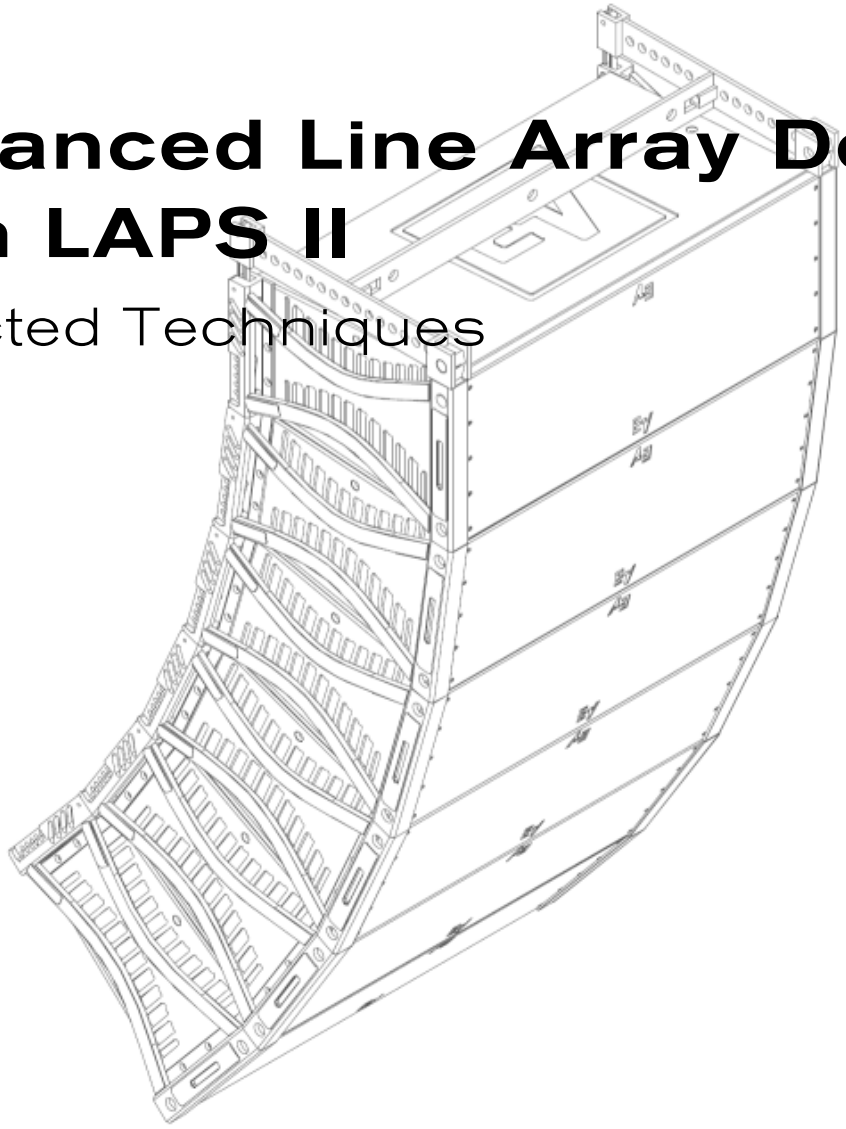
Electro-Voice

Advanced Line Array Design with LAPS II

Selected Techniques



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Advanced Line Array Design With LAPS II

SELECTED TECHNIQUES

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1. Introduction

EV's LAPS II line array prediction program includes several advanced features that help you design better line array systems. This note explains how those features work, and how you can use them to get better sound.

2. Feature: Three-frequency Prediction

LAPS II predicts line array coverage for up to three frequency bands at once. The multiple coverage curves are overlaid on the same graph. This makes it easier to judge whether the array is providing constant tonal balance over the coverage area.

