

The X-Curve: Its Origins and History

Electro-Acoustic Characteristics in the Cinema and the Mix-Room, the Large Room, and the Small

By Ioan Allen

This paper traces the beginnings of the X-Curve in work carried out in the early 1970s and follows the various developments since that time. This electro-acoustic characteristic is now employed in most theatres throughout the world. The “X” stood for “experimental,” an epithet that now seems inappropriate for something that’s been a national and international standard for 30 years!

The “Academy Curve”

The need for standardized tonal characteristics was recognized from the early days of sound-on-film, and the first attempt to codify the system was made by the Motion Picture Research Council (reporting to the Academy of Motion Picture Arts and Sciences) in 1937. A panel listened to a wide variety of material over typical theatre loudspeakers and determined the optimum high-frequency attenuation. Next, a flat frequency response tone run test film was played on the projector and the signal at the power amplifier outputs was measured. This defined high-frequency attenuation would be “the standard.” The characteristic was a consequence of the total de-emphasis in a typical theatre at the power amplifier outputs, resulting from a combination of slit height and electrical filters. Two curves were defined, one for loudspeakers with bakelite diaphragms and one for metal. They (it) became known as “The Academy Curve,” as shown in Figure 1.

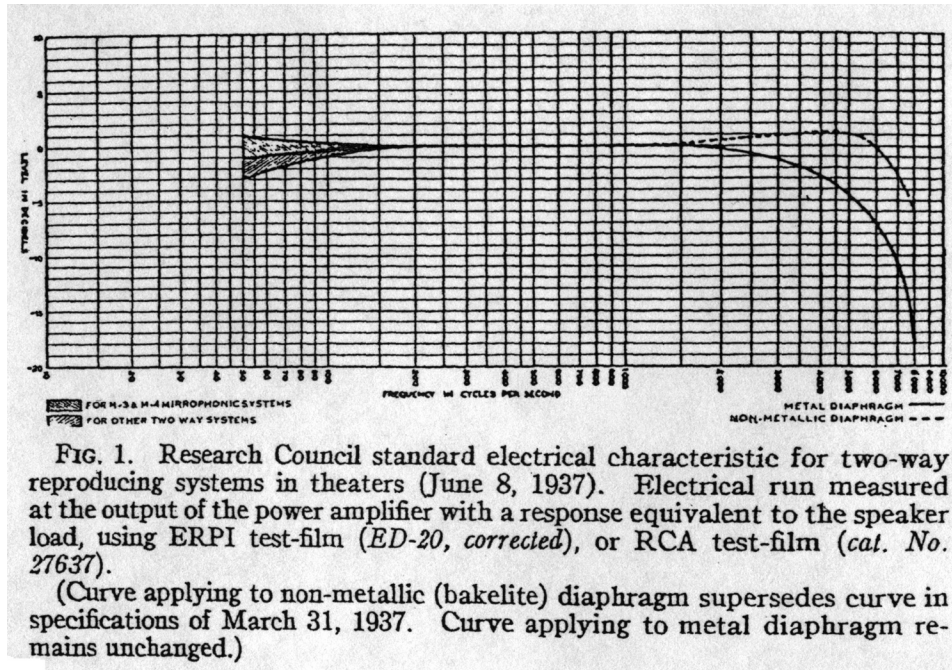


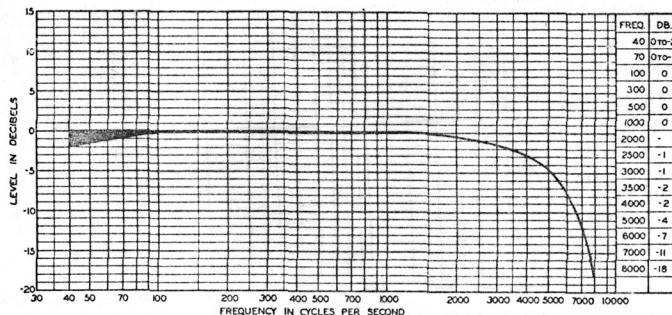
Figure 1 - 1937: The first “Academy Characteristic” – two curves, one for loudspeakers with bakelite diaphragms, one for metal

In 1948, an updated document was issued by the Motion Picture Research Council, “Standard Electrical Characteristics for Theatre Sound Systems,”¹ this time providing seven different curves, with each curve being optimum for a different group of loudspeakers. Figures 2 and 3 show typical curves. (One interesting side note is that the 1948 booklet has a recommended power amplifier wattage table, based on the number of seats. Fifteen watts was considered acceptable for a theatre with up to 700 seats—at 4,500 seats, the recommended power amplifier capacity was 100 W.)

MOTION PICTURE RESEARCH COUNCIL, INC.
STANDARD ELECTRICAL CHARACTERISTIC
for

Altec Lansing (With Energized Units) Systems

Electrical run, measured at the output of the power amplifier with a resistance equivalent to the speaker network load using the Research Council Standard Multifrequency Test Film, Altec or RCA Test Film.



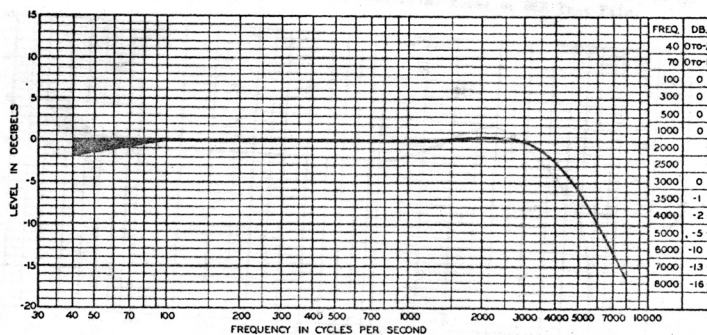
The tolerances of ± 1 db up to 3000 cycles, increasing progressively with frequency to a maximum of ± 2 db at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

Figure 2 - 1948: "Academy Characteristic" for Altec Lansing Systems

MOTION PICTURE RESEARCH COUNCIL, INC.
STANDARD ELECTRICAL CHARACTERISTIC
for

International Projector Simplex Four-Star Systems

Electrical run, measured at the output of the power amplifier with a resistance equivalent to the speaker network load using the Research Council Standard Multifrequency Test Film, Altec or RCA Test Film.



The tolerances of ± 1 db up to 3000 cycles, increasing progressively with frequency to a maximum of ± 2 db at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

Figure 3 - 1948: "Academy Characteristic" for International Projector Simplex Four-Star Systems

One remark is well worth quoting: "Whenever such conditions exist that the particular characteristic recommended does not give satisfactory results, it is recommended that the acoustic characteristics of the auditorium be corrected." This was an acknowledgement that the acoustic behavior of the auditorium significantly affected the sound quality. But it seems probable that after-the-fact acoustic corrections were as rare 60 years ago as they are today. Most likely, the

installation engineer checked the electrical response at the power amplifier, using a frequency response test film. He would then listen to some typical program material. If the tonal balance seemed wrong, he would make a subjective judgment and adjust “the padding.”

All the loudspeakers described in the Research Council booklet were two-way units, with a passive crossover centered typically at 500 Hz. Resistive pads could be applied to the low-frequency or high-frequency units, and this relative adjustment, the padding, was the only tonal correction available to suit a particular auditorium’s acoustic characteristic.

The Situation in 1970

Even though a few films were being released with magnetic stripe, both 35mm and more rarely 70mm, the ubiquitous format in the late 60s and early 70s was 35mm with a mono optical soundtrack. There was significant high-frequency attenuation during playback in the theatre, resulting from the constraints described above—projector slit height and electrical filters—but in addition, the loudspeaker characteristic, the perforated screen, and even high-frequency air absorption increasing toward the back of large theatres.

The dubbing theatre mimicked the commercial cinema, with similar loudspeakers and screen. For optical sound releases, a filter in the monitor would simulate negative/positive print losses, projector slit loss, and any typical electrical filters in the playback theatre. The mixers would equalize the soundtrack elements, dialog, music, and effects, for the best audible quality. More often than not, this meant applying significant HF boost—on typical dialog this would mean 6 dB or more of boost centered around the 3 kHz region—a low-pass filter would be applied at ~8 or 10 kHz to reduce the risk of sibilant distortion and a high-pass filter at ~ 100 Hz to provide a better balance to the sound.

So, even though there was no fixed pre-emphasis and de-emphasis, the system had all the effects of pre-emphasis and de-emphasis. On the positive side, high-frequency grain noise (hiss) was attenuated by the roll-off in playback. On the other hand, the bandwidth was severely curtailed, and excessive pre-emphasis led to distortion, progressively increasing through magnetic pre-mixes and then onto the optical release print.

