New Concepts for Cinema Calibration

It appears that the film industry is going to move forwards with systems using many more channels. The newer techniques for programme storage will allow a new look at the whole concept of cinema sound, and hence will provide an opportunity to break away from the restrictions of the older concepts. In effect, we now have the possibility to re-invent cinema sound, as though we were beginning from today, with all the modern knowledge and measurement techniques. It is becoming apparent that the 'legacy' standards are not very open to modification, and some of the (arguably) erroneous thinking around them may be too entrenched to change things now. However. if we look at the concepts from first principles, we can perhaps bring new light to bear on some of the problems, and find solutions that are far more robust than the ones in current use.

1) The rooms

If we begin by imagining that the sound sources are real, perhaps we can start on more solid ground. If we went into different rooms to listen to the 'live' soundtracks, it would be similar to going to a touring variety show in different theatres. Despite the acoustics of many theatres being very different, we would soon begin to recognise the voices of the different actors and the instruments in the orchestra or band. In some theatres, the sound may be better than in others. 'Better', in this instance, could mean either improved intelligibility of the voices, or a more enjoyable sound from the musicians, but, by definition, all the sounds would be natural because they were coming from the real sources. The **source** sounds would always be the same.

There is no way of making any of these sounds **more** real by equalisation (even if one **could** equalise a person's voice). In fact, the ear and brain do such a good job in separating the direct sounds from those imparted by the rooms that changes to the direct

sounds would, in most cases, be perceived to be a move **away** from 'natural', even though in some difficult circumstances the intelligibility may have been improved.

In rooms designed for the performance of acoustic music, it is standard practice to deal with any serious room problems by acoustic means, and once the main problems have been satisfactorily reduced, the performances are what they are. They may not sound **identical** in every room, in fact they almost certainly will **not** sound the same, but the satisfaction for the audiences will probably not be significantly different from one theatre to another if the intelligibility is adequate and the music is well-balanced. The situation should not need to be any different when relating to cinemas. The rooms should be reasonable in themselves, and should not suffer from any serious acoustic problems. What is more, you **cannot** 'standardise' rooms by equalisation from analysis in the far reverberant field. It is not doable!

If we now replace our live performers with loudspeakers, not much will change, provided that the loudspeakers are capable of a smooth frequency response (in terms of both amplitude and phase) and an adequate directivity for the circumstances under which they will be used. Whether or not the response should be flat, or contoured, is a separate issue which will be discussed later.

Essentially, however, as it has been shown that rooms cannot be corrected by means of electronic equalisation, it becomes rather self-evident that any major problems that they do posses must be dealt with acoustically. Nevertheless, as most cinemas now exist in purpose-designed rooms, there is no real justification for presenting films in rooms with gross acoustic problems. Creating decent rooms is not that difficult these days, and a decent room is an indispensable starting point if the rest of the signal chain is to perform well.

2) Screen loudspeakers

The **flush-mounting** of the loudspeakers in a substantial

wall is already recognised as a worthwhile requirement. As well as eliminating phase cancellations from rear-radiated sound, it also provides a set of known and standard mounting conditions as long as the walls in which they are mounted have a certain minimum mass, damping and rigidity.

It would seem that loudspeakers for cinema use should have an inherently uniform **frequency response**, which should be well extended and adequately smooth under the standard mounting conditions. It would seem to be advantageous if the frequency range could stretch from 20 Hz to 20 kHz. It is hard to now justify why the range should be curtailed. Those cinemas that do not invest in the full-range equipment will not get as full a sound as the ones which do. At least this way, commercial forces will favour aiming at better quality, and not so much towards the cheapest way of meeting the limited standards. Those owners who wish to ave a better sound will have the option open to obtain a better sound.

The **directivity** of any cinema loudspeaker should be smooth in its characteristic, and of adequate horizontal and vertical coverage to reasonably uniformly deliver the direct sound to all *required* parts of any room. However, there is no requirement for a 'one pattern fits all' approach, because the rooms in which they will be used will have differing dimensions and geometry. What is more, the required area for uniform coverage in the dubbing theatres may be considerably less, and other, more critical aspects of the loudspeaker performance may be able to be enhanced if the wider directivity requirement is not an issue.

