BEAMING FREQUENCY

Examining curved and straight line source behavior.

by Merlijn van Veen

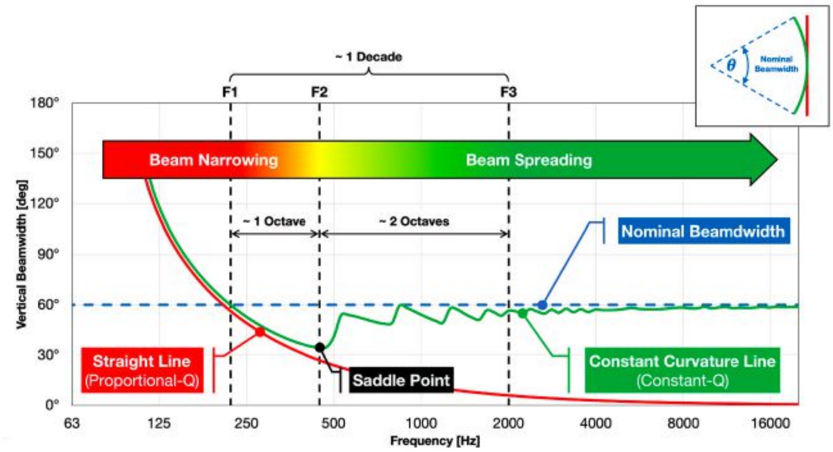

Figure 1: What's happening with a Beaming Frequency.

The "Beaming Frequency" is where curved line source behavior strays from straight line source behavior. Line arrays are hybrid approaches that exhibit both straight as well as curved line source behavior.

The former causes Proportional-Q – in the vertical plane – whereas the latter causes Constant-Q. And there will be an inevitable frequency span where one behavior transitions into the other. During which vertical beamwidth will narrow, by as much as one-third less than nominal. The frequency where vertical beamwidth is at its narrowest is historically known as the Beaming Frequency.

Figure 1 shows the vertical beamwidth as function of frequency, for straight and constant-curvature continuous line sources of the same length. The straight line source beamdwidth (shown in red) narrows with increasing frequency. With each octave increment, it is halved. Directivity factor Q is inversely proportional to coverage angle, i.e., beamwidth. And since beamwidth decreases with increasing frequency, Q rises with increasing frequency, hence Proportional-Q (Q is proportional to frequency).

The constant-curvature line source (shown in green) at first follows the same progression. But come saddle point, its beamwidth starts to diverge. While the straight line source continuous to narrow (Proportional-Q). The constant-curvature line source begins to spread and converges towards nominal where it becomes Constant-Q. At the saddle point, the vertical beam, for curved arrays, is the narrowest. Hence "Beaming Frequency."

Figure 1 shows that for lower frequencies, up until the Beaming Frequency, line sources, curved and straight alike, in general exhibit Proportional-Q behavior, whereas higher frequencies – curved arrays – do respond to inter-element splay and effectively become "point and shoot."

ANALYSIS

While being familiar with the phenomenon from other publications (H. Olson, etc.), the author first read about the term Beaming Frequency in product collateral[1] from the early 1990s, but failed to reconcile the published equations with the published values. As such, the author ended up doing his own preliminary far-field analysis and adopted the same major milestones' labels.

The lowest frequency F1 where vertical beamwidth equals nominal:

$$F1 \approx \frac{21 \times 10^3}{l \times \theta^{0,935}}$$

The beaming frequency F2 where vertical beamwidth is roughly one-third narrower than nominal:

$$F2 \approx \frac{42 \times 10^3}{l \times \theta^{0,935}}$$

The frequency where vertical beamwidth recovers back to nominal F3:

$$F3 \approx \frac{189 \times 10^3}{l \times \theta^{0,935}}$$

For all three equations, l is line length in meters, and θ is the nominal – constant-curvature – coverage angle (read: total splay) in degrees.

*F*1 and *F*2 are spaced roughly one octave a part (Figure 1), whereas *F*2 and *F*3 about two octaves. Subsequently, the entire transition lasts about one decade.

In all instances, the major milestones frequencies are inversely proportional to line length and nominal coverage angle. So either making the array longer or wider will lower the beaming frequency as well as all other milestones.

Figure 2 shows an overview for different coverage angles (columns) and various line lengths (rows). Notice (as forecast by the equations) that the Beaming Frequency drops for both longer or wider arrays.

