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A DISCUSSION OF LOW FREQUENCY SPEAKERS FOR MOTION PICTURE THEATRES

BY

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Since the advent of sound with motion pictures, there has been a noticeable lack of bass response in theatre sound Systems. Indeed this was intentional in the early days of Academy mono when both the high and low frequencies are attenuated. Recording and processing techniques such as Sensurround, Kintek and wide range Dolby Stereo have been noted for their ability to deliver bass to the speakers. The problem in many cases has been the speaker's ability to deliver the bass to the audience. Sensurround employed large low frequency horn systems to do the job.

Even small theatres are big rooms when it comes to producing bass. Consider the size of the actual instruments and devices that produce low frequency sound in the first place. Think how big the tuba is. Trains, planes, bombs and 30 inch bass drums produce loud bass sound because they produce large movements of air at low frequencies. This large movement of air is what a low frequency speaker, or woofer, must do.

One way to move large amounts of air in a theatre might be to move the screen. Now the air behind the screen would have to be largely if not completely isolated from the air in the theatre. The screen would need stiffening and the holes would have to go. It would take a motor of some sort to move the sheet back and forth and the motor would require lots of electrical watts to operate, but this scheme would move a lot of air. The screen would be a kind of piston moving in a cylinder, which, in this case, would be the theatre.

Because of its size, the screen would not need to move very far to produce deafening sound pressure levels. If you made the screen smaller, say 1 1/2 square feet, or the theatre bigger, the movement of the diaphragm (screen) would have to be increased to produce the same level.

Well no one is suggesting this approach. We all know that a 15 inch woofer mounted in a box called a baffle can produce bass. Returning to the piston analogy, a piston (as Paul Klipsch has said) would fail as an effective pump if it were placed in the middle of a pond without a cylinder around it. A low frequency speaker has the same problem

without a baffle. Put the cone in a box, move it back and forth and you will effect a pressure change in the atmosphere. Attaching wings to the box or mounting the system in the wall increase the speaker's ability to deliver deep bass.

A 15 inch speaker has about a 12 inch cone with about .8 square foot piston area. A 12 inch cone can produce all the bass frequencies. But it must move through very large excursions to produce even moderate bass levels in a room the size of a theatre. Frequency Modulation (FM) distortion is produced in all speakers to higher frequencies when the moving diaphragm is also producing lower frequencies. The greater the cone excursion, the faster it must go and the greater the FM distortion. Not only would a 15 inch direct radiator woofer require a lot of power in a theatre, its larger excursions would produce larger levels of distortion resulting in a muddy sound.

This is why theatre woofers need to be efficient and are designed with 18 inch drivers, two 15 inch drivers or with horns. Because of its greater area, the 18 inch driver doesn't have to move quite so far as a 15 inch unit to move a certain amount of air. The same holds true for two 15 inch drivers. They give twice the cone area of one 15 inch cone, of course, but they couple together in such a way to give four times the low frequency output, if one doubles the amplifier power as well. It's a case where one and one equals four.

Were these two 15 inch cones to speak into a horn instead of directly into the room, a greater acoustic coupling would occur. If the horn had a mouth area of 10 square feet, you would have a radiating area of 11 square feet acting on the air in the room but controlled by a piston area of only 1.6 square feet. As a result several things are improved. For the same input level, you will get as much as 10 dB or 10 times the output. In such a case the horn system requires only about 1/10 th the amplifier power to do the same job as the non horn-loaded speaker. Since the cone excursion is also about 1/10 th as great, the frequency modulation distortion produced by the horn system will also be about 1/10 th that of the non-horn system. The transient response of the horn type speaker would also be much improved. You would feel the impact much more.

The horn has the disadvantage of being relatively large, heavy and expensive compared to the direct radiator. They are a real pain in portable road systems. The reason horns work so well is the way they couple the movement of air by the speaker cones, to the air in the room. The horn acts like a cylinder for the piston and makes a better pump. It's a step up transformer allowing a small amount of cone excursion to move a large amount of air. A good horn with a mouth area of about 10 square feet can produce floor shaking levels of 30 hertz information without the aid of wings or walls behind the screen and with much less power.

