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THE MYTHICAL "X" CURVE

The curve that's not a curve

BY

JOHN F. ALLEN

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THE MYTHICAL "X" CURVE

The curve that's not a curve

By
John F. Allen

Of all the topics I have covered over the last 21 years, one of the most important - sometimes controversial - is the subject of cinema sound system measurement and equalization. Without a doubt, the misinterpretation of the present pink noise based measurements along with the improper equalization that results, are two of the most difficult and perplexing problems in the world of motion picture sound.

Technicians are familiar with the drill. Microphones are placed in the theatre and connected to a real-time analyzer. Steady state pink noise is played through each channel of the sound system. Equalization adjustments are made to each channel until the measurement of the pink noise, as seen on the analyzer, conforms to a specified curve called the X curve. See Figure 1. Once this is completed, the sound system is deemed to meet "industry standards" and everything will sound just perfect every time.

Right?

Well, not exactly. While these methods have been questioned by some and abandoned by others, the majority of technicians have valiantly struggled to implement them. Though sometimes successful with older theatre speakers, these methods have proven unpredictable, particularly when used with modern loudspeakers. Technicians can encounter channel to channel measurements that might differ as much as 8 dB in a given 1/3 rd octave band. Unfortunately, too few have recognized that it is simply impossible for identical speakers in the same room to measure so wildly differently when they sound so similar, unless the speakers are defective or the measurements are wrong.

As I have described in previous articles, the reason for these measurement difficulties stems from the fact that real-time analyzers do not distinguish between the first arrival of sound directly from the speaker, and the reverberation in the room. Our brains do make such distinctions. Indeed we suppress some reverberations, focusing our hearing towards the direct sound. By including the reverberation in the measurement, real-time analyzers corrupt the relevant data we are really trying to obtain. The result is that the equalizations done solely according to such methods are often nothing more than the inverse of the reverberation's accumulated frequency response being applied to the direct sound. We typically wind up with a sound system in which none of the screen channels

sound the same, except that they often tend to sound shrill with poor bass. The stereo image is reduced in both width and depth. Worst of all, the equalization can be so radical, that some sounds, particularly dialog in loud scenes as well as a large percentage of the background effects, are wiped out and never heard by the audience.

