SMPTE STABLE DOCUMENT

The attached SMPTE Engineering Document has been declared "Stable" by the controlling Technology Committee.

The SMPTE Operations Manual for Standards states:

> *A document should be stabilized if it is believed to be substantially correct, does not contain harmful or misleading recommendations, may still be relevant to equipment or practices in use, is stable, but does not represent current technology, and need not be subject to future reviews.*
>
> *A Stable document shall still be made available and offered for sale by the Society, but it shall be prefaced by a cover page explaining its current status.*
>
> *At any time, a Technology Committee may revise, amend, or otherwise initiate a new Project on a Stable document.*

A Stable document is "In Force", and not deprecated or withdrawn.

*** * * * * * * * * ***

Note:

SMPTE "Stable" documents were previously described as "Archived" and the attached document may be marked as "Archived". The status of a SMPTE document described as "Archived" is exactly as described above for a "Stable" document.

Stable documents may not adhere to the latest style and format of SMPTE documents, or to current usage of normative language. Suitable care should be taken in interpretation.

RP 104-2005
Revision of RP 104-1994

SMPTE RECOMMENDED PRACTICE

Cross-Modulation Tests for Variable-Area Photographic Audio Tracks

1 Scope and purpose

1.1 This practice describes the cross-modulation method of measuring high-frequency distortion introduced during the production of variable-area audio motion-picture release prints. Through measurements of distortion at various negative densities, it is possible to choose negative densities that will produce audio prints having minimum distortion and optimum quality under the particular method of processing employed.

1.2 Cross-modulation tests are used extensively in establishing and maintaining photographic control of variable-area audio tracks. In consideration of waveform, output level, and noise reduction, it is necessary for variable-area prints to have high density contrast. At satisfactorily high track densities, an appreciable amount of image spread occurs, producing partial rectification of high frequencies. To compensate for this, an equal and opposite amount of image spread is introduced into the negative. Therefore, to establish the correct negative- and print-density combination, amplitude-modulated high frequencies are recorded and printed over a suitable density range. By measuring the rectified component from the prints, the correct density combinations are indicated.

2 Test method

2.1 The test track described in clause 3 is recorded and developed under standard conditions for the process being checked. A series of recordings is made at different lamp currents to give a range of negative densities above and below the expected optimum density. A print is then made of the negative series under standard conditions of exposing and printing for the print film under test. There should be sufficient unspliced film ahead of the test track to permit stabilization of printer speed. Alternatively, a single negative can be made and a series of prints made from that negative. A third and more comprehensive test method involves exposing a negative series and printing it at a series of print densities.

The distortion content of the test track print is then measured. In making the measurements, the test track print is threaded through the audio head of the film reproducing device in the proper manner according to the position of the audio track. The distortion of each section of the print is then measured using one of the methods described in 4.1.5.

The negative density that results in the least amount of distortion in the print is considered the optimum negative density for the set of conditions used.

2.2 Since the method described here measures the overall distortion for a process involving numerous variables, each of which may affect the total distortion, it is necessary that all such variables (except the negative density, which is purposely varied to find the optimum) in the recording and processing of the test track be maintained at the same values as they are normally in the process to be checked. The variables include film stock (both audio negative and print), printer exposure, negative and print gamma, color temperature of printer light, and type of printer.

Approved December 16, 2005

3 Test track

3.1 The test track consists of three sections recorded in sequence at the same negative recorder lamp-current setting.

3.1.1 Section 1: 400 Hz ± 10 Hz constant amplitude sinusoidal signal at (80 ± 5)% of full modulation (or 2.0 dB ± 0.5 dB below full modulation).

3.1.2 Section 2: A high-frequency sinusoidal signal amplitude modulated to (80 ± 5)% of full modulation (2.0 dB ± 0.5 dB below full modulation) at 400 Hz ± 10 Hz. The peak amplitude of this modulated signal will be (80 ± 5)% of that required for full modulation of the audio track (or 2.0 dB ± 0.5 dB below full modulation). The high frequency will be 6000, 8000, or 9000 Hz ± 100 Hz for 35 mm, and 6000 Hz ± 100 Hz for 16 mm.