Measurement of the Electro-Acoustic Response

The difficulty in measuring the acoustic output of the cinema system led to the “Academy” technique of measuring the frequency response at the power amplifier outputs, and then using subjective tests to assess the response at the audience’s ears. Needless to say, single-frequency spot measurements of the electro-acoustic response are extremely unreliable because of room tone effects (resonances). Early attempts at objective testing of the electro-acoustic response are described in “Characteristics of Film Reproducer Systems” (1939) by Durst and Shortt,² who used steady-state and warble tones as the test signals.

Wide-band noise (white or pink) is a more efficient and accurate test signal, and its use was first described by Ljungberg in his 1969 *SMPTE Journal* paper, “Standardized Sound Reproduction in Cinemas and Control Rooms.”³ This paper is also noteworthy as introducing the concept of breaking the entire playback chain into halves for measurement purposes. What is now universally known as the B-chain consists of everything after the switch point for different sources, i.e., nonsync sources (disk or tape), on-film magnetic stripe, or optical sound. In most theatres this

²“The X-Curve” by Ioan Allen, *SMPTE Motion Imaging Journal*, July/August 2006, www.smppte.org, page 4 of 24

common point would immediately precede the volume control (fader), and the B-chain comprises everything that follows, such as power amplifier, loudspeaker, screen, and any modifications caused by auditorium acoustics and distance to the listener. A-chain frequency response for analog optical playback is determined by high-frequency slit attenuation and any low-pass (Academy) filters; a magnetic A-chain is nominally flat, as is the A-chain for nonsync sources (disk or tape).

The December 1969 issue of the *Journal* also contained two other relevant papers: one from Denmark, “A Report on Listening Characteristics in 25 Danish Cinemas” by Rasmussen⁴, and one from the U.K., “The Evaluation and Standardization of the Loudspeaker-Acoustics Link in Motion Picture Theatres” by Lumkin and Buckle⁵. All three papers reported multiple theatre B-chain measurements, and instantly noticeable is the wide variation in characteristics in different theatres—more on this to follow. A fourth paper in the same issue of the *Journal* was a reprint of a draft international standard for a B-chain response prepared by ISO TC36—Cinematography. Work on the project had started at a meeting in Moscow in May 1969. This was an attempt to codify the B-chain response for the average theatre and at first received initial basic agreement from the U.S., the U.S.S.R., and most European countries. The response is about 14 dB down at 8 kHz, as shown in Figure 4.

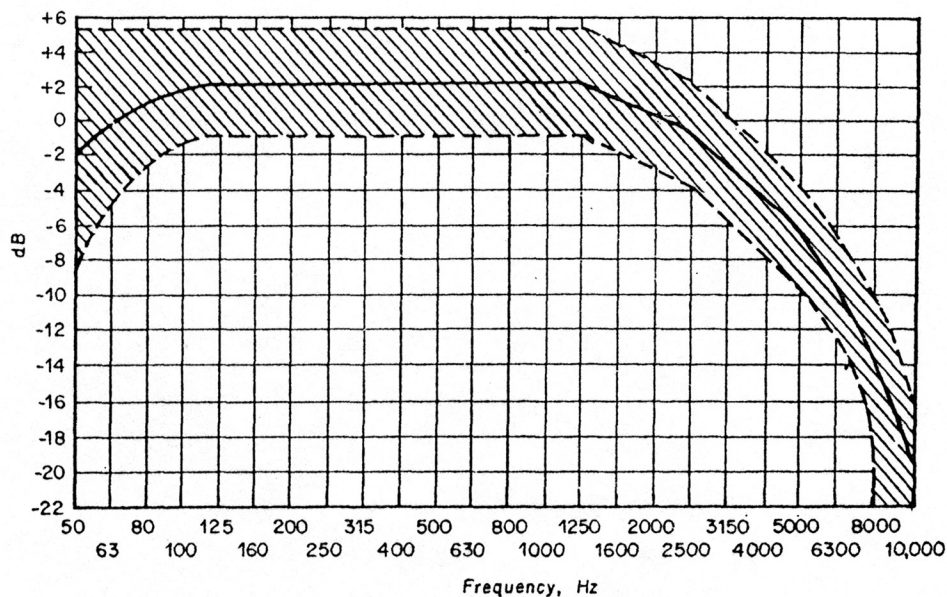


Figure 4 - 1969: First ISO draft of B-chain characteristic -- -14 dB at 8 kHz

These papers all quoted the use of noise for B-chain measurements, typically played off film or tape. A tape recorder allowed direct insertion of noise into the B-chain. Noise on film, on the other hand, would require the subtraction of any A-chain characteristics from the measured (A + B) response. Buckle and Lumkin quote the use of white noise in 1/3 octaves, Rasmussen both whole and 1/3 octaves, and the draft ISO document cited the use of pink noise in sequential 1/3 octaves, typically measured with a sound level meter.

First Dolby Excursions into Film Sound

The year 1969 marked the first use of Dolby® noise reduction in the film industry, with the music recording of *Oliver*. At that time, Dolby A-type noise reduction was widely used by the music recording industry, initially for two-track classical recording and then to counteract the noise build-up inherent with eight, and later sixteen, track recorders. A-type noise reduction was next used in the film industry for music recording and some magnetic generations on *Ryan's Daughter* (1970).

The author was frustrated at the limited benefit heard from this process when the films were released in theatres. In 1970, a test was conducted at Pinewood Studios in England with a remixed reel of *Jane Eyre*, with A-type noise reduction actually applied to the mono-optical release print itself. Again, the results were disappointing in playback, as the reduction in noise did nothing to help the limited bandwidth and audible distortion.⁶

During 1971, Walter Carlos was retained by Stanley Kubrick to compose and perform the music for *A Clockwork Orange*, which was undergoing post-production at Elstree Studios in England. Carlos introduced the author to Kubrick, who agreed to use Dolby noise reduction on all premixes for the film, a much wider deployment of noise reduction than ever used previously on a film soundtrack.

Even by the standards of the time, the Elstree main dubbing theatre was large (2,400 m³, 84,700 ft³). It is now a supermarket check-out area. At the time, it was equipped with three behind-the-screen Vitavox loudspeakers, two-way units with passive crossovers. The high-frequency unit used a sectored horn, and the whole assembly could probably be considered loosely similar to an Altec A4 of similar vintage. Even so, the author seems to recall a single Altec A4 being situated in the half-left behind-screen position, where it could have been used to check how a mix would sound in the U.S., where Altec was the dominant speaker manufacturer.

The Wide-Range Optical Soundtrack

It seemed obvious that the monitor characteristic for conventional optical sound mixing caused severe quality limitations. An (A+B) response well over 20 dB down at 8 kHz led to excessive pre-emphasis. This in turn led to excessive distortion. Limited high-frequency response led to the mixer rolling off low-frequencies, to make the sound “more balanced” (see below). If the monitor response was flattened, less equalization would be required, and the distortion would be lower.

In an effort to explore the viability of wide-range optical soundtracks, Dolby was allowed to use sections of *A Clockwork Orange* (which was being mixed at the time) for experimentation. Attempts were made to adjust the equalization of the Vitavox loudspeakers to some ill-defined but broader characteristic. A whole-octave graphic equalizer was used, in conjunction with whole-octave pink noise as a test signal. The process was difficult, and it was suggested that some material be mixed with wide-range music industry loudspeakers much closer to the mixing position. Lockwood and KEF loudspeakers were used, at ranges of 10 or 15 ft from the console.

A series of tests were carried out spanning two months at the end of 1971. The mixers initially expressed some trepidation that a wide-range soundtrack would reveal background noise and other defects in the original dialog recordings, but found this not to be the case. There was no doubt that voice quality was significantly improved with a soundtrack that could be recorded “flat.” In other words, on average, no equalization was required.

Another test to evaluate close monitoring involved equalizing the near-field loudspeakers to the

⁶“The X-Curve” by Ioan Allen, *SMPTE Motion Imaging Journal*, July/August 2006, www.smppte.org, page 6 of 24

same curve as measured from the far-field cinema loudspeakers. A Dolby engineer's notes for November 15, 1971 contain the following interesting passage: "Stan found KEF's (when equalized for same response as theatre speaker) much cleaner and tighter. He could hear details in effects (chewing, etc.) that escaped when played on theatre speakers. Tried listening to KEF from a distance. Stan found sound similar to theatre speaker's sound." (The author is amazed that anyone referred to Stanley Kubrick as Stan!) On November 17, one reel of *A Clockwork Orange* was remixed over unequalized wide-range near-field monitors.

These experiments at Elstree Studios paralleled other work Dolby carried out at Pinewood Studios. There, a different approach was taken, in an effort to extend the theatre loudspeaker response—an extra passive crossover was installed, and a conventional dome tweeter mounted just above the screen. Although the extended response helped the playback quality, the diffuse quality of high-frequency distribution led to abandonment of this concept.

Measuring Theatres to Find Out the Average Responses in the U.S. and the U.K.

