REAFFIRMED 2002

EG 13-1986

SMPTE ENGINEERING GUIDELINE

Use of Audio Magnetic Test Films

1 Scope

This guideline is intended to describe the usage and practical limitations of audio magnetic test films made to SMPTE specifications.

2 Definitions

2.1 flux level: The absolute short-circuit recorded magnetic flux level in nanowebers per meter (nWb/m).

2.2 frequency response: The amplitude vs frequency characteristic of a circuit or flux given as the frequency-by-frequency deviation in decibels from either zero deviation or from a specified response.

2.3 mechanical adjustments:

2.3.1 azimuth: Rotation of the head about a line perpendicular to the reference edge of the film in the plane of the film. For a single-gap head, azimuth aligns the gap perpendicular to the reference edge of the film. For a multiple gap head, azimuth adjustment brings the best fitting line through the centers of the gaps perpendicular to the reference edge of the film.

2.3.2 height: The position of a head or record along the plane of the film with respect to the reference edge of the film. Adjustment aligns the gap(s) to the center of the recorded area for the corresponding record.

2.3.3 rotation: Rotation of a head around a line parallel to the plane of the film (drawn through the centerline of the head) and perpendicular to the reference edge of the film. Adjustment is made in order to bring the gap(s) into best contact with the oxide surface on the film.

2.3.4 zenith: Rotation of a head around its center which brings the gaps in or out of parallelism with the magnetic oxide surface of the film. Adjustment optimizes contact across the width of the head gaps.

2.4 peak value: The true peak value of the signal, measured by observing an oscilloscope and comparing the peak-to-peak amplitude of the observation to the peak-to-peak amplitude of the reference stated.

2.5 pink noise: A random noise signal having equal amplitude in equal logarithmic frequency intervals over the bandwidth of interest.

2.6 record: The magnetic flux recorded on the film. A record may extend across the whole width of the film, or it may be segmented into tracks which correspond to channels.

Approved September 30, 1986

3 Uses of the test sections of the films

3.1 General note

An oscilloscope connected in an X-Y mode, with one signal applied to an input to produce vertical deflection and another signal applied to a second input to produce horizontal deflection, provides a method of making a number of useful measurements when used with the various parts of the test film. The resulting displayed pattern is called a Lissajous figure. For the tests as described, the most common type of display is assumed: with two identical inputs for the X and Y axes, and with the oscilloscope gain controls set for equal sensitivity in the two inputs, a line sloping 45° up to the right should be produced.

3.2 Uses of the reference level tone

3.2.1 The reference level tone may be used for setting the preliminary head mounting adjustments such as coarse rotation, azimuth, and zenith (in the case of test films with individual records, the head height as well) by setting the appropriate mechanical adjustments for highest and most level-stable output.

3.2.2 The reference level tone may also be used as a relative channel polarity test by using an X-Y display to check that each of the preamplifier outputs corresponding to the records, compared to a reference channel output, have the same slope, not the opposite slope, which would indicate a polarity reversal in the head or preamplifier wiring.

3.2.3 The reference level tone may also be used for calibration purposes to produce the reference voltage for setting the operating point of level-dependent noise-reduction systems.

3.2.4 An X-Y display of the reference level tone on an oscilloscope may be used for coarse azimuth setting using the following method:

> Connect the signals from the preamplifier outputs corresponding to the outside tracks to the X and Y inputs of an oscilloscope. With the sensitivity of the preamplifier channels set to play the film at equal voltages at the oscilloscope connection points, and the sensitivity of the X and Y oscilloscope channels made equal, adjust the azimuth for a 45° diagonal line on the oscilloscope, not an ellipse. (Setting the azimuth coarsely at medium frequencies before making adjustments at the higher frequencies assures that, when the small adjustments are subsequently made for best high-frequency azimuth, they take place on the same peak of the high-frequency cycle without the possibility of displacement by one full cycle which can lead to a false peak.)

3.3 Uses of the azimuth tone

3.3.1 Azimuth tone use

The high-frequency azimuth tone can be used for fine adjustment of playback head rotation, azimuth, and zenith by adjusting the appropriate mechanical controls for highest and most level-stable output.

3.3.2 Multitrack heads

To obtain the best azimuth across a multitrack head, it is useful to sum the outputs of one half of the tracks into one axis of the X-Y display, and the other half to the other axis of the display. Assign the tracks to one half or the other based on the mechanical layout of the head: bisect the head down the center of the film. This method eliminates error due to gap scatter among the individual head gaps.

3.4 Uses of pink noise

3.4.1 The pink noise can be used to obtain the best overall azimuth by observing a Lissajous pattern on an oscilloscope with the X and Y axes connectcd to the signals from the outside records: when the reproducer sensitivity and equalization have been set for equal performance in both channels, and the azimuth is correct, a line will be displayed at a 45° angle, not a fuzzy ellipse. Pink noise has an advantage over sine-wave tones for azimuth adjustment because it produces unambiguous results (one cannot misadjust by one full cycle).

3.4.2 Pink noise can also be used with a constant-percentage bandwidth spectrum analyzer, such as a one-third-octave band analyzer to set equalization adjustments. Pink noise may thus be used for many of the same purposes as the frequency response tones (but see the condition in 3.5.3).

3.4.3 Pink noise reproduced from magnetic film is not recommended for adjustment of theater sound pressure level vs frequency because it does not have adequate level stability.

3.5 Uses of the frequency response tones

3.5.1 The frequency response tones are in ascending order because errors become more apparent at high frequencies. It is easier to make adjustments at the low frequencies first, followed by more critical adjustments as the frequencies increase.