Direct radiators have the advantage of being smaller than horns, lighter and cheaper - though there are horn systems that cost the same as some well known direct radiators. Direct radiators have the disadvantage of needing much more power and of coloring the sound because they produce more distortion. Were an amplifier to produce as much distortion as speakers do, it would be laughed off the market.

Good direct radiators can have flatter frequency response than many older horn systems by perhaps 2 dB. But since they are distorting more, and sound less clear, many feel that the slightly less flat horn systems sound much better; bigger, more open, more natural, more punch. As I have also found this to be the case, I've chosen horn loaded woofers in all my sound systems.

Another coloration to low frequency sound occurs in some bass reflex type direct radiator speakers because of the ports (holes) in the cabinets. In a bass reflex system, the radiation from the rear of the cone is 180 degrees out of phase (reversed polarity) with the front radiation. This energy is added (in phase) to the output of the speaker through the port in the box to help produce bass below 100 hertz.

Ported bass speakers produce large amounts of turbulence in the air moving through the port. This is very audible and sounds like breathing or "whoomping" as I sometimes call it. This sound is characteristic of this type of speaker and is not part of the recordings. Nothing I've heard in music or nature sounds like this except ported direct radiator woofers.

Referring to this problem, Small pointed out in 1974, that using a passive radiator instead of a port eliminated the "wind and resonant tube noises which are often generated by a vent (port) operated at high volume velocity". A passive radiator is simply a diaphragm or speaker cone without a voice coil and magnet to effect motion. It is mounted in a sealed box just as the speakers are, and is moved by the air inside. Currently there are no theatre systems that I know of using passive radiators instead of ports. I only mention it here for your information.

Throughout the history of sound systems, there have been many many bad speakers, especially woofers. There have been so many awful sounding horn systems, that those who haven't heard a good one don't believe there are any. There have been so many woofers deficient in bass response below 100 hertz that some manufacturers are now offering special low frequency systems now called subwoofers. Essentially these are nothing more than real woofers and are not needed in conjunction with a wide range speaker system

that is able to produce full range bass with low distortion. Subwoofers are a welcome improvement for theatre sound systems using speakers lacking bass response.

Finally, a note about amplifier power needed for theatre woofers. Stereo systems for theatres have three main channels, five in some 70 MM installations. This helps improve bass performance of the system since all the woofers can be used at once to deliver the low frequencies. This reduces the load on any one woofer. Stereo often requires one channel's woofer to deliver an entire effect all by itself. Therefore, we should power each channel to deliver peak levels in the theatre. To determine the power required in your theatre you must know the speaker's sensitivity. The greater the sensitivity, the less power you will need. A speaker that is only 3 dB more sensitive than another will need 1/2 the power to do the same job. As mentioned, horn systems are as much as 10 times more sensitive than direct radiators. Theatre woofers are available in both horn and direct radiator configurations and range in 1 watt 4 foot sensitivity from 96 dB to 107 dB Sound Pressure Level. The three main large horn type speakers offered by manufacturers for theatres have the same sensitivity, though they vary widely in performance.

Each time you double your distance from a speaker the level you hear drops-about 6 dB or 75 percent. The drop in level follows the inverse square law. This assumes certain conditions but in general you can assume this is the case in theatres for determining power requirements. The following table uses the inverse square law to find the amount of power speakers with different sensitivities need to produce 100 dB and 106 dB in the middle of a 100 foot theatre.

SPEAKER'S ONE WATT FOUR FOOT SENSITIVITY*	WATTS NEEDED FOR 100 dB	WATTS NEEDED FOR 106 dB
96 dB	390 watts	1570watts
98 dB	248	992
104 dB**	62	248
107 dB**	31	124

***Add about 2 dB for the one meter sensitivity.**
****Horn systems**

100 dB per channel is a typical peak measured in a theatre with some films. Adding a 6 dB safety margin assures the amplifier won't distort, or clip, and burn out the speakers. Six dB is not much louder, but it does seem an adequate safety margin in theatre sound

systems. Therefore, we power all our 35 MM theatre speakers to produce about 106 dB Sound Pressure Level in the center of the room and 109 dB in 70 MM systems.

Stereo systems require more bass and more dynamic range than did their monophonic predecessors. 70 MM films require more and future digital soundtracks; even more. This article has attempted to review the issues theatre owners should consider when choosing low frequency theatre speakers.

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.