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THOUGHTS ON EQUALIZATION

BY

JOHN F. ALLEN

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In the days before graphic equalizers were available for cinema sound systems, many theaters were equipped with the same kind of loudspeakers that were being used in the mixing studios. The mixers would endeavor to make their recordings sound best on their speakers as they behaved in their rooms and hope that the film would sound pretty much the same when released to the theaters. The sound system equalization that we do today in each theater was therefore done in the mix. This worked reasonably well for theaters that actually had the same speakers. The sound engineers of that time deserve credit for making it work as well as it did. But it worked less well in those theaters with different speakers and theaters with different acoustics. Of course, one realizes that different theaters and studios all have their own acoustic characteristics. So while we had a workable situation, it was less than ideal.

Back then, sound systems in places other than movie theaters could be equalized. But the process was very difficult and time consuming. Engineers could spend days using what measurement equipment they had as well as their ears. They would determine the equalization they needed and sometimes build the circuits on the spot. This might even include winding their own coils. After they installed these parts, they would listen to the result and make further changes.

When Don Davis joined Altec Lansing, he and his staff had a better idea. They developed something called one-third octave equalization. Marketed as AcoustiVoicing at the time, this was a device that contained 27 adjustable filters, three for each of wideband audio's nine octaves. It was like having 27 bass and treble controls instead of two. This pioneering equalizer was originally intended for the control of feedback. An engineer could easily adjust one or more of these 27 frequency bands and carefully reduce the level at the appropriate frequencies to stop feedback -- all without having to build anything on site. This was a major advance in professional audio. Today we still have one-third octave equalizers and depend on them. We also have one octave, two-thirds octave, one-half octave, one-sixth octave, one-tenth octave and parametric equalizers. We also have a number of Digital Signal Processors that can be programmed to be any of the above type of equalizers, including various combinations. Each of these has its place and its cost. The more complex the unit, the more expensive.

In the 1970s Dolby Laboratories first began investigating motion picture sound. Dolby's revolutionary noise reduction circuits reduced audible hiss and print-through noises on magnetic tape recordings. One obvious place to sell these units was the motion picture business. With soundtracks made from so many individual recordings, noise buildup was a real limitation.

> **We would like to see a display that shows the frequency response of the sound as heard by the audience. This is not what we see**

But Dolby soon faced another problem. The sound systems in the theaters, particularly the loudspeakers, presented a major obstacle to the playback of the wideband soundtracks that their noise reduction system made practical. One obstacle was the limited frequency range or bandwidth of the speakers themselves. They worked best in the midrange dialog region from about 250 Hertz (cycles per second) to around 3000 Hertz. In addition, the problem of the interaction of the speakers with the particular rooms they were in, needed to be tackled. Newer modern loudspeaker designs would ultimately fix the bandwidth limitations of the older speakers. But as the subject continues to be studied around the world, I think it's fair to say that many are still struggling to fully understand and cope with the effects of airborne auditorium acoustics.

When "third-octave" real time analyzers began to appear, they complemented the use of third-octave equalizers. Technicians now had a fairly simple and relatively inexpensive measurement system. Though limited in its accuracy, especially in large rooms, it ultimately became widely adopted in the cinema business due to its ease of use and low cost. Other segments of professional audio soon abandoned this method in favor of more complicated and often computer based measurement systems.

For the older motion picture speakers, the two issues of limited bandwidth and room effects could both be improved by the use of one-third octave equalizers. To address this, Dolby offered the first modern "room equalizer" for movie theaters. Ever since those early pioneering days, not only Dolby's cinema processors but those of almost every other manufacturer has included one-third octave equalization for all of the screen channels. Today's units include equalization for the surround channels as well.

The term "room equalizer" is somewhat of a misnomer. Dolby was not the first or last to employ this term and its use has caused much debate. "How does a 'room equalizer' equalize a room," some would ask? They argued that the only way to equalize a room was to grab a sledge hammer or a wreaking ball and change the room itself. Others simply said that equalizers were best for fixing frequency response problems of the speakers. In retrospect these arguments, typical as they are for the audio business, were kind of fun.

In reality, everyone was right or at least partially so. Equalizers can indeed correct some loudspeaker frequency response problems if they aren't too narrow or extreme. Equalizers are also very good at compensating for sound-degrading room influences in the frequencies below 500 Hertz. However, they do this by selectively reducing the excitation of those frequencies. So one might say that they can equalize for certain effects of a room. Equalizers can do nothing for problems such as distortion, bad walls, echoes or poor coverage.

