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# LOUDSPEAKERS FOR MOTION PICTURE THEATRES

## PARTS 1 and 2

BY

JOHN F. ALLEN

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# LOUDSPEAKERS FOR MOTION PICTURE THEATRES

## PART 1

**by**
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**Better sound systems for theatres is a subject very important to me, so you can imagine how pleased I was to hear so much discussion about sound at the recent NATO convention in New Orleans. It is generally acknowledged that one key to bringing people out of their living rooms and into your theatres is big clear pictures and big clean sound. Jack Valenti, President of the Motion Picture Association of America, seemed to sum it up best when he implored theatre owners to exploit their "natural advantage" over home stereo systems and install full fidelity stereo systems including surround speakers in their theatres. Later in a speech by Harmon (Bud) Rifkin, he advised exhibitors not to scrimp on speakers..**

**This makes sense. After all if restaurants can thrive while every home has a kitchen, how difficult can it be for a modern motion picture theatre to eclipse a color television? And as one who has some experience with the home Hi-Fi industry, I can assure you most domestic stereo systems are considerably less adequate than most kitchens. Certainly they are no match for a good theatre sound system.**

**I sometimes wonder what is going to happen when the gadget crazy distortion plagued Hi-Fi industry discovers the theatre market. I suspect theatre owners will suffer a barrage of sales promotions for all sorts of small items with large claims. At the moment the theatre sound industry is doing a good job at sticking to basics. Let's hope it stays that way and that theatre owners can be better prepared than consumers when purchasing sound equipment.**

**A week after the NATO convention the Audio Engineering Society held its own gathering in New York City. Several excellent papers dealing with the development of better tools to diagnose acoustical problems in rooms were presented. If room acoustics is not a subject of deep interest to theatre owners, it should be. The acoustics of the listening room are as**

**important to the sound as anything else in the playback chain, including the speakers. In the past the equipment (when there was any) used to evaluate room problems was cumbersome, expensive and often insufficient. Todays packages are still expensive but considering their abilities they represent a bargain.**

**Two conventions in a row are exhausting, but I did return home with a good feeling. With the theatre industry getting serious about sound again and with the tools to help being rapidly improved, one can only conclude that this is a very exciting time in audio.**

**Bud Rifkin's advice on speaker systems for theatres is so basic and so important that it seems appropriate to offer an expanded edition of my loudspeaker article first published last June. This is the first of two installments. The conclusion will appear next month.**

**The most wonderful sound ever recorded plays poorly through anything but first rate speakers. Sound systems in modern theatres are asked to reproduce increasingly demanding soundtracks, sometimes at high levels. While the familiar two way speaker systems have served well when used between 300 Hertz and 6000 Hertz (the academy characteristic), they prove unsatisfactory to many when asked to reproduce material from 35 Hertz to 12000 or 15000 Hertz, for simply they cannot do this.**

**With these shortcomings in mind and the requirements for the additional speakers needed for Dolby, Eprad and Kintek installations, exhibitors are looking for new theatre speakers. Some have tried the home type direct radiators, or speaker in a box, while others chose to purchase more two way horn bass-reflex combinations. The smaller direct radiators, even in multiples, should never be considered for use behind the screen. In fact, this may be a good opportunity to dispel the rumor that these speakers are even adequate in living rooms.**

**While they can do a fair job with low level or background music, they are simply incapable of accurately reproducing a symphony orchestra at concert levels or a rock group at the desired levels. There are two basic reasons for this; speaker distortion and room reflections. I leave out frequency response for the moment though it is important. Large response errors can be helped by a graphic equalizer. As much appeal as all the knobs of an equalizer have for the audiophiles and engineers, there are no knobs anywhere, save the volume control, that can lower speaker distortion.**

**All dynamic loudspeakers produce distortion, that is frequencies not present in the original signal. Harmonic distortion is the generation of frequencies harmonically related to the original. It is not as objectionable as modulation distortion where the generated**

**frequencies are not harmonically related. Harmonic distortion does tend to cause increased modulation distortion though and therefore should be minimized. There are two types of modulation distortion; amplitude modulation distortion and frequency modulation distortion. Modulation distortion occurs to the higher frequencies radiated by a driver while that driver is also radiating lower frequencies. The louder the level, the greater the driver's excursion and the greater the modulation distortion. This is a physical fact since this type of distortion is caused by the driver's motion or, to be more specific, the driver's velocity. Since all dynamic loudspeakers must move to produce sound, we cannot eliminate it.**

**An eight inch midrange speaker can produce more than 10% Total Modulation Distortion while delivering only 90 dB sound pressure level into a living room or 1/100 of the peaks required to reproduce concert levels. The poor old direct radiator has to move through very large excursions at high speed to do this. The audible result is a significant loss of clarity. This is the reason for the so called muddy sound characteristic of home systems.**

