Master-tape Equalization Revisited[1]

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Optimum signal-minus-noise level of a commercial tape or disk-record requires the signal- and noise-spectra of the studio master tape to be matched to those of the commercial record. The use of the NAB 380 mm/s (15 in/s) equalization (3150 Hz transition frequency) with modern tapes results in frequency- and noise-spectra which have much higher levels at high frequencies than the final records. Other practical equalizations are studied, and a 12 500 Hz reproducing transition frequency is suggested for further evaluation.

1 INTRODUCTION

The studio-master tape for most commercial magnetic-tape and mechanical-disk records is recorded on low-noise, high-output tape at 380 mm/s (15 in/s), on 2 mm-wide tracks, using the flux-frequency characteristic established for broadcasters by the National Association of Broadcasters (NAB) in 1953 [1].

It has long been realized that the high-frequency noise-spectrum level of such a system is too high to reproduce the full dynamic range of a symphony orchestra. When several channels of a multi-channel master are "mixed down" to form a 2-channel stereo recording, or if the program is rerecorded in the production process, the noise level is even further increased. Therefore, in many cases the noise level is decreased by the use of a dynamic noise reduction system [2], which in effect changes the equalization in accordance with the instantaneous signal spectrum, in order to minimize the effect of the noise added by the tape recorder.

There are, however, also many cases where the dynamic noise reduction system is not used. This often occurs in multi-track recorders, where the cost of the many noise-reduction systems is considered by the studio to be prohibitive. Unfortunately, these very multi-track recordings are the ones which most greatly need the dynamic noise reduction systems!

Thus, for the reasons of economy and also for simplicity it is desirable to optimize the fixed equalization used in studio mastering. The division of the equalization for tape short-wavelength (high-frequency) losses, into pre- and post-emphasis is based on the particular characteristics of the tape in use. The recorded flux vs frequency is then standardized – which in effect standardizes the post-emphasis – and any change in the tape characteristics is made up by adjusting the pre-emphasis, which is ***not*** standardized. Thus when the short-wavelength losses are sufficiently decreased by improvements in the tape manufacturing art, a standard will outlive its usefulness, and the division of equalization will need to be reevaluated and a new standard written.

In this paper we consider the 1953 NAB equalization which is still used in master recording, and propose a different and more suitable equalization, based on the use of modern-day tapes and applications.

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[1] Authors' manuscript of a paper presented at the 42nd Audio Engineering Society Convention, Los Angeles, 1972 May 02...05. Corrected text modified from AES Preprint 856.

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2 EQUALIZATION APPROACHES

The usual approach to designing studio mastering equalization is to consider the spectrum of the signal to be recorded, and the weighted noise spectrum of the recording and reproducing system. Then the equalization is divided into pre- and post-equalization according to empirical tests, in order to produce the best-sounding master tape [3].

These tests are often done with a single generation of recording and reproduction, but the actual master tape for a commercial record is more often the result of a multi-channel mixdown, or of several rerecordings. Thus, an equalization division which produces an adequately-low noise level in an “A-B” comparison of “live” studio signal with the recorded signal often produces a “brilliant” but noisy final master tape after the several rerecordings, mixdowns, etc.

Altho it is a noble goal to have a studio master whose “brilliance” is indistinguishable from that of the original signal, this approach neglects one very important fact: no customer who buys a finished commercial record (mechanical disk, or magnetic tape in any of the several formats) ever gets to ***hear*** the studio master tape!

Thus the goal of the optimum master equalization should be to produce the *best commercial record*, not to produce the best studio master per se. We will show here that the two criteria – best master per se, or best commercial record – give very different results for the “optimum” division of equalization, and that the present NAB equalization is not appropriate for recording studio master tapes.

3 MATCHING MASTER TO COMMERCIAL RECORD

If our goal in designing the compromise between signal level and noise level of the studio master tape is to best match the signal level and the noise level of the commercial record, we obviously first need information on the signal level and noise level spectra of the several popular commercial record media. Such data have been published by Gravereaux et al [4]. The data in their Figure 10 shows that, of the “commercially important” record formats – mechanical disk, and the tape records in the cassette and 8 track cartridge packages – the disk has the best signal-minus-noise level spectrum, so we will use that data as a basis for further discussions here.

