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Backstage Class: In Search Of The Power Alley

Don't blame the subwoofers, look at their interaction

By José Brusi

Subwoofer cancellation is a relatively common occurrence, particularly in open-air system applications. Essentially, low-frequency performance can be lacking in certain points of the coverage area.

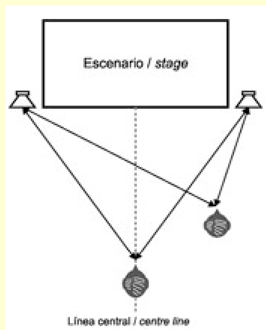

Figure 1: When the distance to both sides is the same, sound from both sides arrives at the same time. As we are closer to one side and farther from the other, sound from one of the sides arrives before the other.

Sometimes blame for this problem is placed on the subwoofers themselves, but in reality, the underlying problem is that of the interaction between subwoofer stacks located on each side of the stage. So let's shed some light on this problem and remove part of the "veil of mystery" surrounding it.

WHAT'S GOING ON?

When loudspeakers are positioned on both sides of a stage - the normal configuration for live audio events - there is always interference between them. Assuming, of course, that both sides are carrying the same signal.

The reason for this interference is relatively simple. As seen in **Figure 1**, when the distance to both sides is the same, sound from both sides arrives at the same time. But as we move closer to one side, and farther from the other, sound from one of the sides arrives before the other.

This time arrival difference produces comb-filter effects. Destructive interference occurs when two signals, one of which is delayed in time with respect to the other, are produced from two sources (loudspeaker groups).

Note **Figure 2**, which shows the resulting frequency response of summing two signals with a time difference of 7 milliseconds, equivalent to 8 feet (about 2.5 meters). The spacing between the troughs (or "combs") increases as frequency goes down. Absolute cancellation occurs at frequencies where the time arrival difference results in 180 degrees of phase difference between the two signals, so these frequencies get wiped out.

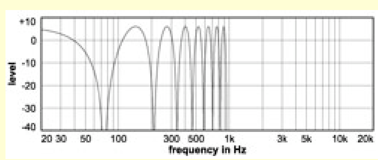

Figure 2: Frequency response of two signals spaced 7 milliseconds in time.

As any frequency response anomaly, the audibility of comb filtering is a function of the width of the troughs. These are wider for the lowest frequencies, which makes comb filtering more audible for those frequencies.

Comb filtering cannot be corrected by using equalization, since there is absolute cancellation at the bottom of the troughs.

Only if one of the two signals is greater in level than the other will the effect be diminished and the combs reduced in depth.

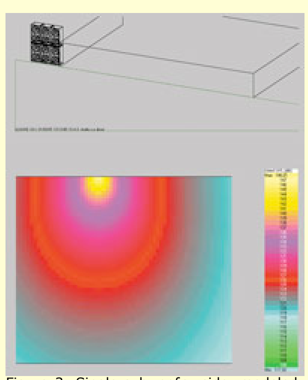

Figure 3: Single subwoofer side, modeled at 100 Hz.

WHERE ARE THE COMBS?

If the time arrival difference were constant, we would simply compensate by delaying one side and go home happy. However, each listening position (except the center line) gets sound arriving from each side with a different delay between them, which means that delaying one subwoofer stack would just shift the sweet spot elsewhere.

Also, the combs are in different frequencies at different positions, which means that the frequency response is widely different through out the audience area. The problem is not nearly as significant at mid and high frequencies. First, because the troughs are narrower, and hence less audible, and second, because the zones created are smaller.

With bass frequencies, one can literally walk the different cancellation areas, whereas the high frequency zones may be so small that our left and right ears do not share zones. Thus the effects of cancellation are not as destructive.

In addition, sources are more directive as frequency goes up. This means that when the audience is closer to one of the sides, they tend to be (at least to some extent) inside the main coverage beam of one side of the system and outside of the other. Comb filtering effects are reduced.

But with the low-frequency energy generated by subwoofers, this situation easily can become a nightmare.

Combs are wide and very audible, while "kick and punch" just disappears in some coverage locations. And, because the wavelengths involved are so large,

Figure 4: Left and right subwoofers (at 100 Hz).

for example, 16 feet (about 5.5 meters) at 70 Hz, these "bad" zones can be enormous.

Subwoofers are omni-directional below, say, 150 Hz, so the entire audience area is within coverage of both sides of subwoofers.

Let's be very clear: ALL types of subwoofers suffer from interference effects no matter the type (direct radiating, folded horn) or brand.

The result is the "power alley," which describes the fact that only a narrow center line of a left and right subwoofer system produces interference-free bass.