**Horn type speaker systems offer the most practical solution to the reduction of modulation distortion. They are as much as 100 times more efficient as typical direct radiators. This means they produce louder levels from a given input level. To put it another way, a horn system produces a given loudness with much smaller driver excursions. The result is at least a 90% reduction of frequency modulation distortion, the virtual elimination of amplitude modulation distortion and much cleaner sound. All this at true concert levels.**

**Obviously if a direct radiator falls short in a living room, think how dismal it would sound in a theatre. The distortion would be incredible. One would need many more speakers per channel to achieve the desired levels, not to mention a pile of amplifiers.**

**The other factor mentioned is room acoustics. Theatres are very big rooms, all with their own acoustical characteristics. Some rooms are considered good for live music or speech (these items should be considered separately) but poor for playback. A concert hall is designed to disperse, or reflect in many directions, the sound from the stage. The hall is really an instrument of the orchestra. The audience sits in a very deliberate reverberation field. While this is desirable for music, speech tends to get lost in the reverberations or room reflections and becomes unintelligible.**

**The radiation pattern of direct radiators can be very wide, both vertically and horizontally. In a theatre most of their energy is wasted bouncing off the walls and the**

**ceiling. Relatively little would go where the audience sits. The levels in the front rows or near-field would have to be excruciating in order to even approach normal levels in the rear. With all the misdirected energy reflecting off the walls and the ceiling, the sound at the rear would consist of so much reverberation or room sound that dialog would be at best hard to understand. No audience would be happy under such circumstances. They might wait a long time to pay their inflated dollars to sit through another film in such a theatre.**

**Here again, the horn comes to the rescue. A horn is in a real sense a sound projector. Its function is analogous to a headlight. Horns of different radiating angles may be selected to cover rooms of different shapes and sizes. They offer the engineer the ability to build a playback system that delivers clean sound over long distances while keeping room reflections to a minimum and without blasting those in the front rows. These same advantages apply to living rooms and control rooms as well.**

**While a horn type speaker will increase the ratio of direct vs. reflected sound heard by the audience, theatre owners thinking about updating their facilities should consider acoustically treating those offending walls. Reducing undesirable reflections increases the number of seats where patrons can hear good sound. This is particularly true in the rear where most people sit.**

**While covering entire walls may be best for appearances it may not always be necessary for the desired acoustical benefit. This is where an experienced acoustical engineer can help. He will be able to determine how much treatment your theatre needs and where it is needed.**

**The area behind the screen can be a major source of reflections. Even with horn type speakers close to the screen, treatment of the wall behind the horns should be considered mandatory. This is especially true when those horns have a curved mouth. Curved mouth horns, called radial horns, have one disadvantage when used behind a screen. Since only a small part of their mouth can be near the screen, they spray sound all over the back of the screen. This allows the screen to reflect a good deal of energy backwards towards the rear wall where it is bounced back to the entire audience delayed, distorted and determined to inhibit dialog intelligibility. Horns with a flat mouth, called axial horns, are better for theatre use. Their entire mouth opening can be placed near the screen thus reducing the amount of direct sound bouncing around backstage.**

**For those interested in more complete and theoretical discussions of modulation distortion, I refer you to papers by Beers and Belar, Paul W. Klipsch and others. There**

**have been many books and papers over the years on room acoustics. Highly regarded are those by Leo Beranek, Don Davis, Vern Knudsen and Cyril M. Harris. A brief introduction to the subject may be found in a fine piece by Ted Uzzle in the August 25, 1980 issue of BOXOFFICE, page 9.**

**Next month; Speakers for theatres, which horn systems are best and more about surround speakers.**



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# LOUDSPEAKERS FOR MOTION PICTURE THEATRES

## PART 2

by

**JOHN F. ALLEN**

**Last month I discussed horn type loudspeakers and why they are the preferred choice for theatre installations. But which horns are best? When selecting speakers for stereo systems, I offer these criteria: Output at one meter with one Watt input should be at least 106 decibels sound pressure level. Total modulation distortion should be 1 per cent or less at that level. Remember that modulation distortion is a function of level.**

**Frequency response and bandwidth are important. Not only for minimum coloration but because a speaker which is flat across a wide band of frequencies to begin with will require much less equalization. No speaker is truly flat. They deviate plus and minus from some average. These deviations should be minimal. The frequency response of a theatre loudspeaker should be less than 10 decibels down at 35 Hertz, ±5 decibels from 45 to 400 Hertz and ±2 1/2 decibels from 400 Hertz to 15,000 Hertz. John K. Hilliard, in a paper dated March 3, 1936 and published by the Academy Research Council, called for a frequency response of ±2 decibels from 50 to 8,000 Hertz. We're getting there.**

**Continuous power handling is important as no one wants to hear speakers breaking up and no theatre owner wants to replace burned out drivers. The capacity of a theatre speaker should be 300 Watts for the woofer, 120 Watts for the midrange and 30 Watts for the tweeter. Such a speaker system with the efficiency described above will be very reliable and capable of delivering a wide dynamic range without distortion.**

