
Do the Math

[Editor's Note: At FOH, we find very few things more valuable than a combination of knowledge and passion. So, when we have a passionate, knowledgeable reader with something on his or her mind, we try to find space to print it. In the coming months, you will see more of this kind of content on the fohonline.com Web site and in some new electronic projects we are getting ready to unveil. In the meantime, check out what one reader has to say about stadium sound systems.]

I love my sports, but I hate the live experience. One of the reasons for this is because I'm an audio engineer by trade, and I hate the sound in stadiums. It is always terrible, but it shouldn't be. When I do go to a game, I sit through the entire thing struggling to understand the announcer and calculating how to correct it. I can't help but repeatedly bother the person next to me with statements like, "What did he say? Do you understand what he's saying? Does the sound bother you?"

I've been designing custom speaker enclosures for 32 years, and I spent 18 years of that on the road, touring as an audio engineer with regional and national performing artists. I know what I know after years of trial and error and on-the-job experience. I don't claim to have all of the technical terms perfected.

When I started in this business, professional sound engineers were excited by the latest development in live sound engineering, the electronic crossover. We were still using a tape repeater called an Echoplex to create delay, and reverbs were spring-loaded. We all had our share of blown Phase Linear power amps and moved from Shure VocalMaster column speakers to the new JBL 4560 Perkins bins with a JBL 2441 driver and defracted lens on top. If you were really hip, you had the JBL 4550 BKA enclosures, but you had to be 6 feet 2 inches tall and weigh more than 200 pounds to even think about loading them into a truck. They didn't have handles, either.

These days, during the week, I spend most of my time in front of a calculator or a computer, designing sound reinforcement speaker enclosures and systems.

I've asked myself countless times, "Why do public address systems in so many stadiums sound so bad?" I attribute this "Incoherent Sound Phenomenon" (ISP) to many things, most of which are not technology based. The technology of sound is just math, so if the math is done, and done correctly, the people will be able to hear and understand clearly. Large rooms are a challenge to sound designers because of reflective surfaces, distances and the slow way that sound travels, but these challenges can be met when you know what you're doing. Think about it. The physics of sound do not change from year to year, no matter how large the room or how many people are packed into it.

ISP can be attributed partly to salespeople from major sound companies.

Over the years, I have reviewed many sound system proposals, which are based on the equipment readily available for sale, rather than the appropriate equipment for the venue. Since salespeople are usually not speaker designers, they have limited knowledge about what equipment is appropriate for a particular room. A "less is more" principle typically is not applied, meaning that if 80 of the wrong boxes aren't enough to do the job, then 120 of the same wrong boxes must be enough. At least this way, the sound company sells more product and makes more money. Right?

This is sheer laziness. Designing a new enclosure that will meet the need of the facility to deliver clear and full range audio to the audience is not brain surgery, but it does require some thought. Just do the math.

Low-Freq. Design & Understanding

If you front-load a single 15-inch woofer into its appropriate vented enclosure, and the woofer has a sensitivity of 98dB 1W/1M, assuming that the reasonable usable frequencies are 35Hz (at -9dB, and 0dB at 45Hz) with no great dips through 300Hz, you will receive 98dB 1W/1M. If you add an identical enclosure alongside this enclosure with the exact same woofer, they together deliver 101dB 1W/1M. In order to receive 104dB 1W/1M, it requires twice as many loaded enclosures, or in this case four single 15-inch vented enclosures. To receive 107dB 1W/1M, you will now need eight of these enclosures. 110dB 1W/1M requires 16 enclosures, and so on.

The cubic feet, or space, of all of these enclosures is significant. These boxes would require an area of approximately 120 inches in height, 80 inches in width and 18 inches of depth (120 inches by 80 inches of face-space).

The challenge is to design an enclosure that will deliver 110dB 1W/1M of low frequency using half of the woofers and half of the face-space. By designing a horn-loaded enclosure, one gains 3dB SPL right out of the gate. By retaining the allotted venting appropriate for this woofer, we retain the speed and recovery of the sound of the combination of the original enclosure and the 15-inch component. This is unique in a horn-loaded enclosure. Most horn-loaded enclosure designs skimp on the volume of the enclosure, but it drastically changes the sound and raises the floor of the very low frequencies.