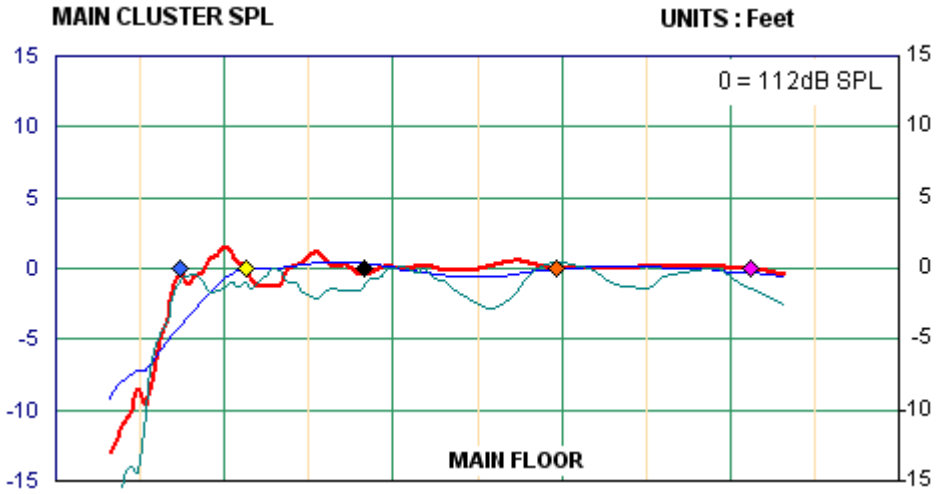

Figure 1. Three-frequency prediction

By default, the three frequency bands are centered at 500, 3000, and 8000 Hz, and are each 1/3 octave wide. You may change these values as you wish.

LAPS I, EV's previous line array modeling program, showed only one frequency band (a one-octave band centered at 3150 Hz). While that band was a good choice for estimating midrange coverage, it did not tell the whole story.

Here is an example of an array design that looks fairly good in the 3000 Hz band, but clearly needs work when the other frequencies are also considered. This is an actual example from an EV client. The venue is a large exposition center, the array is twelve XLC-DVX loudspeakers. Maximum throw is approximately 76 meters to the farthest balcony. Maximum main-floor throw is approximately 36 meters.

Figure 2 shows the 3000 Hz plot of the main-floor SPL coverage of the original configuration. It's a bit rough, but still within a ±3dB window over the coverage area.

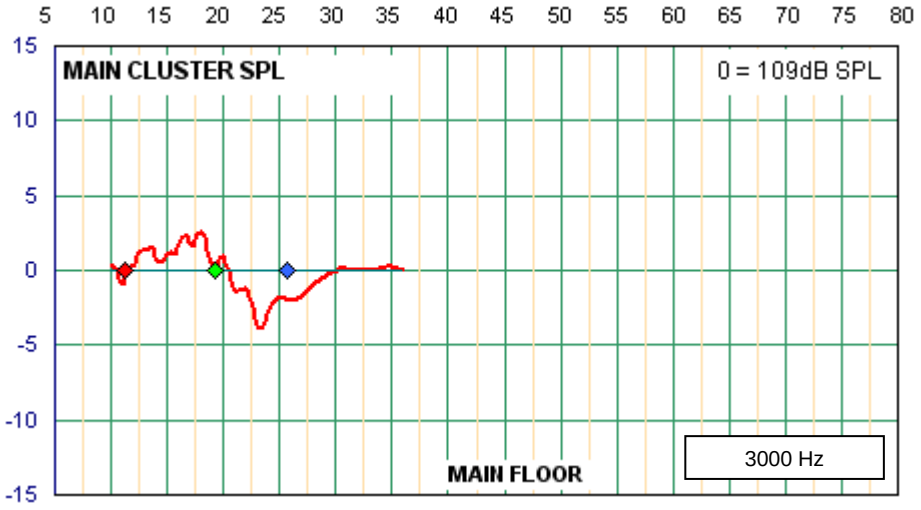

Figure 2. Exposition center, 12 XLC-DVX, main floor, original configuration.

Now for the bad news. Figure 3 adds the 500Hz and 8000 Hz curves:

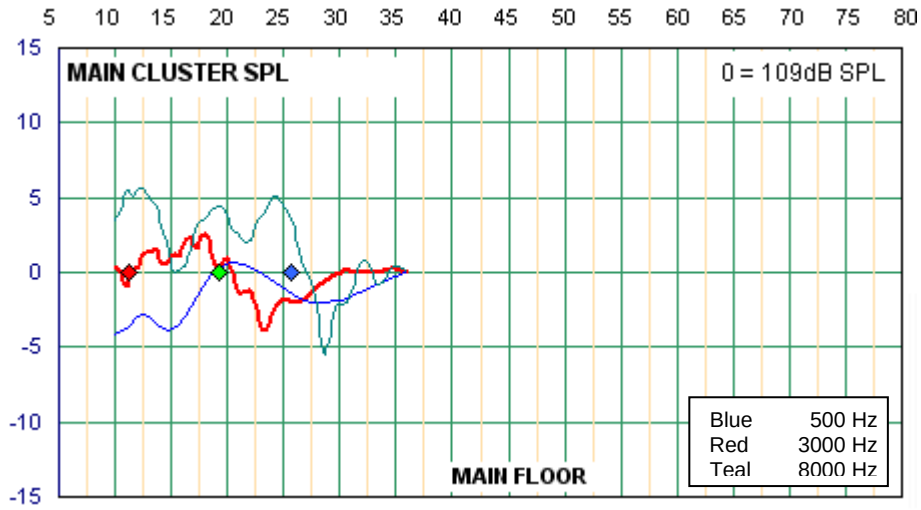

Figure 3. Exposition center, 12 XLC-DVX, main floor, original configuration,

This graph tells us that the tonal balance of the system will vary quite a lot over the listening area. Close to the array, there is too much high-frequency level and too little midbass; at middle distances, the midbass is more in balance, but the high frequencies are still excessive; at the back of the room, things are more or less in balance, but the high-frequency coverage is still uneven.

Figure 4 shows the result of revising the box angles and introducing gain shading at the ends of the array. Gain shading is an important topic, and will be discussed in detail below. These changes required no additional investment in loudspeakers, amplifiers, or cabling.

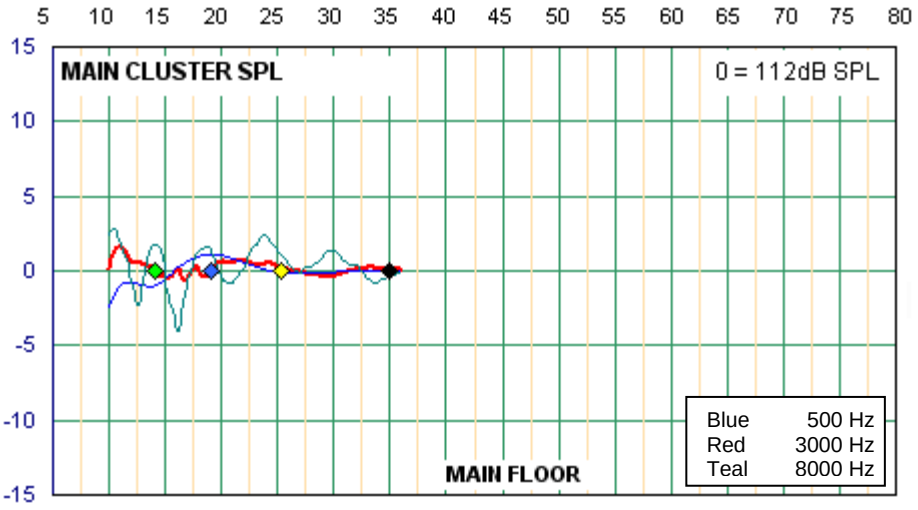

Figure 4. Exposition center, 12 XLC-DVX, main floor, revised configuration.

Clearly, this is a significant improvement.

3. Feature: High-Resolution Prediction

Many early spreadsheet-based modeling tools -- LAPS I and others -- operated at relatively low frequency resolution, thereby omitting possibly significant detail from their results. Figure 5 is LAPS I's prediction for the original exposition center array discussed above. Compare it with the LAPS II prediction shown in Figure 2.

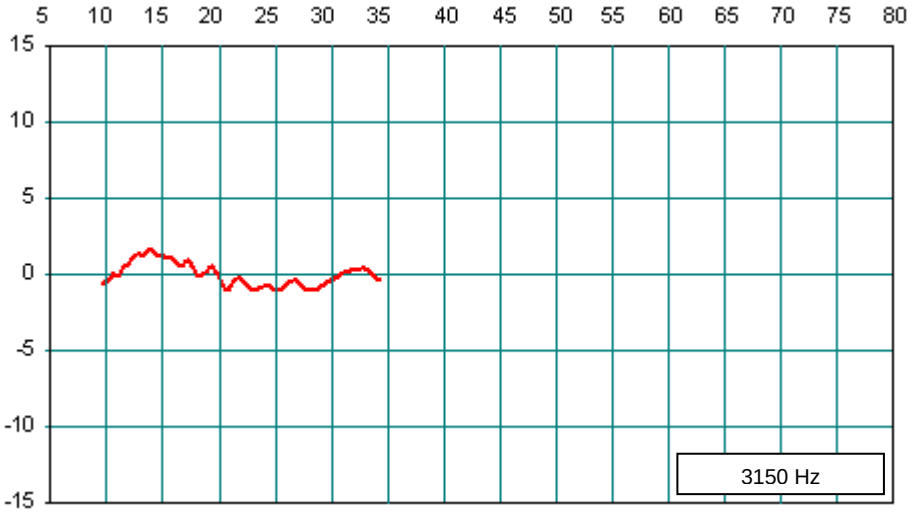

Figure 5. LAPS I low-resolution prediction:
Exposition center, 12 XLC-DVX, main floor, original configuration.