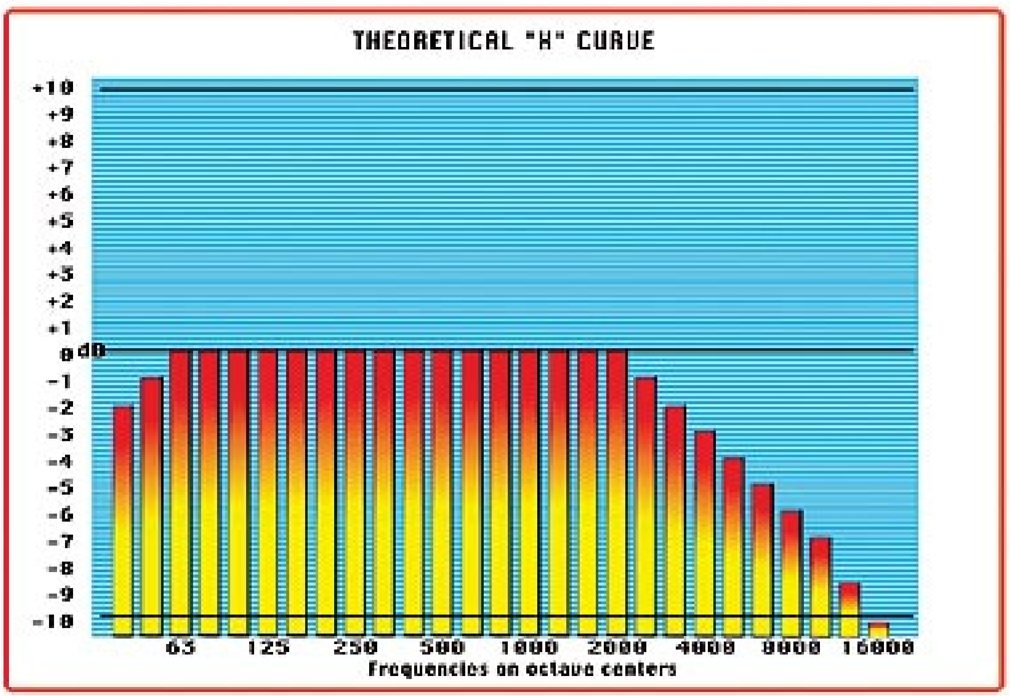

Figure 1

In the 1970s technicians began to be trained to adjust equalizers based on measurements made with steady state pink noise and real time analyzers. These were often the first measurement tools that many of the technicians had been able to afford. There may have been better approaches but they could cost ten times as much.

The real issue isn't the benefits of equalizers or which one is best, although some will debate the latter. The real issue has been and remains how equalizers have come to be used. Perhaps I should say misused because they so often are. Most equalized sound

systems are in fact mis-equalized. Another way to look at it is to say that most sound systems are mistuned and could sound better than they do with nothing more than more appropriate equalization settings.

The reason for this is the lack of a measurement system that accurately measures what something sounds like. We need such a system if we are ever going to make accurate equalization adjustments based on measurements alone. Without such a system, technicians are handicapped by often very bad data when attempting to equalize sound systems.

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Cinema technicians are all familiar with the rolled off high frequency response that they are supposed to see on a real time analyzer when they are finished equalizing a speaker in a movie theater. (See Figure 1) There are indeed measurement techniques that will display this response when a system is properly tuned, but they are generally not employed. The problem is that a properly tuned system might very well fail to produce this response on a real time analyzer when the signal source being measured is steady state pink noise -- the very test signal technicians are using. So we end up with the common complaint that it "measures great and sounds terrible." The measurement may indeed "look good," but what the technician has actually done is to add the inverse of the room's reverberation response to the direct sound from the speaker. This would be perfect if our ears and measurement microphones worked the same way. Unfortunately they don't. I believe this is why the sound systems in so many cinemas sound shrill with poor bass. (See side bar.)