There is also a natural compression that exists in a horn-loaded/vented combination enclosure. This compression is

created by the degree of off-axis centering of the woofers. The trick is to create a natural-sounding launch of sound from the enclosure without over-compression.

You might ask what all this has to do with stadium sound? A ton! The compression, focus, power and delivery of the enclosures required for stadium use is key. If you can't reach the audience before you hit the wall, you've lost the battle from the start. You've actually added noise to the room. This is the case of the Twin Cities Metrodome. (Note that I am not just slugging on the Metrodome. Variations of this kind of problem exists in a lot of stadiums around the world. It just happens that the Metrodome is close to me and I know it well. Hence, it is used as an example only.) The sound in that room hits everything before, or at the same time as, the audience, and the sound waves virtually stand in the center of the venue for more than 10 seconds. The source-sound from the enclosures does not reach the audience.

Also, by suspending front-loaded enclosures as they did, they eliminated the opportunity for natural coupling. This reduces the sensitivity of the enclosure by half. Now you require twice as many enclosures. (And power and amps).

Now let's talk about the client, who typically knows little or nothing about sound, and who is forced to blindly follow the advice of the salesperson. After spending millions of dollars and relaxing in the comfort of the brand name thrown at them, the sound system goes up and sounds like crap! Then, one of two things will happen. Either the client believes it must sound good because it's brand new and it's a brand name, or the client realizes it doesn't sound good, but they are unwilling or unable to reinstall due to the expense, frustration and lack of expertise available to do so effectively. So, like the Metrodome, they just leave it in and deal with the complaints for decades. Consequently, after spending millions of dollars, the Metrodome is widely known as one of the worst sounding domes in the world.

Land of 10,000 Reflections

The installer of this system clearly didn't understand enclosures, their purpose or their design. If you'll notice, all of the low-frequency and low-mid-frequency enclosures are designed as front-loaded, meaning that the cone is mounted from the front of the cabinet, and there is no push (or directedwave) design. The characteristic of this cabinet is that it will project 30 feet forward and drop off in its volume. The simple math is that there is nobody hanging out in the middle of the airspace of the dome to receive that sound within its effective area. Maximum effectiveness of the enclosure design exists within 30 feet of these enclosures. In layman's terms, beyond 30 feet of the cabinet, the sound then meanders around the building, trying to find a place to land. The soundwaves move at 100 degrees from the enclosure, and they continue to bounce off of reflective surfaces within this 100-degree directivity until the crowd absorbs them. Over the past few decades, we've all been dissatisfied with the audibility of this failed design. The resolution is to direct as many of the sound waves as is physically possible toward the audience, which is the absorbing surface. This is impossible with the existing enclosures.

An equally damaging part of the design of the sound system is that, while bringing the enclosures from the upper center of the dome forward towards the audience makes sense, they created an open, non-applicable reflective void in the arena. The enclosures hanging there now are not close enough to the audience to do any good, because of the reasons explained above, so while sound waves look for a place to land, they wander in the center of the dome between the back sides of the enclosures. This is where a majority of the delay in sound occurs. However, if they moved the enclosures forward to meet the audience, they would create a larger standing void in the room. The only option is to suspend all enclosures from the center of the dome and cluster them all together, called "point-source." The enclosures would require a folded-horn, long-throw design for this purpose, and positioning. Instead, they went right down the middle and caused a nightmare in audibility.

What I've reported here concerning the Metrodome sound system, the worst case that I'm aware of in the country, can be corrected. I would recommend a demonstration at the dome itself, because the dome is a specific arena, with its own specific problems. The most cost-effective way of demonstrating would be to set this demo system up on the field in the center of the dome. I would set it up inverted to its flown design on the ground. This point-source, horn-loaded or folded-horn design could then be turned on and observed over a period of about five hours, start to finish. You could then walk around the dome and hear the difference. This would be the most cost-effective way of proving that the sound problems can be resolved.

I would love to someday sit in the Metrodome and enjoy the game, hear every word and celebrate the addition of an exciting new sound design. So would the people who sit next to me when I'm there.

Bradford Thompson is a speaker designer and audio engineer based in Minneapolis, Minn. Bradford has designed and built a number of speakers, including the BE/HL-4/3200. His designs have also been bought by the likes of JBL and Klipsch.