Although LAPS I's curve shows the same hills and valleys, everything looks much smoother. LAPS II shows quite a bit more of the (sometimes ugly) truth.

4. Feature: Equalization Prediction

4.1. Theory

Curved line arrays require significant equalization to deliver flat frequency response at normal listening positions. This is true even when the individual loudspeakers of the array have perfectly flat frequency response on their own.

The reason for this is that the tweeters of line arrays are more directional than the woofers. The tweeters are made that way intentionally, so they won't interfere with each other and make bad sound. That's the purpose of the E-V Hydra®; and other waveforming devices. Thus, when you're listening to a line array, you're hearing only one tweeter (or perhaps a few of them), but you're hearing all the woofers.

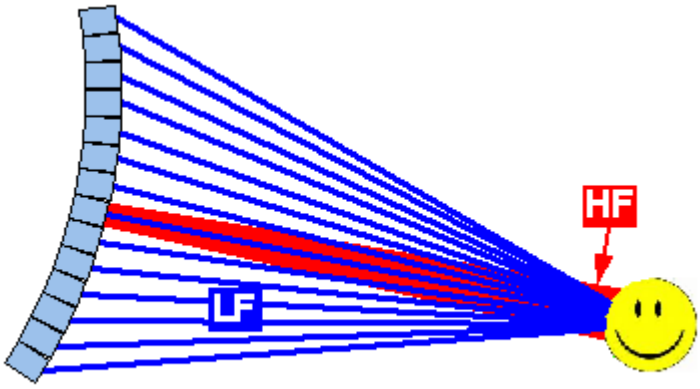

Figure 6. Line array listening geometry.
Hearing all the woofers, but only a few tweeters.

The farther away you are from the array, the more tweeters you'll hear. However, the distance from your ear to the loudspeakers in the array varies, especially with curved arrays (and all practical arrays are curved). Therefore, the sound takes longer to reach your ear from parts of the array not pointing directly at you. This is true even at great distances from the array. This means that the sound from outlying loudspeakers is delayed.

At low frequencies, these delays are not large enough to matter because the path length differences are small compared to wavelength. All of the loudspeakers sum together at low frequencies because the phase differences between the delayed arrivals are small. At high frequencies, however, the delays are significant - often with many wavelengths different in arrival times - and cause the high-frequency waves not to add up well because the delayed arrivals are not in phase. The result is less summation at high frequencies. The higher the frequency, the less the summation. This is true of all line arrays, regardless of size, cost, or manufacturer.

Figure 7 shows the frequency response of a theoretical line array of loudspeakers, each with perfectly flat frequency response. The loudspeakers in this example are 10.5" high, approximately the size of an EV XLD-281, and are curved and flown in a typical arrangement. The listening position (i.e. the point at which the frequency response is measured) is on the central axis of the array, 100 feet distant.

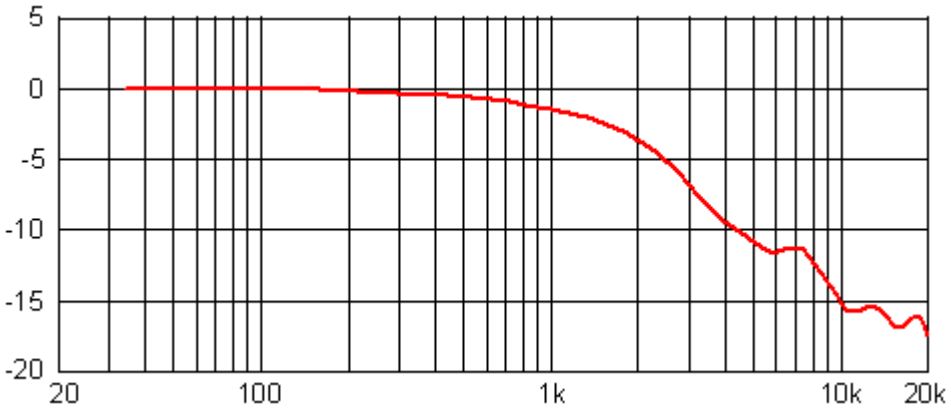

Figure 7. Axial frequency response of a curved line array.

From this curve, it is apparent that for good tonal balance, equalization will be required. For typical line arrays, the equalization curve will take the form of a fairly smooth ramp that rises from low to high frequency. With practical arrays, the total rise from 100Hz to 10kHz will be between 6dB and 18dB, depending on length and curvature of the array.