The early 1970s saw the introduction of the third-octave realtime analyzer for audio analysis. This made measurement of the theatres' B-chains much easier, both in terms of time taken and increased detail. Dolby made extensive measurements of electro-acoustic responses in theatres, both in the U.K. and the U.S. Figure 5 shows the average U.K. B-chain response of 45 theatres. There are several interesting issues. First, the crossover dip at 500 Hz is clearly evident, suggesting that in some cases there was a very deep notch. Secondly, the response is about 16 dB down at 8 kHz—very close to the 14 dB suggested in the 1969 ISO draft document referred to earlier. Finally, it can be seen that the response is remarkably "balanced," with the high-frequency droop symmetrically matched by the low-frequency characteristic. This supports the old maxim that "you have to cut the lows if you cut the highs." Olson⁷ quoted "some investigators" as saying the product of the upper and lower limits of the frequency range should be 500,000 cycles.

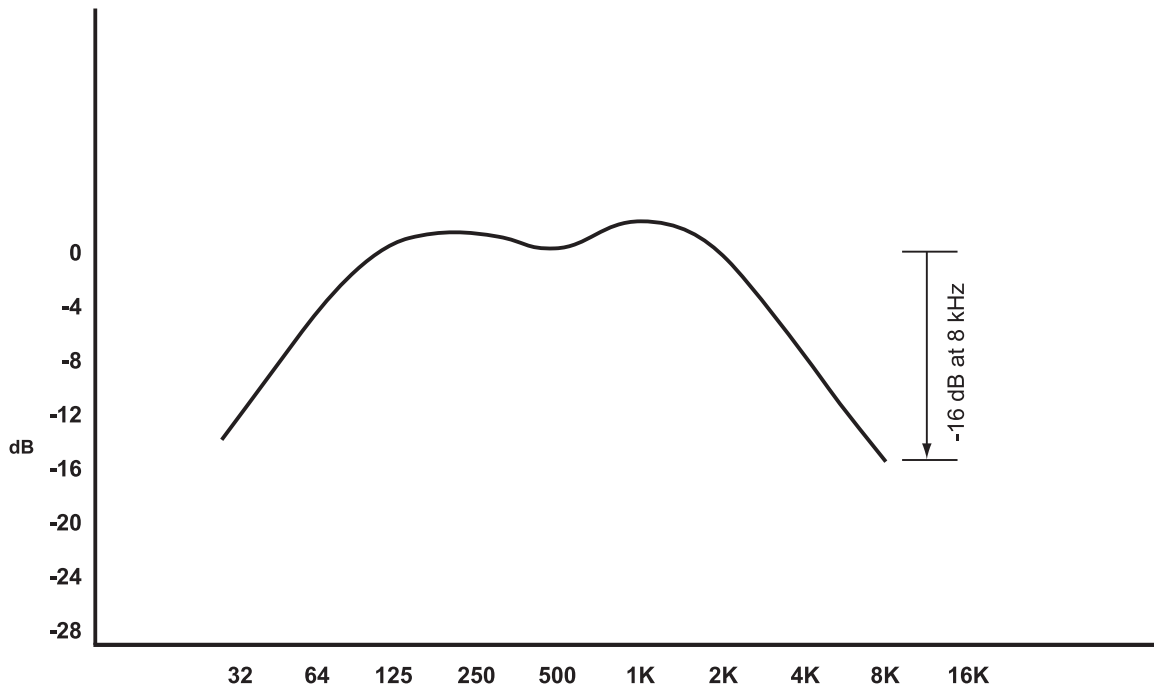
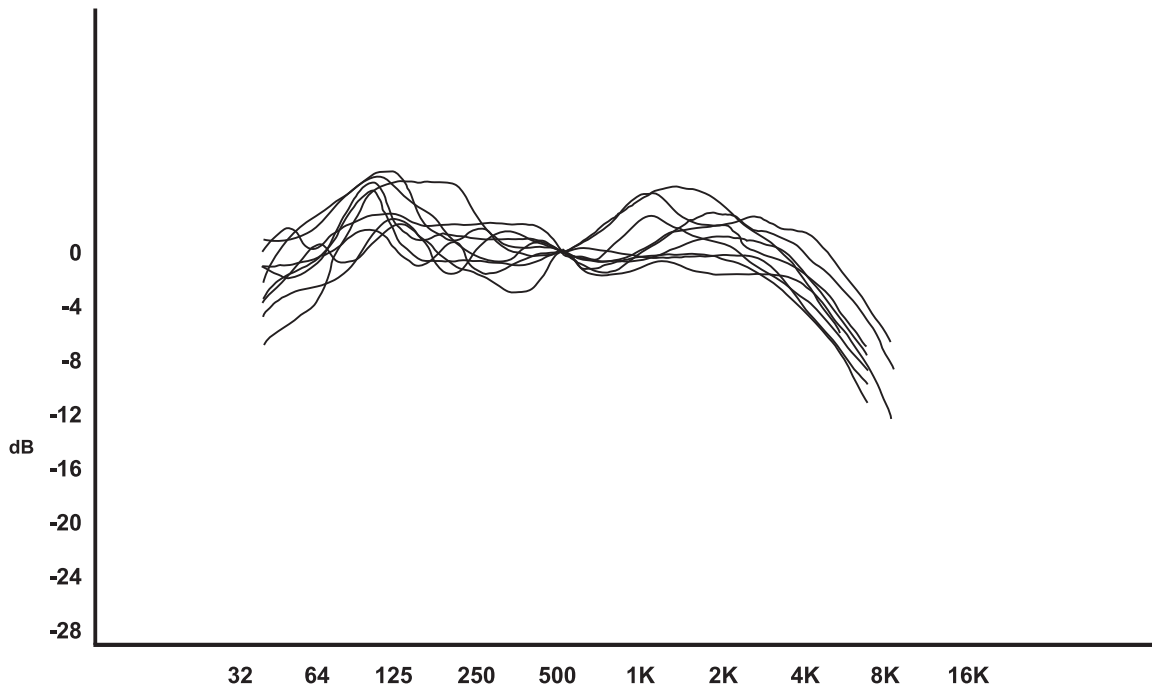


Figure 5 - 1973/4: Average of 45 UK theatres – B-chain only. -16 dB at 8 kHz

Another interesting phenomenon is the width of the spread—how much deviation there was between theatres. Even within Hollywood, there were significant variations between mix-rooms, as seen by the family of nine curves shown in Fig. 6.



*Figure 6 - 1974: Nine Hollywood dubbing stages – B-chain only
(normalized at 500 Hz)*

A comparison of U.S. and U.K. average B-chain responses at the time can be found in Fig. 7, showing how the U.S. had a characteristic extending slightly further, both at low and high frequencies. Figure 8 shows that the 1969 ISO recommendation was not far removed from the actual curves found in U.S. and U.K. theatres.

