CHOOSE YOUR BATTLES

Examining dispersion and pattern control in line arrays. *by Merlijn van Veen*

If a battle can't be won, don't fight it.
— Sun Tzu

Whenever we experience too much of a particular frequency or frequency range, we're tempted to resort to equalization to resolve the situation. In this article, we'll see that the effectiveness of EQ relies entirely on the relative level separation from other sources.

I design line arrays (**Figure 1**) as modular composite coupled point sources. Each individual module is effectively a perfect symmetrical arc. The splay angles are purposely set to achieve a 6 dB level drop (**Figure 2, Plot 6**), front-to-back, in the frequency range where the waveguides become sole custodians (typically 2 kHz and up).

Mid and high frequencies approximate cylindrical wave behavior (3 dB per doubling distance) up to a certain distance, and this way, the low frequencies that are typically bound to spherical waves (6 dB per doubling distance) for finite-length arrays have a chance of keeping up, once their loss rate has been decelerated by LF buildup/room gain (not shown in SPL plots).

With the waveguides as sole custodians, designing line arrays is a relatively simple matter of "point-and-shoot" (amplitude steering). Unfortunately, at

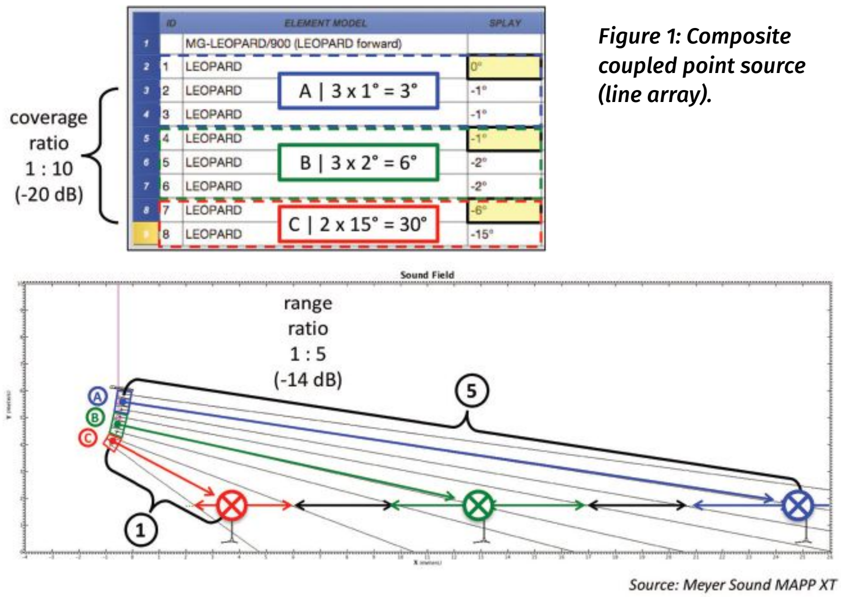


Figure 1: Composite coupled point source (line array).

