philip newell <philiprnewell@gmail.com>
A New Draught Proposal for the Calibration of Sound in Cinema rooms. (21/1/12)
22 April 2012 2:03 AM

A New Draught Proposal for the Calibration of Sound in Cinema Rooms (21/4/12)

1) Background to the proposals

The cinema industry standards for the calibration of both commercial cinemas and professional dubbing theatres seem, to a growing number of professionals, to be lagging behind the current state of the art for achieving both better overall sound quality and better room-to-room compatibility. In a presentation in late 2010 to the UK's Institute of Acoustics [1] it was clearly shown how the current calibration procedures were failing to achieve their goals.

In the music-recording world, the use of one-third-octave analysis and equalisation began to be abandoned in the late 1970s; only about seven years after it was first introduced. In the cinema world, Dolby began applying similar techniques to both the dubbing theatres and the public theatres around the same time that the music industry was beginning to question the procedure. Despite the use of such equalisation being even less appropriate for large acoustic spaces than for small ones, the idea took root in the cinema industry, and became a standard that has lasted well over 30 years.

Some of the cinemas in the 1960s were very poor by the standards of today, with some truly unsuitable combinations of loudspeakers and room acoustics. Many were left over from an era when soundtracks were predominantly dialogue, with some incidental music, and all in mono. A great proportion of the rooms were converted theatres, with little or no acoustic changes from their original requirement for projecting actors' voices, and it was widely recognised that improvements were necessary if cinema sound quality was to progress. Large-scale, short-term renovating and re-equipping of the world's cinemas was an unlikely prospect, but third-octave equalisation was seen by many people to be a viable and affordable option as a way of increasing the compatibility of the soundtracks when reproduced in some very different rooms and via different loudspeaker systems. In the third-octave analysis frenzy of the early-to-mid 1970s, all things seemed to be possible to many people via the use of these tools. However, in far too many cases, they were in the hands of people with a totally inadequate understanding of both the concept itself, *and* its pit-falls.

As already mentioned, in the professional music-studios of the day, many recording engineers were unhappy about the one-third-octave equalisation of the large monitor systems. The use of the monitor equalisers was often seen as something that had been imposed upon them by the studio designers and the technical/maintenance engineers. Concurrent with the growing use of third-octave analysis there began the trend towards using smaller, unequalised loudspeakers in the close field. With hindsight, this was clearly a call for hearing a more accurate direct sound, unadulterated by either the frequently marginal room acoustics, or from what was often perceived as the 'artificial', equalised sound from the large monitors. Room design philosophies began to emerge which would extend the close field to the large loudspeakers, but it would be the mid 1980s before the techniques really began to reach their goals. As the rooms got better, there also began a trend to dispense with the 'room' equalisation being applied to the monitor systems, and more natural sounds began not only to return, but also to be preferred.

Reassessing this chain of events, and knowing what we now do about the importance of an accurate direct/first-wavefront responses in relation to how sounds may be deemed to be natural and easy to listen to, it is clear that the application of room equalisation was in many cases severely compromising the integrity of the first-arriving sounds. The direct sound is important because it establishes the reference against which all later sound arrivals are interpreted, both with respect to their localisation *and* timbre. We now

understand that no room acoustic, with all its complicated time and phase characteristics, can be anything even close to the inverse of the equalisation that has customarily been applied to try to achieve a flat spectrum deep into the room. Therefore, if the equalisation is not the *inverse* of the problem, then it is not *correcting* it, but is merely *altering* it. In many cases, it has also been unmistakably *worsening* the problem.

In general, except where the room is providing extra loading on a loudspeaker diaphragm (such as when loudspeakers are flush-mounted in walls, or when LFE loudspeakers are placed at wall/floor boundaries), and where this effect gives rise to response changes which are both almost simultaneous with the direct sound and equal for all points in the room, electronic equalisation of the loudspeaker drive signal *cannot be corrective* in any overall sense.

The limitations of the third-octave equalisation were probably detected in the music recording industry much earlier than in the film industry because of the generally more critical listening conditions then prevailing. Cinema studio acoustics in the 1970s were still, in most cases, far from what would now be considered to be desirable, and so it was therefore not difficult, even by using flawed practices, to bring about at least some improvements to the responses of many of the then current rooms and loudspeaker systems. However, the understanding of the subject has since moved forwards considerably, as has the corresponding technology.

2) Psychoacoustic matters

It is now known that except in extreme cases (and which should not apply in any room dedicated to the professional mixing of sound), the ear/brain combination has a very considerable ability to 'hear through' the acoustics of a room by latching on to the direct sound, which is the first wavefront of any signal to pass the ear. It is described in the Benade paradox, in which we begin with a clearly defined source, pass it through a room which is irregular from place to place, from time to time, and from frequency to frequency, and yet we still perceive a well defined, easily recognisable sound. However, this paradox does begin with a *clearly defined source*. If we change the source, we change the perception. This fact will be central to the following discussion.

The last thirty years have seen enormous progress in the field of our knowledge of how the ear and brain process sound. We now have information that was simply not available to us in the 1970s, when the third-octave analysis concept began to be introduced on a large scale. At that time, it was even widely believed that because the critical bands of human hearing are about one third of an octave wide, that this somehow represented the *resolution* of human hearing: a concept that we now know to be erroneous.

Given our current knowledge it is simply not reasonable to expect that the direct sound from a loudspeaker can be grossly linearly distorted (linear distortion being a disturbance in the amplitude and phase of the frequency response) and that the subsequent sound in a room can still seem to be natural. Clearly, as it is the direct sound which drives the reflexions, if the former are distorted, then so will be the latter. Conversely, in many cases, if a sound *appears* to be natural in different circumstances, despite the existence of different room decay characteristics, there will be a tendency towards conformity. This is inherent in the concept of the direct sound being required to be natural, or at least to have the *desired* final frequency balance (irrespective of how the source was derived). It thus follows that even an intentionally *un*-natural sound will still tend to sound essentially similar from room to room if the source response is the same in all cases.