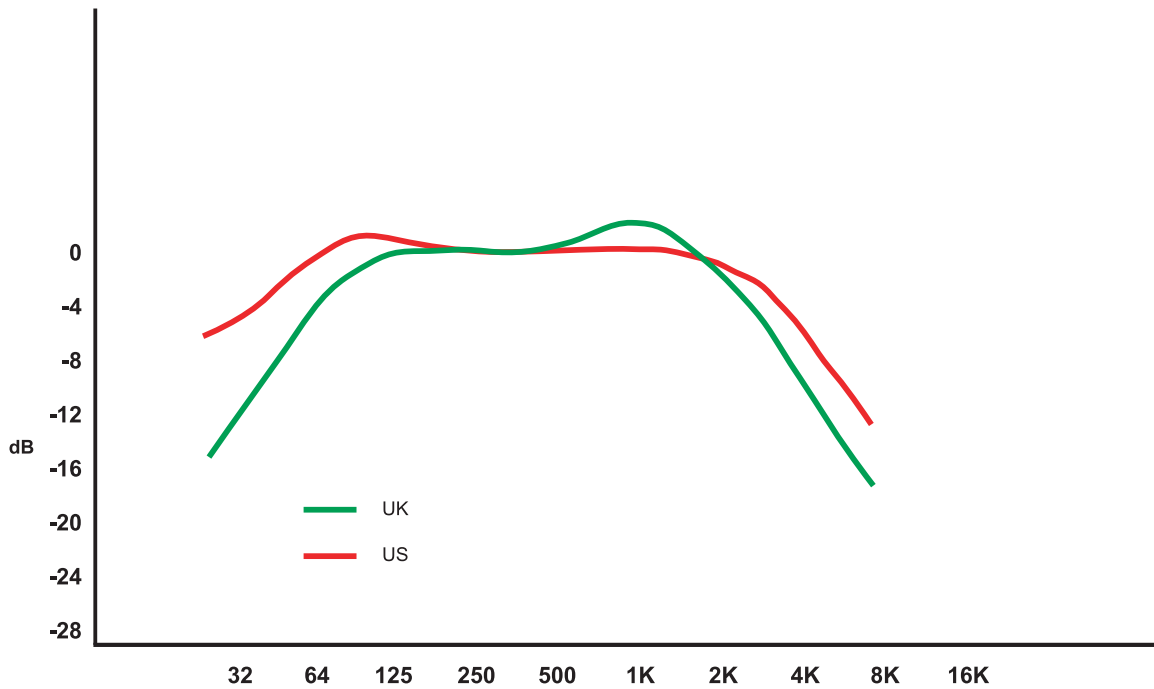


Figure 7 - 1974: Comparison of UK and US average theatre – B-chain only

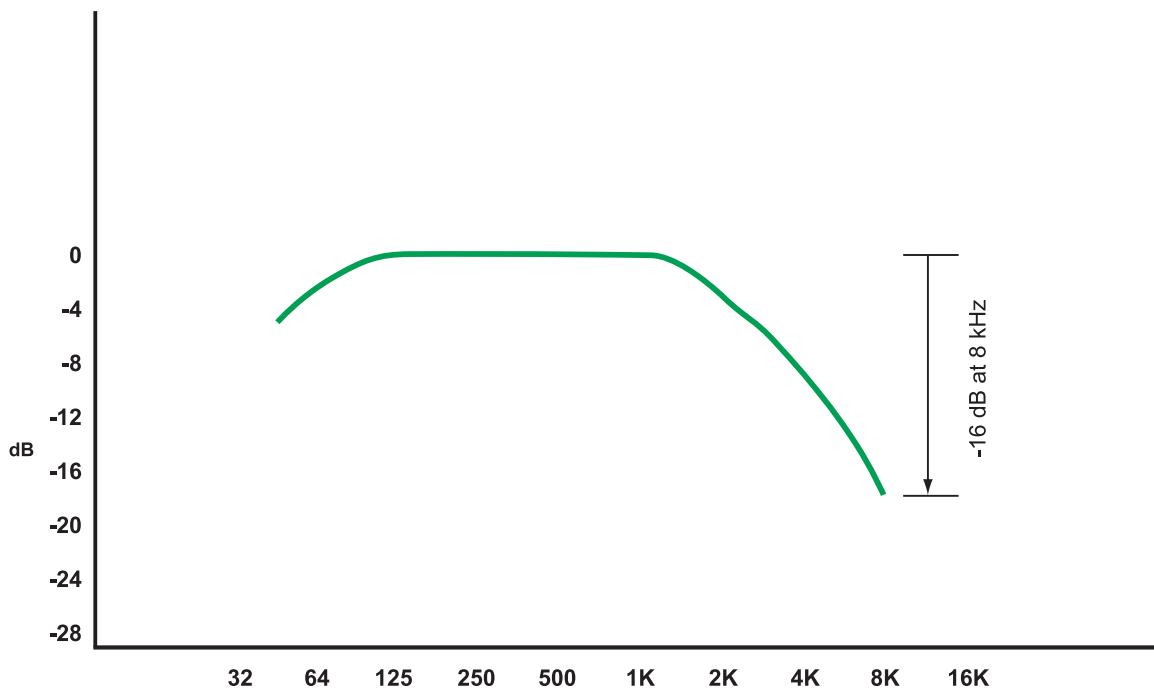


Figure 8 - 1974: New ISO B-chain draft -- -16 dB at 8 kHz

The Academy A-chain

It should be remembered that the above measurements are of the B-chain. Although magnetic tracks were theoretically played back with a flat A-chain response, as were nonsync sources, optical soundtracks had significant high-frequency attenuation, as discussed previously. Figure 9 shows the average A-chain response added to the B-chain, giving a total (A+B) U.K. response about 28 dB down at 8 kHz. Measurements in the U.S. suggest that the overall response there would, on average, only have been 25 dB down—but let's not nit-pick!

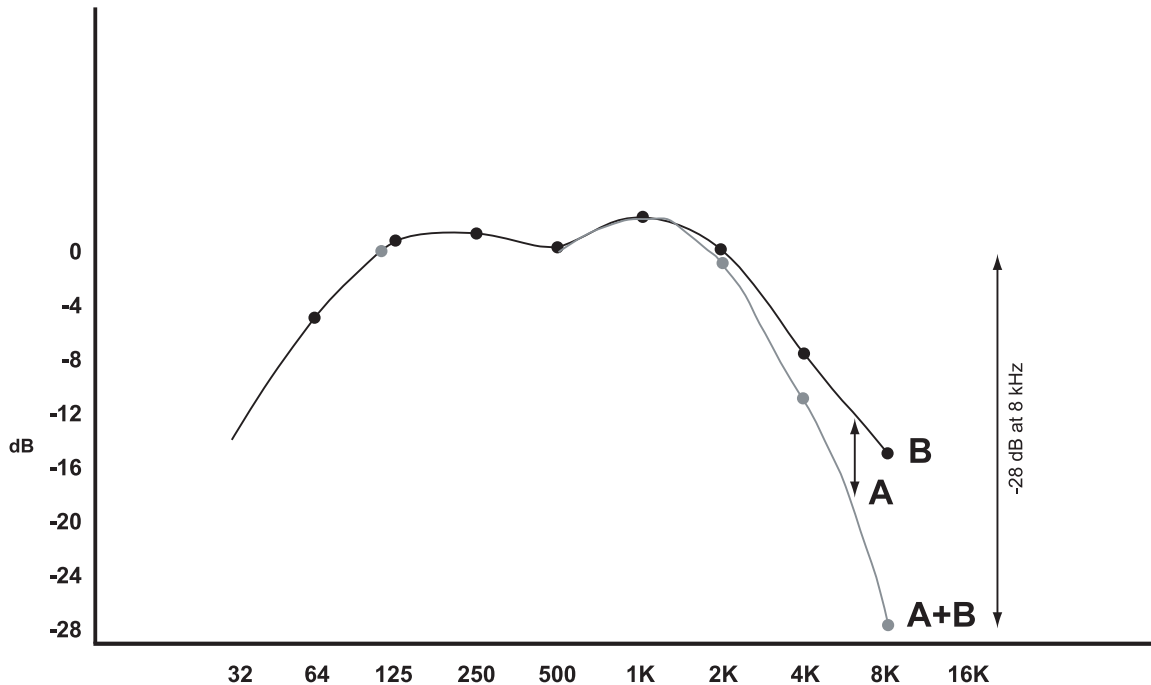


Figure 9 - 1974: Average UK A-chain and B-chain response – total (A+B) -28 dB at 8 kHz

Raising the Bar

As was discussed previously, this overall system had severe limitations. These included extremely limited bandwidth and high distortion. However, throwing out the Academy Curve in the A-chain and extending the loudspeaker characteristic would lower distortion and improve the bandwidth, but would inevitably reveal significant high-frequency hiss, and probably hum, caused by a 50- or 60-Hz power ripple from tungsten lights in the projection booth landing on the photo or solar cell.

Noise reduction on the release print was the obvious answer, allowing the bandwidth extension without a buildup of noise,⁶ but with an extended monitor characteristic, unlike the *Jane Eyre* test described above. The next step was to determine an optimum B-chain characteristic. It was fortuitous that around this time third-octave equalizers were becoming available,⁸ and this (along with wide-band pink noise and third-octave analyzers) made experimental B-chain characteristics easier to implement. By this time we had abandoned the idea of near-field monitoring for film mixing

especially for stereo mixing, where there are severe location problems with a picture 40 or more ft away, and speakers only 10 or 15 ft away!

Loudspeaker Efficiency

An interesting realization at this time was that the typical two-way cinema loudspeaker was very “equalizeable.” The relatively high costs of power amplifiers in the early days of sound films had made loudspeaker efficiency of paramount importance, and this in turn meant that the response could fairly easily be improved by equalization (within limits) at some cost in efficiency. What had to be determined next was the ideal extended loudspeaker characteristic in a cinema, and what was possible with the loudspeakers in use.

Matching the Near-Field to the Far-Field

An experiment was set up at the Elstree dubbing theatre. Near-field monitors (KEF’s) were positioned close to the console, as shown in Fig. 10, and the response confirmed as being close to flat. A variety of flat (unequalized) recordings of dialog and music were played to confirm that, on average, no equalization was deemed necessary.