The heavy curves of Figure 1 show the saturation signal level and the ⅓-octave-band noise level spectrum for a four-channel mixdown, or for a fourth generation master tape.[3] The light curves reproduce the corresponding data for a mechanical disk record from Gravereaux’s Figure 7.[4] It is apparent that the maximum signal spectrum of the master tape exceeds that which the disk will accept by 3- to 13-dB at 8 kHz, and 5- to 20-dB at 16kHz. Therefore in the transfer from tape to disk the large-signal response of the system must be reduced by these amounts in order to avoid distortion on the disk. If this reduction is done by a high-frequency limiter (of which several commercial models[5] are available), then the “punch” of the master is reduced, but *the high frequency noise of the master is transferred at full level!*

The above-described combination, then, produces the “pessimum” results: a drooping high-frequency response for large signals, with all of the high frequency noise that might accompany a system with flat response for high-level high-frequency signals.

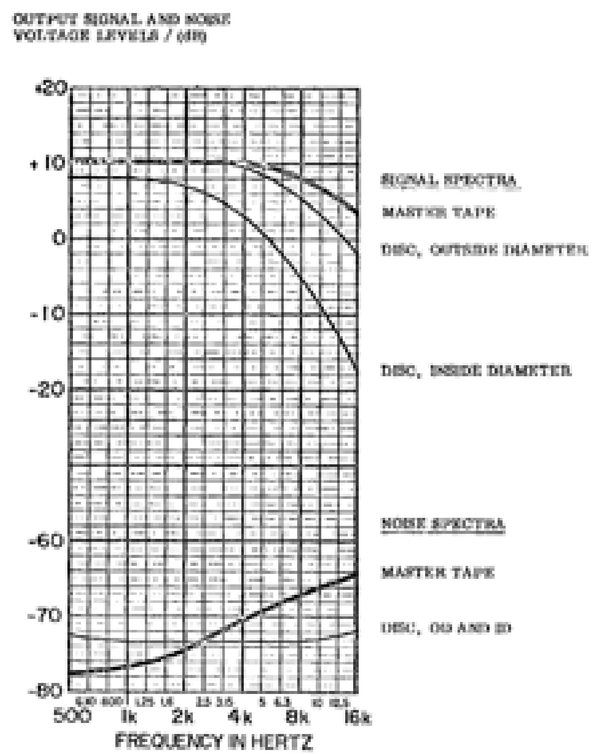

Fig. 1 Saturation signal and ⅓-octave noise spectra. Heavy curves: For a fourth-generation master tape with NAB equalization. Light curves: For a 33⅓ rev/min vinyl disk pressing. See footnotes 3 and 4 for detailed conditions.

[3] Conditions for the master tape: Tape: Ampex 406 or 3M-206. Tape Speed: 380 mm/s (15 in/s). Equalization: according to the NAB standard [1]. Track width: Approx. 2mm. Bias: overbiased to reduce 10 kHz recording sensitivity by 2dB below maximum sensitivity. Signal spectrum is the maximum possible fundamental-frequency output voltage from the reproducer at the stated frequency, without regard to distortion. Noise spectrum is for a ⅓-octave band.

[4] Conditions for disk: Disk: vinylite pressing. Rotational speed: 33⅓ rev/min, Equalization: according to IEC Pub. 98 (also RIAA and DIN standards). Signal spectrum is the maximum possible fundamental-frequency output voltage from the reproducer at the stated frequency, as determined by geometrical limitations given by Gravereaux [4]. Noise spectrum is for a ⅓-octave band.

[5] High-frequency limiters are manufactured by GRT, Ortofon, Neumann, Fairchild (“Conax”), and CBS Labs (“Volumax”).

3. 1 Other Possible Divisions of Equalization

For practical equalizer design and specification, and for good fitting of the total tape losses, 6dB per octave RC equalizers are very satisfactory [3], and only this type will be considered here. Figure 2 shows the signal-level and noise-level spectra for three reproducing transition frequencies: solid curve, 3150Hz (NAB Standard), dotted curve 6300 Hz, and dashed curve 12 500Hz. The disk record signal- and noise-spectra have been drawn in again (light curves) for reference.

When we compare the various master tape noise spectra with that of the disk record, it is apparent that the best match (of the several transition frequencies considered here) comes with the 12 500 Hz reproducing transition frequency.