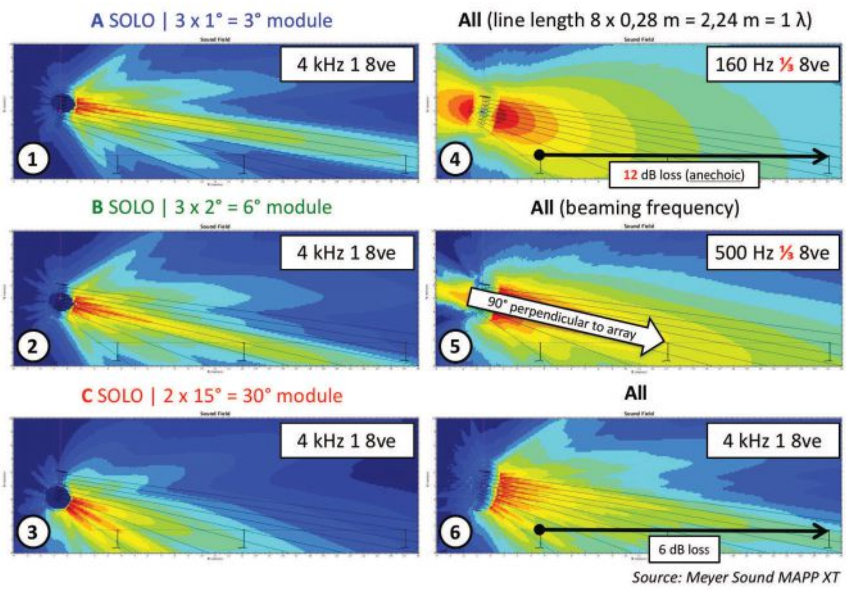


Figure 2: Vertical pattern behavior.

low frequencies, single line array elements are effectively omnidirectional. This renders them immune to rotation and therefore splay. Instead, the overall array geometry is the driving force (phase steering) behind low frequency control.

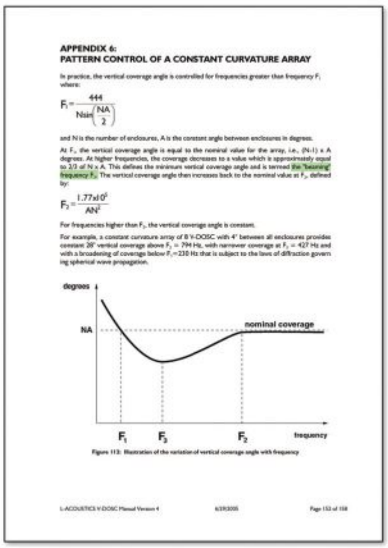
Ultimately, vertical pattern control is achieved by committee. It's a balancing act of "beam-narrowing" in the low end versus "beam-spreading" in the high end. Vertical pattern control begins with roughly 72 degrees (**Figure 2, Plot 4**) at the frequency whose wavelength matches the length of the array (number of speakers times their spacing).

Conventional arrays, however, tend to do a little too much of a good thing after the onset of pattern control. L-Acoustics refer to this as the "beaming frequency" (**figure 3**) since the introduction of the V-DOSC line array in the early 1990s. For this particular array, the beaming frequency is approximately 500 Hz (**Figure 2, Plot 5**).

We can clearly see a concentrated beam of energy, perpendicular to the entire array, overshooting the beginning of the audience and making a nosedive before the end of coverage. This beam is typically about one-third narrower than the array's nominal coverage angle observed at higher frequencies.

Figure 4 shows the "raw" anechoic system response (no processing). The traces have been aligned by means of an offset in order to assess uniformity. In reality, frequencies below line length (160 Hz) will show matched responses with help of LF buildup/room gain.

Local HF attenuation caused by humidity is proportional to distance and can easily be remedied with EQ, provided the array is subdivided in zones, which the



APPENDIX 6:
PATTERN CONTROL OF A CONSTANT CURVATURE ARRAY

In practice, the vertical coverage angle is controlled for frequencies greater than frequency F_1 where:

$$F_1 = \frac{444}{N\sin\left(\frac{NA}{2}\right)}$$

and N is the number of enclosures, A is the constant angle between enclosures in degrees.

At F_1, the vertical coverage angle is equal to the nominal value for the array, i.e., (N-1) x A degrees. At higher frequencies, the coverage decreases to a value which is approximately equal to 2/3 of N x A. This defines the minimum vertical coverage angle and is termed the "beaming" frequency F_3. The vertical coverage angle then increases back to the nominal value at F_2, defined by:

$$F_2 = \frac{1.77 \times 10^5}{AN^2}$$

For frequencies higher than F_2, the vertical coverage angle is constant.

For example, a constant curvature array of 8 V-DOSC with 4° between all enclosures provides constant 28° vertical coverage above F_2 = 794 Hz, with narrower coverage at F_3 = 427 Hz and with a broadening of coverage below F_1=230 Hz that is subject to the laws of diffraction governing spherical wave propagation.