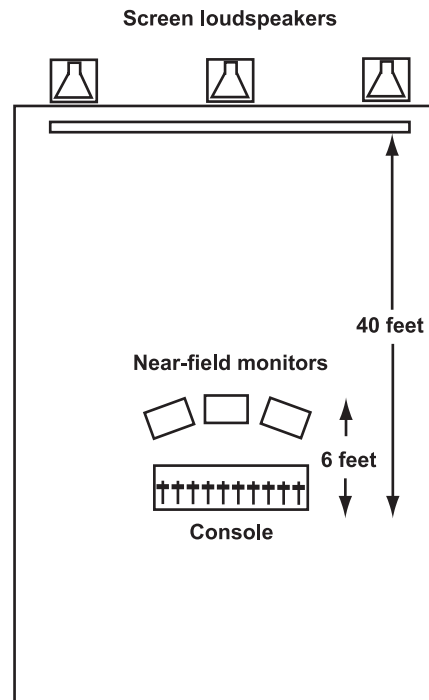


Figure 10 - 1971/72: Elstree Studio – Near-field vs. far-field timbre matching experiment

The far-field stage Vitavox loudspeakers were now equalized to achieve a best timbre match with the near-field sound. Obviously, the three main steps were to extend the high-frequency response,

extend the low-frequency response, and smooth out the crossover region. A surprising development was the discovery that the best subjective match still showed an apparent slight HF droop. A slope of around 3 dB per octave from about 2 kHz seemed to give the best results, along with a slight limitation to low-frequency bandwidth, as seen in Fig. 11. The low-frequency limitation is easy to explain—more low-frequency energy would probably overload the loudspeaker and generate distortion components. The reason for the apparently desirable HF droop is not very easy to explain. There are three possibilities, singly or in combination:

- (1) Some psychoacoustic phenomena involving faraway sound and picture.
- (2) Some distortion components in the loudspeaker, making more HF objectionable.
- (3) The result of reverberation buildup, as described below.

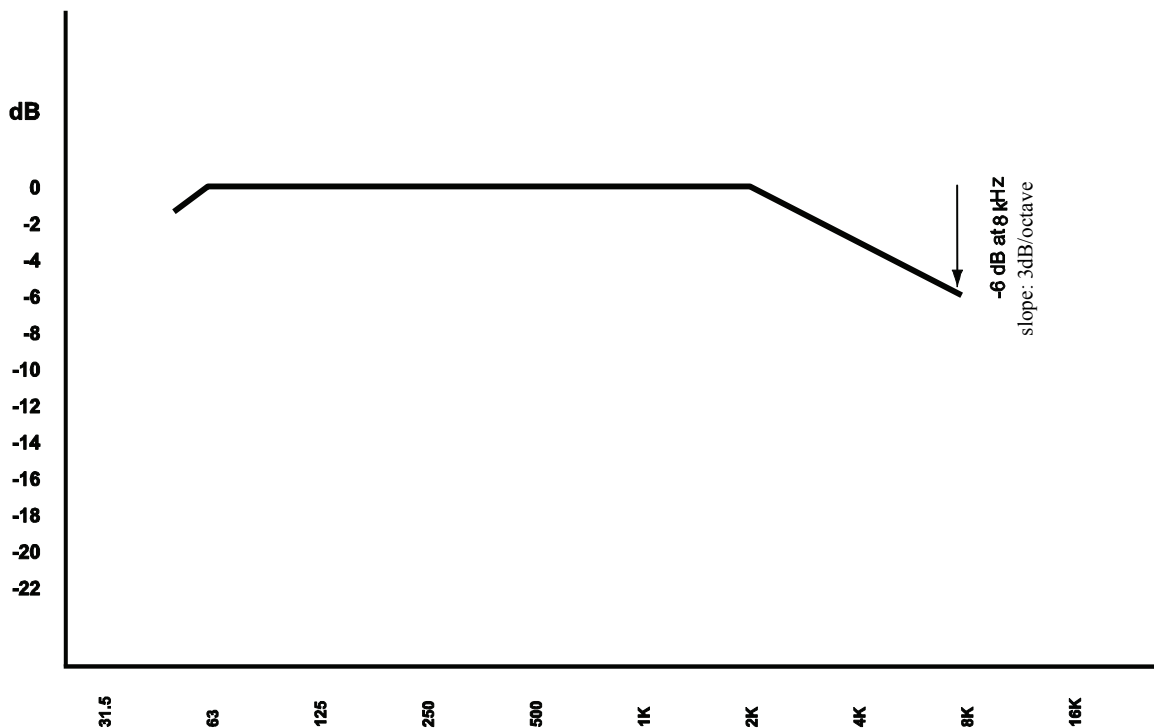


Figure 11 - 1972: The first wide-range B-chain characteristic – later called the X-Curve

The Reverberation Model

It is obvious that as far as possible, the mix-room should match the typical replay theatre—the sound mixer and the director want to hear how their film will sound to the ticket buying customer. This led to the typical large dubbing theatres in Hollywood and the U.K., where the furnishings, screens, and loudspeakers all emulated commercial cinemas.

Every bounded room (i.e., with surfaces) has reverberation. Generally, the larger the volume of the room, the greater the reverberation, as shown in Fig. 12. More often than not, the reverberation will be greater at low frequencies and reduce at high frequencies. For a room to reach a steady-state acoustic condition, the audio signal must be sustained for a time proportional to the reverberation behavior at that frequency.

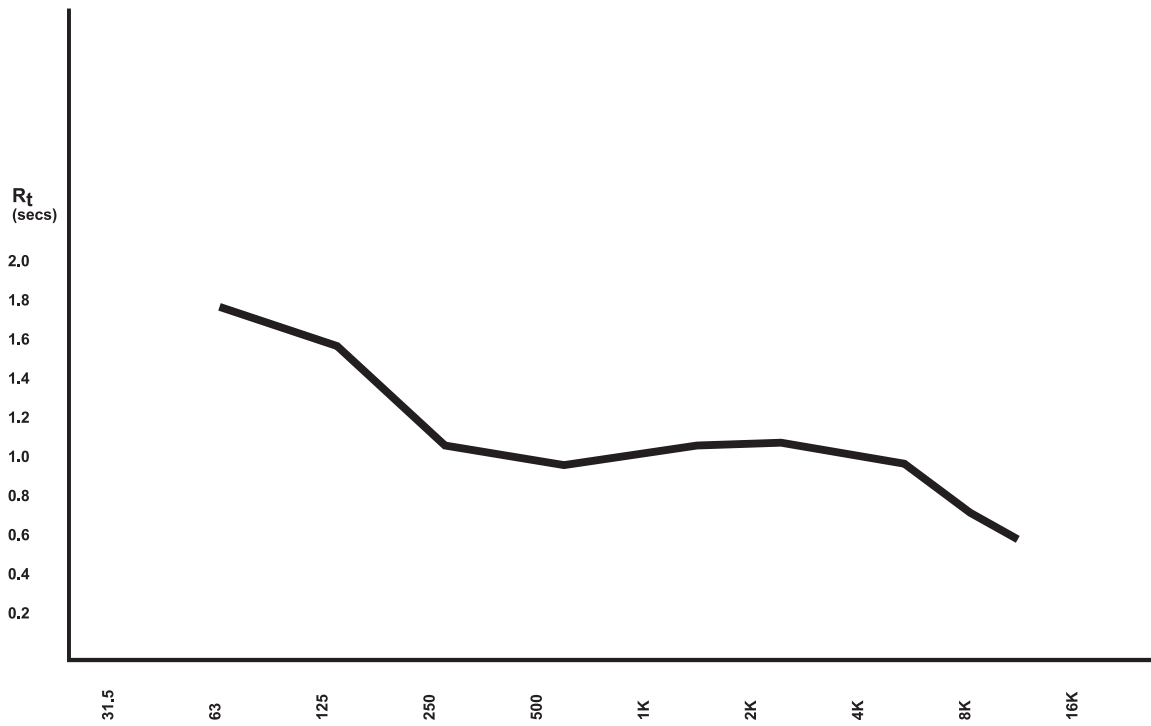


Figure 12 - Typical medium to large size theatre reverberation characteristic

Measurement of a steady-state signal (like pink noise) will show the combination of the signal coming directly from the loudspeaker and the component added by room reverberation (Fig. 13). Consequently, there will be a difference in frequency response between the first-arrival signal (before reverberation build-up) and that when the audio has reached a steady-state condition (Fig. 14).