3.1.3 Section 3: Track fully modulated at 30 Hz or less, or forward and reverse bias applied with no modulation present, suitable for density measurement of both clear and opaque areas.

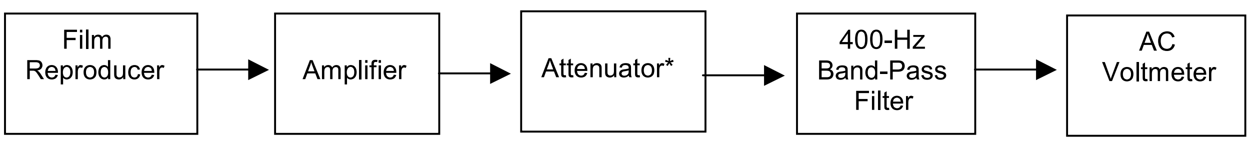
3.2 Sections 1 and 2 should have a running time of 10 seconds, and section 3 at least 1 second. Neither the 400-Hz nor the high-frequency modulated signal shall contain more than 5% total harmonic distortion. The modulated wave of section 2 shall not contain a 400-Hz component greater than 50 dB below a 400-Hz signal with the same peak-to-peak amplitude. The recorder should be adjusted correctly for slit azimuth, track location, and focus.

4 Reproducing and measurement methods

4.1 400-Hz filter method

4.1.1 Reproducing equipment

The reproducing equipment should consist of an audio film reproducer, an amplifier, an attenuator, a 400-Hz band-pass filter, and an AC voltmeter. A typical equipment arrangement is shown in figure 1. The attenuator is optional in some measuring system setups (see annex A.1).



*See 4.1.1

Figure 1 – Reproducing equipment

4.1.2 Signal-to-noise ratio

The signal-to-noise ratio of the entire system shall be at least 55 dB.

4.1.3 Filter

The 400-Hz band-pass filter should have uniform transmission ± 0.5 dB from 370 Hz to 430 Hz. The filter shall have an attenuation at 4000 Hz of at least 45 dB greater than passband attenuation and an attenuation at frequencies of 6000 Hz and above of at least 55 dB greater than passband attenuation. No specification of attenuation within the passband is required other than the condition of uniform transmission.

4.1.4 Distortion

Care should be taken that the photocell or photodiode and its associated coupling circuit to the amplifier input stage do not introduce a significant amount of cross-modulation distortion. The complete reproducing system should be checked for indications of distortion by use of a suitable test film.

4.1.5 Measurement and calculation of distortion

The amount of cross-modulation distortion may be expressed either in decibels of cancellation (also known as cross-modulation product) or in percent distortion.

4.1.6 Cross-modulation product

The cross-modulation product is determined by the following equation:

$$\text{Cross-modulation product} = 20 \log_{10} (V_{ref} / V_{xm})$$

where V_{ref} = voltage at output of filter for section 1 of test track, and V_{xm} = voltage at output of filter for section 2 of test track.

4.2 Real-time analyzer method

4.2.1 Reproducing equipment

The reproducing equipment should consist of an audio film reproducer, an amplifier, and a third-octave real-time analyzer. The arrangement is shown in figure 2.

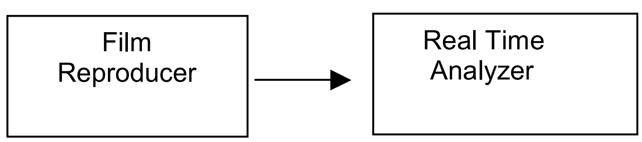


Figure 2 – Reproducing equipment real time analyzer method

4.2.2 Measurement and calculation of distortion

The amount of cross-modulation distortion may be expressed either in decibels or cancellation (also known as cross-modulation product) or in percent distortion.