Distortion is something that it is difficult to specify in any meaningful way, except to say that the loudspeakers should be rated with regard to their ability to reproduce a subjectively clean sound at the maximum levels required from them. The current standards for power requirements seem to be oriented more towards the ability of the systems to be capable of producing **any** sound at the required maximum levels without either tearing themselves to pieces or melting. This can lead to some truly awful sounds at the louder levels (at least in the cinemas, if not in the dubbing theatres). The question of how to specify the quality at high

SPLs needs to be addressed.

Equalisation of the loudspeakers should be avoided, except in cases where it is deemed to be either subjectively beneficial (see Section 7) or to correct the response due to different mounting conditions. It should be limited to the correction of minimum-phase problems; which s all that it can do correctly, anyway. Typically, the left and right loudspeakers may receive more low-frequency support from the side walls than do the centre loudspeakers, and hence parametric equalisation or fixed equalisation can be used to restore the similarity of the sources. This is both desirable *and* feasible.

The ***power handling capacity*** of the loudspeakers will depend upon their sensitivity, the size of the room, the acceptable distortion levels both for percussive and sustained sounds, and the use, or otherwise, of equalisation. In fact, if equalisation *is* used, it effectively changes the system sensitivity, and so. in turn, would affect the power handling requirements. This question is currently dealt with in a very arbitrary way, as are the 'acceptable' limits for equalisation boosts. Obviously, gross distortion can result when programme material at certain boosted frequencies reaches high levels with inadequate amplifiers and loudspeakers. Perversely, according to the standard specifications, they may well ***be*** adequate bureaucratically (i.e. when filling in the forms and 'calculators').

The required power handling capacity should also be derived from ***measured data at the maximum levels***, and should not be extrapolated from low level sensitivity ratings. Due to thermal compression, many loudspeakers are not capable of the maximum output levels that are quoted in the brochures. These figures cannot be relied on.

3) Screens

The screens should be considered to be a part of the loudspeaker systems for measurement purposes. Woven screens are becoming available, at least for the smaller rooms, with

excellent acoustic properties which only minimally interfere with the loudspeaker outputs. Some of the older screens are both acoustically very poor and are often mounted with little concern for their disturbance to the sound. To some degree, this situation has been allowed to exist because of the permitted (by virtue of being unspecified) direct response mutilation which has allowed poor screens to be **equalised** into specified **overall**, far-reverberant-field, third-octave response limits. Whilst the results might look fine on a spectrum analyser, the sound can be truly awful. Screen performance needs to be re-assessed. If woven screens cannot be used, the mounting of the screens should be done with great care and consideration for the sound quality.

Commercial forces cannot be used as a realistic excuse for the poor mounting of screens. If people want to mount screens in an inadequate manner, they cannot expect good quality sound. If people want to mount good screen well, they *can* expect good quality sound. There is little hope for improving the situation if things are eternally tied to the lowest common denominators.

Certified dubbing theatres with a metre between the loudspeakers and the screen are not professional studios. Unfortunately, though, they do exist.

4) Surround loudspeakers

The surround loudspeaker channels are usually connected in arrays, in order to try to create a more diffuse source for the ambient sounds. However, new concepts are being discussed which may, at times, use them as individual sources for certain effects.

There is currently no precise mounting arrangement, and the loudspeakers are positioned within somewhat flexible guidelines. They are then equalised with pink noise over a predetermined area of the room. This technique is highly questionable, and experiments will be under way in Vigo University, this spring, to investigate the whole concept of how to best cover a given area with a widely distributed array. However, as the interference pattern for each

position in a room would be different, and given that each loudspeaker will couple to different modes in different ways, it could be that the best solution for a subjectively neutral sound will be achieved by using loudspeakers with a relatively flat response in their given mounting conditions (i.e. against a hard wall or an absorbent surface). There is no convincing evidence to suggest that equalisation of the arrays as a whole can help to 'improve' the sound in the theatre, except to make up for the deficiencies in poor loudspeakers which should not be there in the first place. Source quality is important.

5) Frequency response measurement and calibration techniques

There are basically only two justifiable cases for using equalisation in cinema rooms. The first is to compensate for response anomalies due to different mounting conditions for different loudspeakers. The second is to apply any desired or standardised response contours. The loudspeakers should be capable of delivering a flat frequency response prior to the application of any response contouring, any need for which will be discussed separately, in Section 7, below.

