA standard. But all this is of little help to a studio's maintenance engineer when faced with the decision of how he should calibrate his level meters. So, in analyzing this historical retrospect, it comes almost as an automatic conclusion that 250 nWb/m (or even 320 nWb/m) would be a good reference for calibrating a VU-meter to its 0 VU reference deflection, as it would allow the modulation peaks to reach up to 800 or 1,000 nWb/m. In the case of a quasi peak-reading meter or PPM, however, the 510 nWb/m (or 500 for simplicity's sake, being twice 250) would be an equally good reference because its assumed 4 dB overshoot would again result in a peak magnetization in the range of 800 ~~percent~~ nWb/m, still well below the accepted MOL of 3 percent third-harmonic distortion.

It's up to the individual engineer's discretion, of course, as to how hard he intends to drive his tape into saturation. It should be borne in mind, however, that for every dB gained in signal-to-noise, one must pay with a disproportional increase in distortion, a fact which was discovered long ago by a pioneer in the development of new recording techniques.[5]

Analog recording may still be around for a while, and so it is hoped that useful conclusions can be drawn from this article which help to ensure that the inherent quality of analog is not given away unwisely, as may all too often be the case. ■

References

1. Krones, Dr. F. "Herstellung und elektroakustische Eigenschaften der AGFA Magnetbander, Filme und Bezugsbander." *Sonderdruck aus den Forschungsloboratorien der AGFA Leverkusen.* Band I, (Nov. 1955), Seite 304.
2. McKnight, John G. "Absolute Flux and Frequency Response Characteristics in Magnetic Recording." Preprint 447, 31st AES Convention, Oct. 1966. Published in revised form: *Journal of SMPTE* Vol. 78, (June 1969), pp 457-472.
3. Silver, Sidney L. "VU-Meters vs Peak Program Meters." *db* (Jan. 1980), pp 46-49.
4. DIN 45 511, "IEC Draft 94-5." *NAB Magnetic Recording And Reproducing Standards* (1965), Section 2.11: Distortion.
5. Langevin, Robert Z. "Intermodulation Distortion in Tape Recording." *Journal AES* (July 1963), Vol. 11, pp 270-278.