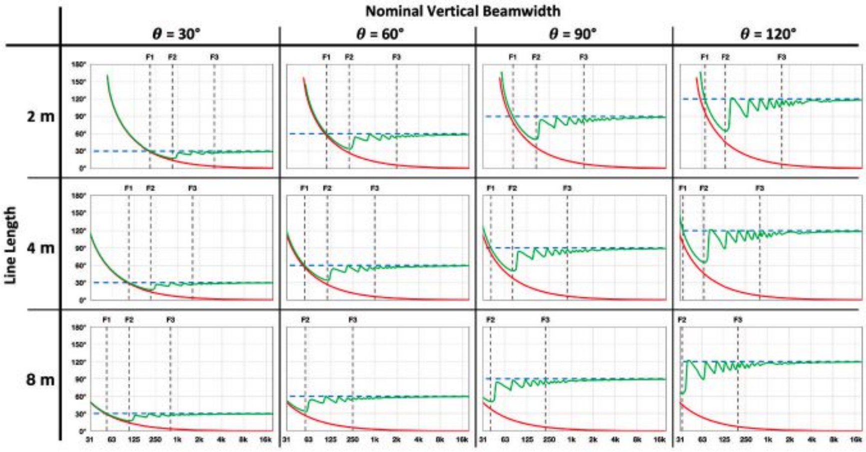

Figure 2: Either making the array longer or wider will lower the Beaming Frequency.

DIRECTION

The direction of the Beaming Frequency, with respect to overall array orientation, is easy to forecast. The Beaming Frequency lives along the trajectory where there is – the least phase offset – between array elements, and source receiver path differences are minimal.

If we do a quick ripple-tank exercise (**Figure 3**), we clearly see that roughly along the perpendicular (to the array), all ripples' crests intersect, i.e., are most in phase, whereas everywhere else there is "coordinated" chaos.

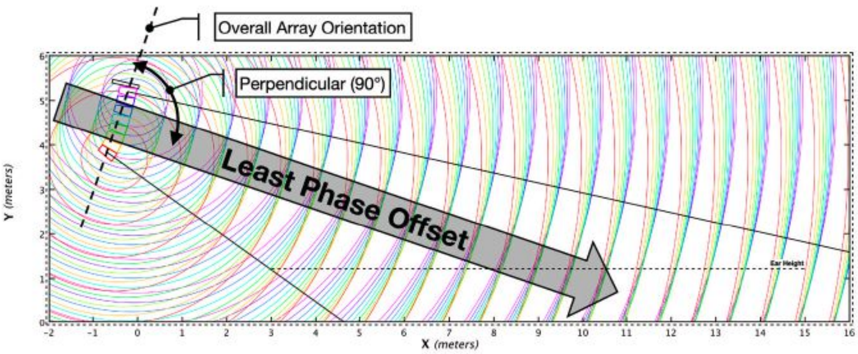

Figure 3: The Beaming Frequency runs perpendicular to the array.

Whether or not array elements will actually interfere depends on whether their vertical coverages overlap. In that case, we can fall back on a tried and tested rule of thumb that states that a piston driver's (axial) coverage angle exceeds 90 degrees for all frequencies whose wavelengths are longer than the driver's diameter – for example, below 2 kHz for a 6.5-inch driver, down to below 800 Hz for an 18-inch driver, and so on. In fact, individual piston drivers also exhibit Proportional Q behavior which is worthy of a separate article.

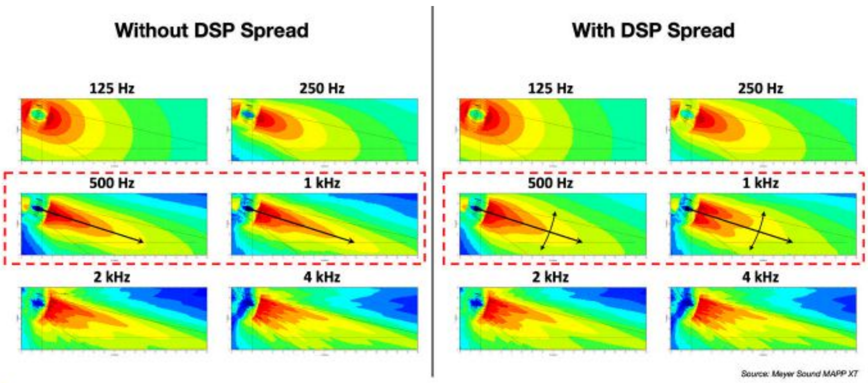

Figure 4: A small 1.5-meter-long array at 5-meter height, throwing 15 meters.

Suffice to say, the individual elements of small and large arrays alike, the frequency ranges of interest are effectively overlapped. Where the Beaming Frequency ultimately falls, i.e., within operating range or not, and where the Beaming Frequency touches down within the audience, may audibly affect tonality throughout the audience.

In order for tonality to be preserved with increasing distance, all frequencies need to lose market share at the same rate. However, when vertical beamwidth is a function of frequency, preservation of tonality over distance is compromised.

TONAL IMPLICATIONS

There are many use-cases beyond the scope of this article that are worthy of separate consideration. For now, I'll limit to two typical scenarios – a short and a long array covering a level audience.

Figure 4 shows a short array. For its given length and total splay, the "beamy" frequencies occur throughout the decade centered at 630 Hz, right in the middle of its operating range while leaving lows and highs unaffected.

