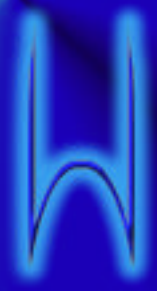

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JUST WHEN YOU THOUGHT YOU'D HEARD ENOUGH ABOUT LOUDSPEAKERS...

BY

JOHN F. ALLEN

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Perhaps no topic in audio has been debated more than the subject of loudspeakers. This is because there is as much art as there is science in building a speaker, let alone listening to one. The designer must balance many, sometimes conflicting, factors such as cost, size and weight vs. distortion, frequency response, bandwidth, beamwidth, efficiency and power handling. It goes on and on. One of the main controversies concerns horn loaded speakers vs. direct radiators. There are strong opinions on both sides each saying that one is better than the other. As is often the case in debates such as these, there are advantages and disadvantages to both types. But, the two designs are very different, produce different results and are made for different markets.

I've often said that there may not yet be any such thing as a good speaker. The live original sound is so much more satisfying. When you think about it, the "sound" in theatres was best in the silent film era when live orchestras provided the musical accompaniment. To my ears, at least, most speaker systems fall far short of sounding natural. I personally know of only four people who have ever designed and marketed a clean and smooth midrange, only one whose woofer really woofed as a real orchestra can and I won't even mention tweeters. Building good sound reproducers is hard to do.

Obviously today's theatres must use loudspeakers. Modern analog and tomorrow's digital soundtracks as well as the contemporary market, require theatre owners to seek out and install the best. But how does one know what that is, especially when there are such opposite opinions? Perhaps some perspective may help.

WHERE WE'VE BEEN

The earliest speaker systems were horns. This was out of practical necessity as there was generally too little power available from amplifiers. The unequaled efficiency offered by a horn was mandatory. Quite simply, they played louder. These early horns were usually long and very large. Bass horns could have an 11 square foot mouth area, too large to be practical for living rooms, but not for movie theatres.

In the 1950's development of theatre loudspeakers more or less stopped, while the development of the necessarily smaller systems for home Hi Fi took off. In the opinion of many, though not all, the *well designed* horn is and always has been the ultimate speaker. The horn acts as an acoustical transformer or impedance converter, that more efficiently and more effectively couples the motion of the speaker's diaphragm to the air in the room. This is one of the fundamental reasons behind the superior sound reproduction possible with fully horn loaded loudspeakers.

In their well known book "How to Build Speaker Enclosures" (H.W. Sams Co. #20520), Don Davis and Alexis Badmaieff, then of Altec Lansing, wrote, "Horns, when the design goals are left uncompromised, produce results that are uncompromised. *Once compromise is accepted*, the use of a combination type enclosure should be considered."

Many of the early home speakers were do-it-yourself types. The industry was slow to get going and today remains basically low volume and low tech. Market pressures forced designers to reduce the size and cost of speakers for the home. Therefore the race was on to build the best sounding, yet admittedly, compromised home loudspeaker. The large, expensive and hard to build horn systems were generally left aside in favor of the cheaper, smaller and easier to sell direct radiator type systems. Much progress has been made in battling the limitations of direct radiators in the past 30 years and today these generally affordable systems account for the majority of home speaker sales.

The professional speaker market has also seen the same need for smaller woofer cabinets. The full range horn systems are considered too large for many installations, especially for road groups where portability is important. In recent years manufacturers have devoted most of their woofer research to the more compact and portable direct radiator designs. Though not generally intended for the theatre market, these systems have recently been offered to the movie theatre market as well. The justification often mentioned is that these direct radiators have about the same sensitivity in the bottom octave as the older ported horn combinations of the early 1950's. It would seem that what many have forgotten over the years is the reason these smaller compromise systems were designed in the first place and what the ultimate speaker type, the horn, still remained. Perhaps this is the cause of some of the confusion.

