BASS IN THE PLACE

Improve Your PA's Bass Performance

Proper subwoofer placement is often overlooked but, as you're about to find out, the difference it makes to bass reproduction can be vast...

DAVID PURTON

All venues work effectively as two different sound environments. Above a certain frequency they will act as a reflector and diffuser, and below this it behaves as a resonator. The dividing point between these conditions is known as the Schroeder frequency, and it usually falls between 100Hz and 200Hz, depending on the room's dimensions and shape. For this article we will confine our interest

It's extremely common to see subwoofers placed on either side of the stage, in roughly the same position as the mid/top speakers — even though this is quite possibly the worst way to arrange them!

to looking at ways to optimise bass reproduction up to around 100Hz.

Due to the impact of these changing conditions, the requirements for producing optimal mid-range and treble performance are likely to be different for low frequencies, and that's just one of the reasons bass is often dealt with by separate cabinets.

The advantages of removing bass frequencies from the satellites, stacks or arrays are numerous. The resulting reduction in cone excursion brings benefits in terms of reduced distortion, as well as substantial gains in power handling. There is also a dramatic reduction of bass energy into the cabinet structure itself. All these factors combine to add up to a cleaner sound.

The only practical problem with subwoofers is their size. A loudspeaker is effectively a band-pass filter, and you don't get something for nothing: if you want bass extension to the lowest octaves then efficiency is determined by the cabinet volume. We know we can reduce the cabinet size by using 'leaky' cabinets (single aperiodic loading), or mounting two drivers in a push/pull configuration (known as 'isobaric'), and this will halve the required cabinet volume — but it will also halve the efficiency. These alternative cabinet-loading methods have advantages, but in all cases, EQ and more power are required to match the equivalent response of a single driver in a larger bass-reflex or sealed cabinet.

To put that into perspective, hi-fi loudspeakers may well extend into the lowest octaves in relatively small cabinets, but their efficiency is rarely above 86-88 dB/Watt. For sound reinforcement we are looking at efficiency requirements around 10dB/Watt greater than this!

The Sub Way

So you have decided that the purchase of one or more subwoofers is a Good Thing in all respects. The good news is that many manufacturers are now bringing 18-inch and 15-inch subwoofers to market at unbelievably low prices — mostly driven, I suspect, by the company that now owns Midas and Klark Teknik (Behringer!). There is also a move to wireless control, which aids remote placement, and some have DSP on board to take care of EQ, crossover and delays. Many also have built-in amplification, with manufacturers increasingly opting for power amps that run in efficient Class-D, producing prodigious power with little weight or cost penalty. In terms of your investment this quality/performance ratio just wasn't available a few years back. But where to position them? The placement of your satellite loudspeakers, stacks or arrays for best intelligibility and audience coverage is unlikely to coincide with the optimum bass cabinet positions — and this will be the main subject of discussion for this article.

Spaced Out

I am not sure who advises schools and theatres as to where to place their subwoofers, and loudspeaker manufacturers don't help bands either, by suggesting their products have pole mounts for mounting the satellites, resulting in the subwoofers ending up either side of a stage — which is the worst possible position!

The evenness of bass reproduction is determined by the placement of the bass cabinets (and/or implementing delays, which I'll discuss later in the article) and the physical distance between them. The nulls and peaks in bass response throughout the venue are mostly a result of cabinet placement, and not the room!

Where there are deep nulls in the bass response, the relative positions of the subwoofers are almost certainly the culprit. At the longer wavelengths we're dealing with, the physical distance between the subs is enough to produce the interference effects we see in Figure 1 (red = 40Hz, Blue = 60Hz, Green = 100Hz). This is a polar response of frequency distribution, showing the response and deep nulls when bass loudspeakers are placed some 20 feet apart. Put simply: don't do it!

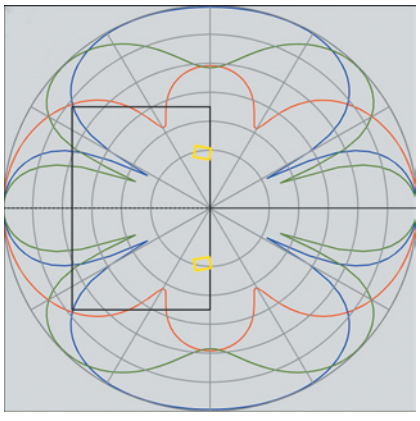

Figure 1. This plot shows the deep nulls in the bass coverage you'll get when you position two subwoofers 20 feet apart. The red line shows the coverage at 40Hz, blue at 60Hz and green at 100Hz.