4.2.2.1 Cross-modulation product

The cross-modulation product is determined by noting the signal level in dB on the analyzer from test signal section 1, and then noting the signal level at 400 Hz for section 2. The cross-modulation product is then the algebraic difference between the two measurements, which will have a negative sign.

4.3 Percent cross-modulation distortion

4.3.1 Percent cross-modulation distortion for the 400-Hz filter method is determined by the following equation:

$$\text{Percent cross-modulation distortion} = V_{xm} / V_{ref} \times 100\%$$

where V_{xm} and V_{ref} are defined as in 4.1.6.

4.3.2 Percent cross-modulation distortion for the real-time analyzer method is determined by:

Percent cross-modulation product = 100*10 ↑ (cross-modulation product / 20)

Annex A (informative)
Additional data

A.1 There are a number of techniques that can be used to measure cross-modulation distortion. The following methods are typical:

A.1.1 For this method, the attenuator of figure 1 is omitted and the AC voltmeter is calibrated in decibels and has range-changing facilities. The voltages corresponding to sections 1 and 2 of the test track are measured in decibels and the difference taken, thus obtaining the cross-modulation product in accordance with 4.1.6.

A.1.2 For this method, the attenuator of figure 1 is omitted and the AC voltmeter is calibrated in volts and has range-changing facilities. The voltages corresponding to sections 1 and 2 of the test track are measured in volts and the percent cross-modulation distortion calculated according to 4.3.1.

A.1.3 For this method, the attenuator of figure 1 is uncalibrated and the AC voltmeter is calibrated in decibels and has range-changing facilities. While section 1 of the test track is being reproduced, the attenuator is adjusted for a reading of 0 dB on the meter. Then, when section 2 of the test track is being reproduced, the cross-modulation product, in decibels, can be read directly from the meter.

A.1.4 For this method, the attenuator of figure 1 is uncalibrated and the AC voltmeter is calibrated in volts and has range-changing facilities. While section 1 of the test track is being reproduced, the attenuator is adjusted for a reading of 1.0 volts (which is interpreted as 100%). Then, when section 2 of the test track is being reproduced, the percent cross-modulation distortion can be read directly from the meter.

A.1.5 For this method, the attenuator of figure 1 is calibrated in decibels and the AC voltmeter may be just a single-range instrument. While section 1 of the test track is being reproduced, the attenuator is adjusted so that the meter reads at a reference mark on the meter. The attenuator setting is noted. Then, when section 2 of the test track is being reproduced, the attenuator is readjusted so that the meter reads at the same reference mark. The difference between the two attenuator settings is the cross-modulation product.

A.2 The equation in 4.1.6 will always yield a positive number for the cross-modulation product. The greater this number, the greater the amount of cancellation of distortion or the lesser the amount of distortion in the print. Nonetheless, cross-modulation product is normally plotted with the magnitude increasing downward, as shown in figure A.1. The optimum negative is determined by visually estimating the position of the center of the cusp.

A.3 The equation in 4.3.1 will always yield a positive number for the percent distortion, since AC voltages are always positive. It is customary, however, to plot the percent distortion as negative for negative densities greater than the optimum density. (For negative densities less than the optimum density, the print may be considered to be overexposed for the negative used, and thus the percent distortion in the print is "over" or positive. Conversely, for negative densities greater than the optimum negative density, the print is underexposed, and thus the percent distortion is "under" or negative.) A sample plot is shown in figure A.2 The optimum negative density is that density at which the plotted line crosses the zero percent distortion line.

A.4 The specification of the high frequency (i.e., the carrier frequency) of the modulated signal of section 2 of the test track covers a fairly broad range. Characteristics of the recorder, especially the amount of film-loss equalization as well as the characteristics of the sibilant speech sounds, affect the choice of optimum frequency for a given system. The range of carrier frequencies was specifically chosen to include 9000 Hz, a frequency which has been widely used for cross-modulation tests on 35-mm audio tracks for a number of years. In addition, it is recognized that 4000 Hz is being used by some laboratories as a carrier frequency for 16-mm audio tracks with apparently satisfactory results.
The most important characteristic of the cross-modulation signal, in terms of its use for measuring distortion on various kinds of test equipment in different laboratories, is the modulating frequency, which is set at 400 Hz.

