Tech Topic

THE CHEESE GRATER

A word of caution on horizontal subwoofer arrays.

by Merlijn van Veen

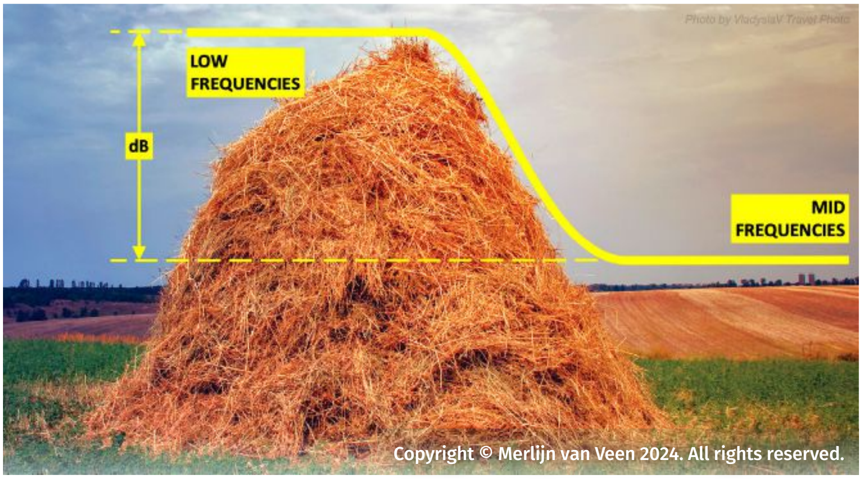


Figure 1

This may come as a shock – coming from the author of the Subwoofer Array Designer – but over the years I've grown an increasing dislike for horizontal subwoofer arrays. The only thing they've really got going for them is left-to-right spatial uniformity, provided they don't fall victim to one honest mistake.

This article assumes that readers have a working knowledge of horizontal subwoofer arrays and are familiar with the usual reasons why audio professionals tend to deploy them.

POINTS OF CONTENTION

My primary objection against horizontal sub arrays is their lack of efficiency at front of house that's typically anywhere from -3 dB to as much as -9 dB (depending on the amount of delay tapering), thus leaving precious SPL on the table.

It can be recovered by doubling, or even tripling, the box count to make up for losses, but since every audio professional I encounter tends to be a member of the "SPL Preservation Society," yielding to such losses makes me wonder about double standards.

However, rather than efficiency, most audio professionals tend to object to horizontal arrays' alleged time smearing, a concern I believe is greatly exaggerated and do not share for an array's usable frequency range when properly designed. This can easily be disproved by auditioning select third-octave-wide tone bursts.

It begs the question: which frequencies are usable and which are not? Hold on to that question…

MORE DOUBLE STANDARDS?

Ever since I entered this industry, I've been a firm proponent of equality for listeners. If everyone pays the same price for an admission ticket, they're all entitled to a similar experience. However, power alleys and valleys (inherent to left/right subwoofer deployments) have become increasingly less of an issue to me.

If left/right subwoofers are somehow unacceptable, we should also have a conversation about left/right main PA, with its unbeaten track record in having withstood the test of time for decades. Left/right main system lower octaves nowadays are subject to the same issues, but it doesn't seem to cause anyone to lose sleep over it. Which makes me wonder even more about double standards… Apologies, I digress. Back to the topic at hand.

Nobody contests whether or not horizontal subwoofer arrays ultimately suffer from artifacts in space, time, and frequency – most of which will be shown in this article – which is fine as long as these artifacts remain concealed and thereby inaudible. And therein lies the true culprit of our own making.

ELECTRICAL RATHER THAN ACOUSTICAL

Ask any audio professional for the maximum allowable spacing between subwoofers in a horizontal array (center-to-center) and you're likely to receive one of two answers: 1) half, or 2) two thirds' wavelength of the "crossover" frequency. Below crossover, that is – the array is expected to be well behaved, whereas above crossover, it is not.

The most common misunderstanding I encounter in the field: basing the subwoofer spacing on the electrical crossover, without taking into consideration the height of one's "haystack."