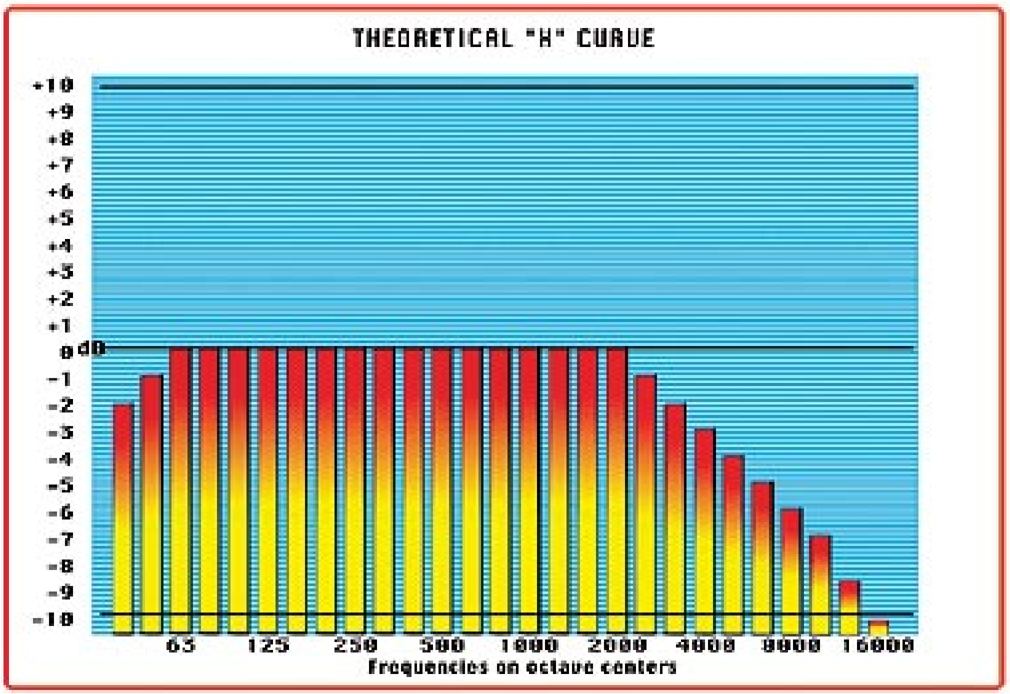


Figure 1

Despite its shortcomings, the pink noise based measurement method as well as the X curve actually evolved from some excellent, though often misunderstood, work done by Dolby's Ioan Allen in the 1970's. Theatre loudspeakers of that time suffered from both a limited frequency range as well as a rather poor frequency response. Both of these deficiencies can be helped, sometimes dramatically, with the careful use of 1/3 rd octave equalization. In the 1970s, if one wished to take advantage of these benefits, a simple and affordable method of measuring a loudspeaker in a theatre was needed. The relatively inexpensive method using steady state pink noise was gaining popularity at the time. Although it was later replaced with newer and far more costly methods such as the Time-Energy-Frequency (TEF) system and other computer based systems, the cinema world has stayed with it.

While pink noise can be very convenient when working with electronic circuits and magnetic tape recorders, it has always been problematic when used with loudspeakers.

This is because by including the reverberation, loudspeaker measurements done with a real-time analyzer do not always correlate well with the superior swept sine wave measurements made in an anechoic chamber - let alone what we hear. In addition, it was quickly realized that when using pink noise, loudspeakers measured very differently in rooms the size of living rooms and much larger rooms the size of theatres.

While a directional speaker that sounds right to the ear in a living room may indeed exhibit a flat upper frequency response with a real-time analyzer and pink noise, such will not be the case when a speaker is in a room the size of a theatre. When equalized with pink noise to show a flat response in a theatre, speakers deliver sound with too much treble. The resulting sound is unnatural, way too bright and impossible to listen to. This, again, is due to the far greater reverberation of the larger room being included in the measurement. Since there is more low frequency reverberation, the lower frequencies appear to have a greater amplitude than the higher frequencies. Looking at such a measurement on a real-time analyzer, the higher frequencies appear to be rolled off. See Figure 1.

The X curve was an attempt to normalize the shape of such a measurement in a large room. It resulted from measurements made of theatre speakers after they were equalized to sound the same as a set of studio monitors placed at the console position. When the two sets of speakers sounded as close as they could, the theatre speakers exhibited a frequency response that was basically flat from 100 to 2000 Hz and rolled off at a rate of 3 dB per octave above 2000 Hz, when playing pink noise and measured on a real-time analyzer. Below 100 Hz, the X curve showed a roll off of these lower bass frequencies. But this primarily due to the weakness of the older theatre speakers in the bottom octave. Rolling off the bass a little would help prevent these systems from being overloaded and damaged.

It was also noted that larger theatres would exhibit a somewhat steeper high frequency roll off, and that smaller theatres would exhibit a slightly reduced roll off of the high frequencies. This finding was officially noted in 1990. Beyond that, there have been few additional guidelines to aid technicians in the interpretation of these measurements and the equalization of cinema systems.

Several years ago, the measurement system evolved with the use of four microphones placed around the auditorium to pickup the sound. While some have steadfastly defended this approach, in the final analysis it is no better than a single microphone pickup. Different, yes. But whether one uses a single microphone or four, by including all the reverberation, the resulting measurements are equally unreliable. While some have been critical of the way cinema sound systems are measured and equalized, I think the real

disappointment is that as the loudspeakers have evolved, the methods employed to measure their behavior in theatres have not evolved far enough or quickly enough.