The question of how to **verify** the flatness of the response is a subject for research. Floyd Toole has suggested that the anechoic data on the frequency response and the directivity should be basic starting points. As an alternative, evidence needs to be gathered on the viability of the various windowed measurement techniques applied to signals captured at 2 to 4 metres distances, dependent on the size of the loudspeakers and the distribution of the drivers. To what degree these can be relied upon is still not known.

The goal would be to deliver the most accurate direct sound. As explained in Section 1, above, because **real** sources do not change their response according to which room they are in, and as they are still perceived to **be** natural, there seems to be no obvious reason why an accurate loudspeaker, as a source, should be considered in any different way. For this reason, all screen

loudspeakers, including LFE loudspeakers, should have the same direct (close field) responses in all rooms. If this cannot be achieved because of the screen, then something needs to be done **about** the screen. *Equalisation* cannot be expected to fix this sort of problem.

The attachment labelled Figure 3 b shows the way in which the responses of a set of reasonably controlled cinema rooms have been equalised to fit into the allowable margins of the current, standard response curve. These measurements were made after a rather arbitrary, although quite normal, method of equalising 'the room' by analysis of the response in the far-reverberant-field. However, Figure 4 b shows the degree to which the direct sounds, as approximated to by the windowed measurements from two metres distance, have been linearly distorted in order to achieve the 'standardised' performance shown in 3 b. This degree of **difference in the direct sounds** violates all concepts of response uniformity. The attachment labelled Figure 10 (from Floyd Toole) highlights the fact that what we measure and what we hear do not always coincide. The ears and brains **can** separate the effects of a room from the response of a direct sound, and quite effectively, but the measurement systems cannot. The uniformity of the direct sounds is a fundamental requirement for room-to-room compatibility. If the direct sounds are **not** equal, then under no circumstances **should** the reverberant-field responses *be* equal. If **different** sources sound **the same** in the reverberation of the room, then something is badly wrong. Source differences should **be**, an in fact **are**, detectable by ear.

What is more, as shown by the attached Figure 9, the sort of equalisation that may be necessary to bring reverberant-field responses into the required limits can often only be achieved by amounts of equalisation that are bound to cause audible colouration. Under no circumstances is such colouration desirable. Especially in complex soundtracks of already marginal intelligibility, such equalisation can create problems with dialogue, and consequently the following of the plots.

It would seem to be a fundamental requirement of response standardisation that the **sources** (including screen losses and any

correction for mounting conditions) should **be the same** in all cases.

6) Level response calibration

The question of the subjective loudness of a soundtrack is difficult to define. However, by whatever means is chosen for overall level calibration, there should be a curve relating the reference SPL to the room size. Such a curve was proposed in Figure 3 of the attached document, 02, relating SPL to screen distance. The size would not change much with distance given that most films are mixed from an approximately 45º viewing angle.

Whilst it **is** perfectly normal for our expectation of perceived sound level to reduce as we move backwards from a screen, it is certainly **not** normal for us to expect the same sound level from the same images projected on to different sized screens. To listen with LF peaks of 115 dBC whilst watching an action film on a large screen in a large room can be exhilarating, yet it would appear absurd to listen at the same sound level whilst watching the same film on a television screen at 60 cm (2') distance. The curve shown in the above-mentioned Figure 3 has been found, empirically, to be reasonably representative of expectations.

Applying one calibration level for all cinema rooms has been shown to lead to an unpleasant, overpowering sensation in smaller rooms. Calibration levels must be related to screen distance and size, the two of which are usually closely related.

Also, as discussed in the paper (02) the low frequency levels may also need to be proportionately reduced as screen size decreases. This will be discussed further, below.

7) Standard equalisation curves

It has been customary to apply the X-curve to the responses of cinema loudspeakers, although no conclusive treatise ever seems to have been put forward to explain why this should be

necessary. Many of the arguments put forward in its defence seem to be flawed.

If all films are to be mixed to a standard response, then it should make little difference whether it was to the X-curve. the Y-curve. the Z-curve or *flat*. A reference is a reference. However, it is the application of that reference that can be critical. Measurements from 2/3 distance back into the room is not the way.