The haystack (**Figure 1**) occurs when subwoofer level is increased above and beyond the mains' level to emphasize low frequencies rather than extend them. This results in a shelf-like elevation in the combined system response.

Erecting a haystack makes the acoustical crossover between the main PA and subwoofers – the frequency where both passbands' airborne – sound meet at the same level, wander up in

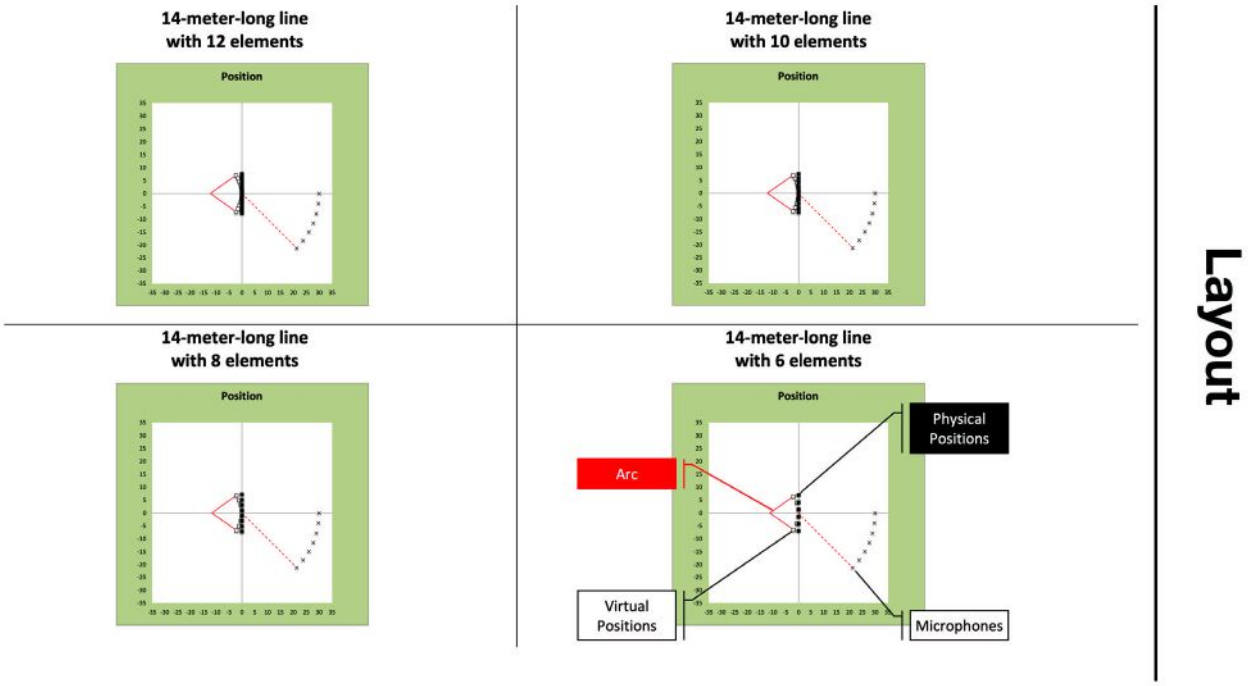


Figure 2

frequency and move away from the electrical crossover. This effectively broadens the subwoofers' pass-band by boosting higher, otherwise concealed out of band frequencies.

Failing to realize this invariably results in a subwoofer spacing that is too wide, and it also raises our awareness of frequencies for which the array is neither designed nor optimized. These frequencies are unambiguously subject to artifacts in space, time, and frequency.

BEAMWIDTH PLOTS

Figure 2 shows four designs in Subwoofer Array Designer where each subwoofer line is equally long, but the number of elements is decreased from 12 to as little as six. In other words, the gap size increases and loudspeaker density becomes sparser. In all cases, delay tapering has been optimized to yield a 90-degree spread.

Figure 3 depicts the beamwidth plot for each design. For frequencies whose half-wavelength is equal or larger than the center-to-center spacing between elements, the array works as expected. The intended 90-degree coverage is attained throughout with variance of less than 6 dB.

