Proposed Equalization For 15 in/s Studio Master Recording on High-output Low-noise Tapes[1]

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A new equalization and reference fluxivity are proposed: no LF pre-emphasis, reproducing HF equalization +3 dB at 6300 Hz ("25 µs") and reference fluxivity of 250 nWb/m. Measured data and a demonstration compare the NAB and proposed performances. Pre-emphasis at 4 kHz is increased from -2 to +1 dB; at 16 kHz, from +1 to +6.5 dB (NAB was +11 dB in 1950, when developed). Noise and maximum signal at 4 kHz are thus reduced 3 dB, and at 16 kHz, 5.5 dB. Recording response with less than a total of 0.5 dB ripple up to 20 kHz is achieved with one RC recording equalizer.

0 INTRODUCTION

The division of pre- and post-emphasis in studio master tape recorders should be chosen: 1) to minimize background noise, while matching the maximum signal spectrum of the subsequent discs, tapes, etc; 2) to have sufficient overload margin at both high- and low-frequencies (HF and LF) when monitoring with traditional flat-response standard volume indicators (SVI); and 3) to be easily equalized to flat overall response, considering the losses inherent in the tape used, when optimally biased.

The present 15 in/s NAB equalization was developed around 1950, and adopted in 1953 June, (was 20 years, now 60 years, ago!), using 3M Type 111 tape. The standardized NAB recorded flux rises 6 dB per octave below 50 Hz, is flat between 50 Hz and 3150 Hz, and falls at 6 dB per octave above 3150 Hz. Typical pre-emphasis in the l950s was +8 dB at 20 Hz, and +11 dB at 16 kHz.

When used with studio tapes of the 1970s (e.g., 3M 206 and Ampex 406), the 15 in/s NAB reproducing equalization standard fails to meet all three criteria; 1) the HF noise spectrum is too high, and so is the HF signal spectrum; 2) LF overload occurs with SVI readings well on scale; and 3) recording equalization is +8 dB at 20 Hz, but a 2 dB droop at 4 kHz, and only +l dB at 16 kHz. This high-frequency response requires two RC networks to remove the response ripples in recording.

Considering these facts, we propose changing to a standard flux response that is flat at LF, with a HF droop from 6300 Hz (25 µs time constant). Measured data compare the NAB and the proposed equalizations. Noise and signal are both reduced 3 dB at 4 kHz, and 5.5dB at 16 kHz; LF pre-emphasis is reduced from +8 dB to 0 dB at 20 Hz; HF pre-emphasis 15 increased from -2 dB to +1 dB at 4 kHz, and from +1 dB to +6.5dB at 16 kHz (compared to +11 dB at 16 kHz in 1950); and 3) this new equalization provides an overall response with less than 0.5 dB ripple up to 20 kHz with one simple RC recording equalizer. A demonstration accompanying the presentation of this paper will show how recordings made with this equalization actually sound.

The proposed recording and reproducing equalizations can be achieved by simple re-adjustment and/or minor modifications of existing equalizers on present master recorders.

1 MATCHING THE SIGNAL SPECTRUM OF COMMERCIAL RECORDS

For a given tape and biasing condition, the ratio of the maximum signal flux at a given wavelength, to the noise flux at that wavelength, is fixed by the characteristics of the tape. But (assuming equalization for flat overall response) the division into recording (pre-emphasis) and reproducing (post-emphasis) will determine whether the high-level high-frequency signal spectrum is of large amplitude, with a concomitant large noise spectrum amplitude; or vice versa. One approach to this division (used by McKnight and Hille [1]) is to consider the signal and noise spectra of the various comrnercial records – that is, mechanical disc records, or tape records on open reels or in cartridges or cassettes. On this basis, the authors conclude that the present NAB equalization at 15 in/s has much too great a high-frequency signal spectrum at high levels, and an excessively large high frequency noise spectrum. We suggested a post-emphasis transition frequency of F = 12 500 Hz (as opposed to the NAB value of 3150 Hz). This would reduce the high frequency saturation signals spectrum and the high frequency noise spectrum both by about 10 dB at 16 kHz.

The noise reduction would of course be welcome. The matter of high frequency headroom in mastering operations is open to question, and will be discussed next.

2 OVERLOAD MARGIN IN STUDIO MASTERING

Audio tape recording frequency response standardization for interchangeability is accomplished by standardizing the recorded flux vs frequency on the tape. Thus all reproducers can be set to the same response, and they will play all tapes properly. The recording equalization is not standardized, but is adjusted so as to produce this standardized recorded flux.

But the recorded flux to be standardized must be found in the first place by measuring the total equalization required (considering the tape used and how it is biased), and by experiments on the compromise between the noise and the distortion produced by using more or lese pre-emphasis [2]. One good practical clue is the experience with existing commonly-used recording equalizations.