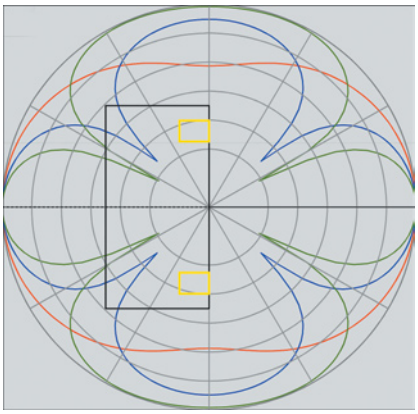

Figure 2. This time, the subwoofers are slightly closer together, at a distance of 16 feet. It's an improvement, but there are still some very deep nulls throughout the audience area.

A similar problem is encountered when they are placed at a more normal 'live band gig' separation of around 12 feet. While this might produce an optimal performance for the satellites, Figure 2 shows what happens to the bass response. Due to their coupling at very low frequencies, you will note that 40Hz is able to produce a well-controlled pattern, but the 70Hz and 100Hz traces still reveal very deep nulls.

If you are in a position to place the subwoofer centre stage, this avoids all the problems of cabinet spacing, and an even bass response may be achieved. It must be noted that the venue itself will play its part in dictating the final bass performance, but at least you'll be giving yourself a fighting chance! If, because of level requirements, you have two subwoofers, you will also benefit from close bass-cabinet coupling. The baffle area is doubled and, like coupling horn mouths, you will gain some additional »

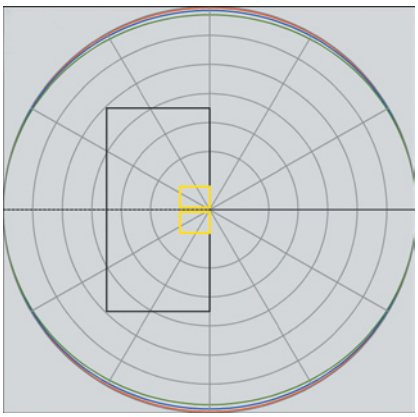

Figure 3. Placing two subwoofers next to each other yields much more even coverage!

"The evenness of bass reproduction is determined by the placement of the bass cabinets..."

bass extension. It's not often you get something for nothing in this world!

Figure 3 shows that two normal subwoofers placed next to each other, both facing forward and in the same polarity, will effectively produce bass

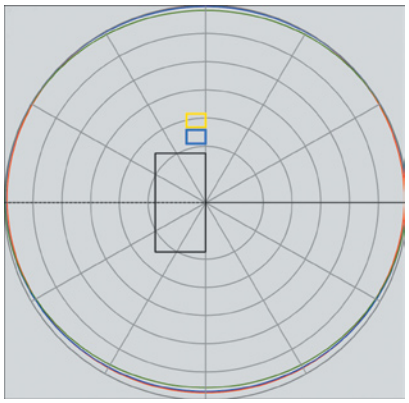

Figure 4. Even with your two coincident subs to the side of the stage, the results are much better than when spacing them some distance apart.

omnidirectionally. Even if you place both cabinets off centre stage, however, the response is practically the same, as shown in Figure 4 (although, depending on the size of the venue, the level of the off-centre pair will start to reduce its response at the furthest point).

The same polar plots will be achieved in other locations, including the back of the stage against a wall, or at the back or side of the hall against a wall. These locations will provide even better loading, providing natural bass boost from the large floor/wall area the cabinets are placed against, but may not be practical locations. I don't suppose the drummer would enjoy the experience, for instance, and if you can't see the subwoofers, you can't be sure what your audience may be doing to them!

The Third Alternative

For larger venues, where more level, coverage and some directional control is required, you might want to look at using a three-subwoofer setup. Adding a centre bass speaker to two spaced subs can certainly be beneficial, the only proviso being that it must be matched to or at a slightly higher level than the two either side. If the main FOH speakers are full-range types — say, 2 x 15-inch speakers or larger loudspeaker stacks — you can even use those as your 'outer' subs, but the same applies: the central subwoofer must be at least equal in level.

As you can see from Figure 5, bass is not always omnidirectional. This configuration provides great even audience coverage with some directivity

Photo: Bontempi Enzo / fotoriders.com

A row of cardioid sub arrays in action, comprised of Fohhn PS9 active subwoofers.