DISTORTION

Distortion is the introduction of frequencies that are not present in the original audio signal or sound. These distorting frequencies can be harmonically related to a given frequency, i.e. harmonic distortion. They can also result from the mix of two or more frequencies. This kind of distortion is called modulation distortion and, in loudspeakers,

is typically greater than harmonic distortion. Since this distortion is not harmonically related to the sound, modulation distortion is by far more degrading, obscuring clarity and contributing to listening fatigue.

In speakers there are several ways distortion can occur. However, it's best to remember that distortion is proportional to the magnitude of the diaphragm's excursion. In general, a well designed horn system can produce less distortion because the diaphragm is required to move about 90 percent less than that of a direct radiator to produce a given level. To illustrate this, an experiment was conducted. A four inch speaker from a large US manufacturer was mounted in a specially built sealed box that could also be attached to a midrange horn. In this way the performance of the same speaker could be measured as a direct radiator and as a horn system. With a one watt input and the horn attached, the output available from the speaker increased 15 dB over the same unit operated as a direct radiator. Of course the increased level could have been achieved by "simply" increasing the amplifier power 31 times.

However, while the output increased 15 dB, distortion with the horn attached dropped an even greater 24 dB, or about 94 percent. In both tests, modulation distortion exhibited by the speaker was greater than harmonic distortion.

OTHER FACTORS

Loudspeakers must offer more than low distortion. High output, smooth frequency response and good coverage count too. This is even more important for theatre speakers since they must cover a much larger area. Historically, many horns have had a reputation for coloration, ragged frequency response and uneven coverage. Fortunately, there are some horn loaded systems now available that have all but eliminated these problems. This is most welcome because in theatres we especially need the directional characteristics horns provide.

COMPARING MODERN SYSTEMS

Today's professional theatre loudspeakers are either fully horn loaded types, horn tweeter with direct radiator woofer combinations, or the familiar horn tweeter with a partially horn loaded / bass reflex woofer combination. In 1983, the Japanese Audio Consulting Society (Nippon Onkyoka Kyokia) tested theatre speakers. Their report compared eight systems from manufacturers based in the United States, Great Britain and Japan. Some of these systems were fully horn loaded. One was a 4-way fully horn loaded system. The combination types were two-way and horn loaded only for the high frequencies, employing a vented box woofer with two 15 inch direct radiators for the bass.

One might carefully note that the low frequency radiating area of just one of the largest woofer horns tested, exceeds, by 30 percent (read; moves more air), the low frequency radiating area of an entire 70 MM sound system using five direct radiator woofers. In this sense, it is unfair to compare the two, accept to acknowledge that the modern direct radiators do actually perform quite well considering their smaller size and reduced output capability. Such combinations are ideal for surround speakers, in as much as there are so many of them, the output required from each is less.

What is so interesting about this test is that among the speakers evaluated were the most popular of the new systems currently being installed in US theatres. The tests were conducted in a real theatre environment with over 800 participants as well as in an anechoic chamber. The results for a 3-way fully horn loaded system (3-way horn), the 4-way fully horn loaded system (4-way Horn) and three 2-way horn / direct radiator combinations (combo 1, combo 2 and combo 3) are shown below.

FREQUENCY RESPONSE ON AXIS (ANECHOIC CHAMBER)

These numbers represent the difference in dB between the highest peak and the deepest dip in the frequency response of the speakers. The greater the number, the poorer the response. Column 1 shows the wideband response, that is the entire system. Column 2 gives the midrange response alone where dialog intelligibility is important. As a point of reference, in the speaker world these particular numbers are considered quite good.

It is also evident that neither design necessarily results in a smoother response. The fact is that a speaker with a greater variation in overall frequency response may, for other reasons like lower distortion and reduced early reflections afforded by directional radiation characteristics, sound better than a smoother system. In other words, frequency response is not by any means the whole story.