Part of this equalization may be provided by the loudspeakers themselves, since line array loudspeakers are often engineered with built-in high-frequency boosts, but the rest of it must be provided in the drive chain, prior to the crossover filters.

4.2. LAPS II Equalization Calculation

For all line arrays, the specific equalization required will depend on:

- Array height and tilt angle
- Incremental vertical angle of each box
- Gain shading (i.e. gain of drive signal to each box)
- Frequency response of individual loudspeakers.

LAPS II calculates a recommended equalization curve that takes all of these factors into account.

While the LAPS EQ curve does not include any venue effects (reverberation, room resonance, surface reflections, etc.), **it is an excellent starting point** for room tuning. Experience has shown that starting with the LAPS curve leads to clean-sounding system tunings that have fewer narrow-band equalization points, and that suit a wide range of program types with surprisingly little adjustment.

In use, LAPS computes an equalization curve each time it does an acoustic prediction. This curve applies to a specific point in the venue called the **Acoustic Reference Point (ARP)**. You can

specify the position of the ARP on the LAPS "Venue" page, where all the venue size and shape parameters are entered. Normally, the ARP is situated at the front-of-house mix position.

The LAPS EQ curve is computed to provide a defined **target frequency response** at the ARP. The target frequency response curve has been chosen to provide good tonal balance in most applications. It is flat up to approximately 7kHz (depending on loudspeaker model), then gently rolls off above.

Although the EQ curve is calculated at the ARP, it will apply well to the rest of the listening area as long as the array has been designed to provide even coverage.

Figure 8 shows a LAPS EQ graph. The curve is for 10 XLC-DVX loudspeakers in a typical theater. The ARP is located 100 feet downstage, a normal front of house mix position for such a venue.

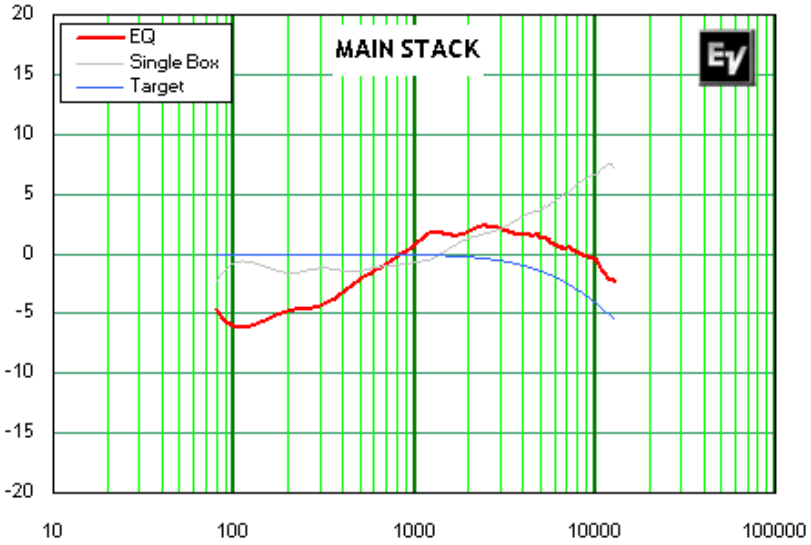

Figure 8. Typical LAPS EQ curve (10 XLC-DVX in theater).

The red trace is the recommended equalization curve. The light gray trace shows the frequency response of a single XLC-DVX box, as measured in the laboratory. The blue trace shows the target frequency response.

4.3. Practical Advice: Creating the LAPS EQ Curve

"Dialing in" a LAPS EQ curve usually requires three or four parametric sections. All EQ curves are different, but here is a starting point that we have found useful:

#	Type	Freq	Gain	Q	Note
1	6dB low shelf	600	-6	n/a	LF rolloff
2	Bell	3kHz	+3	0.5	Mid-high contour
3	Bell or 12B high shelf	7-12kHz	varies	varies	HF contour
4	Bell	varies	varies	varies	Optional, to fix small wiggles

Table 1. Suggested starting point for setting up LAPS EQ

5. Gain Shading

Here at EV, our experience with LAPS advanced prediction features has highlighted the importance of gain shading for line arrays. By "gain shading", we mean adjusting the gains of the signals driving different parts of the array, and particularly reducing the gains for loudspeakers at the top and bottom of the array.

Many line array designers will have used gain shading at the bottoms of their arrays, to reduce excessive loudness in the first few rows. In this application, gain shading is thought of as a simple nearfield technique -- "if a box is too close to a seat, turn it down." However, gain shading is more than that, as we will describe.