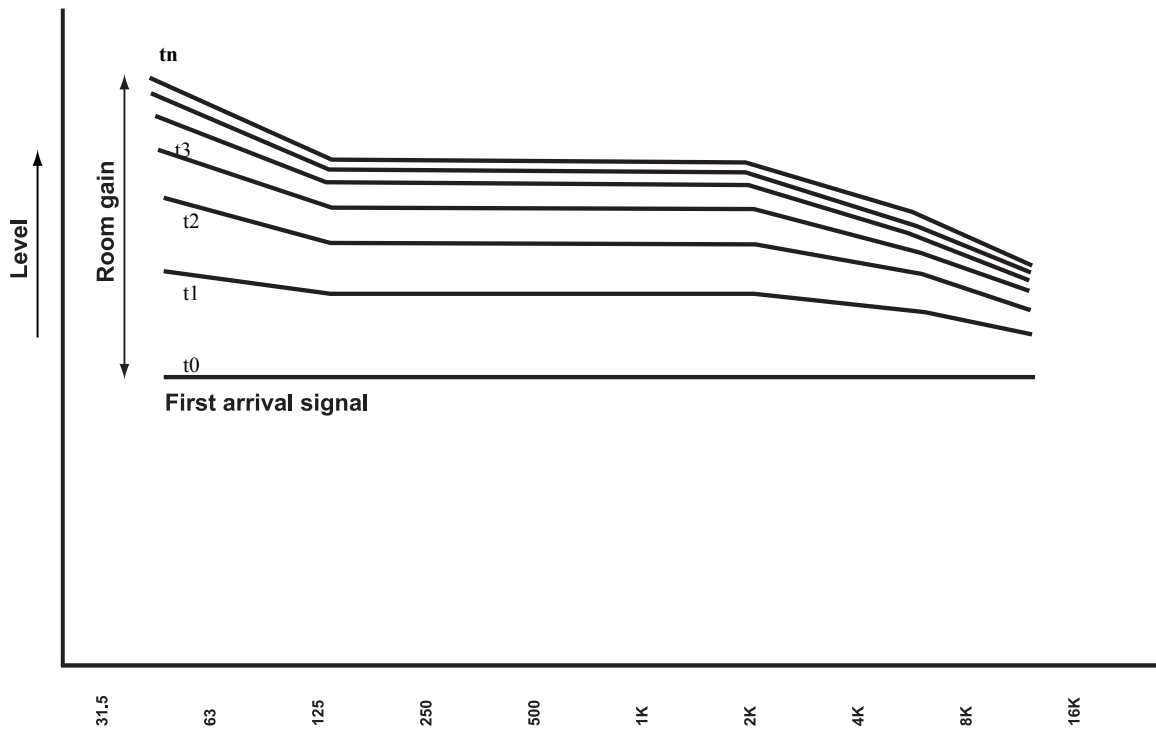


Figure 13 - Pink noise build-up over time in medium to large size theatre

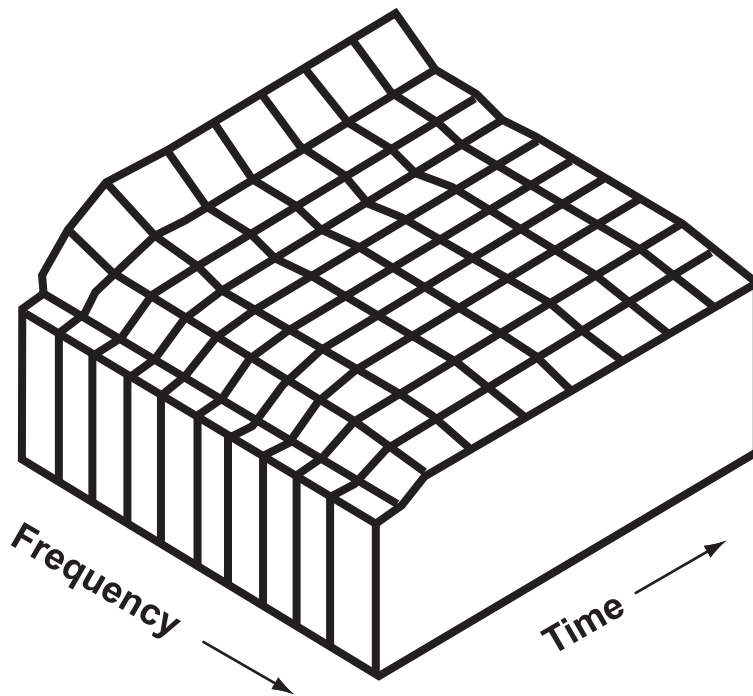


Figure 14 - Frequency response changes with duration of signal

If the perceived spectral characteristic of a signal is therefore determined by its duration, some judgments have to be made about the duration of typical material. It is a somewhat broad-reaching statement, but perhaps 80% of movie soundtracks are dialog. And many speech elements such as “t,” “p,” “d,” and so on, are short in duration. Certainly these have a duration so short that they will have been and gone in an average-sized theatre before the first reflection and the commencement of any reverberation.

So, if the requirement is to have the short-duration sounds moderately flat on the soundtrack, that is, not needing any consistent pre-emphasis, then the steady-state condition will show an apparent HF droop. In other words, if a room is tuned with pink noise as a test signal to have a 3 dB per octave slope from 2 kHz, the first-arrival signal will be closer to flat than the 3 dB per octave seen on an analyzer would suggest. Indeed, if a large room were to be tuned flat with pink noise, it is possible that the first-arrival signal would show a rising high-frequency characteristic, as shown in Fig. 15.

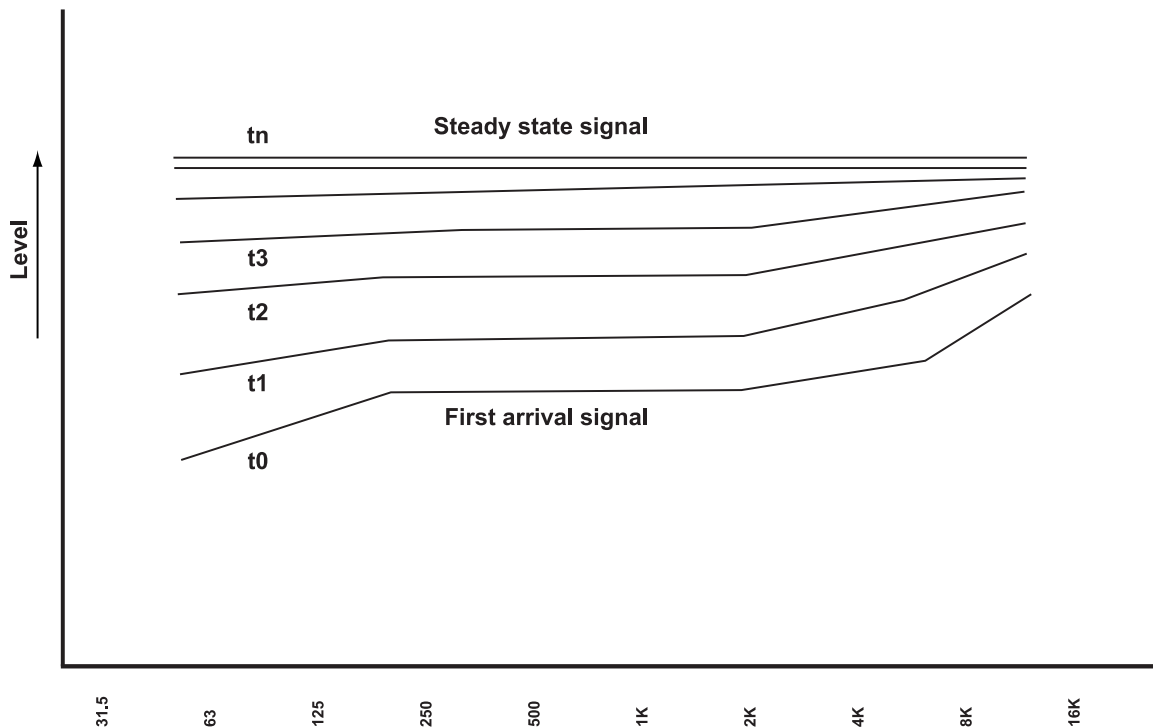


Figure 15 - What would happen to first-arrival signal if pink noise was tuned for flat

This also leads to the conclusion that the amount of apparent HF droop should vary according to the reverberation slope. Usually, the bigger the room, the greater the amount of apparent HF droop needed to maintain a constant voice tone. The phenomenon is discussed by Schulein⁹ and later Queen.¹⁰

It should be repeated that the foregoing is only one suggestion as to the mechanism that requires apparently different measured characteristics to achieve the same subjective response with different-sized rooms. All that can be said for sure is that with a pink noise test signal, the apparent tuning should be flatter in a small room than in a large cinema.

The Standards

As was mentioned earlier, a draft International Standard (ISO DIS2969 Cinematography -- B-chain electro-acoustic response of motion-picture control rooms and indoor theatres -- Specifications and measurements) was in circulation in 1969 for B-chain monitoring. This had an HF droop of about 14 dB at 8 kHz. Recall that this was only part of the playback characteristic, and there would also be an A-chain roll-off, the old Academy Curve. After a meeting in London in June 1971, a modified draft was circulated to member countries in April 1972. Another editorially modified version was circulated for voting in November 1972.

Eleven countries voted yes, and three countries disapproved—Germany, Italy, and the U.S. Germany felt that its theatres had a much flatter characteristic than shown in the document. A primary reason for the U.S. “no” vote, was the belief that only an (A+B) chain document would be of use. The U.S. pointed out that one country could have a steeper A-chain roll-off and a flatter B-chain than another, but demonstrate the same overall response. This case was further argued in a comment by Petro Vlahos, U.S. correspondent to ISO TC36, circulated in August 1973.¹¹ In an effort to solve this impasse, ISO TC36 now agreed to start work on an A-chain document to augment their work on the B-chain.