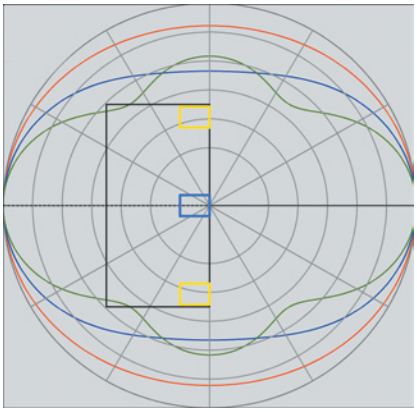

Figure 5. If you have three subwoofers, or one sub and two full-range satellites, arranging them as shown here yields both smoother coverage than spaced speakers alone, as well as reduced dispersion to the left and right sides of the stage.

» at all but the lowest frequencies. This might be a good arrangement for venues in close proximity to those who may complain about the noise!

Other configurations with a three bass unit set are shown in Figure 6

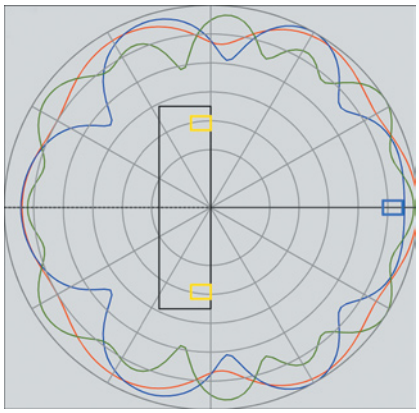

Figure 6. The dispersion characteristic of two spaced subwoofers either side of the stage, and one subwoofer 20 feet in front, firing towards the stage.

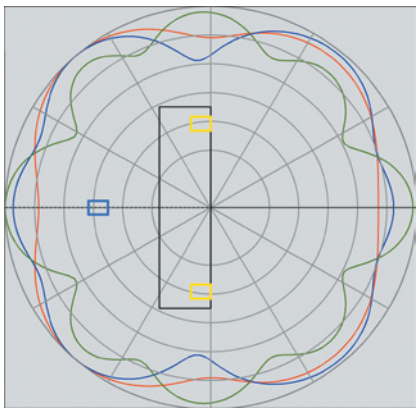

Figure 7. A similar arrangement to Figure 6, but with the subwoofer 12 feet behind the stage.

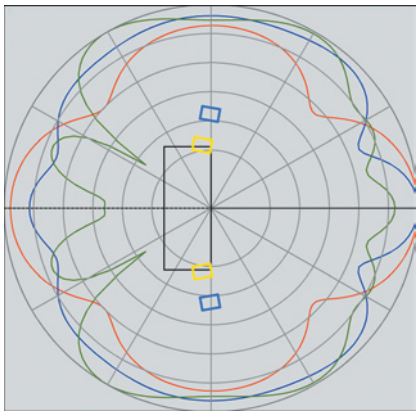

Figure 8. The inner two subs are 16 feet apart, with the outer pair being 24 feet apart, and spaced one foot further in front. By applying a 4ms delay to the outer pair, a useful degree of directivity (in this case, attenuation of low frequencies in the direction of the stage) can be achieved.

and 7. Figure 6 has the flanking speakers spaced wider, and the central subwoofer turned 180 degrees and placed 20 feet from the stage. In Figure 7, the centre sub is placed some 12 feet behind the front loudspeakers.

These might be good arrangements for a fixed installation, such as a cinema, where there would be benefits to having the subwoofers mounted in or in close proximity to wall/floor surfaces. Again, the level from the subwoofer must be matched or just above the output level of the main stacks.

Delayed Reactions

If you have four subwoofers, you can try the configuration shown in Figure 8. The spacing here is quite critical, with the inner pair 16 feet apart and the outer pair 24 feet apart. Again, the inner pair might be a full-range loudspeaker but the optimum would be four identical subwoofers, and two satellites that could sit on stands mid-way between the subs on either side.

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To achieve the response in Figure 8, you need to apply a delay of 4ms to the outer (blue) pair. They are offset by one foot in front of the inner pair (the toe-in shown is purely cosmetic as far as bass reproduction is concerned). You will also note that, despite these all being monopole loudspeakers, there is some cancellation and level reduction happening behind the loudspeakers.

The Heart Of The Matter

For live music the benefit of being able to cancel bass behind the loudspeakers is well known. Apart from the performers not being subjected to high SPLs, there are also gains to be had in terms of reduced feedback risk through the microphones. There are now various cardioid-pattern subwoofers available, with the directionality either built into a single cabinet, or achieved through arrays. Figure 9 shows what an ideal cardioid response should look like.