**Loudspeakers for mono houses will not be called on to deliver the dynamic range of a stereo system and as such may be smaller. Output at one meter with one Watt input should be no less than 104 decibels sound pressure level.**

**Hilliard recommended a two way fully horn loaded speaker system with a range from 50 to 8,000 Hertz. Today's stereo soundtracks can range from 30 to 12,000 or 16,000 Hertz and so a three way horn loaded system is more appropriate. I prefer a full base horn instead of the bass reflex types found in most theatres. A horn can produce deeper fuller**

**bass and deliver impact farther than most, if not all, bass reflex systems of similar efficiency. The sealed air chamber behind the driver provides it some protection against sudden pops such as those caused by film splices. The open bass reflex design provides no such protection.**

**In most situations, it still seems preferable to use passive crossovers instead of the active ones employed with bi-amplification. The crossover frequencies are somewhat determined by the horns but 400 Hertz and 6,000 Hertz seem to offer a few advantages. Crossing over at 400 instead of 800 Hertz, for instance, eliminates the modulation distortion in that range caused by the longer excursions of the woofer driver(s). Covering 400 to 6000 Hertz with one speaker prevents crossovers in the important speech areas and provides virtually perfect phase relationships or "time alignment" in the octaves where errors would be most audible.**

**Why have a tweeter you say? Haven't we got along fine with two way systems? Well yes we have but the weight of a midrange diaphragm rugged enough for theatre use limits its dependable usefulness above 8,000 to 10,000 Hertz. Midrange drivers that claim flat response out to 15,000 Hertz can be prone to failure in theatre use. In addition, there's still that old modulation distortion of the higher frequencies by the lower ones. A tweeter section is a better solution.**

**Surround speaker installations are a problem because it is expensive to do them well. Many speakers are required to produce the desired even sound field without directional cues. There is some disagreement about the best approach. Some are installing very inexpensive arrays of "full range" direct radiators. Others are using more costly home type bookshelf speakers. When the surround becomes a more important part of the action such as when helicopters and spaceships fly overhead, these direct radiators become a liability. The sound should not change as it moves from the screen to the surrounds unless the producer wants it to. The speaker with the highest distortion determines the distortion of the entire sound system. So with good speakers behind the screen, bad surrounds stand out like a sore toe.**

**Fortunately the frequency range of the optical soundtrack's surround channel is limited to 100 to 8,000 Hertz. This enables us to use smaller systems. I have given much thought to the pros and cons of the various surround approaches and have concluded that a horn system is still the best choice. We do not need a horn woofer, but a horn midrange using the same driver as the midrange speakers behind the screen offers the advantages of the same low distortion and frequency response. A horn allows the designer to build a predictable sound field around the audience as horns can be aimed.**

**The first two surrounds should be placed in the rear corners. The next one or two (or more, depending on the width of the theatre) should go on the back wall. The rest are installed periodically along the side walls ending about one half to two thirds the way to the screen. The total number of surround speakers depends on the size of the auditorium and the beamwidth of the speakers used.**

**Many complain about the "honking" quality of horn loudspeakers. I too complain when I hear it. But there are horn systems that do not have this quality. In 1976, I was privileged to build the present sound system at Boston's Hatch Memorial Shell. Concerts there were founded by Arthur Fiedler in 1929. The system is an enormous three channel outdoor stereo system employing horn loaded speakers throughout. This is a particularly demanding situation as one can well imagine. With a live symphony orchestra present, there's no fooling anyone in the audience as to what constitutes "good sound". I can report that the live versus reinforced sound comparison shows that when the sound system is turned off, the sound quality does not change, only the level. The horns do not "honk".**

**In placing the speakers behind the screen, spread the left and right units out as far as practical, but never behind the masking unless it is acoustically transparent. Install all speakers as close to the screen as possible. Toe the outboard high frequency horns in. A good aiming point in many theatres is the center seat in the back row.**

**For those using cinema processors made by Christie, Dolby, Eprad or Kintek, refer to the instruction manual for the appropriate speaker equalization procedure. They are all different in terms of the electronics used but the goal is the same. I will discuss this subject more thoroughly in a future paper.**

**A trained ear is still the best judge of overall sound quality. You may find a small adjustment of the treble band is desired. If so, adjust only the control marked "Treble". One word of caution: Please don't tamper with equalization controls without the proper training and equipment, you can only make things worse. If there is a problem with the sound refer it to a qualified serviceman.**

**It has often been said that the more things change the more they stay the same. Since the pioneering work in audio done by Bell Labs and the film industry during the 1920's and 30's, many things have been considerably improved while others seem to simply get reinvented every so often. For those in the market for theatre loudspeakers, the properly designed, well made horn fitted with a properly designed, well made driver remains the best sound reproducer.**

*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.*