Somewhere deep into the thinking about the X-curve seems to be the concept that an orchestral recording, for example, made and mixed in a music studio with flat monitors, will sound reasonably spectrally balanced when played back in a large cinema room with the X-curve applied to the loudspeaker responses. This seems to be the core of the argument, and it has been shown by experience to be acceptably valid. However, it relates to **large rooms**, and **measurements made towards the back of them**. Ioan Allen, in his 2006 SMPTE paper (attached, here, for quick reference), clearly described the need for a **family** of curves, which changed either the slope or the turnover frequency in proportion to the size and reverberation time of the rooms to which they were applied. In practice, however, **one** curve (perhaps more appropriate for **large** rooms) is applied to **all** cinema rooms. This clearly cannot and does not work. If any curves **were** to be applied, they would **not** be the same for all rooms. Allen correctly identified that a family of curves would be necessary, but it still is unclear whether any such curves are needed at all.

In conjunction with the level calibration needing to be adjusted for room size, and the need for reduced low frequencies in smaller rooms (as mentioned in the previous section), it is evident that if any such overall response curve **were** to be applied, it must take into account the need to be tailored to room conditions. However, it is still not certain that any overall curve is necessary. More experimental work needs to be done, here.

There is no doubt that large monitors in large rooms can sound over-bright if equalised conventionally. Nevertheless, we need to consider the concept of how we determine flatness. If the

flatness is determined by the response to pink noise in the far-reverberant-field, 2/3 of the distance from the screen to the back wall of the room, this may well not be the response to be expected in that zone if the monitors were flat in the close-field, especially in large rooms. Once again, orchestras do not change the sound of their instruments according to the size of the room in which they are playing, so why should we need to equalise loudspeakers differently? Perhaps one answer could be to avoid problems in bad rooms, but we should not, these days, be using bad rooms.

Ioan Allen, in the 1970s, did not have the analytical equipment to separate the direct responses of the loudspeakers from the global responses within a room. The ears and brain *did* have, and *still* have, a far better ability to discriminate between the different components of the sounds in a room. The X-curve was based on a combination of limited measurement ability supported trained ears. It has certainly worked to some degree, but now we have the experience and the analytical capability to do much better. Room and equipment have also improved.

It is not beyond the bounds of credibility to expect that if the loudspeakers are generally flat in terms of their *direct* responses, the natural forces of acoustics and psychoacoustics will automatically take care of the different room responses, but this needs to be verified.

Once again, if the source were *natural*, even if it was a natural (i.e. live) electric guitar and amplifier, we would not even dream of equalising it according to the room size (although we may, without even thinking, adjust its *volume* [SPL]).

8) Floor reflexion dips

Floor reflexion dips are not correctable by equalisation. They are an integral part of listening to sounds in most rooms. They can give rise to narrow-band cancellations from hard, flat floors, or broader cancellations where a floor is more diffuse in nature. Perceptually, they tend to be innocuous, which is more than can be

said for the equalisation that is often applied to try to reduce their visible presence on a spectrum analyser. *Floor dips cannot, and should not, be equalised.*

9) Engineer/technician inconsistencies and automated analysis

It has been shown in practice, and will soon be tested at Vigo University, that even one single person, if asked to equalise the same room from zero, even within the same hour and with stable atmospheric conditions, will rarely, if ever, arrive at the same equaliser settings when asked to achieve a predetermined response via reference to a 1/3-octave analyser.

Much has been said over the years about loudspeaker systems 'drifting' with time, but the reality seems to be that in large rooms, the drifts are due to atmospheric conditions and they will drift around a mean. There is no necessity to 'chase' these conditions by regular, routine re-equalisation. In fact, there is very little reason to expect a good quality loudspeaker system to drift significantly once its low frequency drivers are run in. Many years of consistent performance can be expected.

Experience is showing that it is *the people adjusting* the systems who are more responsible than any other factor for the apparent need to re-set the equalisers. Most of the time, the adjustments are totally unnecessary. Given 1/3-octave analysers and equalisers, tests have shown that no two people will arrive at the same equalisation setting when given a loudspeaker and room to adjust to a given curve. (OK, perhaps two out of an infinite number of monkeys might get the same results.)

Engineers and technicians who are asked to calibrate systems should be aware of the limits of what is achievable and when to leave things alone. Some organisations are committed to removing this aspect of human variability by trying to automate as much of the process as possible. However, the automatic systems have no ears at all, and so are likely to give rise to as many

problems as they solve. How could an automated system, for example, discriminate between an innocuous floor reflexion dip and a similar dip of a different origin, which might indeed be a problem requiring a solution?