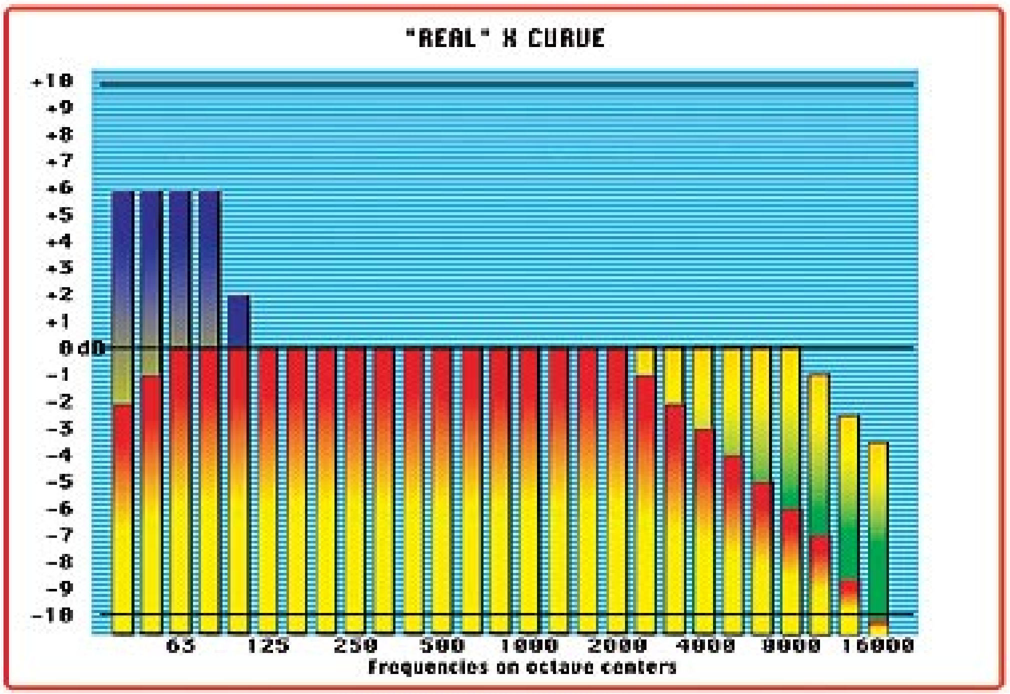
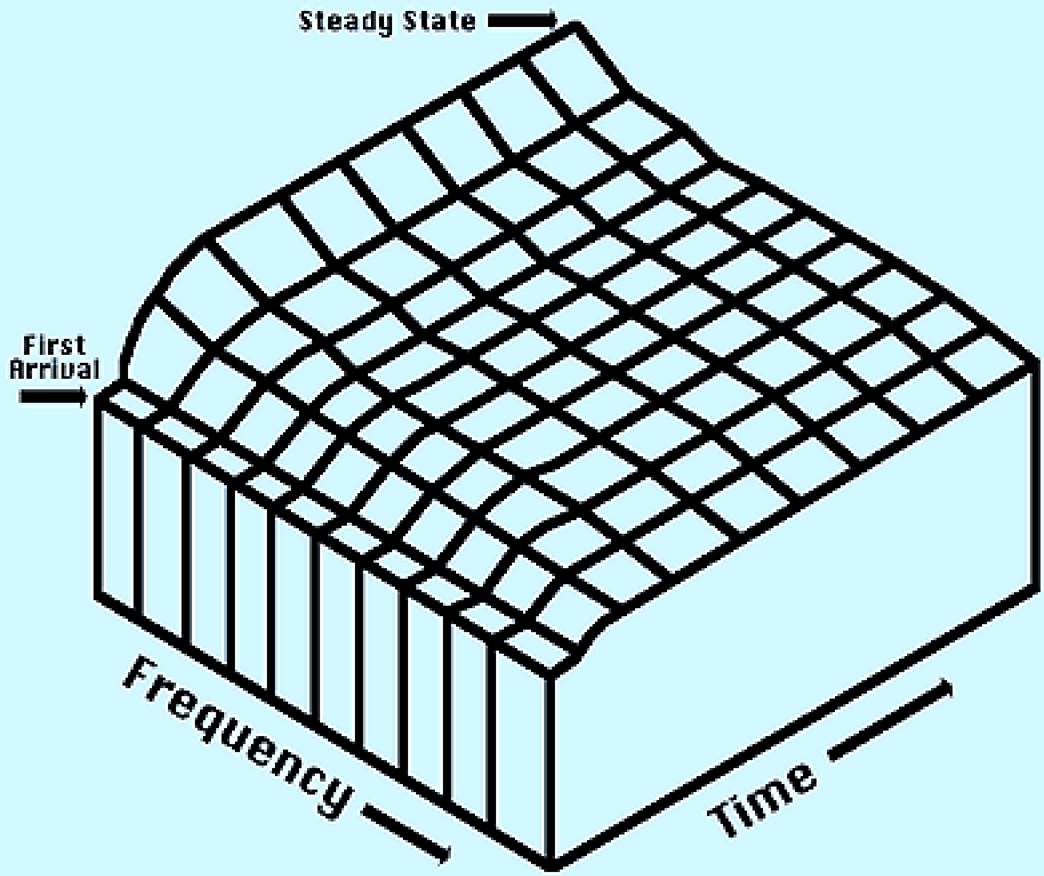