5.1. Theory

In physics and electronics, sharp discontinuities often have side effects. For example, when a light wave beam passes through a narrow slit, a phenomenon called "single-slit diffraction" occurs, which causes the beam to be split into a set of narrowly divergent beams of graduated strength:

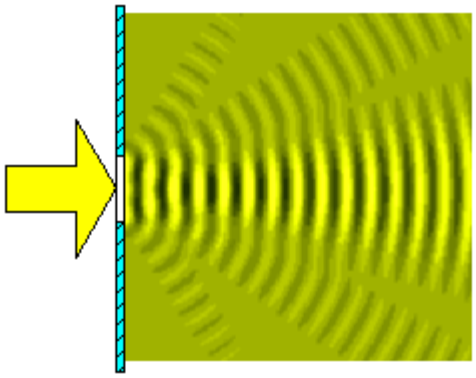

Figure 9. Single-slit diffraction

Single-slit diffraction is an example of what is known as an "aperture effect", and it occurs for all kinds of waves, including sound waves. The properties of the effect (number of beams, strength of each, etc.) depend on the slit size and the wavelength.

A line array is like the slit in Figure 9 -- it's a long, narrow wave source -- and it exhibits aperture effects of a similar nature. These effects show up as irregularities in the coverage pattern.

Physical theory tells us that the **severity of aperture effect can be reduced by gradually reducing the amplitude of the wave to zero near the edges of the aperture**. For line arrays, this means reducing the gain at the top and bottom of the array. This is the gain shading we're talking about. It's also called "tapering".

5.2. Example 1

Figure 10, Figure 11, and Figure 12 give an example from an actual installation -- a large church with arrays of ten XLC-DVX boxes. Figure 10 shows the starting point, for both main floor and balconies. There is no gain shading. Horizontal scale is 25 feet per division.

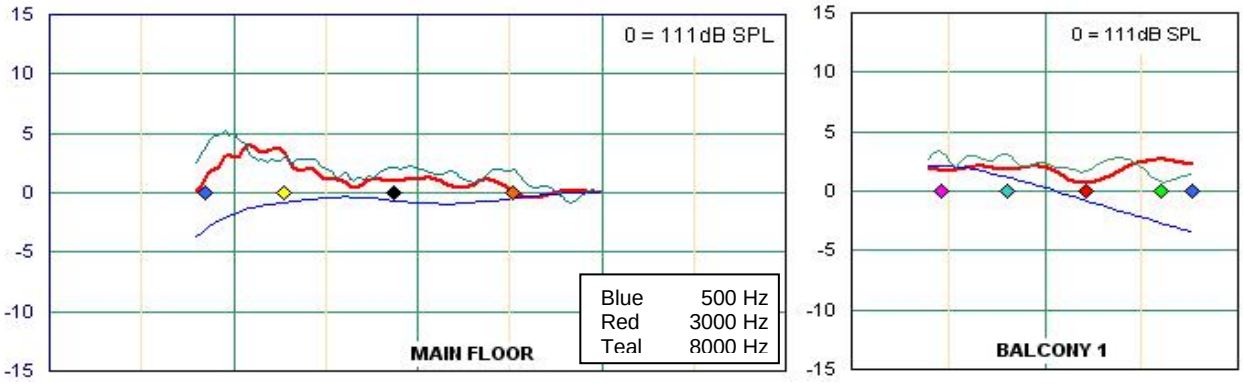

Figure 10. Church, (10) XLC-DVX. No gain shading.

In fact, these curves are fairly good already. But look what happens with a bit of gain shading. Figure 11 shows the same array, with Box 1 (the top box) turned down 3dB, Box 9 turned down 2dB, and Box 10 turned down 4dB.