It would seem that not only automated analysers, but also calibration personnel, can introduce errors into the responses of the theatre systems. Highly skilled and experienced people are not available in the quantities necessary to calibrate even a fraction of the commercial cinema rooms. For these reasons it would seem to be both highly desirable **and** practical to develop equipment and installation procedures that are robust enough to function without routine re-calibration. This would seem to be well within the bounds of what can be achieved.

Robustness of room and equipment specifications would seem to be a key element in future standards for cinema theatres. It would be greatly beneficial to reduce the need for any 'calibration' to an absolute minimum. The current calibration practices have been shown in our papers to be a **source** of response variability. (However, some people who earn a living from this may not agree!)

The current concepts of calibration were developed at a time when reasonably good room acoustics and high output, low distortion, wide directivity loudspeaker systems were by no means as easy to find as they are today. Good systems in good rooms should automatically produce good sounds.

10) Dynamics

There is still a potential problem that is discussed in the attached '02' paper: **dynamic range**. If we accept that not all theatres should be calibrated to the same reference level, the reduced calibration levels could lower the quietest sounds into the noise floors. There would seem to be no simple technical answer to this question. It is a fact of life that the enjoyable dynamic range in a large room with a large screen is greater than the enjoyable dynamic range in a small room with a small screen. We have evolved to feel uncomfortable with high SPLs at close distances. In

nature, they surely signal danger.

Directors also need to be made aware of the fact that what can be enjoyed on a big screen in a big room will not necessarily translate to a smaller screen. In cinemas, the lowest usable SPLs are roughly the same, but how loud we can go without a feeling of being overpowered is screen-size dependent (which tends to correlate with distance).

Older films do not tend to suffer from these problems because the available dynamic range and bandwidth of pre-1970s cinema was much more restricted. Directors were therefore more limited in their ambitions. The introduction of the Dolby SR, and then the digital soundtracks was intended to reduce noise and distortion and give more realistic reproduction, but directors began to use every decibel of the extended dynamic range, often without fully understanding the consequences. Soundtracks also began to become much more complicated, and dramatic tension was increased by making some dialogue only marginally intelligible under a barrage of sound effects and music. A result of this was that balances became more critical, and intelligibility can be lost if inappropriate equalisation has been applied to the loudspeaker systems anywhere in the chain. The concept of applying equalisation to room responses can give rise to some very unpredictable effects on dialogue intelligibility, and for this reason, alone, it would be something that should be avoided. Dialogue does not exist in the form of sustained sounds. Room equalisation, therefore, based on quasi-steady-state analysis, can be totally inappropriate for dialogue intelligibility.

To ask for more self-restraint during mixing is probably futile. Nevertheless, mixing in mid-sized theatres will perhaps lead to more generally compatible mixes than mixing in very large theatres. However, if the levels are calibrated in relation to room size, the larger cinemas will reproduce the soundtracks at higher levels. Even though the dynamic range would not be expanded, it is unlikely that any significant excitement would be lost.
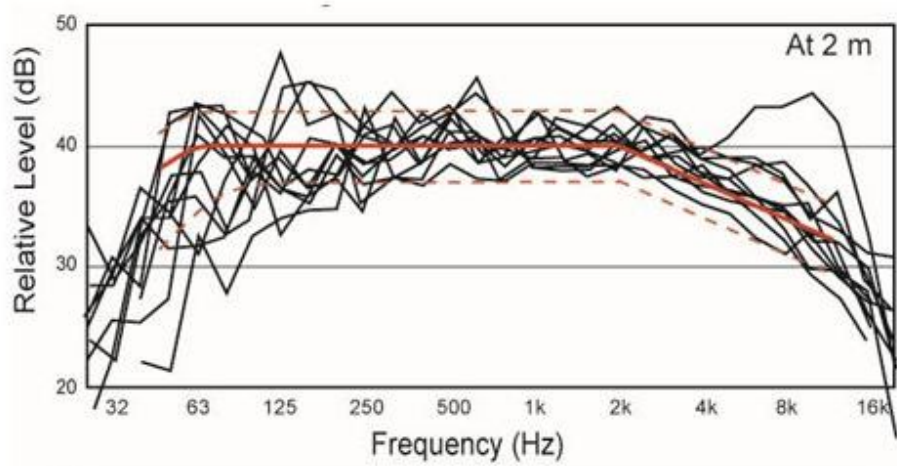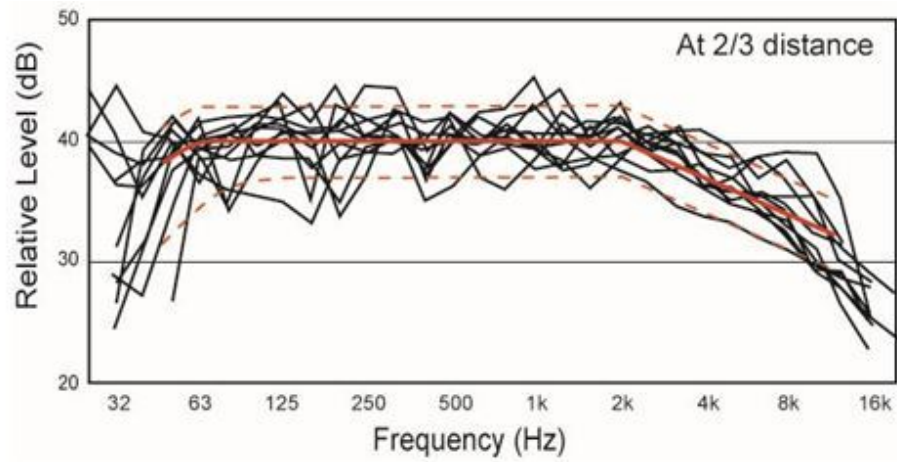
Automatic dynamic control, for many reasons, would not