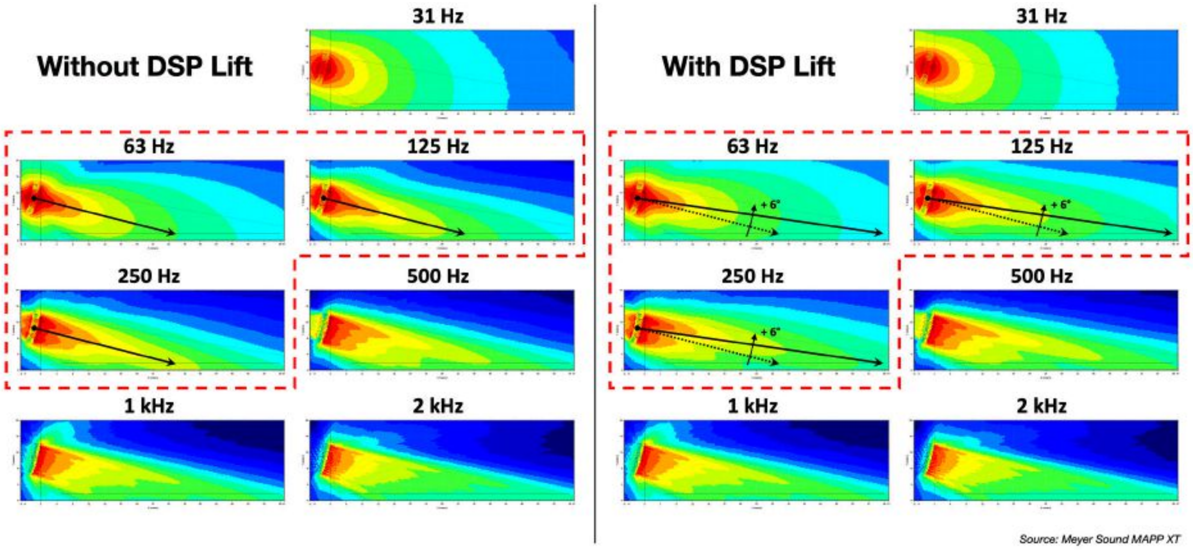

Figure 5: A 7-meter-long array at 14-meter height, throwing 60 meters.

Notice on the left-hand side of Figure 4 (without DSP spread) that both 500 Hz and 1 kHz beams are too narrow and overshoot the audience start, followed by doing a nose-dive halfway into the audience. Whereas all remaining frequencies are louder in the front and taper off towards the back.

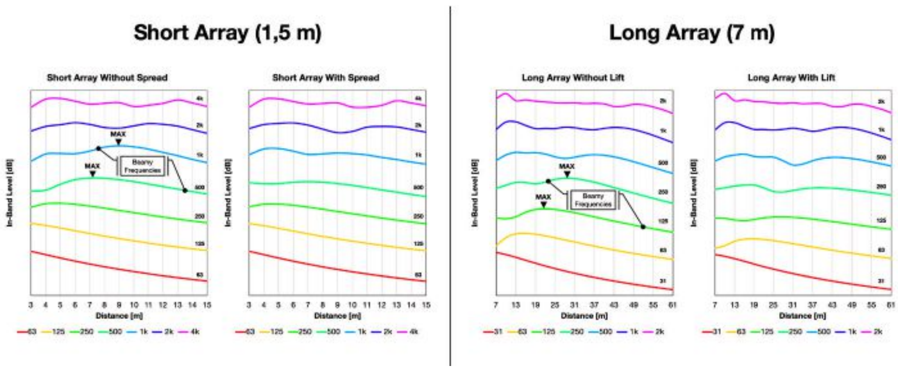

Figure 6: Octave in-band levels over distance.

Here the challenge becomes to redistribute the energy from a region where there is too much – the middle – to a region where there is too little, the front portion of the audience. This can be achieved by, for example, spreading the beam electronically – solely for beamy frequencies – by virtue of signal processing (right-hand side of Figure 4).

Figure 5 presents a long array. For its given length and total splay, the "beamy" frequencies occur throughout the decade centered at 125 Hz, concerning solely lower operating range frequencies while leaving mids and highs unaffected.

Notice on the left-hand side of Figure 5 (without DSP lift) that both the 125 Hz and 250 Hz beams, while being sufficiently narrow due to their perpendicular orientation, land in the wrong place – first half of the audience as opposed to the last row.

Here the challenge becomes to redistribute the energy from a region where there is too much – first audience half – to a region where there is too little, the last row. This too can be achieved by lifting the beam electronically – solely for beamy frequencies – by virtue of signal processing (right-hand side of Figure 5).

Figure 6 shows octave in-band levels over distance, where the traces have been offset for better visibility. Notice in both cases that, without signal processing, not all frequencies drop in level with increasing distance.

Without signal processing, the beamy frequencies gain in level first while all remaining frequencies either maintain their level or taper off, which is a guaranteed recipe for tonal variation. Whereas with signal processing, by and large, all frequencies are louder at first and taper off towards the back.

CONCLUSION

All arrays – without additional signal processing – will manifest this phenomenon. And handling the beamy frequencies is essential for minimizing tonal variation throughout the audience. They cannot be remedied with equalization, since the root cause is a frequency-dependent time problem that requires a "time band-aid" as opposed to a "level band-aid" like EQ or gain. LSI

References

1. *L-Acoustics V-DOSC Operator Manual*

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