This comparison is relatively simple, since the disk noise spectrum is essentially unchanged from the outside diameter to the inside diameter of the disk. The maximum signal spectra comparisons are not so simple, due to the great change from outside to inside diameter of the disk. The maximum signal spectrum from the master tape with the 12 500 Hz reproducing transition frequency falls some 2- to 4-dB *below* that of the disk at maximum diameter, but 2- to 12-dB *above* that of the disk at minimum diameter. It is our judgement that this compromise of signal and noise spectra (using the 12 500 Hz reproducing transition frequency) is worth a field trial.

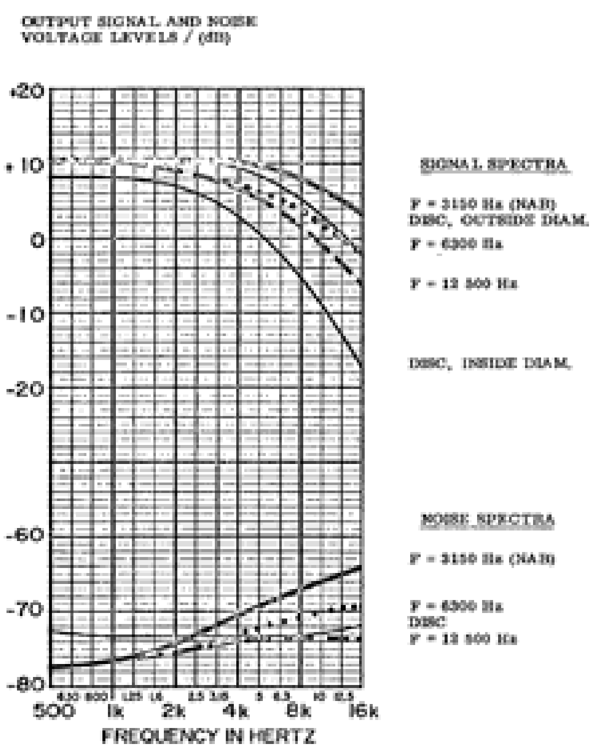

Fig. 2 Saturation signal and ⅓-octave noise spectra. Heavy curves: For a fourth-generation master tape with various reproducing transition frequencies F = 3150 Hz (NAB), 6300 Hz, and 12 500 Hz. Light curves: For a 33⅓ rev/min vinyl disk pressing. See footnotes 3 and 4 for detailed conditions.

A further point of comparison is the amount of pre-emphasis needed for the disk record (relative to a constant recorded velocity response), in comparison to the master tape pre-emphasis for the reproducing transition frequencies under consideration. These are shown in Figure 3: the disk record pre-emphasis transition frequency is 3150 Hz (+10 dB at 10 kHz); and with the present NAB master tape (3150 Hz reproducer transition) the tape pre-emphasis is only 2 dB at 10 kHz – certainly a poor match, The master with 12 500 Hz reproducer transition frequency, on the other hand, requires the same pre-emphasis as the disk. As a further reference, note that this 3150 Hz pre-emphasis transition frequency (+10 dB at 10 kHz) is also that which is used typically for 190 mm/s (7. 5 in/s) recording. The other formats (cartridges and cassettes) – and even FM radio broadcasting! – require even *lower* pre-emphasis transition frequencies, and consequently greater amounts of high-frequency boost (13- to 15-dB at 10 kHz).

Thus altho a master tape with the proposed 12 500 Hz post-emphasis transition frequency would appear to have a slightly poorer large-signal high-frequency response than the outside diameter of a disk, it would be equal to that of a190mm/s tape, somewhat better than cartridges, cassettes,[6] and FM radio, and much better than the disk at inner diameter.

The high-frequency noise of such a master tape, however, would be reduced 5 dB at 5 kHz, and 10 dB at 16 kHz, relative to present NAB master tapes.