seem to be a practical solution. ***How*** we perceive ***what*** we perceive is not something that a machine can easily be 'taught'.
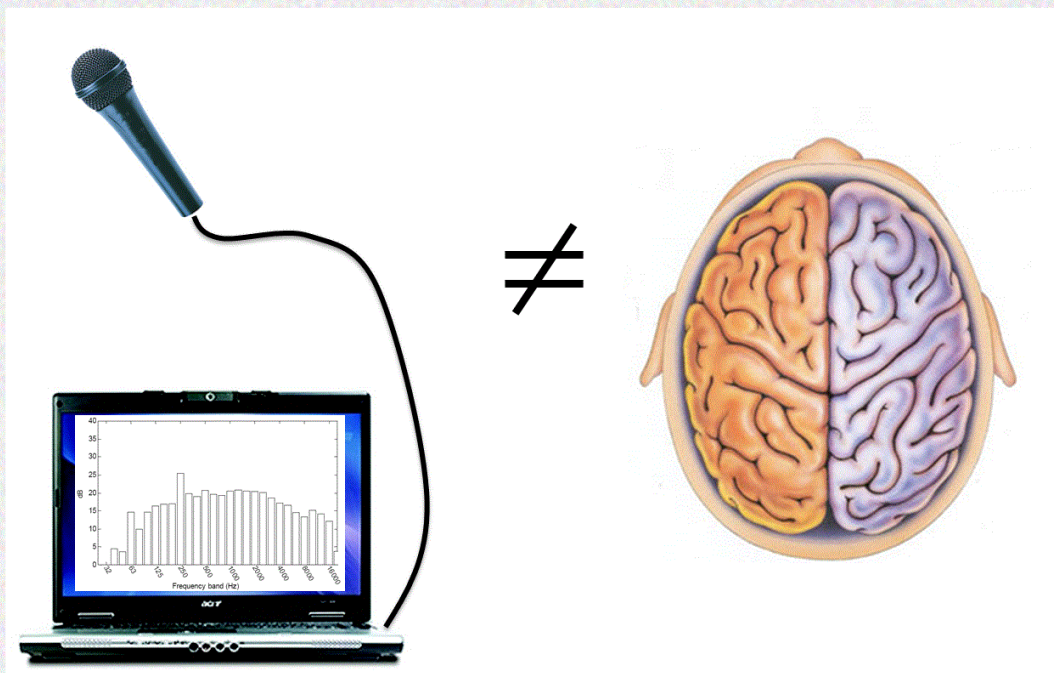