It was the distortion of the direct sound in the 1970s which caused the music recording engineers of the time to complain so bitterly that something was not right when so many of them were first confronted with room equalisation. They were largely 'hearing through' the majority of the room problems, and their brains could correct for them, but if the *direct* sound was corrupted they had no believable loudspeaker reference when they had a real instrument to compare it to, despite the fact that the equalised response was ostensibly flatter at the listening positions than it would have been without the equalisation.

The same overall situation applies in cinemas just as much as in music recording studios (although see next paragraph). In the aforementioned paper [1], the degree of corruption of the direct (close field) sound emanating from the loudspeakers is all too evident. How can an ear be expected to 'hear through' the rooms, and interpret the in-room responses as being compatible, if all of the sounds emanating from the loudspeakers themselves are as different as they have been shown to be? Patently, if all the direct sounds are different, then the ear will interpret the *overall sound in each room*, with all its complex reflexion patterns, as being different,

irrespective of the application of any so-called 'corrective', steady-state (direct and reflected, summed response) equalisation. The integrity of the source of the sound is of very great importance if fidelity and conformity are the goals.

It is worth re-stating here that the term *direct sound* is referring to *the first arrival at any listener's ears of* the sound emanating from the loudspeakers. In the case of commercial cinemas, with many people in the audiences listening from well off the axes of the loudspeakers, it is necessary that the directivity of the sources should be appropriately wide and well controlled. The precise requirements will depend on the geometry of the individual rooms, but in all cases, as the off-axis responses will be driving significant room reflexions, then those responses need also to have characteristics similar to the axial responses, to avoid excessive colouration of the reflexions. In many studios, where the listening area is much more restricted and the room surfaces are perhaps more absorbent, the directivity characteristics may be less demanding. However, in all cases, the effect of the screens on the overall directivity needs to be taken into account. Essentially, the screens are an integral part of the sound sources.

3) The current state of affairs

At present, dubbing theatres and commercial cinemas looking for Dolby certification are aligned by means of passing pink noise through each loudspeaker in turn, and, by means of one-third-octave analysis and equalisation, they are then adjusted to achieve as closely as possible the required response curve (currently the X-curve) in an area roughly two-thirds of the distance from the screen to the rear wall of the rooms. This region of the rooms has traditionally been considered to be the most representative average of the whole room, but this notion is questionable. Techniques vary for capturing the noise, but it can be done by means of multiple, multiplexed microphones, by means of a single microphone being manually waved through a critical region of the space, or, and as still used in many cases, a single, fixed, omnidirectional microphone at the height of the ears, two-thirds of the distance from the screen to the rear wall, and on the centre line of the room.

There are many flaws to this concept, but first we must ask ourselves exactly *what* we are measuring and *why*. In all of the above cases the microphone(s) is (are) sampling a very limited region in the room, and nothing more. The reason *why* this approach has been enshrined in the procedures for so long is now a little difficult to justify. Given the nature of the variability of room acoustics, there is little reason to expect that the designated area in a public cinema will be significantly representative of the other areas. Granted, in dubbing theatres, this region is specified at the position for the mixing console and the people using it. Nonetheless, even though the acoustics of many dubbing theatres have traditionally been relatively close to the acoustics of a 'typical' cinema (whatever that is), these regions of the rooms will still not be representative of the majority of all the other areas in the public cinema theatres. Furthermore, this concept presumes that those calibrated areas in each of the rooms will exhibit reasonably similar responses, but as we can see from the cited 2010 paper [1], this is not the case. Figures 1 and 2 show the overlaid responses of 20, Dolby-certified rooms. The uniformity of the responses is not good, neither in the close field nor at the designated measuring positions.

The problem here is that in all of these cases the rooms and the loudspeakers are being treated as parts of one combined system, and it is implicit in the process that adjustments made in one part of a system can make predictable and corresponding changes in another part of the system. However, these systems are *not* of a minimum-phase characteristic, and so these assumptions are not appropriate. If all of the reference areas of all of the rooms exhibit reasonably similar responses to one-third-octave-analysed pink noise, it by no means implies that they will *sound* similar. A soundtrack is composed of many different types of sound, of both percussive, plosive and sustained natures, and all in various proportions. As very clearly shown in Ioan Allen's deep and insightful paper on the X-curve [2] the sounds of a more transient nature fly past the ears, bounce around a few surfaces and largely disappear before they have time to excite the room resonances to any significant degree. The degree to which the resonant nature of a room can differently affect different instruments, such as percussive bass drums and resonant bass guitars, is highlighted in reference [3]. Therefore, whilst the fast-decaying sounds will largely be unaffected by the room resonances, the more sustained sounds most certainly *will* be. For this reason we can expect that the faster-decaying sounds will be reasonably similar to each other in rooms with different modal (resonant) characteristics, whilst the more sustained sounds may be greatly affected by the rooms. *However*; this presumes that *the direct signals are all equal*. If they are *not* equal, due to the applied 'room' equalisation, then they cannot possibly be expected to

sound equal, neither at close distance nor deep into a room, and not under *any* circumstances. The simple fact is that if they are not equal to begin with, then no room equalisation is going to standardise them because the *reflected* responses will be very different. It can thus be seen how not only the room modes, but also the reflexion patterns, incorporate themselves into the overall sound. The latter are certainly not readily yielding to correction by equalisation, and may respond very undesirably to the application of modal equalisation.

Obviously, if we apply equalisation to a loudspeaker channel, the same equalisation will affect both the short-lived and the more sustained sounds. If it is the sustained sounds which are being rather more closely represented by the pink noise and third-octave analysis, then the attempted correction will be affecting them, perhaps at best, *somewhat* positively, but the same 'room' equalisation applied to the shorter sounds (and, for that matter, *all* the direct sounds) can only serve to distort their frequency balances and reduce their accuracy. What is more, this distortion of their spectra will occur *throughout* the room. Once equalisation is applied to the loudspeakers for any purpose other than flattening their responses in the close field, then *all direct wavefronts will be compromised*, and can never be expected to be accurate. That is to say, if the signals of a percussive or transient nature sound equalised in the dubbing theatres during the decision-making process of mixing the soundtrack (and from Figure 2 it can be seen that this *must* be the case at present), then all reference of what is 'right' will have been lost. Again, from Figure 2, it can be seen that no two of the rooms would sound the same even when listening from a distance only two metres from the loudspeakers. This is absolutely contrary to the needs of any standardisation process.