However, for the remaining higher frequencies, we observe what I've come to call the "cheese grater." Notice the nulls (blue color denoting low levels) perforating the plot throughout this frequency span, as though someone used a die to punch holes in it.

This aspect of the array should remain concealed and inaudible! Arrays of this type are not designed and optimized for uniform coverage at these frequencies. Nobody likes this, including me.

Figure 4 provides more of the same for select third-octave frequencies. When an array has been properly designed, its polar plot for all frequencies of interest exhibits at most 6 dB of ripple, which is within its intended 90-degree coverage angle.

Notice that as array density becomes sparser – that is, wider spacing – the highest third-octave frequencies are the first to exhibit ripple in excess of 6 dB. This is highly undesirable and unusable.

FREQUENCY RESPONSES

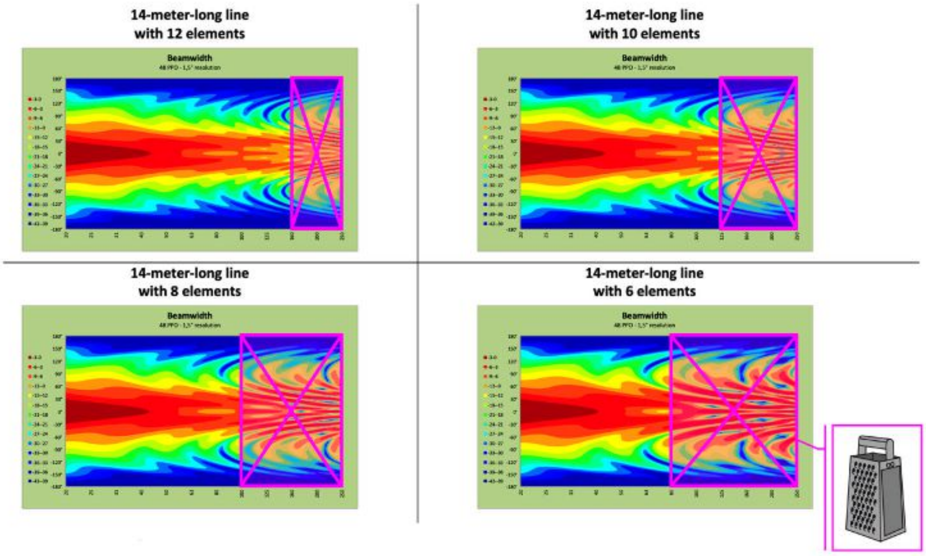
Figure 5 shows, again, more of the same. All frequencies to the left of the green triangular marker on the frequency axis, which denotes half wavelength, for the seven microphones (ranging from 0 degrees on-axis to 45 degrees off-axis) exhibit 6 dB of variance or less.

In contrast, all frequencies to the right of the yellow triangular marker on the frequency axis, which denotes two-thirds wavelength, exhibit ripple in excess of 6 dB and are unusable.

THIRD-OCTAVE WAVELETS

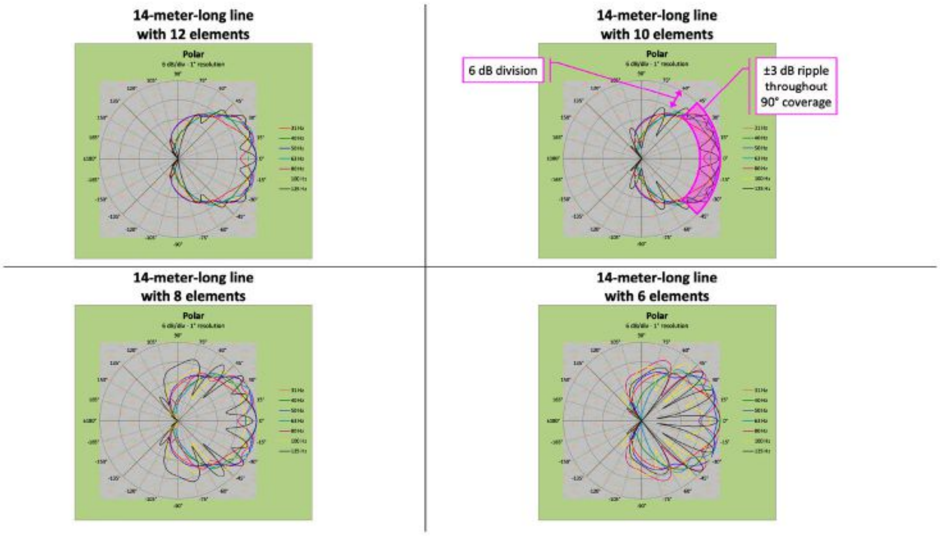
The wavelet-transform (**Figure 6**) clearly shows significant late-arriving energy for frequencies where the spacing is too sparse (Examples 1 and 2 in Figure 6), most notably at the edge of coverage (Example 2 in Figure 6).