So how can we get the most benefit from equalization with the tools we technicians have? I think we need to approach equalization somewhat differently in each of the following three frequency bands: 20 to 500 Hertz, 500 to 2000 Hz and 2000 to 20000 Hz. From 20 to 500 Hz, what we hear from a speaker is heavily influenced by the acoustics of the room and the early reflections occurring in front of the speaker. Real time analyzer measurements of steady state pink noise in this region are the most problematic, if not down right useless. From 500 to 2000 Hz we are in a region that fairly is stable from theater to theater. Real time analyzer measurements in this region are actually pretty good. From 2000 Hertz and higher, we are in a region where our measurement is influenced by the characteristics of the real time analyzer measuring system being used, room acoustics and humidity. This partially explains why we see a rolled off high frequency response on the analyzer greater than we hear with program material. Real

time measurements in this region are very useful, but require expert interpretation.

All of these frequency bands require listening with trained ears to really hear how they sound no matter what measurement system is used. One of the lessons stressed by Don Davis was that it is "the analyzer between the ears that is most important."

Voices sound more natural if the sound system is measured and then equalized using the shorter bursts.

When measuring pink noise with real time analyzers, here are some basics: First, when measuring loudspeakers it is extremely important that the analyzer be set for 3 dB per division, and not less than 2 dB. This is to avoid exaggerating the dips and peaks in the measured response and then mistakenly over-equalizing. It is also important that the averaging time be long enough to produce a measurement that is totally stable and not moving up and down in the analyzer's display window or screen. Finally, it is best to only use equalizers to cut or reduce various bands and not boost. The only exception would be the higher frequency controls of equalizers that have no dedicated treble control such as those of the SDDS processors.

Let's assume we are playing pink noise through the center loudspeaker in a theater and measuring this with either one or four microphones connected to a real time analyzer. Looking at the analyzer, we would like to see a display that shows the frequency response of the sound as heard by the audience. This is not what we see because the reverberation of the room is included in the measurement. The discrepancy comes because our brains filter out much of the effects of this reverberation and as a result we don't hear what the analyzer is showing. We suppress much of the early reverberation and concentrate on the direct sound. Thus it is primarily the direct sound that gives us the tone we perceive. Without knowing it technicians routinely fail to get the best result from equalization because they have radically "disfigured" the tone of the direct sound. But this doesn't mean that we can't use the information that the analyzer gives us.

Before attempting the equalization of a motion picture sound system, it is best to setup the active crossovers first, if the installation is so equipped. Crossovers are meant to balance the various speaker sections with one another and to set the crossover frequencies that define their operating regions. While there may be some adjustments within these crossovers that could be used for sound system equalization, the temptation to use them for such purposes should be avoided. The adjustments of the active crossovers should be done to provide the best balance and smoothest transitions from woofer to midrange and midrange to tweeter. Once this is done, the actual sound system equalization can begin.

Starting with the 20 to 500 Hertz range, as stated, the sound we hear from the speaker is heavily influenced by the room, the seats and the geometry of the reflections from boundaries in front of the speaker. This is not just the floor, but could also be a stage or, worst of all, a pit. I say worst of all because a pit, be it an orchestra pit or a depressed seating area, in front of a speaker, can often produce a well effect. This is the same effect we hear when we blow across a Coke bottle. Typically in a theater this effect produces a peak in the 250 Hertz area. The equalizers provided by the cinema processors typically do not have enough range to completely compensate for this.