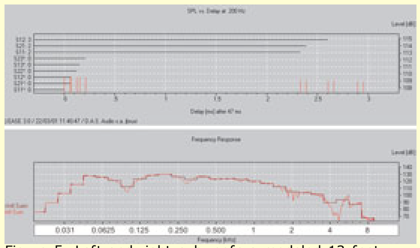
Figure 5: Left and right subwoofers modeled 13 feet off-center.

PROVING THE DEAL

Let's use electro-acoustic modeling to reveal this phenomenon. These predicted coverage maps are very close to what happens in "real life" open-air applications. Closed rooms add a reverberant field, which tends to smooth coverage out, and room modes, which create additional zones of their own.

For our modeling, we've placed a three by two stack of dual-18-inch-loaded subwoofers to each side of a 27-foot (8 meter) wide stage. Our audience area is 200 feet (60 meters) wide by 175 feet (52 meters) long.

The first coverage map (**Figure 3**) corresponds to 100 Hz. We have activated just one side of subwoofers, to see what happens when all bass emanates from a single stack. Sound pressure level expands smoothly in a way that is close to the distance-squared law. So far, so good.

But problems come a-knockin' on our door when both sides are activated, depicted in **Figure 4**, measured at a point 13 feet (4 meters) off to one of the sides. Also at 100 Hz, we can now see some kind of alien hand with five fingers. These are maximum pressure lobes, where the phase difference between the left and the right sides is small.

The areas between the lobes represent cancellation. Level readings show levels down 20 dB from the lobes. That means our 100 Hz pretty much walks out on us.

O.K., so at least some folks are enjoying good bass, right? Wrong. Areas where 100 Hz is in phase also means that other frequencies are out of phase. Thus there aren't any "good" areas, except for that ubiquitous center line.

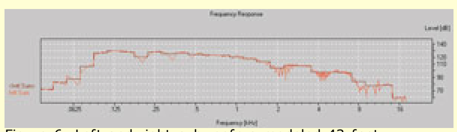
Figure 6: Left and right subwoofers modeled 43 feet off-center.

Naturally, some frequencies are more important than others when dealing with bass guitar or bass drum, so our problems will be more evident in some areas than others.

Figure 5 shows what is taking place in the same location as Figure 4 (13 feet off to the side). At the top, we can see that the closest group of subwoofers arrives about 2.5 milliseconds (ms) before the other. On the bottom, we see the resulting frequency response, where the first comb occurs at about 100 Hz.

Let's try another location in the listening area. **Figure 6** shows data that was modeled from a position more than triple the distance - 43 feet (13 meters) - and again, off to one side. Note how it differs from the previous models, and also note the comb at 40 Hz.

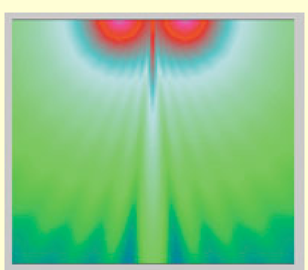
Figure 7: The power alley that results with two sub stacks spaced 47 feet apart.

WHERE IS THAT ALLEY?

For each frequency, we have a map with fingers. Then if several frequencies are summed and plotted on a single map, the alley emerges, because it represents the only locations where bass sums coherently at all frequencies.

The width of the alley depends on the spacing of the subwoofers: as the two sides of subwoofers increase in spacing between each other, the alley will narrow. **Figure 7** shows the alley for two single subwoofer boxes spaced 47 feet (14 meters). It is not as obvious graphically as it is audibly, but it can still be distinguished as an approximately 13-foot (4-meter) band with more intense color.

The only practical way to avoid the low-frequency power alley is to place all subwoofers in a single location. With smaller scale applications, locating all of them in the center is usually not possible, but larger shows often offer this option. In addition, larger shows may also benefit by flying the subwoofers, again at the center position.

It's important to understand what is happening with your subwoofers. This awareness of the zones that occur, and why they occur, can help with both system configuration and mixing decisions.

For instance, if the front-of-house mixing console is located in the center of the coverage area, you might chose to go with a somewhat bass-heavy mix. Off to the sides, destructive interference will kick in and establish some frequency balance between the low frequencies and the rest of the system.

And after all, it's just not fair to blame your subwoofers for something that's not their fault!

José (Joe) Brusi holds a degree in Engineering Acoustics and Vibration from the Institute of Sound and Vibration Research at the University of Southampton (UK). He has worked with JBL Professional and currently manages DAS Audio's Applications and Systems Group as well as the company's AUTOPOL measurement platform.

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