The current technique for supposedly standardising the room responses is, in fact, making the standardisation of the direct signals virtually impossible, and it is *these* sounds that are crucial for the perception of a natural sound characteristic. They are also crucial for the uniformity of the sound of the dialogue, and experiments are already under way to examine the intelligibility differences in the rooms measured in reference [1].

What is more, there is growing evidence that people with some degree of hearing loss are finding it difficult to follow the dialogue in complex soundtracks in many theatres. There is no hope of helping these people, and who form a considerable proportion of the cinema-going public (by some estimates over 20%), until responses become more predictable in the different environments.

4) A new approach

If the loudspeaker channels were to be calibrated in the close field (the precise distance depending on the size of the cabinets and the distribution of the drivers) or, if possible, in anechoic chambers, it would ensure that the responses were as accurate as the loudspeaker systems would allow, and that at least the *direct* sound would be flat (or following a specified curve) in all parts of the theatres where the directivity of the loudspeakers remained within the required limits. Their responses should be reasonably flat, even off axis, and well extended *before* equalisation. With modern loudspeaker systems, this is not the issue that it was in the 1970s, when low distortion, high output systems were less developed. Any further required equalisation to achieve the desired response should be applied with parametric of fixed equalisation, which can be precisely tailored to the necessary curves. The adjustments should most definitely *not* be done by means of third-octave equalisers, because their frequency centres and slopes rarely match those of any 'problems' to be solved. The rooms should then be checked for the presence of any obvious acoustic problems, such as noticeably resonant peaks. Then, and *only if absolutely necessary*, further parametric equalisation should be applied globally to reduce the nuisance. However, the room acoustics should at least be reasonably controlled, which *ought* not to be a problem in modern cinemas, but cost-cutting by cinema owners and installers does sometimes leave much to be desired.

The process described above is also applicable in the older cinemas with poor acoustics, and should be beneficial. Attempts to improve their situation is worthwhile as there is little evidence to suggest that the current alignment procedures are achieving their intended compatibility goals.

By means of these newly proposed alignment techniques, no particular bias would be shown towards any specific area of a room. At all places in the rooms, the first sounds to pass the ear would have their natural, correct, frequency balances, and all the signals of a more transient nature would maintain their proper impact. However, this does put more emphasis on the overall quality of the loudspeaker systems.

With the direct signals accurate and stable, the ears and brains would tend to adjust to the acoustic anomalies

of each space and perceive a much greater compatibility in the soundtracks, from room to room, than is usually currently enjoyed. The accurate direct sounds are very basic audible cues to reality, and modern loudspeaker systems and cinema rooms are quite capable of maintaining their integrity much better if the current practice of third-octave equalisation is *not* applied.

It would seem to be clear from the above description that it would be futile to seek any more advanced way of finding a better spacial average over any given area of a room because the response of the room will not be not consistent over its whole area. Whatever average is arrived at does not mean that it represents any better the response at any individual seat in the house. It is just asks for a different curve. Therefore, inevitably, any applied correction must *still* distort the direct spectrum for the whole room, and this would still be very detrimental to the room-to-room compatibility of the soundtracks. There is simply no way to equalise *a room*, because every place in it has its own characteristic response. (See also Section 10.)

That the direct sounds must be as accurate as possible concurs with the use of close-field monitoring in music recording studios. where a general consensus has long held, consciously or otherwise, that the best compatibility of mixes with the outside world is achieved via monitoring what is essentially the flat response of the direct sound. It also fits with the concepts of acoustic performances, where instruments are still deemed to have their recognisably natural timbral characteristics even in spaces with very different acoustics. Essentially, if the direct, acoustic sound of a violin were to sound different in different circumstances, it would have to be coming from different instruments. Nevertheless, evidence from reference [1] shows that a violin passed through differently equalised loudspeaker systems *would* have different direct sounds. This simply cannot *be* any form of standardisation. It is quite the opposite. In principle, there should be little significance in whether the source of the sound were to be a real trumpet, or a trumpet reproduced via a good quality loudspeaker, so this analogy of the importance of the fidelity of the direct sound holds good. If it would be un-thinkable to equalise the real trumpet to make it sound more like itself, then why would one expect to equalise the accurate loudspeaker reproducing it?

5) Other consequences of the status quo

The fact that the currently applied equalisation has a tendency to spectrally unbalance the direct wavefronts, and thus detract from the naturalness of the sounds, is almost certainly a significant factor behind the many complaints from cinema-goers about hard and tiring sound qualities. What is more, the applied equalisation is often boosting the signals at certain frequencies, which can sometimes stress (and give rise to aggressive, distorted sounds from) the often marginal loudspeaker systems which are frequently used in public theatres. Even non-acoustically-trained cinema goers have a natural tendency to know when something sounds right, and comfortable. If they do not have these sensations, then fatigue often sets in and the quality of their overall enjoyment of a film may be compromised.

6) A study of two cases

Figure 1 shows a set of response curves from the calibration positions of 20 different rooms, most of which are considered to sound noticeably different from each other. Conversely, Figure 3 shows what initially appears to be a rather similarly differing set of response plots, but these were taken in 24 different positions in *one, large room.* At all places where the measurements were taken, the room was considered by experienced professionals to have the *same* general sound characteristics.

The *degree of variation* between the individual plots of Figures 1 and 3 is more or less the same, but in one case the responses all tend to sound different, whereas in the other case the responses all tend to sound rather similar. How can this be? Almost certainly, the reason *why* the sounds of the responses in Figure 1 are so different is that *the direct sounds are also all different*. Consequently, if the direct sounds are not the same, they will give rise to reflexions that are also not the same. There is little doubt that the reason why the responses shown in Figure 3 are all considered to sound so similar is that the direct responses are all the same, because the single source for the whole room was the same, flat loudspeaker.