Figure 2

Ioan Allen's work of a quarter century ago was important and should not be understated. It represented a valuable component in Dolby's efforts to introduce Dolby Stereo as well as improve cinema sound. It later became the basis for the SMPTE 202-M as well as the ISO-2969 motion picture audio standards. It also opened the door for many other improvements in all aspects of movie sound and paved the way for the introduction of wideband three-way loudspeakers as well as sound systems with a nine octave response, first introduced to movie theatres by my company in 1979.

In fairness, since the original work on the X curve was done with older theatre speakers having significant frequency response and frequency range limitations, it was impossible to glean further insights into what the shape of the curve might be with full-range high-output loudspeakers in theatres of different sizes. Such speakers were unavailable at the time. That has now changed and a lot has been learned. Indeed, both Ioan and I have separately presented papers with similar findings on the varying shapes of the X curve. That our findings are so similar is striking because they were arrived at with completely different contemporary speaker systems.



Reverb Build-up of Pink Noise Against Time
Figure 3

In 1995, after 15 years of experience with three-way as well as four-way full range speaker systems in movie theatres, I presented a chart that I called the "Real X Curve", in presentations to the International Theatre Equipment Association and the SMPTE. I later published this advanced curve for the first time in BOXOFFICE in 1997. See Figure 2. Among other things, this chart confirmed Dolby's early finding that the rate of the high frequency roll off changes with the volume of the theatre and its reverberation time. In addition, for the first time it also showed that the knee of the curve also changes depending on the size of the room, and can be as high as 8 kHz before the roll off begins. The Real X Curve also shows that real-time measurements of the frequencies below 100 Hz, are also room dependent. While some theatres will exhibit a slightly rolled off bass region, many will show quite an elevated measurement in these frequencies. From this we see that the practice of automatically and artificially rolling off these lower frequencies, contributes to the lack of bass in many motion picture sound systems.

During the International Theatre Equipment Association technical seminars in 1999, Ioan Allen presented his own findings on the characteristics of real-time analyzer measurements of pink noise in theatres of different sizes. His findings were virtually identical to those in Figure 2. His presentation also included so-called waterfall charts showing how the shape of the pink noise measurement actually evolves as reverberation accumulates over time and results in response curves of varying shapes. See Figure 3. The bass build up below 100 Hz is also seen in this graph that he has kindly provided for this article. He pointed out that the X curve itself "is a myth." That is to say the high frequency roll off seen when measuring pink noise with real-time analyzers does not indicate a roll off in the frequency response of the sound system. He reminded us that the roll off seen in such measurements is a result of the accumulated reverberation being included in the measurement.