	70 to 18 kHz	500 to 5 kHz*
3-way horn	7 dB	4
4-way horn	12	5
combo 1	14	6
combo 2	9	8
combo 3	13	6

Table 1. Axial frequency response.

*** All five systems are horn loaded in this region.**

LOW FREQUENCY CUTOFF

This measurement is room dependent. Results will differ in different rooms. These numbers represent the point where the bass output is 3 dB (1/2 power) less than the average output of the rest of the woofer. This is for comparison only and does not necessarily indicate the lowest usable frequency available from the speakers. Obviously the lower the number shown, the better.

3-way horn	70	Hz (cycles per second)
4-way horn	55	Hz
combo 1	70	HZ*
combo 2	70	Hz*
combo 3	70	Hz*

Table 2. -3 dB low frequency roll off point.
*** As the frequency was lowered, the direct radiator woofers actually showed a pronounced downward slope in the response before the points given here.**

POWER RESPONSE

Some believe this is a very important test. Power response is certainly the industry's latest bandwagon. Indeed some companies have recently advertised their speaker's "flat power response." The fascinating finding in the Japanese test is that of the eight systems mentioned in the report, the three exhibiting the greatest variation in power response were the so called flat power response types.

Power response is the total power output of the speaker, in all directions. It is said by some that if both the power response and the axial frequency response are the same, that coverage throughout the listening area will be more even. Others take the point of view that what is really important in achieving even coverage is even sound pressure at everyone's ears. These designers tailor the radiating patterns of their speakers to accomplish this result.

	Accuracy
3 way horn	10 dB
4 way horn	12 dB
combo 1	20 dB
combo 2	20 dB
combo 3	16 dB

Table 3. Power response accuracy.

HARMONIC DISTORTION

Harmonic distortion for each system was measured with 1 watt input. It would have also been interesting if they had measured harmonic distortion with each speaker at equal output levels as well, since the horns showed as much as 6 dB (four times power) more output, with 1 watt input, than the direct radiators at 100 Hz. Modulation distortion measurements were apparently not taken.

	100 Hz	500 Hz	1000 HZ*
3-way horn	.18%	.25	.32
4-way horn	.45	.36	.40
combo 1	.71	.56	1.78
combo 2	.56	.56	.79
combo 3	1.78	.79	1.00

Table 4. Percent harmonic distortion for 1 watt input.
*** All five systems were horn loaded in his region.**

IN CONCLUSION

It has long been known that one of the weakest links in sound reproduction is the reproducers themselves, the loudspeakers. With so much disagreement and confusion around, is this any wonder? When Dolby Stereo came along, many theatre owners failed to recognize the need to install the newer and more powerful amplifiers and speaker systems capable of reproducing ALL the sound. Beyond that, most surround systems found in theatres today are grossly inadequate. There is so much sound available right now in 35 MM stereo optical soundtracks that never reaches the ears of the audiences. Many actually hearing how good it really is, might well believe that they were listening to

a better than average 70 MM system.

The bottom line is that theatre sound is all too often not good enough. A major marketing tool is being wasted. Is it too late? I'm not sure, but I am afraid that it may be. When people can order factory installed car stereos that outperform their local theatre, that theatre owner is in trouble.

Understanding the performance capabilities of different types of loudspeakers is essential for theatre owners if they are to obtain optimum results from their sound systems.

As Showest convenes, it is hoped that the above discussion will prove helpful as you consider the future. New developments in speaker technology will continue, but the laws of physics will not change. In my opinion, superior full fidelity stereo sound systems need to become standard in movie theatres if they are ever going to re-attract audiences. People must be confident that every film they attend in a theatre will be presented with a magnificent stereo system. As we all know, this is certainly not anywhere near the case now. When compared to modern home entertainment systems with their digital compact discs, Beta Hi Fi VCR's, VHS Hi Fi VCR's and soon digital stereo 8 MM VCR's, the obsolete and compromised sound systems found in too many theatres today are hurting this industry.

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@aol.com.