7) SPL calibration

In a paper published in 2008 [4] it was clearly shown that the 'subjectively natural' level for a soundtrack depends greatly on the size of the image and the distance of the listener from a picture screen. Figure 4 shows a plot taken from that paper, in which it can be seen that if a room with a 12 metre screen at 12 metres distance is calibrated at 85 dBC, a room with a 20 metre screen at 20 metres distance would call for a level of 87 dBC, and a room with a 4 metre screen at 4 metres distance 81 dBC. From the evidence cited in the paper it is clear that an 85 dBC calibration level is not appropriate for all sizes of theatre. Especially in the smaller theatres, there seems to be justification for reducing the calibration level. Such a change would probably reduce significantly the complaints from the cinema-going public about excessive level. What is more, the excessive level is probably exacerbated by the application of the unnatural 'room' equalisation, and any subsequent loudspeaker stress to which it may give rise.

The experiments in reference [4], along with common-sense experiences in orchestral concert halls, clearly suggest that as a listener moves closer to a visible and recognisable source of sound, there is a natural expectation for it to become louder. For this reason, the two-thirds distance can still be used as a good guide to the general loudness of a room, as it will usually be well into the reverberant field (or at least beyond the critical distance in all but the driest of rooms), but the overall 'most appropriate' calibration level for each room will be size-dependent. It is patently obvious that whilst a battle scene in a huge theatre may be very exciting with explosion rumbles at 115 dBC, the same level watching the same scene at home, on a domestic television, would be totally insufferable. Almost any person can easily imagine this situation, and from this concept is is virtually self-evident that there must be a continuum of an appropriately changing level between those two extremes. The concept of one calibration level being right for all shapes and sizes of cinema rooms is simply untenable. The guide provided by Figure 4, as proposed by Beusch, deserves serious consideration.

8) The X-curve

Figure 5 shows the X-curve in its current form. A thorough description of its origins and general characteristics has been given by Allen [2]. In the days before the advent of the application of Dolby noise reduction to analogue soundtracks, and especially before the introduction of Dolby SR noise reduction in the 1980s, there was some justification in the roll off of frequencies above 2 kHz in the reproduction chain as an additional form of noise (hiss) reduction, but modern digital soundtracks and SR analogue soundtracks really need no such additional 'help'. Indeed, with the coming of multi-format releases, especially into the increasing domestic market, many industry professionals feel that a flat response in all theatres would be more appropriate. There is little technological difficulty, these days, in providing meta data for the processors which would enable them to apply the appropriate equalisation to older films. However, there is also evidence to suggest that in many cases, the reproduction of a soundtrack which has been mixed in a room with the X-curve applied does not, in fact, necessarily sound unpleasant. Perhaps this goes some way to explaining why many film soundtracks can go straight to DVD, without 'de-X-curving' and still sound appropriate in the homes. It appears that we may have simply become accustomed to a duller sound in cinemas.

Some of the psychoacoustic justifications which were previously used to support the concept of the X-curve have also now been cast into doubt. Whilst it is true that the perception in large rooms is different from that in small rooms, the differences become less as the decay times decrease, and the reduction of the decay times in theatres for cinema reproduction is a growing trend. The very concept of the X-curve as something which is related to room size is, again, subject to the existence of a continuum, just as has been explained in Section 7 relating to SPL calibration. There is no 'one curve fits all' situation. Furthermore, the question remains as to whether *any* curve can even closely represent the different characteristics of different rooms. As Toole has pointed out in an earlier communication to the SMPTE (August 4th, 2010), and similarly in a recent book [5], *'Unlike a human, the microphone does not take any note of the angle of incidence of the direct and reflected sounds, nor does it make any allowance for the time of arrival of those sounds, nor does it acknowledge spectral variations among any of the sounds. The microphone simply adds them together. .....It is well known that two ears and a brain are vastly more analytical than a microphone and an analyser. Humans respond differently to sounds arriving from different directions at different times.'* No form of room equalisation can take all of this into account. The premise of a generalised 'house curve' can no longer be defended. These aspects of the response of different rooms are relatively easily sorted out by the brain, but, as they are all position-dependent, there is no one curve, or even family of curves, that can be applied to the loudspeaker systems which will unify the responses from room to room. (Again, see also Section 10.)

What is more, if the X-curve, or any other similar response modification, is something which may still have any justification, there is no justification in applying the necessary equalisation via acoustic measurements in the far field. It makes little sense to compound the already dubious idea of equalising a room with the incorporation of the X-curve into the same 'corrections'. If any response correction is to be *reliably* applied, it should at least be done in the close field, otherwise it becomes convolved with the unequalisable non-minimum-phase characteristics of the room acoustics, and 'correction' then becomes an inappropriate word to use for the process. Alternatively, any agreed curve could be more accurately applied within the electronics of a system, as a fixed equalisation, as with NAB equalisation for analogue tape recorders or RIAA equalisation for vinyl discs. However, this still begs the question as to whether any such curve is necessary at all, these days. The answer is probably 'No'.

When the overall X-curve room response is applied in the far field, the equalisation can even make a bad situation worse, especially in the poorer rooms, which, ironically, are the ones which really need the most 'help'. The complexity of the room response, with many non-minimum-phase components, can give rise to some very inappropriate, simplistic, pressure amplitude equalisation 'correction' being carried out. What is more, third-octave analysers do not always indicate a true inverse of the real response, and the precise settings of the controls which result in the desired curve can be significantly different dependent upon who makes the adjustments, at which frequency they begin; and what type of analyser is used. There is always a risk that these factors can conspire to give rise to final, *true* responses which are quite differently equalised, not only from one room to another, but also within one room if equalised by different people. (The question of different people arriving at different equalisation settings for the same room is currently being studied at two universities. The findings will be published in November 2012.) This makes something of a mockery of the intended goal of standardisation, and risks the overloading at certain frequencies of any marginally specified amplifier/loudspeaker systems (of which there are many). In such cases the 'correction' can lead to as many problems as it solves, *or more*.

For these reasons, the application of the X-curve (*or any other curve*) via measurements in the far-reverberant-field is fraught with problems. It will inevitably lead to an unacceptable distortion of the spectrum of the *direct* responses, and, as has already been stated, it is the differences between the *direct* sounds that is a great contributing factor to the perceived differences from one room to another.

9) Outstanding questions

It would be a relatively simple task to verify many of the outstanding questions if a team of academics and professionals were given a selection of theatres, both mixing studios and public performance theatres, in which to carry out practical confirmation of the proposals made in this document. Apart from access to a group of listeners who would have no idea of what programme material would be being presented to them (to keep the tests 'blind'), all that is really required is the will to do it. Surely the cinema industry has the wherewithal to organise this.