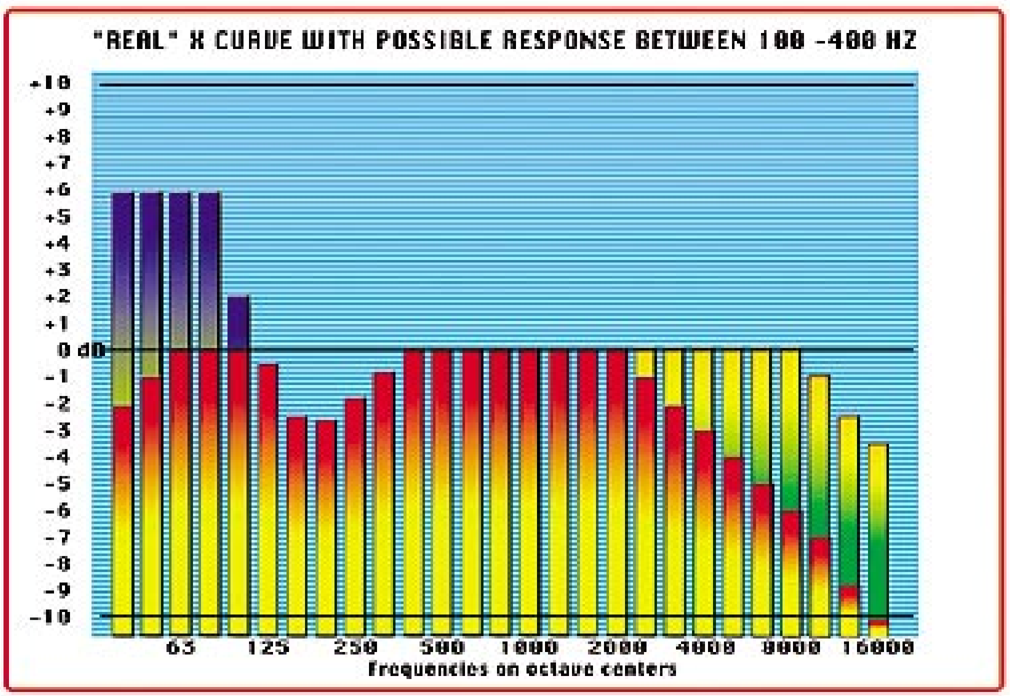

Figure 2

Even in theaters without such sound-degrading pits, we are still in a room dependent region when listening to the frequencies from 20 to 500 Hertz. This is made more complicated by something acousticians commonly call a “seats dip.” This refers to the fact that the seats cause a well tuned system to measure with a dip in the response in the frequencies between 100 and 300 Hertz. (See Figure 2) With all this going on, a real time analyzer / steady state pink noise measuring system is simply terrible at indicating what the equalization adjustments should be in these lower frequencies to achieve accurate sound reproduction. A better approach is to make the measurements for these bands closer to the speakers. I generally recommend the third row of seats. But even this will

still only get us about half way to where we need to be.

Figure 2 shows a 3 to 4 dB dip in the frequency response centered around 160 to 200 Hertz when measuring steady state pink noise with a real time analyzer. This is a common measurement found with steady state pink noise. But the dip mostly disappears when the noise is played in shorter bursts. Voices sound more natural and often far more intelligible if the sound system is measured and then equalized using the shorter bursts. I have always assumed that the steady state measurements show this dip because of effects from the spacing, height and construction of the seats as well as other conditions commonly found in auditoriums, although I have never taken the time to prove it. Nonetheless, all auditoriums seem to exhibit this behavior and we are certainly accustomed to listening in such rooms be they movie theaters or concert halls. If it is a problem in movie theaters, and I am not convinced it really is, proper equalization can be an effective solution. However, using steady state pink noise in movie theaters would appear to be contraindicated for the frequencies below 500 Hertz as the equalization done with such measurements can result in unnatural sounding speech.

One can also listen to known reference materials and adjust the equalization so the speakers have the same tone as heard with good headphones -- a most practical technique. Using this approach, one can truly know if the sound system is accurately delivering the tone of the recorded sound to the ears of the theater audience. Vocal recordings can be a good tool here.

One important note: Unless an audible frequency response problem exists, one should not try to equalize the bands below 100 Hertz no matter what the analyzer shows. See Figure 2.

From 500 to 2000 Hertz, the measurements we see on a real time analyzer are, as I have said, pretty good. The display is giving us a reasonable representation of the frequency response heard by the audience. Equalizing a sound system according to these measurements will therefore give us reasonable results in these frequency bands.

From 2000 Hertz and up we have a different kind of problem. Due to the behavior of the measurement system we are using, the display shows us a roll off of the higher frequencies. This characteristic curve is generally believed to begin at 2000 Hertz in movie theaters, but this is only true in larger theaters. In smaller theaters, the knee of this curve can vary between 2000 and 8000 Hertz. (See Figure 2) The only way to know where it should be is to use loudspeakers with a flat on-axis frequency response. Almost no theater speakers are designed this way these days and so the best advice for technicians is

to gently equalize the frequencies above 2000 Hertz for smoothness rather than a specific roll off beginning at a certain point. One should keep in mind that over-equalizing will significantly degrade clarity as well as dialog intelligibility. Finally one needs to listen to reference material and set the treble controls by ear. This is true of any equalization method.

Once the center channel is done, I recommend that the settings for the center be copied for all the remaining screen channels. This will eliminate the sometimes major measurement differences we might see from the different, and yet identical, screen speakers when the audible differences are in reality quite minimal or nonexistent. In other words, if the equalization is the same for all the speakers, all the speakers will sound the same when they are all working together. This will also have the added benefit of improving the width and depth of the stereo image. Many continue to disagree with this approach. So try it and see how well it works.