These are the out-of-range frequencies that indeed are subject to time smearing whenever content is transient, where time smearing progressively worsens from 0 degrees on-axis to 45 degrees off-axis. For these frequencies, beamwidth plots (Figure



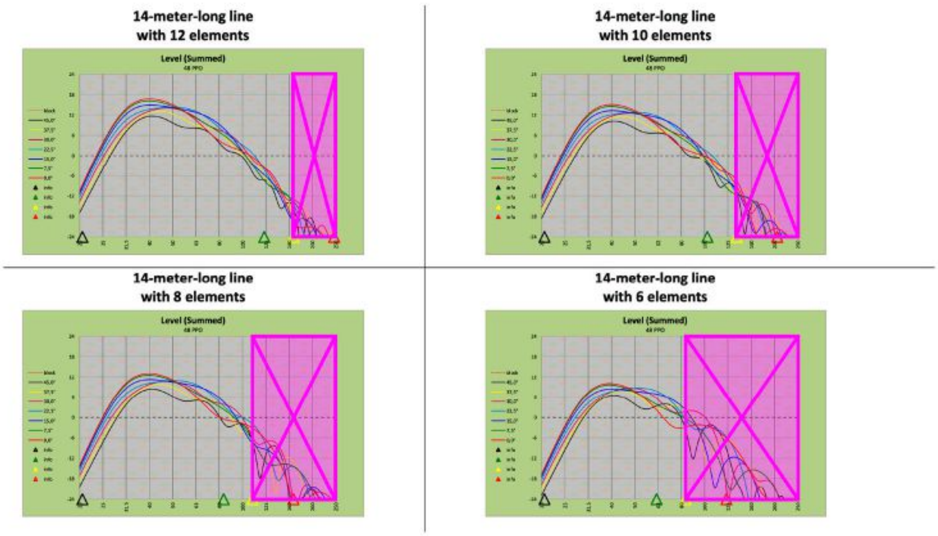
Beamwidth

Figure 3



Polar Pattern

Figure 4



Frequency Response

Figure 5

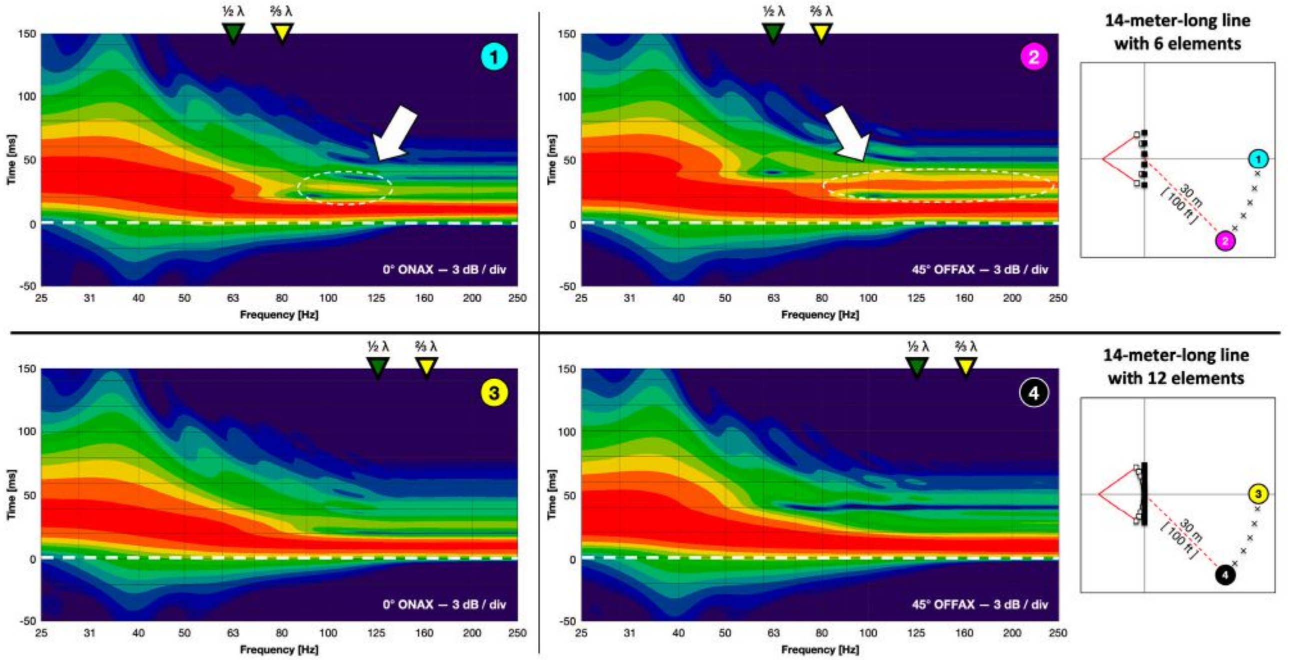


Figure 6

1) and both polar plots (Figure 4), as well as frequency responses (Figure 5) all exhibit ripple in excess of 6 dB.

We don't want to hear this part of the spectrum (for which the array has not been designed and optimized) coming from the subwoofers. The main PA should be the sole custodian. But what determines whether these ill-behaved subwoofer frequencies remain concealed and inaudible? Spoiler alert: the height of the sub haystack!

RELATIVE LEVELS MATTER

Ultimately, the acoustical crossover determines which frequencies the audience hears coming out of the subs and main PA – not the electrical crossover!

Imagine an array solely considering frequencies below the electrical crossover; for example, 63 Hz. Now crank up the array's level to erect an 18-dB-tall haystack, and everyone is made aware of all frequencies, for which the array is neither designed nor optimized, as well as their undesirable artifacts in space, time, and frequency.

By the way, having the subs on an auxiliary is adding insult to injury, because now the size of the haystack may change on a channel-by-channel basis.

ASSUME THE WORST