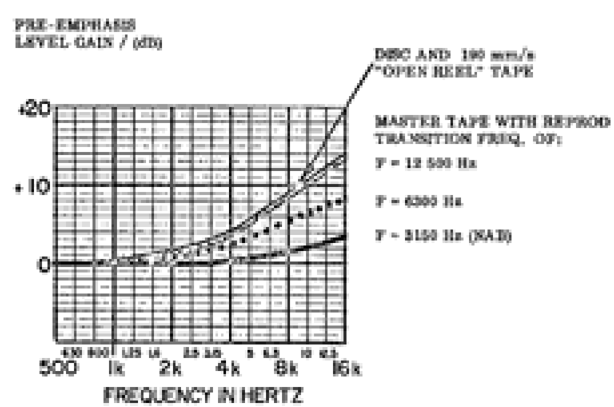

Fig. 3 Recording pre-emphasis for master tape with different post-emphasis transition frequencies F = 3150 Hz (NAB), 6300 Hz, and 12 500 Hz. Pre-emphasis used for disk recording and for 190 mm/s (7.5 in/s) open reel commercial tape records shown for comparison. See footnotes 3 and 4 for detailed conditions.

[6] The wavelength-losses of chromium-dioxide tapes are less than those of traditional iron-oxide tapes. But since most cassette recorders use a special post-emphasis with chromium-dioxide tapes, with a 5 dB higher flux at high frequencies, the pre-emphasis used is about the same for both tapes!

3.2 Comments on Practicality of the 12 500 Hz Reproducer Transition Frequency

Field tests of this proposed equalization change are obviously needed to evaluate its practical advantages and disadvantages. We do have some guiding experience, however: First, the pre-emphasis originally used at 380 mm/s with the NAB standard and tapes and recorders available in 1953 had a 6300 Hz transition frequency (+6 dB at 10 kHz) – not the +2 dB at 10 kHz now used.

Second, all of the 190 mm/s open-reel stereo tapes produced by Ampex Music Division (AMD, formerly Ampex Stereo Tapes, AST) from masters made since 1968 – and this includes in particular the "EX +" series – have been made from duplicator masters recorded at 380 mm/s using the proposed equalization.[7] The high-frequency, high-level response of these 190 mm/s "open-reel" tapes is generally agreed to be the best of all commercial records – tape or disk.

4 CONCLUSIONS

We have shown that the presently used NAB equalization used for 380 mm/s studio masters is inappropriate – it gives a large-signal 10 kHz response which is 4- to 14-dB greater than any commercial record format (mechanical disk, or cartridge or cassette tape record) is able to utilize. The price paid is not only the difficulty of modifying the signal on the master in order to "squeeze it thru" any commercial record format, but also a high-frequency noise level which is obtrusive, especially when multi-channel mixdowns and/or several rerecordings are necessary.

Altho the noise may be reduced by dynamic noise reduction systems now available, a much simpler and less expensive alternative is to reoptimize the mastering equalization. We propose field tests of a reproducing transition frequency of 12 500 Hz, in place of the NAB value of 3150 Hz. This would reduce the noise at 8 kHz by 6 dB, and at 16 kHz by 10 dB.

The increased pre-emphasis necessary with this proposed mastering equalization will undoubtedly cause high-frequency tape compression which will be heard as the session is in progress. Realizing that this compression would have occurred in the transfer to the commercial disk or tape record, we feel it actually to be advantageous for the producer and recording engineer to be aware of the problem during the studio mastering, so that the appropriate change of microphone placement or gain can be made with the greatest artistic control.

A previous paper [5] has discussed the disadvantages of the low-frequency pre-emphasis prescribed in the NAB standard, and the presently proposed change in high-frequency equalization should be accompanied by a flat (nonboosted) low-frequency recording response.

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[7] In the transfers from the inter-masters sent by the various studios to AMD for making the duplicator masters, an equalized peak-reading level indicator with dynamics identical to those standardized in the German Standard DIN 45 506 is used. This indicator in itself helps in optimizing the recorded level, and in preventing high-frequency overloading. Its use may not be necessary in recording studio masters, but this can only be determined by field tests.

REFERENCES

[1] NARTB Recording and Reproducing Standards, See, 2, Magnetic Recording (1953 June). (US) National Association of (Radio and Television) Broadcasters, Washington DC, US. Note: this Standard was replaced in 1965, but the equalization for 380 mm/s tape recording was in effect re-affirmed. The 1965 standard is summarized in detail by George Bartlett in “The New NAB Tape Standards”, *J. Audio Eng Soc.* vol. 13 Nr 3, pp 248...252 (1965 Jun).

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