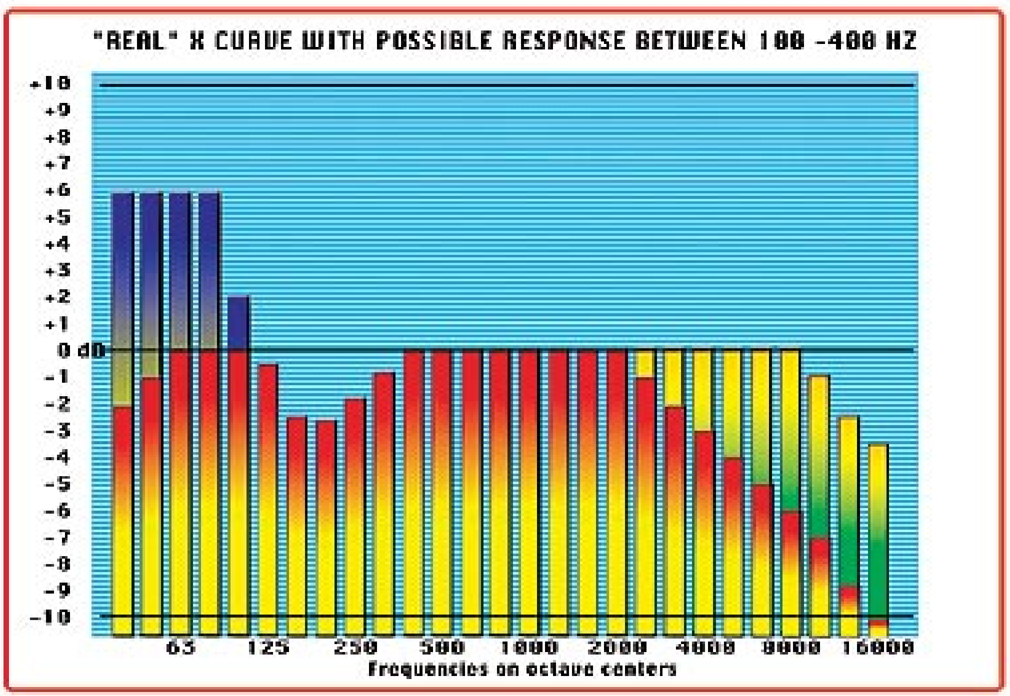


Figure 4

Now that the varying shapes of the X curve are more clearly understood, are we now fully prepared to equalize cinema sound systems to perfection? Well, not quite. We have a problem. Before we can properly equalize a sound system with pink noise, we need to know what the shape of the curve should be for the particular theatre we are in, when the response we actually hear with program material is flat. Determining that requires the

use of screen speakers with a flat on-axis frequency response. Since most high frequency horns used in cinemas are the constant directivity type, with their own characteristic rolled off high frequency response, finding the correct place for the knee of the curve for a particular room is unlikely. Perhaps less difficult is knowing how the lowest frequencies should measure. The best way to handle the frequencies below 100 Hz is to adopt a what you see is what you get policy and do not equalize.

Another equally frustrating problem is the inability of the pink noise / real-time analyzer approach to accurately convey what is going on in the frequency range from about 100 to 400 Hz. For the sake of simplicity, my own Real X Curve chart does not show how these frequencies can sometimes measure at reduced amplitudes, rather than flat, in good sounding systems. See Figure 4. In my experience, however, the actual shape of the frequency response depicted by an analyzer in these frequencies is not consistent from theatre to theatre, even though the sound systems involved may have the same tone. Furthermore, the way speakers behave in these frequencies can be influenced by the room. How they should measure with pink noise is also room dependent. Sound systems tuned so that the analyzer shows a flat response between 100 and 400 Hz will often sound bloated, boomy or "honky," while others will sound fine.

There seems to be as many solutions to the challenges of tuning motion picture sound systems as there are technicians and authors who choose to write about them. Readers of this magazine are surely familiar with my approach. (See IF THEY KNEW WHAT YOU WERE MISSING, PART 3 in the November, 1997 issue of BOXOFFICE. This article may also be downloaded at www.hps4000.com/pages/special/missing.pdf.) It is, however, an admittedly personal approach that relies on art as much as equipment. The proof of the success of any technique is in the listening, however, not in the rhetoric. Those really interested in learning what works best merely need to stick their heads in the different rooms, setup different ways and hear for themselves. Fortunately, the differences are very evident, making judgments easy.

A new measurement system is needed. Whenever it arrives, the inventors will surely find themselves standing on the shoulders of Ioan Allen. Until we have a reliable method for measuring what something sounds like, it turns out that his original approach to the equalization of those older theatre speakers of the 1970s, remains the best solution to tuning a sound system. By comparing the sound heard from theatre speakers to a known high quality source, one can hear the difference and make adjustments accordingly. Since there are still no such measurement methods, we will need to rely on our ears for listening.

John F. Allen is the founder and president of High Performance Stereo in Newton, Mass. He is also the inventor of the HPS-4000® cinema 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.