The X-curve validity is somewhat moot because in no other field of sound production or reproduction in large rooms is anything similar considered to be necessary. A new look also needs to be taken at the whole concept of level calibration and response equalisation in rooms of different sizes and decay times.The problems are by no means beyond solution, at least not to an extent which could make significant steps forward, even if perfection is beyond us.

Another outstanding question is the equalisation of floor reflexion dips. There is evidence that in the equalisation process in many rooms, attempts have been made to equalise response dips given rise to by the interference between the direct sounds and the reflexions from the floors. As the path-length difference varies in each case, for every different distance from the loudspeakers to the measuring positions, so does the *frequency* of the corresponding cancellation dip. If the frequency of the cancellation dip is variable, it is obviously impossible to globally 'correct' the dip from any given measurement spot or zone. What is more, a cancellation is *not correctable* by equalisation, because any added energy in the *direct* sound will yield a proportional increase in the energy in the *reflected* sound, and so the same proportional cancellation will still take place. To make matters worse, attempted correction around the frequency of a dip, even if done for a limited area of a room, such as in the principal working area of a dubbing theatre, will induce disturbances in

the responses either side of that frequency, giving rise to further 'corrective' equalisation which has absolutely no relation to what is really happening in the room. The resulting direct sound can consequently be grossly spectrally distorted, and can again be subject to system overloads when energy in the soundtracks coincides with the frequencies of the boosts. Floor reflexion dips *must* be left unequalised, as also should any response dips due to the regularity of the rows of seating: the so-called seat-dips, which can be evident in some concert halls.

Due to the greater area of flat floor surface at the front of many dubbing (mixing) theatres, as compared to the absorbent/diffusive nature of the seating in the corresponding area in most cinemas, the floor dip problem tends to be more commonly found in the mixing theatres. This situation is particularly disturbing because its 'correction' can lead to the serious, subsequent tonal colouration of the direct sounds. Such changes will affect the mixing decisions as a result of the fact that any floor reflexion in the room would have given rise to a boosted spectrum around the frequency of the cancellation after being 'corrected' by the equalised response at the mixing position. The whole concept is a minefield. It is better to let the ears deal with the floor reflexion dips. They tend to ignore them.

10) Rooms and equalisation: what really happens

Figure 6 shows the responses at 8 positions in a theatre, as measured by a single measurement microphone, from a centre-front loudspeaker. The differences are clear to see, and there is obviously no equalisation that can be applied to the loudspeaker which could make them any more similar to each other. Somewhat contrary to what many people may think after seeing the response plots, the tonal difference perceived by a listener, moving from one position to another whilst listening to a soundtrack, is minimal. There is simply no equalisation, no magic measuring system, and no 'improved' loudspeaker design that can reduce the response differences from one position to another. However, the ear and brain can perceive the sounds at the different positions to be very similar as long as the source is the same.

Figure 7 shows the way in which the response from a loudspeaker had been equalised, using digital, parametric equalisation, to try to achieve a 'better' response at a given position in a room when analysed using various time windows [7]. This is the sort of procedure that some engineers advocate for improved spacial averaging. The problem is that although the results of the equalisation look reasonable on the plots, the black line shows the response of the applied 'correction'. With this type of equalisation applied to the direct sounds, the probability of the ears perceiving a coloured sound is quite high. Conversely, if the direct sound was *flat* without the equalisation, and even though the response at measurement position in the room was not so uniform, the ear would tend to perceive a more natural sound by virtue of the more accurate direct sound.

Figures 6 and 7 indicate that firstly, equalisation cannot do anything to make the responses at different place in a room any more similar to each other, and secondly, that even when 'corrective' equalisation is applied to a signal, its effect on the direct sound should always be considered if colouration is to be avoided, irrespective of the flatness of the response as measured in the far-reverberant field.

11) Conclusions

1) Given what is now known about acoustics, psychoacoustics and measurements, there is no justification in continuing to calibrate the frequency response of film theatres in the far (reverberant/reflected) field. What we now know suggests that it would be *ideal* to begin with comprehensive anechoic data on the loudspeakers, as modified by the screens (see Toole [6]) although this may be hard to come by. A more practical alternative could be to measure the loudspeakers on their nominal axis at a distance in front of the screen which would allow a 10 ms, or better 20 ms, truncated FFT to be made without interference from reflexions. Care should be taken to ensure that the distance chosen remained outside the acoustical near field of the loudspeakers, otherwise errors could be introduced. As the screens add an often unknown variable into these measurements, it may be advantageous to take a series of measurements at different angles in order to get a better average of the directional behaviour, so that the response could be optimised. However, with experience, and as more information would be gathered it is probable that this process could be significantly simplified. Whilst it is understood that it is not possible to obtain definitively accurate measurements of the direct sound from loudspeakers in other than anechoic conditions, adequate evidence exists to suggest that very useful data *can*

be gathered.

2) The practice of using third-octave analysis and equalisation should be abandoned forthwith. All acoustic equalisation should be accomplished using either fixed or parametric equalisation, tailored to the precise requirements of each situation.

3) Level calibration should be dependent upon room size. There is no one level to suit all rooms. The level-versus-theatre-size calibration curve can easily be verified, but to do so requires people and rooms to be made available for the necessary experimentation.

4) The whole question of whether the X-curve (or any modified version of it) is relevant to the cinema industry of today requires serious consideration. At the very least, a reassessment from first principles is required.

5) If *any* room curve is to be applied, it would probably be better to do so via fixed and standardised equalisation in the system electronics, and not via acoustic measurements in the rooms. Room curves are unreliable data, and are especially so when there is no comprehensive knowledge of the combined loudspeaker and screen performances.

6) Care must be taken not to try to equalise the highly positionally-dependent acoustic cancellations given rise to by either floor reflexions, or as the result of the seat-dip effects.

12) Acknowledgement

Special thanks are due to all the other authors of the works cited in the references indicated below, in Sections 13 and 14.