Figure 113: Illustration of the variation of vertical coverage angle with frequency

L-ACOUSTICS V-DOSC Manual Version 4

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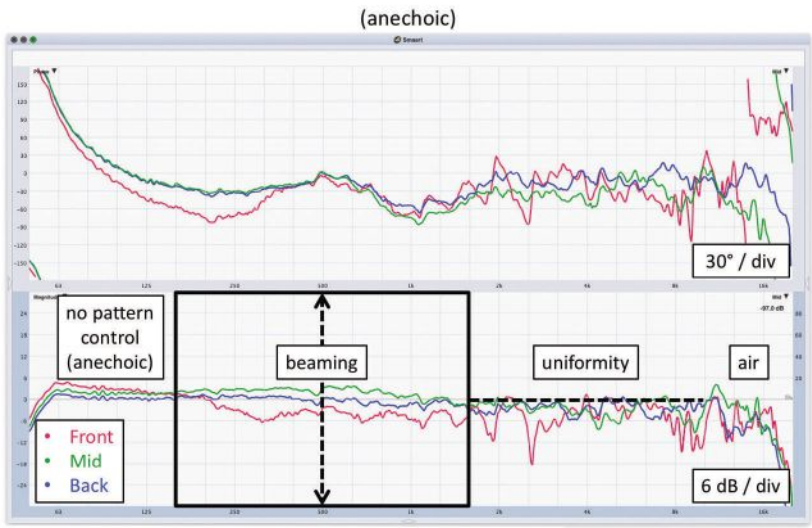
Source: L-Acoustics V-DOSC manual

Figure 3: Beaming frequency.



Source: Rational Acoustics Smaart v8

Figure 4: Composite coupled point source measured at 2.24 meters (7.3 feet).

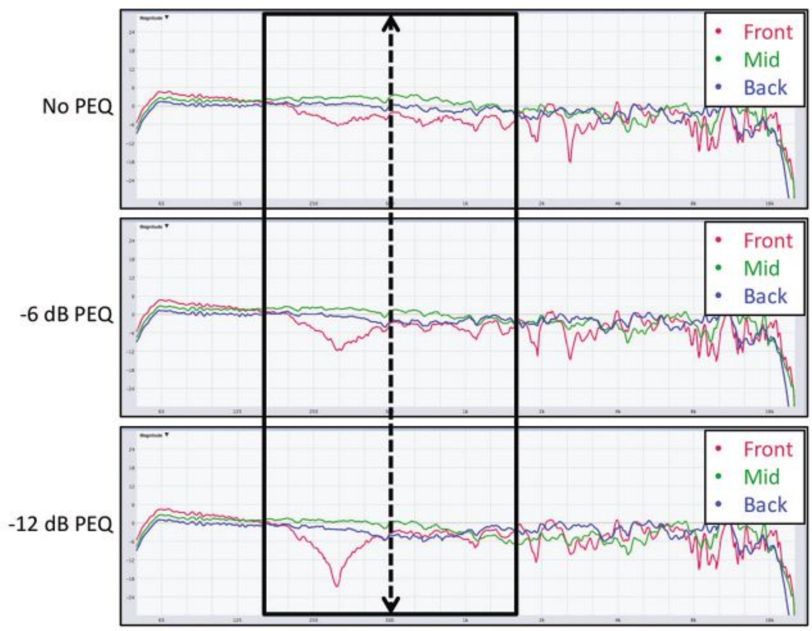


Figure 5: Limited merit.

Source: Rational Acoustics Smaart v8

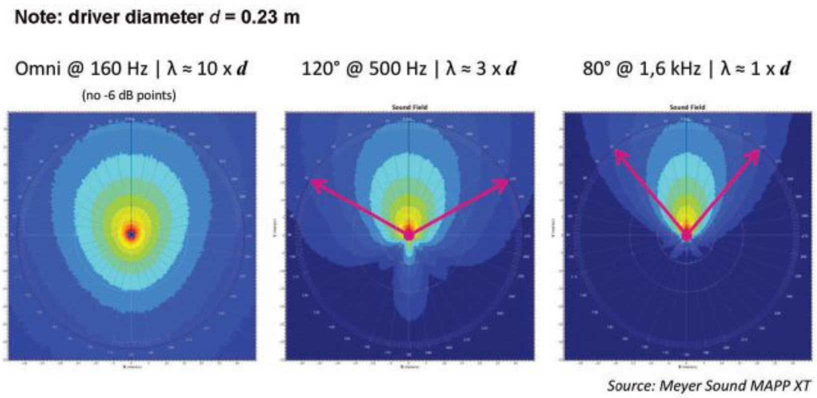


Figure 6: Vertical coverage angle of a single 9-inch line array element.

