SPL Computation

by Mark Amundson

One of the things that still aggravates me are questions about loudness that are formatted like; “How many ampli-fier watts per person are needed for a rock ‘n’ roll show?” And the oft-repeated, “How many speakers do I need for a room of this size?” While the innocent are allowed to ask such questions, I find it disconcerting to hear experienced sound people asking the very same questions. This Theory & Practice column shall attempt to cover the basics on estimating the Sound Pressure Levels provided and—the reverse—to estimate the amount of gear need to achieve a desired SPL.

First of all, there is virtually no such thing as uniform SPL; short of handing everyone personal MP3 players with the volume controls fixed. Once you assume the locations for the speakers, common sense tells you it will be louder near the speakers and softer further away. (*I remember some folded horn bass bins—Altecs, I think—that I had back in the day that were louder 15 feet away than they were right next to the speaker… -Ed.*) The tradeoff will be that you will specify the “range” SPL, and that will drive the choice of speakers and maybe even require more speakers dispersed into the audience if the range is tight. But in most small venue situations, speakers are located above or to the side of the performance stage, and no capability or accommodation will be made for additional speaker locations.

Speaker Coverage

But all is not lost if you are limited to speaker stacks at the sides of the stage. As many of you know, dispersed speaker positions require an electronic delay of the mix audio to get the stage wash and side-stage speakers to align with speakers placed further away. Given your favorite speed of sound number for temperature and humidity conditions (about 1,100 feet/second), just back off about 0.9 milliseconds per foot of distance from the stage front for each dispersed speaker. Of course, the downside is the complexity of having to route delayed signals to the speakers and determine the HF horn coverage to the zones desired.

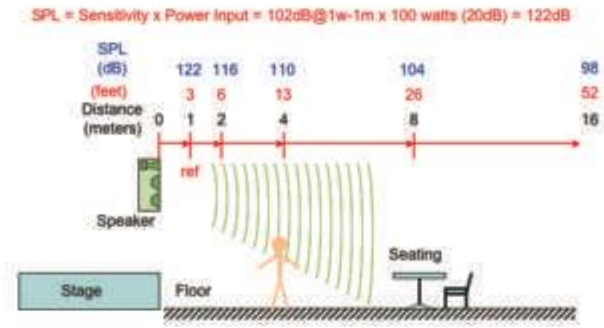
In smaller and straightforward room shapes, the side-stage speaker stacks can do all the work. For smaller rooms, the traditional speaker on a stick (tripod) with the 90º by 40º horn is the standard, to toss fewer-than concert SPLs at the audience. In bigger and louder applications, medium-throw speaker enclosures use 60º by 40º horns enclosed in trapezoidal cabinets, for throw 100 feet or a bit more. In wider rooms, two or three medium throw cabinets are splayed together to widen out the coverage and still keep the SPLs high. As in the dispersed speaker setup, the idea is to have one speaker focused to each audience section, with other speakers not covering the section by virtue of being out of the rated horn dispersion of the cabinets. This way, the dominant SPL source does not have significant competition at mid and high frequencies.

If you did not know it already, most subwoofer cabinets offer very little dispersion pattern control below 100Hz. With this known, most subwoofer cabinets are close to the stage, either onstage, below the stage or sidestage as space is available and the audience locations are factored in. With wavelengths at 10 feet or larger, massing identical cabinets together forms a virtual single cabinet with the same sensitivity, but with the input power effectively summed together.

Inverse Square Law

To get at the problem of delivering SPL into an area, I have created Fig. 1 to show how SPL diminishes with distance from the “point” source. Because a speaker or small cluster of speakers aimed together represents a single point source, when examined from afar; the resulting acoustic wave acts spherically and diminishes its intensity as an inverse square with distance. With speakers as a transducer, dB electrical watts in correlates to dB SPL out via the sensitivity rating of the speakers. In Fig. 1, a 102dB

SPL per watt per meter sensitivity cabinet with 100- watt electrical input (20dB watts) equates to 122dB SPL at one meter.



From the illustration, each doubling of distance away from the speaker drops the SPL by 6dB. So 122dB SPL at one meter equates to 98dB SPL at 16 meters, or about 52 feet away from the speaker. The only way to avoid this rule is to get into line array speaker systems for cylindrical dispersion and 3dB per distance double losses. But even with line arrays, once you get below the critical low frequency, the low frequencies begin drop off faster like the spherical dispersion model. Then you have a real need to add delay low-frequency cabinets to keep up with the mids and highs screaming along in the cylindrical dispersion rate.

Running the Numbers

The old rule of thumb for rock concert SPLs in audience areas is the 90 to 120dB SPL range of loudness. With a normal conversation at 70dB SPL and each 10dB representing a doubling of perceived loudness, you can see that at concert levels, conversations can only be carried on by shouting into each other’s ears. Now, we can assume that most concertgoers will not get within a couple meters of the speaker stacks, so the first 6 to 12dB of SPL loss from the speakers will not normally be hitting eardrums. So, with medium- to long-throw speaker cabinets, it is likely that the maximum SPL capability may exceed 135 to 140 dB SPL at the one-meter reference. And that is why those levels are needed when the demand is 120dB SPL into audience seating.

Looking at Fig. 1 and adding 10dB SPL, this means that 132dB SPL emanates from the speakers (1,000 watts input), and at four meters, the 120dB SPL requirement is met. Doing the math with drops of 6dB at distance doubles tells me that 92dB SPL is still maintained at 64 meters (208 feet) away from the stacks.

Looking at the problem differently, suppose you wanted at least 90dB at 100 feet away (about 32 meters)? Then, in the Fig. 1 configuration, you’d need 96dB at 16 meters, 102dB at eight meters, 108dB at four meters, 114dB at two meters and 120dB at the reference one-meter distance. But let’s say you have 15-inch +1.4-inch top box speakers that only deliver 98dB SPL at one watt and one meter. Then, 120dB minus 98dB sensitivity says you need 22dB watts program into the cabinet from the amplifiers. Then, you must take the 22dB, divide by 10 (power is in 10-log dB scaling) and do the base-10 anti-log computation on 2.2 for 158 watts program power. If 90dB at 100 feet then suddenly becomes 100dB, then you’d need 32dB watts or 1,580 watts of voice-coil melting power. This is where two speakers sharing the 1,580 watts (790 watts per cabinet) on each side of the stage works; or better yet, coupled together to minimize phasing.

Final Thoughts

While people do absorb acoustic power, they do not rob power (loudness) from adjacent areas. Thus, the watts per person theory should be thrown out. And the how-many-speakers computation also falls away, as different speakers have different sensitivities/efficiencies and large quantities of the same speaker rarely couple together well, to place increased SPL into any one location or locations.

What does matter is the intensity of the emitter (speaker with amplifier) that is pointed in your direction, and your distance away from that emitter. Things can get complex in big venues with many emitters and coverage areas that can overlap. That is why the big shows have system engineers, and they are in charge of the math and physics to deliver the correct loudness, in the right areas, with the best sound fidelity.