Of course, you *could* buy ready-made cardioid loudspeakers... or you can create your own! To create a cardioid-response

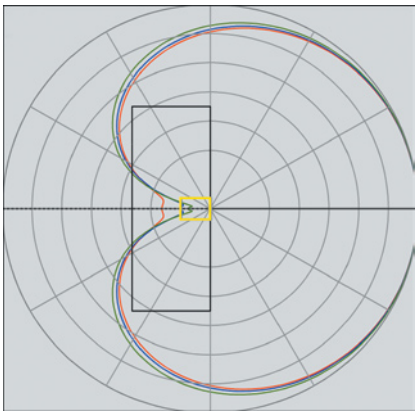

Figure 9. The ideal response for a cardioid subwoofer array.

array you need to stack two cabinets vertically, placing one so that it is rear facing. The rear-facing cabinet must be connected in reverse polarity and a delay applied. Measure the distance between the two drivers. Say the sound from the rear driver has to travel 3.4 feet to reach the front driver. Divide this distance by the speed of sound, which is roughly 1130 feet per second. So, 3.4/1130 = 3, and this is the delay, in milliseconds, that you apply to the rear-facing driver.

It is not *quite* as simple as this in practice, though: the response of the two drivers needs to be matched, and the delay between the two drivers may not be exactly as the theory shows here. A microphone and RTA can be used to optimise the results, or you can just walk behind the array and use your ears! As with 'normal' omnidirectional subwoofers, however, using two spaced cardioid arrays at each side of the stage will again create nulls in the response for the audience — as you can see in Figure 10.

As before, we can improve things by adding a third sound source — in this case, another cardioid array. The three cardioid pairs should have their output delays set to achieve their individual cardioid responses, just as we did earlier. Assuming all the cardioid stacks are the same, all the output delays set to the rear-facing cabinet will be identical. Now, we have to get really clever with our DSP loudspeaker management unit, and work with both the input delays.

To achieve the result shown in Figure 11, with controlled directivity at all bass frequencies up to your crossover point to the satellite loudspeakers, you leave the centre cardioid subwoofers set to 0ms, but apply a 2ms delay to both of the outer pairs, which are some 16ft apart.

In Conclusion

Within the scope of the article it has only been possible to show a few examples of what is achievable by cabinet placement alone, and we've only touched on what is possible with the introduction of delays. Fortunately, there are now many software packages available that will help you picture what you can achieve before you put it into practice — including the free LAPS II from Electro-Voice, which I cannot recommend highly enough for simulating many cabinet placement combinations. Although it's intended to spec out Electro-Voice systems, and so only has models of their own subwoofers, at the low bass frequencies we're interested in you can choose any of their subwoofers to model sufficiently accurate results.

I hope that this article has gone some way to illustrating how you can achieve great sound for every member of your audience, and how you can avoid some of the basic pitfalls of subwoofer or bass loudspeaker placement.

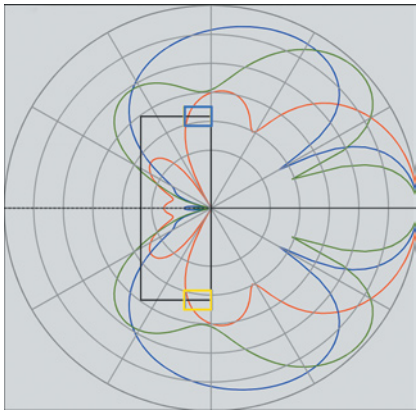

Figure 10. As before, spacing your cardioid subwoofer arrays yields extremely uneven coverage in the audience area.

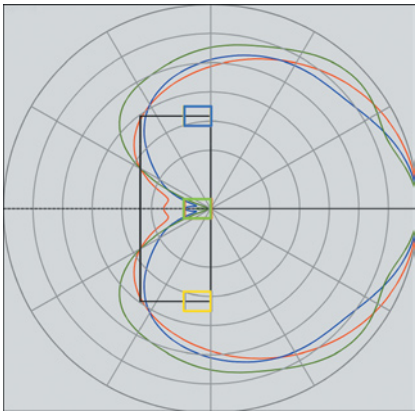

Figure 11. Adding a central cardioid subwoofer array to the two either side, and subjecting the outer arrays to a 2ms delay (assuming a spacing of 16 feet), improves things significantly.

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