log	lin
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
18,1 dB	**8,00**

log	lin
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
-6,0 dB	0,50
-6,0 dB	0,50
-6,0 dB	0,50
0,0 dB	1,00
0,0 dB	1,00
16,3 dB	**6,50**

log	lin
0,0 dB	1,00
0,0 dB	1,00
0,0 dB	1,00
-12,0 dB	0,25
-12,0 dB	0,25
-12,0 dB	0,25
0,0 dB	1,00
0,0 dB	1,00
15,2 dB	**5,75**

Figure 7: Diminishing returns.

modular composite coupled point source happens to be.

In practice, this design approach will result in matched traces for half of the array's operational range in exchange for 6 dB of level variance front to back, leaving only the decade centered around the beaming frequency, which depends entirely on the geometry of the array.

In this specific frequency range, 6 dB of local tonal variance is observed. The bulk of this energy is concentrated in the area halfway through the audience. Suppose we were to resort to EQ in attempt to even out the response over space by attenuating the offending frequencies in this part of the audience (B module) exclusively.

Figure 5 clearly shows that an octave-wide cut at 500 Hz in the B module has limited merit. It reduces the tonal variance to some extent but doesn't really address the concentrated energy halfway through the audience.

If anything, it appears to make these frequencies go down in level everywhere throughout the entire coverage area. In addition, there's also the onset of a particularly nasty octave-wide cancellation at 315 Hz. What's going on?

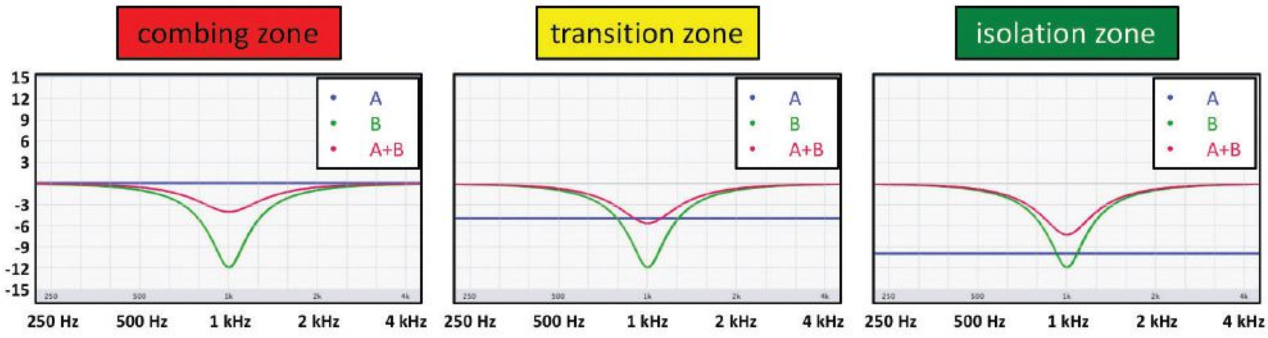
INVERSE PROPORTIONS

Single line array elements in the vertical plane are so-called "Proportional Q" loudspeakers (**Figure 6**). Their coverage angle is inversely proportional to frequency. From omnidirectional in the low-end all the way to their nominal coverage angle, as little as 5 to 15 degrees at 16 kHz.

There's a rule of thumb for piston drivers, responsible for the low end, that states that at the frequency whose wavelength matches the driver diameter, the coverage angle will be roughly 90 degrees (axisymmetric). For any array of this length, driver complement and physical configuration, this implies that the entire "problem" region (160 Hz to 1.6 kHz) surrounding the beaming frequency is joint custody of all loudspeakers that each exhibit coverage angles of 80 degrees or more. There's little to no isolation (level separation) from neighboring sources!