Philip Newell FIOA

Keith Holland BSc, PhD, MIOA

(Both authors are Members of the AES, and PN is also a Member of the SMPTE)

13) References

1) Newell, Philip; Holland, Keith; Torres-Guijarro, Soledad; Castro, Sergio; Valdigem, Eliana; 'Cinema Sound: A New Look at Old Concepts', Proceedings of the Institute of Acoustics, Vol. 32, Part 5, (Nov 2010)

2) Allen, Ioan; 'The X-Curve: Its Origins and History', SMPTE Journal, Vol.115, Nos. 7 & 8, pp. 264-275 (2006)

3) Newell, Philip; Holland, Keith; Desborough, Matt; Fazenda, Bruno; Neskov, Branko; Castro, Sergio; Valdigem, Eliana; Newell, Julius; 'Room-to Room Compatibility of the Low Frequency Content of Mixes Using Resonant and Transient Signals', Proceedings of the Institute of Acoustics, Vol. 31, Part 4, (2009)

4) Newell, Philip R.; Holland, Keith R.; Neskov, Branko; Castro, Sergio; Desborough, Matt; Torres-Guijarro, Soledad; Pena, Antonio; Valdigem, Eliana; Suarez-Staub, Diego; Newell, Julius P.; Harris, Lara; Beusch, Christian; 'The Effect of Visual Stimuli on the Perception of 'Natural' Loudness and Equalisation', Proceedings of the Institute of Acoustics, Vol. 30, Part 6, (2008)

5) Toole, Floyd E.; 'Sound Reproduction', Focal Press, Oxford, UK, (2008)

6) As 5), above, Figure 18.6, page 377)

7) Philip Newell, Glenn Leembruggen, Keith Holland, Julius Newell, Soledad Torres-Guijarro, David Gilfillan, David Santos-Dominguez, Sergio Castro, 'Does 1/3 Octave Equalisation Improve the Sound in a Typical

Cinema?', Proceedings of the Institute of Acoustics, Vol. 33, Pt 6, Reproduced Sound 27 conference, Brighton, UK (Nov. 2011)

14) Further references

Newell P., Holland K., Newell J., Neskov, B., 'New Proposals for the Calibration of Sound in Cinema Rooms', 130th Convention of the Audio Engineering Society, London, UK (May 2011)

Leembruggen G., Newell P., Newell J., Gilfillan D., Holland K., McCarty B., 'Is the X Curve Damaging Our Enjoyment of Cinema?', SMPTE Convention, Sydney, Australia (July 2011)

Figure captions

Figure 1 Overlaid responses of 20 rooms at the two-thirds distance position (a) 9 cinemas; (b) 11 dubbing theatres

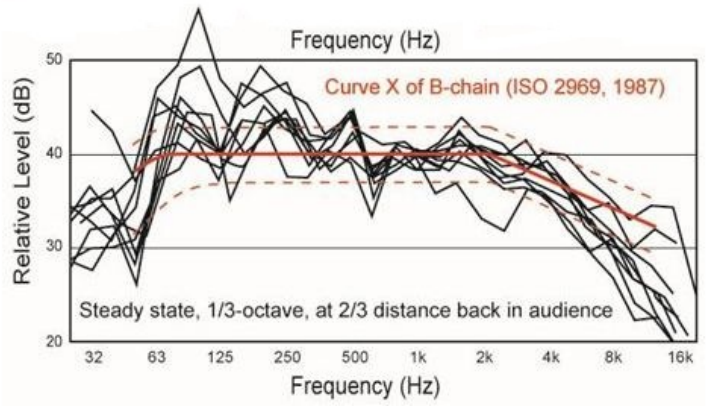
Figure 2 Overlaid responses of the same rooms as in Figure 1 but at two metres from the screen. (a) 9 cinemas; (b) 11 dubbing theatres. From these plots it is clear that the equalisation applied to try to make uniform the two-thirds distance responses is severely corrupting the evenness and similarity of the direct sounds

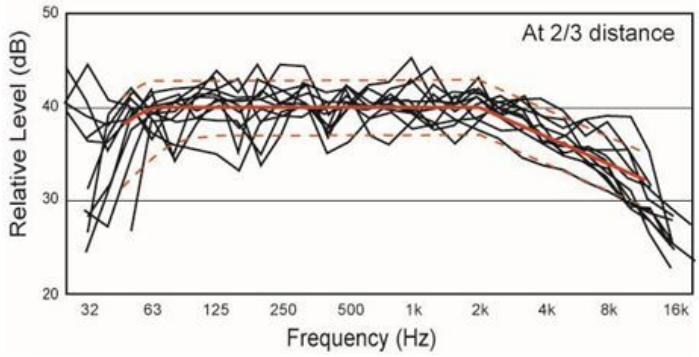
Figure 3 The third-octave plots of the response at 24 different places in the same music venue. In all cases, the same loudspeaker was the source. [Courtesy of Julius Newell]

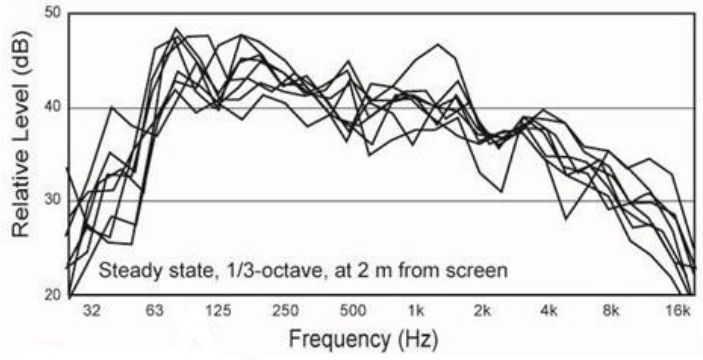
Figure 4 Graph of the screen distance versus calibration level at the two-thirds distance from the screen to the rear wall, as proposed by Beusch, and substantially borne out by experimentation [Figure 3 from Reference 4]