11) General comment

It would seem to be beneficial that any future standards did not 'cap' the specifications. That is to say, future developments should not be limited in the way that the current standards are geared to medium quality reproduction in medium quality cinemas. Rolling off at 45 Hz and 16 kHz, for example, is no longer appropriate, except perhaps for increasing the compatibility with lesser quality cinemas.
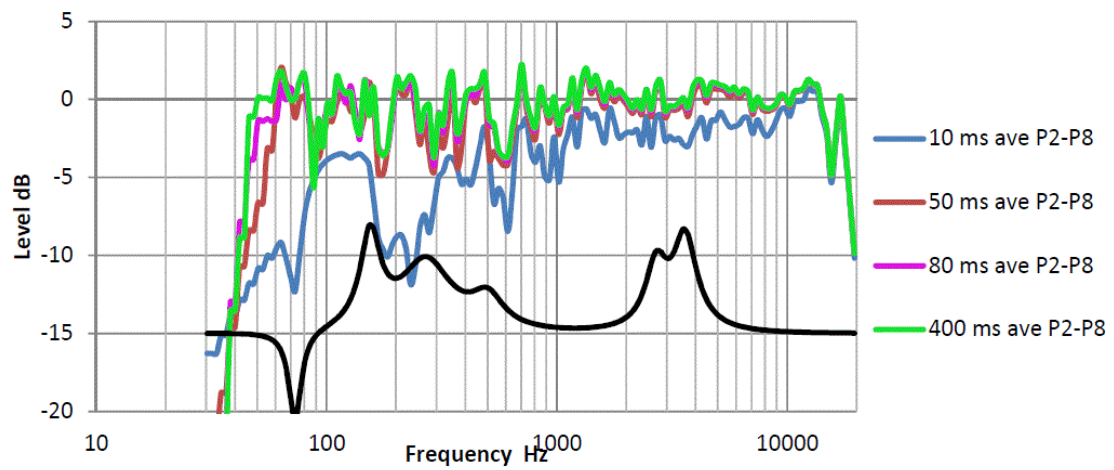
It is eminently feasible to strive for excellence yet still maintain compatibility with less capable equipment. For those cinema owners who wish to invest in better equipment, it should reasonable that they could expect a better sound. Under the current circumstances, this is not necessarily the case if a film soundtrack has been mixed in a room with inappropriate equalisation. If people realise that by buying better equipment they can hear noticeably better sound, it will be a driving force to improve not only the cinema rooms, but the whole industry.

Yes, but . . .

THE EFFECT OF VISUAL STIMULI ON THE PE
OF ´NATURAL` LOUDNESS AND EQUALISATIC

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ABSTRACT

In the world of audio for picture, the two must combine well to create a believab
been known that the visual and audible stimuli are to some degree affected by e
the ways in which these variables interact has not been particularly well docu
presents the results of several controlled experiments, which have dealt with so
variables; individually, and also in various combinations. These experiments re
of compatibility between cinema and domestic reproduction of audio-visual prc
the compatibility between the different mixing environments, themselves. The n
mixing rooms has been with us for many years, but the practical realisation of
enjoyed much success; principally for lack of a fuller understanding of the subje
in this paper.

1   INTRODUCTION

A series of tests were conducted in 2007, on a relatively informal basis, which cu
which was presented at Reproduced Sound 23 [1]. The reason for the experi
determine some of the factors which seem to make it very difficult to achie
between cinema soundtracks which have been variously made in large and sma
despite the fact that all the rooms have been similarly aligned to tight specific
positions. The concept of 'universal' mixing rooms has been a Holy Grail
industries for many years, but 'blockbuster' films still, almost invariably, need t
expensive rooms if good compatibility of the perception of the soundtrack is

The X-Curve: Its Origins a
History

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

By Ioan Allen

This paper traces the beginnings of the X-Curve in work car
early 1970s and follows the various developments since tha
electro-acoustic characteristic is now employed in most the
throughout the world. The "X" stood for "experimental," an
seems inappropriate for something that's been a national ai
standard for 30 years!

The "Academy Curve"

The need for standardized tonal characteristics was recognized from the ea
sound-on-film, and the first attempt to codify the system was made by the Mot
Council (reporting to the Academy of Motion Picture Arts and Sciences) in 193
a wide variety of material over typical theatre loudspeakers and determined th
high-frequency attenuation. Next, a flat frequency response tone run test film
projector and the signal at the power amplifier outputs was measured. This de
attenuation would be "the standard." The characteristic was a consequence o
de-emphasis in a typical theatre at the power amplifier outputs, resulting from
height and electrical filters. Two curves were defined, one for loudspeakers w
diaphragms and one for metal. They (it) became known as "The Academy Cu
Figure 1.