In the absence of isolation, EQ or level adjustment have limited merit. Lowering the level of a single module either by gain or EQ has primarily a global effect, affecting the entire coverage area.

The tables in **Figure 7** show that attenuating the B module exclusively does nothing for the grand total other than



Source: Rational Acoustics Smaart v8

Figure 8: EQ versus level separation (PEQ at 1 kHz)

reducing overall headroom. Eliminating the B module all together only lowers the global level by five-eights (or -4 dB) at the most.

However, if there's level separation, EQ will have a more profound effect. **Figure 8** shows the effect of a notch when competing with another source. The red trace represents the sum of both signals. It's readily apparent that the notch becomes more effective when the other source loses market share.

Note that this also applies very much to mixing. In the absence of crosstalk or "bleeding" – ergo separation – EQ has a profound and tangible impact. The equalizer will feel very responsive. Contrary, tons of crosstalk will require more drastic measures that are typically accompanied by detrimental side effects. The latter very much applies to our array as well!

Figure 9 depicts what happens to the beam should we decide to resort to EQ in the B module exclusively. It's readily apparent that attenuating the offending frequencies has no profound effect on the beamwidth. In fact, we observe the onset of a vertical interference pattern featuring power alleys and valleys.

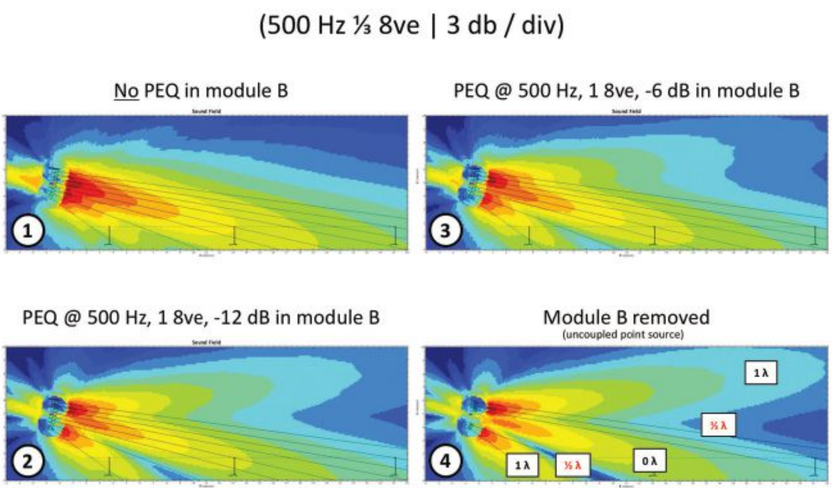
If we're not careful, it's will be as if the entire B module has been eliminated all together (**Figure 9, Plot 4**). This essentially changes a coupled point source into an uncoupled point source, where the physical displacement has serious implications.

The uncontrolled spurious side-lobes seen in Figure 9 could blow up in our faces. What if they end up hitting specular surfaces (e.g., a balcony face or rear wall), introducing discrete echos? The audience on a balcony in the custody of another system? Environmental pollution?

The principal precept in health care is: "First do no harm." Unfortunately, not everything can be simply remedied with a "level band-aid" like EQ or gain. In this instance, that approach clearly has limited merit and is likely to cause more harm.

If these loudspeakers are virtually equally loud, because in this part of the spectrum they are still omni- to hemispherical and fail to steer clear of each others' territories (immune to rotation), so they better arrive in *time*. This is the root cause for this beaming phenomena.

Figure 1 clearly shows path differences. The difference between these trajectories translate into phase offsets and that's when "stuff hits the fans" (plural, and pun intended). There's a time problem that requires a "time band-aid" and the reason it's so audible is because the levels are matched! LSI



Source: Meyer Sound MAPP XT

Figure 9: Attenuating beaming frequency with EQ (in zones).

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