A.5 The amplitude modulated signal of 3.1.2 may be produced by either of two methods. The first method is to actually amplitude-modulate a high-frequency carrier by the 400-Hz modulating signal. This is actually a multiplicative process as indicated by the following equation:

$$V_{xm} = (1 + m \sin \omega_{400}\, t) \sin \omega_{hf}\, t$$

where ω_{400} = modulating frequency and ω_{hf} = carrier frequency.

The other method is to combine, in a suitable electrical summing process, two high frequencies whose difference frequency is the modulating frequency, and whose average frequency is the carrier frequency. It is noted that although the average frequency of the two high-frequency signals is subject to the same tolerance as the carrier frequency, the difference between the two frequencies is subject to the tighter tolerance of the modulating frequency.

A.6 The amplifiers of the recorder should not add a significant quantity of distortion to cross-modulation signal during recording. One way to ensure this is to feed the signals into the recording circuits as close to the light-modulating device as possible and still provide sufficient gain to produce 80% modulated signals. It is also desirable to remove all high- and low-pass filters, film loss equalization, compressors, and limiters from the circuit when recording cross-modulation signals.

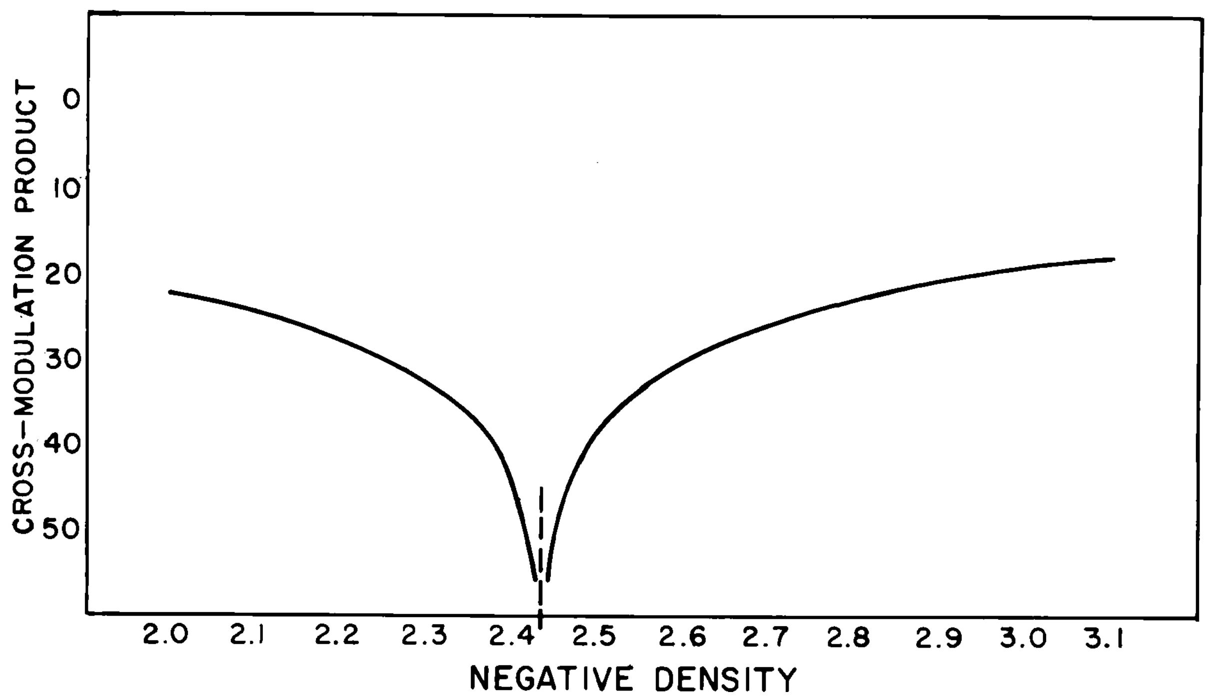


Figure A.1 – Cross-modulation product

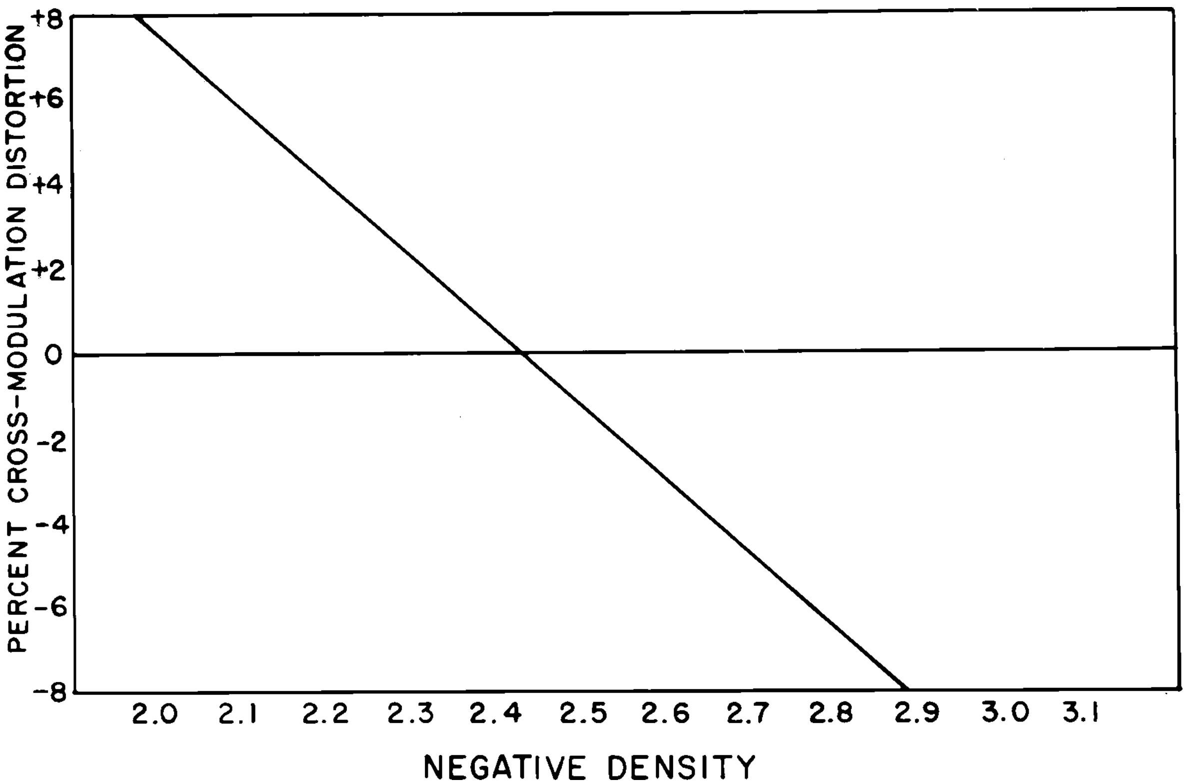


Figure A.2 – Negative cross-modulation distortion

Annex B (informative)
Bibliography

Baker, J. O. and Robinson, D. H. Modulated high-frequency recording as a means of determining conditions for optimal processing. Journal of the SMPE 30(1): 3-17; January 1938.

Uhlig, R. E. The optimum carrier frequency for cross-modulation tests. SMPTE Journal 85(8): 623-626; August 1976.

Williams, G. and Strong, M. Quality control of 16-mm variable-area soundtracks for small studios. Journal of the SMPTE 73(9): 792-796; September 1964.