When equalizing surround speakers, a measured roll off of the high frequencies may not exist. Because we are always close enough to -- and surrounded by -- the surrounds, the response should appear more nearly flat with the microphone(s) in the center of the seating area. This will be more true with the better surround speakers. See Figure 3. Subwoofers should not be equalized unless a frequency response problem is heard.

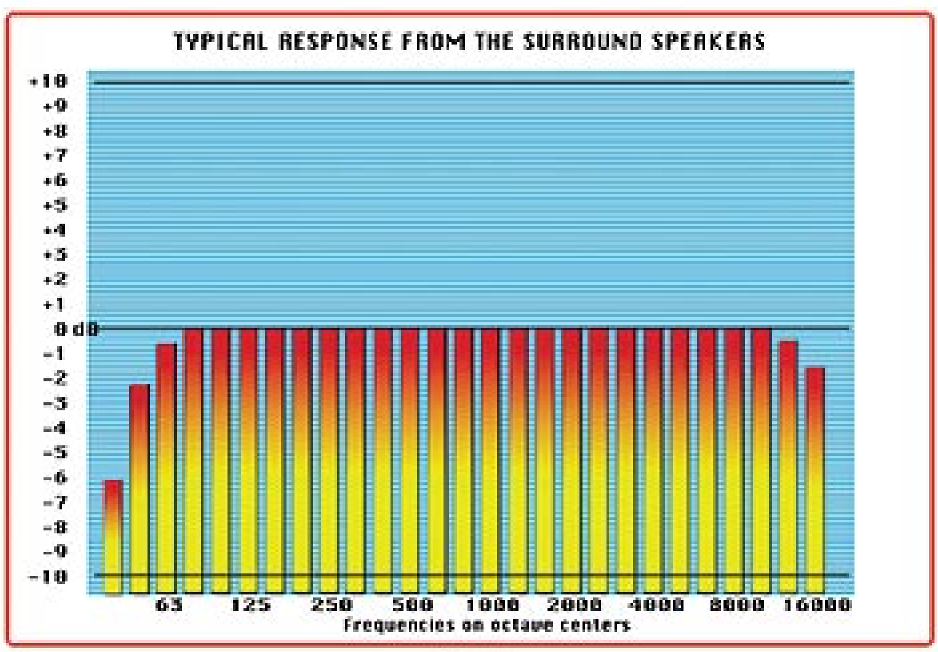

Figure 3

It just so happens that the mid to upper bass frequencies are where, not counting the subwoofers, we find about half of the acoustic power of the program material. Speaker engineers sometimes call this the power band. One of the interesting benefits arising from equalizing the screen speakers is that when we cut these bands at the equalizer, we reduce the amplifier power they will need to be properly reproduced. When we need less amplifier power for these frequencies, we increase the headroom of the sound system.

My hope is that theater technicians can use these suggestions as the beginning of a process of endless learning and self-improvement. Once tried, I am confident that the results will be better sound quality as well as the promise of still further improvement with more time and practice. Those who have used these methods will attest that this is so. When a sound system is properly equalized there should be one unmistakable characteristic of the sound: It should sound NATURAL. It should be crystal clear, free of boom and free of the "honkiness" typically associated with cinema sound. The treble balance should be smooth and not shrill. Nor should the sound be dull and muted. There should be no excessive sibilance when words with the letter "S" are spoken. Music should sparkle, envelop, sound alive and beautiful. Of course beauty is something we can't quantify. But we know it when we see or hear it -- or at least we should -- ever mindful of how fragile it can be. If motion picture soundtracks can sound as beautiful on headphones as they often do, they should sound equally as beautiful to the audiences in the theaters.

John F. Allen is the founder and president of High Performance Stereo in Newton, Mass. In addition, he has served as the sound director of the Boston Ballet. He is also the inventor of the HPS-4000® motion picture sound system and in 1984 was the first to bring digital sound to the cinema. John Allen can be reached by E-mail at johnfallen@hps4000.com. All of Mr. Allen's articles written over the past 27 years are available for download at http://www.hps4000.com.