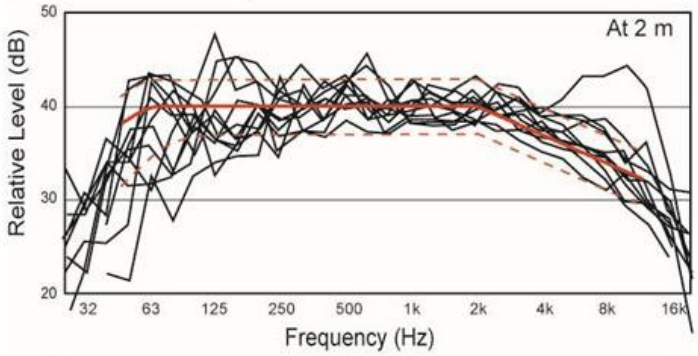
Figure 5 The X-curve. SMPTE 202M - 1998

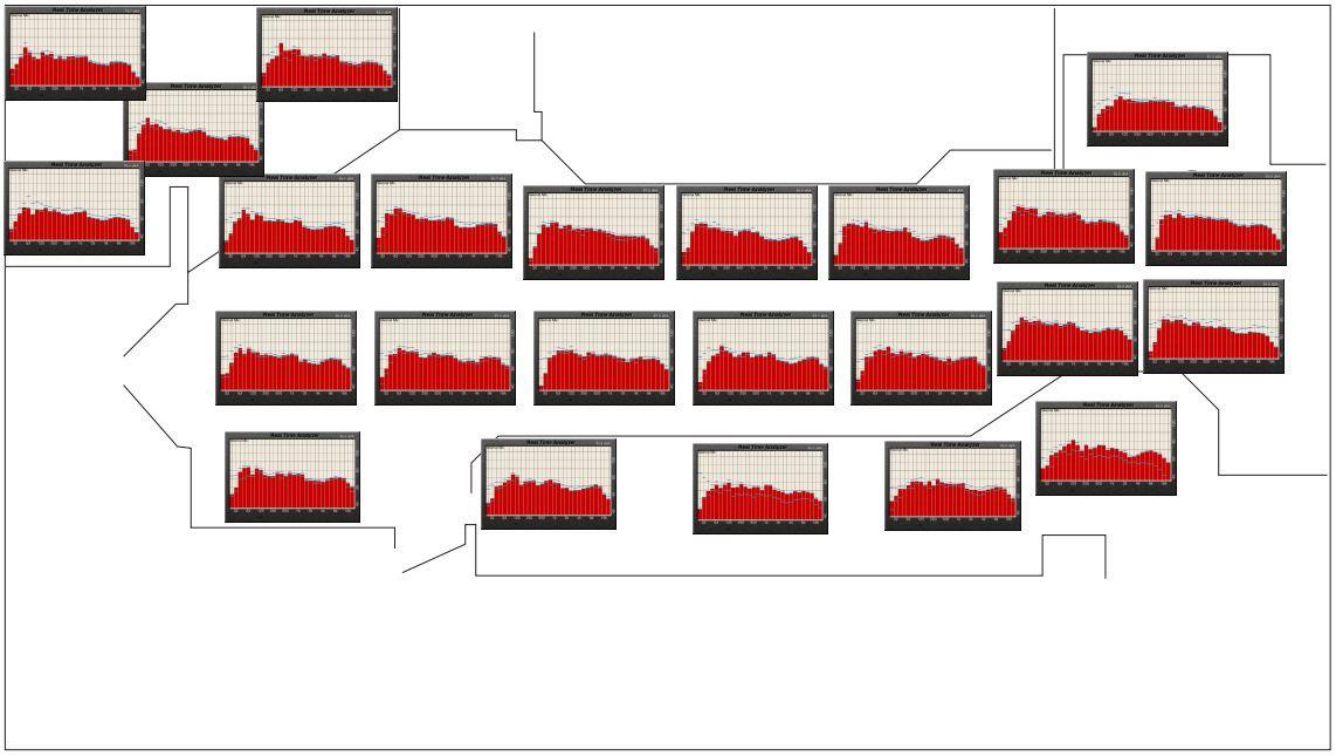
Figure 6 The centre channel response at 8 positions in one cinema room

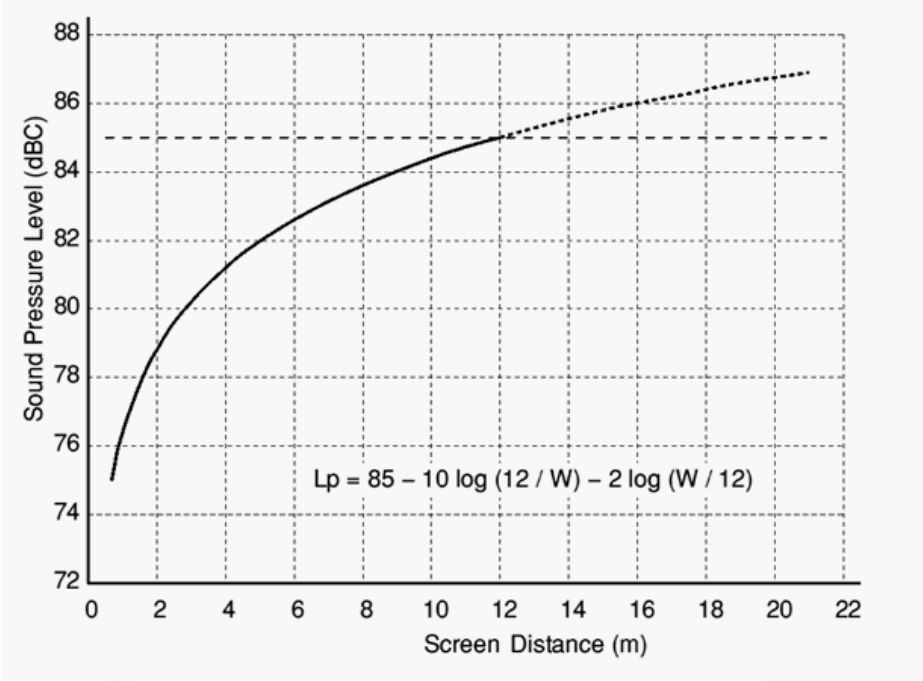


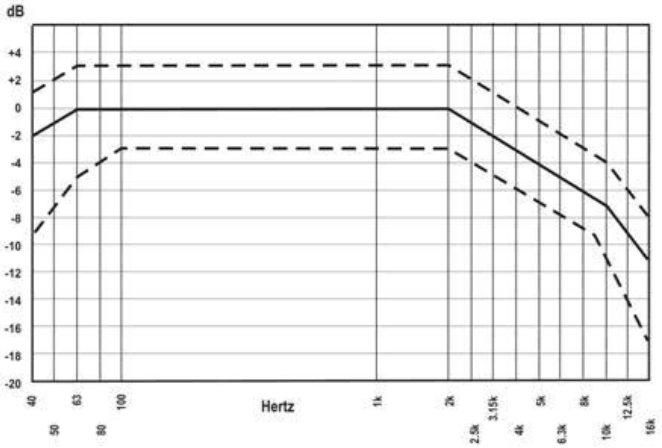

At 2/3 distance
Relative Level (dB)
50
40
30
20
32
63
125
250
500
1k
2k
4k
8k
16k
Frequency (Hz)