The author had started lobbying in the U.K. and U.S. for a much flatter B-chain curve, matching the 3 dB per octave slope discussed in the experimental work described above. This wide-range curve would require a steeper A-chain roll-off than current practice for the playback of “Academy” pre-emphasized soundtracks, but would also allow for the playback of new “flat” soundtracks using companding noise reduction as an alternative to high-frequency roll-offs.⁶

In a heroic gesture, the U.K. drafted a new version of ISO DIS2969, which defined the 3 dB per octave slope. It was apparent that in some countries, this curve was much brighter than current practice, and it was decided that ISO member countries should be asked to survey some of their typical theatres. A new draft of the document was circulated in February 1975, with two curves listed. Both were brighter than the previous 16 dB down at 8 kHz. One was 11 dB down at 8 kHz, and the other, the wide-range curve, down 6 dB at 8 kHz. They were labeled “A” and “B,” and a note in the draft said: “This proposed draft includes two characteristics for the response beyond 4 kHz. The response and tolerances are identical up to 4 kHz. Depending on the replies by Preparatory Working Group 3 Specialists, only one of these characteristics will be chosen.”

At a meeting in London in June 1975, a compromise was reached and it was decided that both curves should be in the next draft document. The wide-range curve was now called Curve X. A new phrase was added: “The Curve X and its tolerance. . . represents the characteristic for future development.” This was fine-tuned in a new version circulated in September 1975, which now tracked the curves out to 10 kHz.

At last, this became the first published version, finally ratified in 1977. This document was mimicked in the

U.S. and became SMPTE 202M Dubbing Theatres, Review Rooms, and Indoor Theatres – B-Chain Electro-acoustic Response, in August of 1978. Several changes were made in 1982, at the time of the first revision of the ISO document. The “normal” curve was now referred to as Curve N, and Curve X was now referred to as “a wide-range curve.” Next, both curves were extended out on a straight-line basis to 12.5 kHz, where consequently the wide-range curve was down 8 dB.

Finally, it was acknowledged that the B-chain characteristic measured with pink noise should change according to room size, and a correction table (reproduced in Fig. 16) was added, which rather crudely used the number of seats as the ordinate! (The latest revision still does.) Figure 17 shows how the correction table translates to the desired characteristics for varying theatre sizes.

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The next revisions of both the ISO and U.S. documents came in 1991, when Curve N, the normal curve, was curtailed at 10 kHz and Curve X extended to 16 kHz. At the same time, a second break point at 10 kHz was added to the X-Curve, which resulted in a slightly steeper slope between 10 and 16 kHz, as shown in Fig. 18.

Frequency	Number of seats					
kHz	30	150	500	1000	1500	2000
2.0	0	0	0	0	0	0
4.0	1.0	0.5	0	-0.5	-1.0	-1.5
8.0	2.0	1.0	0	-1.0	-2.0	-3.0

Figure 16 - 1982 SMPTE 202M – X-Curve Correction Table for theatre size

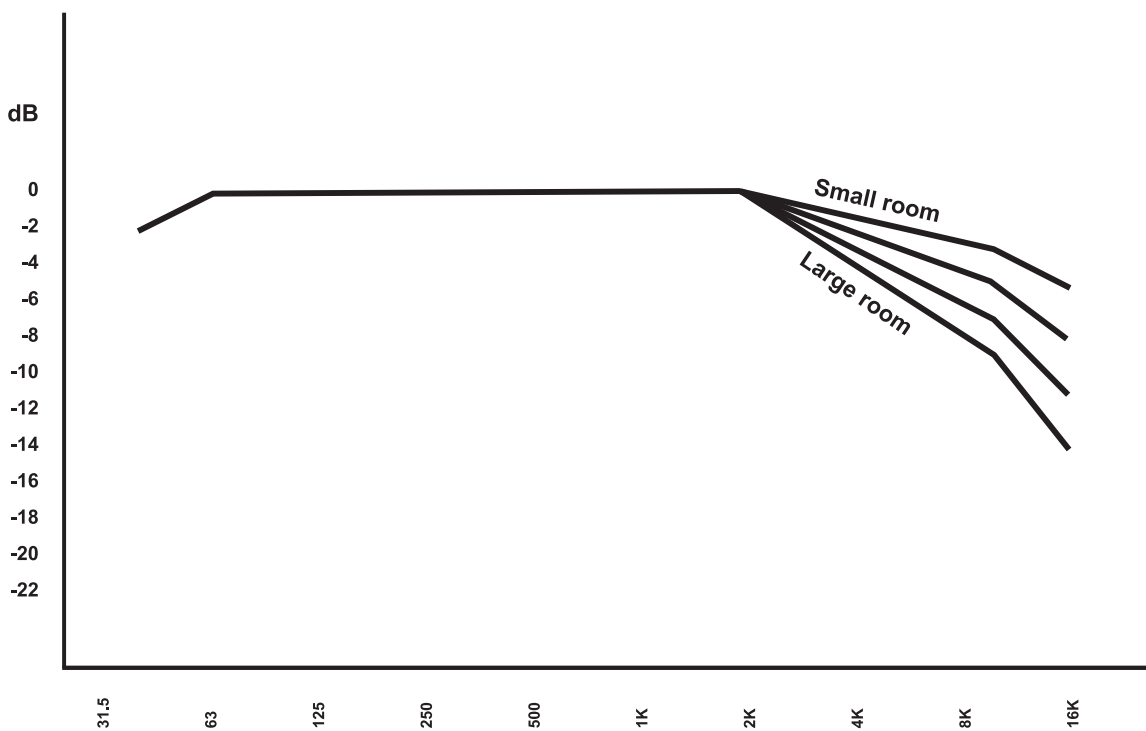
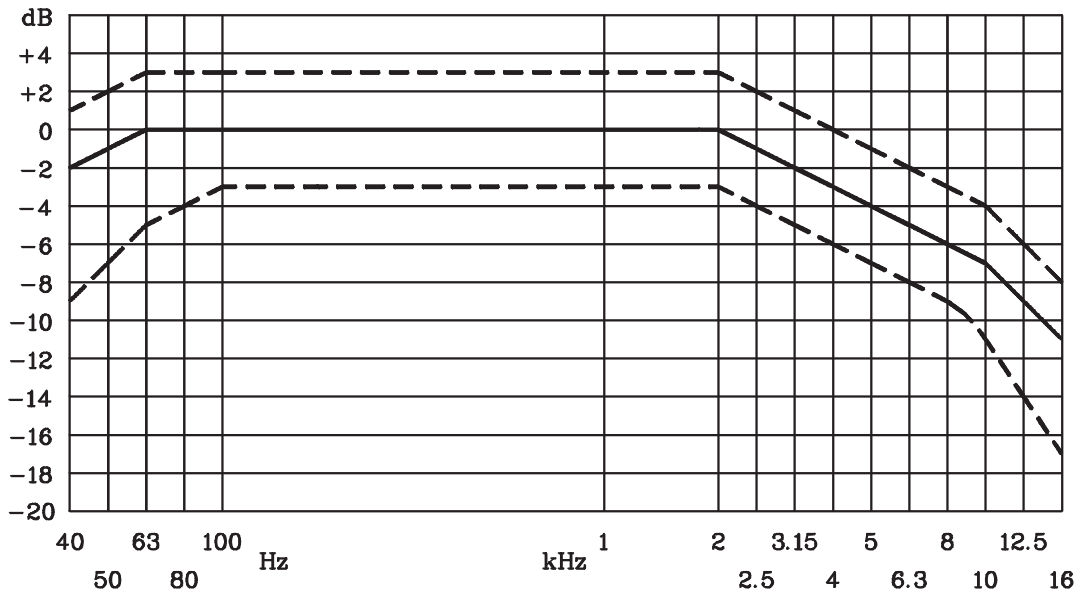


Figure 17 - SMPTE 202M – 1982 - Corrections for theatre size



NOTE – Tolerances are based upon 1/3-octave measurements. If 1/1-octave measurements are used, reduce the tolerance by 1 dB.

Figure 18 - SMPTE 202M – 1998 – X-Curve extended to 16 kHz with second break point at 10 kHz

Translation: The Holy Grail

The target of standardization of monitor characteristic, whether cinema, television, music recording, indeed any environment, has to be that material can pass from one to another without requiring any by rote equalization. This was the target of the original drafters of the X-Curve. But the slope in the original documents was initially adopted as a rigid regulation. In a small “dry” room set up at the nominal 3 dB per octave slope, with a moderately flat reverberation characteristic at high frequencies, flat material would sound dull— a mixer would elevate the high frequencies. In a very large theatre the same material would sound bright if set to the same 3 dB per octave slope. In the mid-1980s this became a problem. New mix-rooms were being built, with short and moderately flat reverberation times. Tuning to a 3 dB per octave slope with steady-state pink noise led inevitably to overly bright mixes.