The question of low-frequency pre-emphasis has been discussed before [3], with the conclusion that no low-frequency pre-emphasis should be used. In support of this, many recording studios have

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experienced low-frequency overloading problems using the present NAB equalization, which has a low-frequency boost of 3 dB at 50 Hz and 8 dB at 20 Hz. On the other hand, low-frequency noise problems in modern master tape recording are practically unheard of. Therefore, we conclude that the low-frequency pre-emphasis of the present NAB standard should be eliminated.

At high frequencies, noise is always a problem, so that the maximum practical high-frequency pre-emphasis is desirable. But what is "practical" without excessive distortion at high frequencies? FM radio broadcasting uses a high-frequency boost of 6 dB per octave, with a transition frequency (the frequency where the response is +3 dB) of 2200 Hz (response +10 dB at 7 kHz), and complaints of high-frequency distortion because of excessive pre-emphasis are common.

In disc recording and 7.5 in/s tape recording, the pre-emphasis transition frequency typically is F = 3150 Hz (+10 dB at 10 kHz). This is generally felt to be a marginal situation: excellent results may be obtained, but this requires considerable care to avoid high-frequency overloading. For instance, an equalized peak level indicator is very useful, and sometimes high- frequency limiters are used [1]. Furthermore, the intermasters used in tape duplicating are always copies of studio masters; thus, one can always preview the exact levels, and one can always re-do the recording if the commercial copy is found to have excessive distortion. A more conservative approach is obviously necessary for the original studio recordings, where exact levels are not known in advance, and "doing it over" can be extremely expensive.

The recording pre-emphasis used with the 15 in/s NAB standard when it was developed early in the 1950s employed a transition frequency of F = 5000 Hz or above, with an additional lift at higher frequencies to +10 dB at 16 kHz. In studio recording, where recorded levels are monitored with a flat standard volume indicator (vu meter), high-frequency overload problems were uncommon, if not unheard of. Thus a recording transition frequency of 6300 Hz or above, giving less than 5 dB pre-emphasis at 10 kHz, would still be "conservative" for studio mastering.

3 DESIGN OF THE RECORDING EQUALIZER

The third criterion for the tape flux versus frequency to be standardized is that, in combination with the usually-used studio mastering tapes, the required pre-emphasis should be easily generated with a simple equalizer. A common equalizer, and the simplest circuit, is the single RC network.

The usual mastering tape now (in 1973) is 3M 206 or equivalent, such as the Ampex 406. The response of any tape is considerably affected by the biasing current amplitude. Several criteria for "optimum" biasing have been used. The most common in the USA is to adjust the bias current so as to give the maximum recording sensitivity at a long wavelength, say at 1 kHz at 15 in/s. This is generally called "peak bias", or "optimum bias". This bias criterion has the fault that it is difficult to find this point exactly (especially with the shorter recording gap-lengths used with "selective synchronization" systems), plus the fact that this criterion does not result in minimum third harmonic distortion, nor in minimum modulation noise. In other words, it is *not* "optimum" bias at all!

The other biasing criterion, used for instance in the current German Standard on tape testing [4] is derived from that bias which gives minimum modulation noise, which is also close to the point giving minimum distortion. These points come when the bias is increased somewhat over that for maximum recording sensitivity at long wavelengths; it corresponds to an overbias such that the recording sensitivity at 10 kHz and 15 in/s is reduced by approximately 2 dB, depending on the tape being used. This type of overbiasing has long been used in the magnetic film (motion picture) industry in the USA. We recommend this biasing criterion, and have used it for taking the data in this paper[3].

With this tape and biasing, and the NAB-standard post- emphasis, the necessary pre-emphasis for flat overall response will be as shown in Fig. 1, the solid curve. To achieve this response a dual RC network is required; this takes more components, and is usually more difficult to adjust than a single RC network.

If the post-emphasis transition frequency is changed to F = 6300 Hz, the necessary pre-emphasis for flat overall response will be as shown Fig. 1, the dashed curve. This response can be achieved with a single RC network: it is also within the equalizer adjustment range on most professional audio recorders, by removing the "droop shelf", if it is used, and adjusting the existing equalizer.

4 THE PROPOSED EQUALIZATION

In summary, then, we have shown that the flux versus frequency standardized by NAB (reproducing transition frequency 3150 Hz) is not suitable for studio mastering because of the resultant high noise level. The use of a 12 500 Hz transition frequency previously proposed [1] requires too much pre-emphasis for studio mastering, and would probably result in overloading of the tape at high frequencies. The optimum value would be half way – a tape flux with a transition frequency of 6300 Hz. The following would then result:

1) The saturation signal and noise spectra would be as shown in Fig. 2. The tape signal spectrum is still well above that of the disc record, even at the outside diameter. But now the tape noise spectrum more closely matches that of the disc.

2) The required pre-emphasis would have a transition frequency of 8- to 10- kHz, giving a saturation signal spectrum which is greater at high frequencies than the original (1950) NAB-equalized system, and not requiring special care in the studio to avoid high-frequency overloading while recording the master.

3) The standardized flux versus tape wavelength would be the same for 3.75-, 7.5-, and 15-in/s. Thus, one test tape could be used at all three speeds. While not a necessity in any way, this is sometimes a convenience, especially in cross-checking equipment and test tapes.