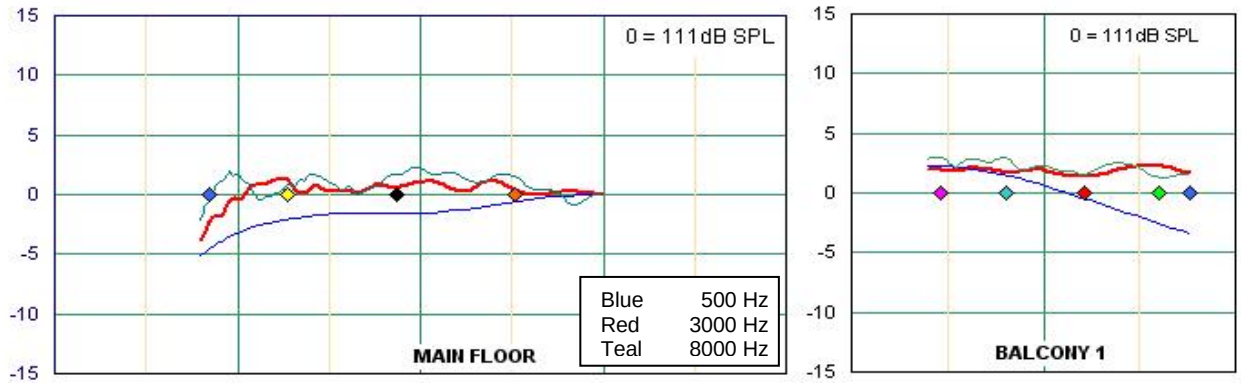

Figure 11. Church, (10) XLC-DVX with gain shading.

As mentioned above, in current practice it's common to turn down boxes down at the bottoms of array, but not at the tops. What would happen if we turned down only the bottom boxes in this example? Figure 12 shows the same configuration as Figure 11, except that the top box is at 0 dB instead of -3 dB. It's good, but not as good.

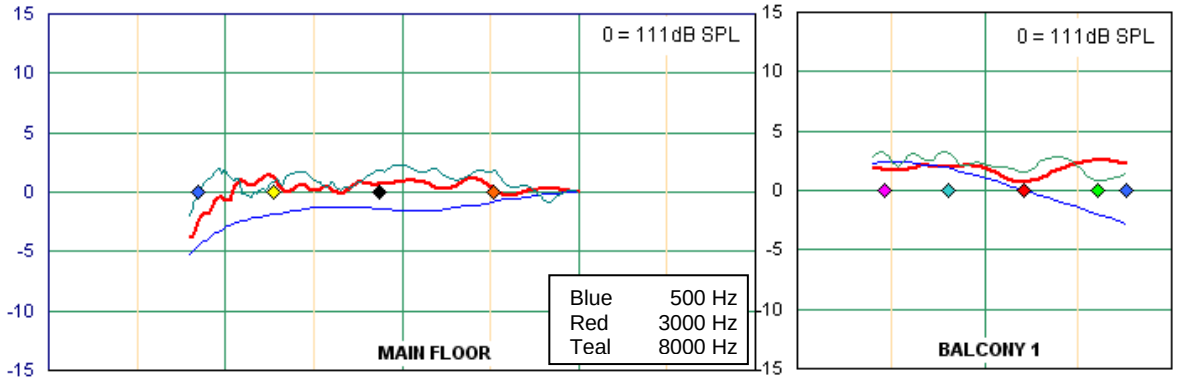

Figure 12. Church, (10) XLC-DVX, bottom gain shading only.

5.3. Example 2

Here's another example, showing the use of gain shading for short line arrays. This is for a flown array of six EV XLE181 loudspeakers covering a flat-floor venue 100 feet deep (it could be a hotel meeting space). This is a difficult case, since the array is actually a bit too short.

Figure 13, Figure 14, and Figure 15 show the benefits of gain shading. Horizontal scale is 12.5 feet per division, maximum horizontal value is 100 feet.