Relative Level (dB)
50
40
30
20
Steady state, 1/3-octave, at 2 m from screen
32
63
125
250
500
1k
2k
4k
8k
16k
Frequency (Hz)

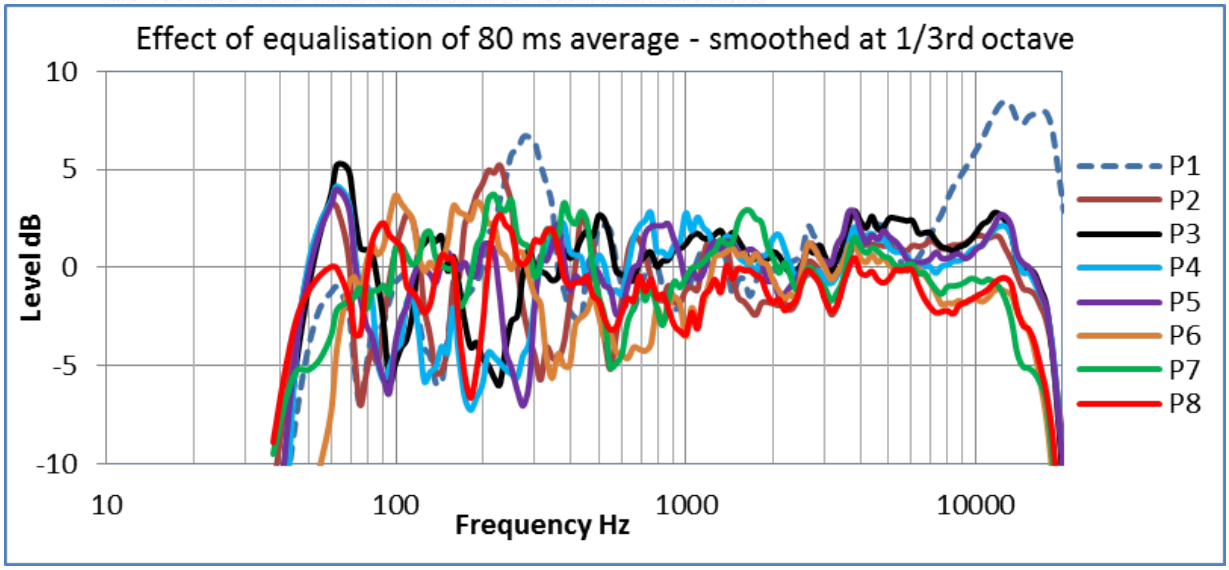

At 2 m
Relative Level (dB)
50
40
30
20
32
63
125
250
500
1k
2k
4k
8k
16k
Frequency (Hz)

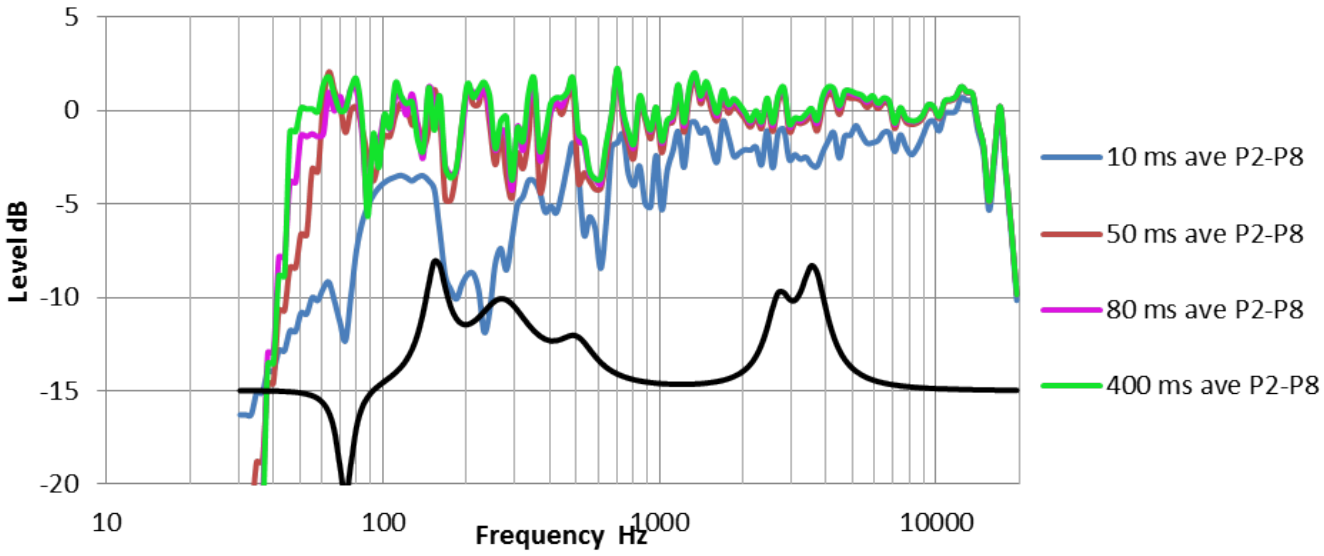






NOTE - Tolerances are based upon 1/3-octave measurements. If 1/1-octave are used, reduce the tolerance by 1dB.




5
0
-5
-10
-15
-20
Level dB
10
100
1000
10000
Frequency Hz
10 ms ave P2-P8
50 ms ave P2-P8
80 ms ave P2-P8
400 ms ave P2-P8