4) This easily-achieved pre-emphasis can give an overall response that is flat ±0.5 dB up to 20 kHz.

5 REFERENCE FLUXIVITY ("RECORDING LEVEL")

The calibration of the recording volume indicator -- that is, the fluxivity recorded on the tape when the volume indicator deflects to the reference mark (0 dB) -- is dependent on the saturation fluxivity of the tape used [5]. The saturation fluxivity of 3M 111 and 3M202 tapes is (according to the manufacturer's data sheets) 1000 nWb/m. The saturation fluxivity of 3M 206 tape is given as 1480 nWb/m, or 3.4 dB greater. The high-frequency noise spectrum of the 3M 206 tape is roughly 2 dB greater than that of the 3M 202 tape.

Since, especially in recording systems not using a dynamic noise reduction system, noise is still a greater problem than overloading, it is appropriate to increase the reference fluxivity (and thereby the program recording level) so as to retain about the same overload margin ("headroom") with the new tapes as with the older tapes.

The usual reference fluxivity used with 3M 111 tape was 185- to 200-nWb/m. Increasing the reference fluxivity by 2.0-dB to 2.8-dB, to 250 nWb/m, restores the previous relative noise level, while still giving a slight improvement in low-frequency overload level.

[3] We now (2012) recommend the simpler technique of overbiasing to reduce the 1 kHz sensitivity by 0.2 dB, because this is effective with any mastering speed, tape type, and recording gap length.

6 RECOMMENDATIONS

Given the mastering tapes used in 1973 (3M 206, Ampex 406), and the level monitoring system (a flat-response standard volume indicator), the present NAB-standard tape flux versus frequency (transition frequencies of 50 Hz and 3150 Hz) and reference fluxivity (185- to 200-nWb/m) are far from optimum.

New values of transition frequency F = 0 and 6300 Hz, and reference fluxivity of 250 nWb/m, are proposed. These will give a high-frequency noise improvement of 4- to 6-dB, a general signal level increase of 2 dB, and elimination of low-frequency overloading.

Change from the present reference fluxivity and the NAB equalization require only a readjustment of presently available gain and equalization controls, and, for some equipment, the removal of one RC circuit.

The Scully 280 B recorder/reproducers employ a plug-in equalization card which may be set up for the new equalization. A test tape is available from Magnetic Reference Laboratory, having the proposed equalization and reference fluxivity. In lieu of this, one may simply play a 7.5 in/s NAB- equalization test tape at 15 in/s, and set the equalization for constant output for frequencies of 500 Hz and above. The 250 nWb/m reference fluxivity may alternately be achieved by setting the "reference fluxivity of 200 nWb/m" recording on other MRL test tapes to read -2 dB on the volume indicator; or the "operating level" tone of Ampex or STL test tapes to -2.8 dB; then set the recording calibration so the SVI reads 0 dB when the recorded tone causes the SVI to read 0 dB in reproduction.

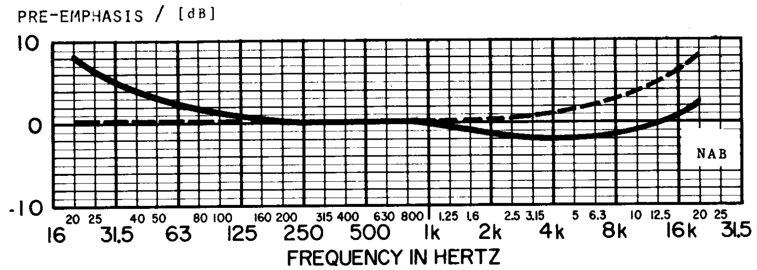

Fig. 1 Recording pre-emphases required for flat overall response, for a master tape when using different reproducing post-emphases: solid curve, with the NAB post-emphasis (F = 50 Hz and 3150 Hz); dashed curve with the proposed mastering post-emphasis (0 Hz and 6300 Hz).

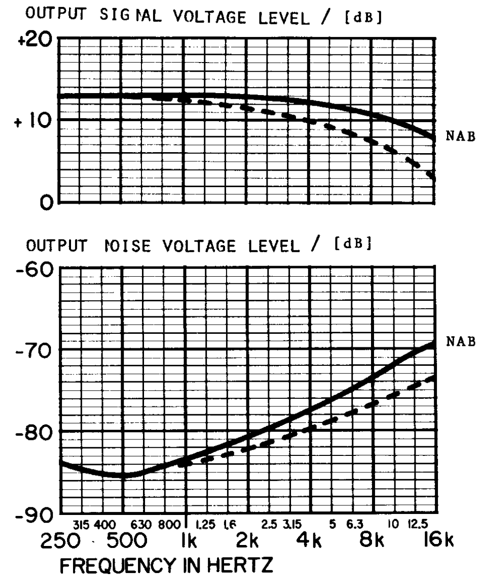

Fig. 2 Saturation signal and 1/3-octave noise spectra: solid curve, with the NAB post-emphasis; dashed curve, with the proposed mastering post-emphasis.

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