3.5.2 Setting the playback preamplifier equalization adjustments for the flattest possible frequency response, using either the frequency response tones or the pink noise from the test film with appropriate test equipment, ensures that the system will match the characteristic of release prints to be played (but see the conditions in 3.5.3 and clause 4).

3.5.3 Playback heads are subject to fringing at low frequencies; i.e., reproducing flux recorded outside the area swept by the playback head gap. When test films are recorded across the full width of the film, fringing compensation must be made by the user for accurate calibration of low-frequecy playback response.Although fringing compensation generally means that the head captures more flux and thus has greater output than it would with equal width recording and playback, cases do exist where the added flux is captured out-of-phase with the main flux. To calibrate the low-frequency response accurately, swept sine-wave recordings of full width vs equal record and playback width must be compared. (Pink noise gives too limited frequency resolution, and, being a stochastic, i.e., random, signal, does not stimulate the mechanism of fringing as greatly as do sine tones.)

4 Notes on playback preamplifiers

Practically all magnetic heads differentiate the recorded flux over most of the operating frequency range, producing a rising characteristic from low to high frequencies at 6 dB per octave. A corresponding integrating response, falling at 6 dB per octave, is included in preamplifiers for use with magnetic heads. The time constants published in the respective standards specify transition frequencies corresponding to the RC time constant $\tau = R \times C$, according to the equations:

$$f_{low} = \frac{1}{2\pi\,\tau_{low}} \text{ and } f_{high} = \frac{1}{2\pi\,\tau_{high}}$$

(Note that τ low is a large number representing a low frequency, and the equations above are a 1/x function.) These transition frequencies mark the points where the equalization departs to slopes 6 dB per octave away from the playback integrating function. Thus, a theoretical playback preamplifier to be used for example with a test film recorded with 3180 µs and 35 µs time constants and using a theoretically flat frequency conventional head has flat frequency response from dc to –3 dB at 50 Hz, with the response falling at 6 dB per octave to a frequency of

4550 Hz where the level is 3 dB above a shelf, and at higher frequencies, a flat shelf extends to past the required bandwidth of the system.

A number of effects require frequency response in the playback preamplifier differing from the theoretical. These effects can be divided into those generally affecting low frequencies and those generally affecting high frequencies.

At low frequencies, undulations in response occur due to head bumps; i.e., the response of parts of the head other than the gap to the recorded flux (a long wavelength and thus low-frequency phenomenon).

Another factor at low frequencies causing a response anomaly results when very low-impedance heads are used to overcome the effects of long cable lengths, such as in projector penthouses. With such heads, it is customary to employ a step-up transformer; thus, the quite low head impedance is reflected to a higher impedance so that the active input stage can be designed for a low noise figure. Such a step-up transformer will have a high, but nonetheless finite, primary inductance. When combined with the resistance of the head, this inductance forms a 6 dB per octave low-frequency rolloff, which must be considered in the overall system design.

In addition, the effect of fringing must be considered as a potential source of low-frequency measurement error (see 3.5.3).

At high frequencies, losses occur due to the finite gap length in the direction that the film is running, azimuth inaccuracies due to multiple gaps in multichannel heads not being perfectly colinear (gap scatter), spacing loss due to imperfect contact between the film and the head, as well as electrical circuit losses due to the complex head impedance loaded by the complex input impedance of the preamplifier and connecting cable.

The approximate gap length loss is given by:

$$\text{Gap loss (dB)} = 20 \log_{10} \left(\frac{\sin\left(\frac{\pi l}{\lambda}\right)}{\frac{\pi l}{\lambda}} \right)$$

$$\lambda = \text{recorded } \textit{wavelength} = \frac{\text{film speed in/s}}{\text{frequency in hertz}}$$

where the sin function is in radians, and l is 1.15 $\times$ physical gap length in inches.

For a high-quality head with a 250 µin gap, the gap length loss is listed in table 1 for 90 ft/min systems.

Table 1 – Frequency response in dB

Frequency	Level in dB
1 kHz	– 0.004
6.3 kHz	– 0.15
8 kHz	– 0.23
10 kHz	– 0.37
12.5 kHz	– 0.58
14 kHz	– 0.73
16 kHz	– 0.95
20 kHz	– 1.51

The equation for gap scatter loss due to azimuth error is of the same form as the gap length loss, with the $\frac{\pi l}{\lambda}$ term replaced with $\frac{\pi \omega \tan\beta}{\lambda}$ where

ω = track width in inches, and β = misalignment angle.

The spacing loss is unpredictable, since the distance between the head and the film is unknown, but has the form:

$$\text{Spacing loss (dB)} = 54.6 \frac{d}{\lambda}$$

where d is the spacing in inches and λ is the wavelength specified above.

For these reasons, it can be seen that simply reproducing the time constants of the relevant standard in the playback preamplifier does not produce overall flat response.

5 Use of low-frequency record boost on 35- and 70-mm test films

Some documents call for 3180 µs low-frequency equalization. Equalization with no low-frequency record boost (a time constant of infinity) has been shown to better use the overload characteristic vs frequency of the magnetic medium when recording typical program material. However, there is some theater equipment in the field which reproduces a flat response only when low-frequency record boost has been applied to recorded material. The use of the 3180 µs time constant is seen as a transitional compromise between the best practice that can be obtained currently and the desired future practice with an infinity time constant. In addition, some older prints may exist which were recorded with a 1590 µs time constant which must, on occasion, be accommodated.