However, a better understanding of room size scaling has improved the situation. The author’s understanding is that most material arriving today at mix-rooms in Hollywood and New York (dialog location recordings, ADR, music, etc.) doesn’t require any consistent up or down high-frequency re-equalization. At the next step, translation of a film soundtrack from the theatrical version to a consumer release on DVD or TV, is much more likely to need adjustment for the home listening environment (dynamics, limiting, and etc.) than for any need for re-equalization.

Surrounds

Pink noise measurements inevitably contain a combination of both direct signal and reverberation, and much film soundtrack content is made up of short duration content; therefore, it would seem that the listener’s location becomes significant. Is it close to a loudspeaker or far away

and in the diffuse field? A more difficult question to resolve would be how much short duration material (speech or impact sounds) on a given movie is on the surround speakers. What can be assumed, however, is that in a well-designed theatre with a length-to-width ratio of about 1.5:1, more listeners will be closer to surround speakers than to screen channels. In a 1999 publication,¹² the author suggested that surround loudspeakers being tuned with pink noise should show a brighter characteristic than the stage channels. Subjective listening tests seem to support this concept.

However, the scaling described is different from that in ISO DIS2969 and SMPTE 202M. These two standards suggest that room size scaling (and implicitly the difference in distance to loudspeakers) should be adjusted by the slope of the measured characteristic with a turnover at 2 kHz. A “medium-sized” room should be tuned with a 3 dB per octave slope, a “large room” at 4 dB per octave, a “small room” at 2 dB per octave. However, the quoted document suggests that the slope should be constant, but the turnover point should be adjusted, as shown in Fig. 19. So, where the average listener is much closer to surrounds than screen, and clearly in the direct field, the optimal surround tuning should show a slope starting at ~4 kHz.

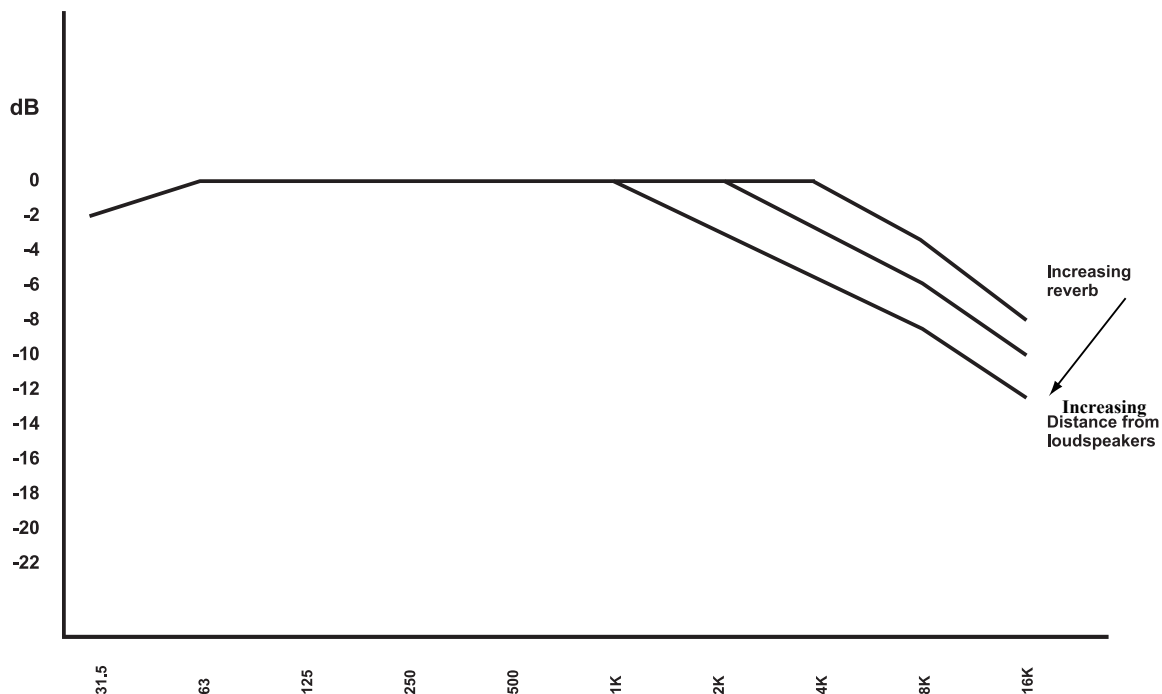


Figure 19 - Adjustments for room size and distance to surround loudspeakers – adjusting the turnover frequency as opposed to adjusting the slope

Making an exact determination of correct tuning, however, is no trivial task, whether for screen loudspeakers or for surrounds. The calculation would have to take account of the room dimensions and volume, the shape of the room, and its reverberation characteristic. Even more problematic, if material were mixed in a small room, in a large theatre it would have to have information about the content as it varied between short-duration (speech) signals, and long duration (music and possibly effects) to have perfect playback translation.

Standardized Levels

Although it is not a part of the B-chain, mention should be made here of the other aspect of a standardized playback experience: sound level. The first version of SMPTE RP 200 was issued in 1999, even though the practice had been employed in the field since the late 1970s. RP 200 was modified in 2002,¹³ and in its current form covers standardized playback levels for both film and digital cinema recording and playback monitor levels.

In the way that the X-Curve is applied in both the mix-room and the playback theatre, translation of the director's and sound designer's vision to the playback theatre requires the same playback level as heard in the mix-room. The standard calls for pink noise to generate 85 dBC at reference level, originally at 50% optical modulation for optical soundtracks. From the introduction of wide-range optical soundtracks in the mid-1970s through to the late 1980s, most theatres played back films at the recommended level in the RP. The peak level on these soundtracks was physically limited to 6 dB above the reference point. The late 1980s saw the industry shift from Dolby A-type noise reduction to Dolby SR, and this permitted an increase in peak capability of a further 3 dB. In the early 1990s, digital soundtracks allowed a further increase in peak levels to 18 dB above reference, which more and more directors began to take advantage of, but unfortunately throughout the film! The result has been a tendency in recent years for playback theatres to reduce the playback level below the calibration point. Some rural theatres may play films as much as 8 dB below reference, a tendency to be deplored, as it frequently results in dialog unintelligibility. The blame lies with both the director and the theatre. The director should realize that if the peak level capability of the new media is used throughout the film, the playback level will be reduced.¹⁴

Why the Dialog Seemed Quieter in Big Theatres

Verna Fields, one of the industry's most respected editors in the 1970s, took the author to task on several occasions, claiming that dialog intelligibility of wide-range soundtracks was worse in preview screenings than on the dubbing stages and that music and effects swamped the dialog. This was at a time when the playback theatre was accurately set up to mimic the monitor level in the mix-room. One possible explanation for such a phenomenon is that the theatres selected for preview screenings in the 1970s were typically much larger than mix-rooms.

If the playback B-chain characteristics of both frequency response and level are set using pink noise, then reverberation becomes a critical issue. The greater the reverberation time, the greater the disparity between steady-state levels (after reverberation buildup), and the first-arrival signal level. In a large theatre, steady-state effects and much music material will be augmented by reverberation, in contrast with short-term speech sounds. The subjective result may well be what was complained of—the dialog will sound increasingly swamped by effects and music as the playback theatre's volume increases. This is probably less of a problem now than it was 25 years ago. New theatres are now smaller and built with much more absorptive surfaces and materials, with consequently shorter reverberation times.

Steady-State vs. First-Arrival Measurement Techniques

The dominance of dialog in a typical movie was discussed previously. If the words are the lifeblood of the movie and 80% of the movie is words, and if many of the sounds that make for

¹⁴“The X-Curve” by Ioan Allen, *SMPTE Motion Imaging Journal*, July/August 2006, www.smppte.org, page 21 of 24

speech intelligibility are of short duration, one may ask why steady-state measurement techniques are used to calibrate theatres, as opposed to measurements of first-arrival signals.

There are two answers. First, in the mid-1970s, when theatre equalization became practical, pink noise and a realtime analyzer were the only tools and technique available and at a cost practical in the commercial theatre world.

But a more interesting possibility is that setting a flat first-arrival frequency response may not be a good thing. Ear and brain do not have a flat frequency response integration time; the combination takes much longer to determine loudness at low frequencies than at mid and high frequencies.¹⁵

Indeed, it seems possible that as yet, no perfect technique for B-chain measurement exists, requiring, it would seem, some combination of first-arrival and steady-state analysis.

Conclusion

The X-Curve is probably not perfect, and neither are the measurement techniques employed. But it should be remembered that the introduction of the X-Curve represented a radical change in film sound practice and led to a revolution in film sound quality. No one has suggested that any further radical change is needed at this time. The fine-tuning of the standards over the last 20 years, and the education process on the meaning of the standards, has brought the industry closer to the holy grail of easy translation. For any standard as “ethereal” as a monitor characteristic (as opposed to a precise sprocket dimension or a clock speed) to last 30 years suggests that it’s very close to correct.

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