The Debate

BY
JOHN F. ALLEN

Sir David Lean at the Century Plaza theater in Los Angeles following the world premier of his last film A PASSAGE TO INDIA, grabbed me by the shoulders and started to shake me. "The sound was wonderful," he said. This legendary director of such films as THE BRIDGE ON THE RIVER KWAI and LAWRENCE OF ARABIA went on to note that his film sounded better in this theater than it did at the studio where it was mixed. To fully appreciate what he was saying, one needs to remember that the sound he heard at the studio was the soundtrack's magnetic master vs. the 35 MM Dolby A-type encoded stereo optical print in the theater. This is the same theater that following the installation of my sound system was noted in one Los Angeles paper as having "the best sound system in the area if not the country." I mention this only to establish that the Century Plaza's sound system was recognized as being superior.

And yet in it's 18 year life before the building was torn down in favor of an office tower, there were also many criticisms. These would always occur after another premier when a studio hired a technician to check the sound and said technician would ruin the sound system by changing the equalization. Why would this happen? Because the measurement system used provided the technicians with bad data and they used it to re-equalize. How reliable was this data? Not very. If one looks at the equalization done to this sound system by various technicians, one can't help but notice that not one of them repeated the same adjustments in 18 years. If there was ever proof of a faulty measurement system, an 18 year lack of repeatability is it. So not only were all those re-equalizations different from one another, they resulted in inferior sound from a superior sound system located in the heart of the motion picture industry.

I happened to visit this theater after one of these episodes. The sound was so bad that I insisted that the technician come back and fix it himself. I was back in Boston by the time he got there and called to ask what to do. I asked him to run some film and listen to it for a while. Then to simply restore my equalization settings and listen to the same film again. He did exactly what I had requested and called again. "It sounds MUCH BETTER," he said. "Why?"

Past articles I have written about the subject of sound system measurement and equalization have often sparked debate, some of it heated. However, the arguments are not what some might think. When discussing these issues with some of the strongest dissenters, I find that they don't so much disagree with my findings that measuring a sound system with steady state pink noise gives unreliable data, but rather with my notion that good ears are required to get the best results when tuning a sound system.

"If we let technicians use their ears," they argue, "we will have chaos. At least we have some consistency with the current measurement practices." This is a case where, it seems to me, that we are both right. I honestly do not know how good the ears of the bulk of theater technicians are. It's obvious that there is some substantial doubt among some senior sound people in this industry.

But can we leave it there? I don't think we can afford to. We have chaos now. Theaters currently sound substantially different from one another when they should all sound good. I recently visited two brand new 16 complexes. Most of the theaters employed the same model cinema processor and amplifiers. The speakers differed in the two complexes. The sound I heard in all of the auditoriums I listened to was a mess. In one theater I listened to a fight scene that contained dialog with loud crowd noises in the background. The dialog was unintelligible until the crowd noise was gone. Another problem was the complete lack of surrounds. The surround speakers could have been disconnected and no one would have heard the difference.

I had the opportunity to measure this sound system and sure enough, it "measured" according to "industry standards." After retuning this system with better methods, the dialog in the same fight scene was completely understandable. This was with far more sound in the theater because the surrounds were now in proper balance and in this scene, quite loud. So while the system had met industry standards by one measurement, it really didn't. Unintelligible sound is not an industry standard.

For those who distrust the ears of theater technicians, I think I can offer some hope. For nearly 30 years now I have worked with and trained many technicians. I have found them quite eager to learn and talented enough to learn how to listen analytically. It takes us all a long time to learn the diagnostic listening skills required, but we can learn them and cinema technicians have an advantage in that they listen to a lot of films.

But herein also lies a problem. Anyone who tries to train their hearing by listening to sound systems cannot achieve the skills they seek. They will instead become expert in the

sound as they personally like it from the speakers they have come to prefer. But this isn't real sound. To hear real sound, we have to listen to real live sound and lots of it, not sound from loudspeakers. Only this way can one "calibrate" one's ears. In one respect this is easy. We hear live voices every day.

So ultimately I cannot disagree with those who criticize my writings on sound system equalization and measurement. I just think that it would be far better for this industry to stop arguing and start finding better and more reliable methods of measurement and provide better training as well as equipment for the technicians we rely upon to keep the theaters open. Criticism is best when it offers light rather than just heat.

Audio and aviation technologies are roughly the same age. Today we cross oceans in less than a day with complete confidence that after flying for 16 hours with our feet up and eating caviar, not only we will land safely, but when we do we will be at the right airport. For movie theaters to be stuck in the rut where the audio "measures great but sounds terrible" is pretty sad indeed.