When I'm asked to design a horizontal subwoofer array, the first thing I ask: "How tall is your haystack going to be?" Because this determines which frequencies we'll hear coming out of the subs or the main PA. And once this question has been answered, I know for which frequencies array performance needs to be artifact-free – which invariably results in an atypically small spacing.

If the client can't answer this question, I assume the worst and err on the side of caution, where I anticipate a taller rather than shorter haystack.

When it comes to horizontal subwoofer arrays, most audio professionals want to have have their cake and eat it too. That is, long lines (at least stage-width) and wide coverage. And yet anyone who understands array theory is aware that short lines are naturally wide and long lines are naturally narrow.

Meanwhile, the desire for long lines – with finite means – is conducive to large gaps. It also inflates the spacing between subwoofers, which in turn limits the array's usable (artifact-free) frequency span.

Without a significant haystack; that is, a low-frequency extension rather than low-frequency emphasis, this is perfectly acceptable. The very same un-optimized frequencies are delivered by the main PA instead, but it imposes a cap on the subwoofer level (relative to the mains).

However, whenever a haystack is desired – the rule rather than the exception – one should factor this into the design of the horizontal subwoofer array. Specifically, the spacing between the elements.

I'll close by noting that I've never been able to make a horizontal subwoofer array work with less than six positions, regardless of how many elements are placed in each position. And I've never been able to successfully spread a horizontal subwoofer array beyond 120 degrees (almost a perfect square) without tearing it apart. LSI

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