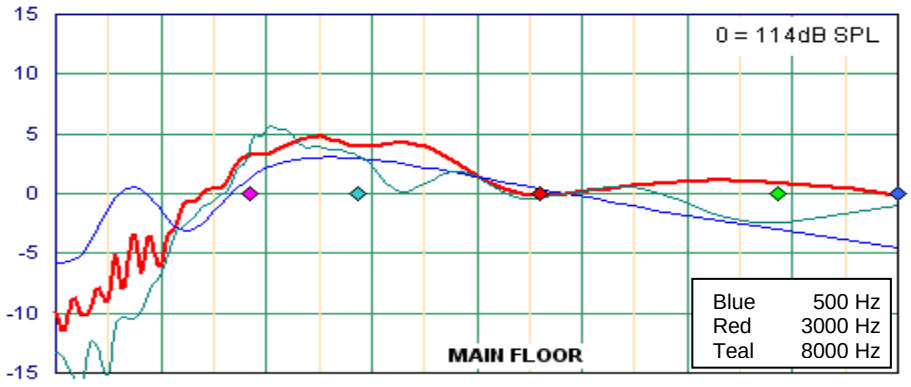

Figure 13. Flat venue, (6) XLE181, no gain shading

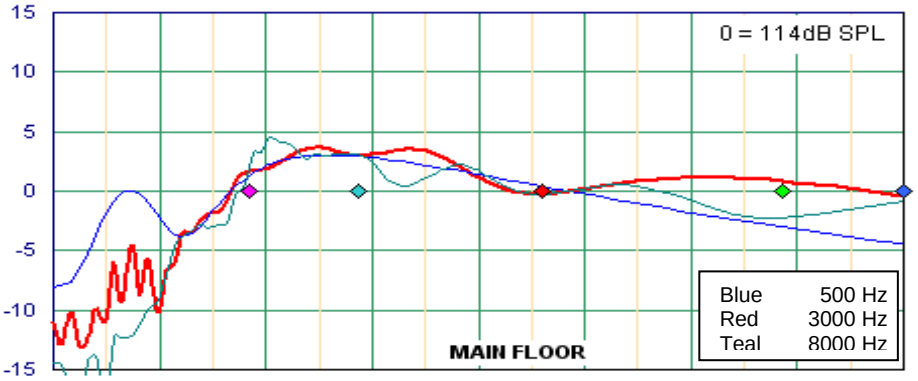

Figure 14. Flat venue, (6) XLE181, 2dB bottom box gain reduction

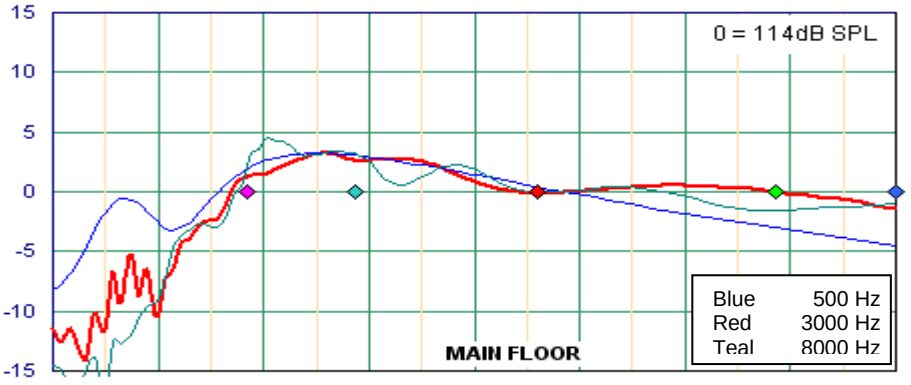

Figure 15. Flat venue, (6) XLE181, 2dB top and bottom box gain reduction

5.4. Practical Advice

At EV, we have generally found that gain shading often works best with a bit less tapering on top, and with a bit more careful and gradual tapering on the bottom to maintain good control of the nearfield. This is particularly true for longer arrays.

One of the surprises of this approach is that tapering the top doesn't really reduce balcony SPL very much, *as long as you have enough boxes*.

With shading, the best results are always obtained when you can adjust the levels of each box separately. However, in most situations there will not be enough amplifier channels available to do that. In such cases, it will often be necessary to use a loudspeaker cabling arrangement that allows top and bottom boxes to be wired in parallel.

The sample files distributed with LAPS II include a number of shading scenarios that have been optimized for most cost-effective use of amplifier channels.

5.5. Gain Shading vs Equalization Shading

In large arrays with sophisticated drive systems, some designers use “equalization shading” (EQ shading for short), i.e. the use of separate equalization for different sections of the array. LAPS II does not predict EQ shading, but in our experience, we find EQ shading helpful in long-throw applications, where it can help offset the high-frequency attenuation of air. For this purpose, shelving filters are often used to increase high-frequency output of the top few array elements, the ones whose high-frequency output must project over a long distance.

EQ shading may also be helpful at the bottom of the array, where it can be used subjectively to create a better tonal balance in the first few rows of the venue, where there is a mixture of sounds from the main arrays, from frontfill loudspeakers, and directly from the stage.

5.6. Delay Shading

Delay shading (i.e. the use of different electronic delays for different line array elements) is never useful for full-range line array loudspeakers of normal construction. Such arrays are not finely divided enough to allow proper alignment of high-frequency waves, and any attempt to apply delay shading to them will produce disastrous results.

Delay shading may be used very helpfully with subwoofers, to control steering of bass radiation. For a comprehensive discussion of subwoofer arrays and steering, please see the EV white paper entitled **Subwoofer Arrays**.

6. Conclusion

LAPS II's advanced prediction features, taken in conjunction with a bit of physics, can lead to better-sounding line arrays with no increase in cost. Designers are encouraged to spend some time with the program to develop their own success approaches. Multifrequency prediction may seem more time-consuming at first, because it disqualifies many array designs that may have looked good before. However, the results are worth the work.

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