Question: Why Line Arrays?

First, **what's the goal** with any quality sound system? To **provide well-defined, full-frequency coverage as consistently as possible from seat to seat**. However, traditional speaker cluster approaches have been inherently limited in their ability to address this goal because of interference created by the interaction between the cabinets.

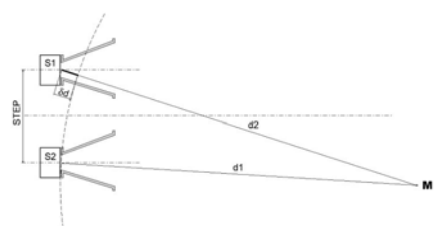
The solution? Provide a system with better sound (less comb-filtering), better coverage (more even) and more efficient use of amplifier power. Here's the overview:

Issues:

1) Covering large audiences with sufficient SPL requires multiple loudspeakers (one speaker, theoretically the ideal solution, can't produce the necessary SPL or coverage).

2) Traditionally, this means multiple trapezoidal enclosures, arrayed as compactly as possible, with each enclosure covering a specific area. This is an attempt to minimize destructive coverage pattern overlap (which causes time-arrival/phase anomalies and results in comb-filtering, uneven frequency response, poor intelligibility, etc.) The result is the traditional fan-shaped multi-tiered trapezoidal speaker array.

3) Even with tight pattern control, pattern overlap between adjacent devices still occurs, causing frequency- and position-dependent interference (comb filtering) because of differing path lengths and signal arrival times. The resulting cancellations cause wide variations in frequency response and SPL from seat to seat.



4) Another inherent limitation of the fan-shaped array is that only one set of components should be directed to a given audience area in order to minimize pattern overlap. Overall SPL is therefore limited by the capabilities of that component set. Attempts to increase SPL to a given area by directing multiple sources to the same audience area (in essence, flattening the array) results in increased phase cancellations from the overlapping patterns (comb filtering).

5) Traditional systems project a spherical wave front that expands evenly in both horizontal and vertical planes. Sound pressure level (SPL) obeys the inverse square law, which indicates that SPL will decrease by 6 dB for every doubling of distance. The practical effect is that for a conventional system to present sufficient SPL to the back of the coverage pattern, the front of the coverage pattern may be excessively loud.

6) As the number of devices is increased in an attempt to provide sufficient SPL, the various arrival times and phase cancellations result in a "chaotic" sound field. Additional power is thus required in order to overcome the effect of phase cancellations on total SPL within the room.

www.l-acoustics-us.com • e-mail: info@l-acoustics-us.com

Solutions:

1) **The solution to these problems is to create a virtual single sound source**. This theoretically ideal solution, by definition, eliminates pattern overlap, phase cancellation from adjacent sources, etc. However, implementation across the entire audio frequency bandwidth gets complicated.

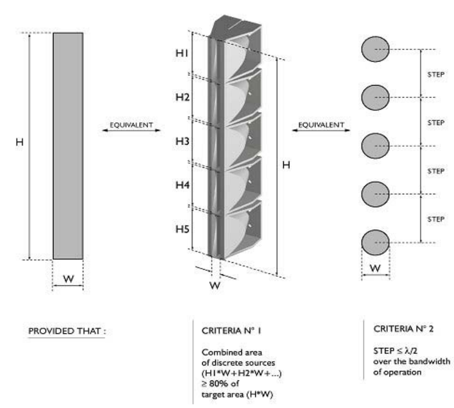
2) Traditional line array concepts were developed by Olson, Beranek and others. **In 1988, Dr. Christian Heil and Professor Marcel Urban embarked on research that resulted in the definition of the conditions required to effectively couple individual sound sources across the audible frequency range, creating the virtual single source**. Relevant parameters include wavelength, surface area of each source, shape of each source, and the relative source separation.

3) An integral part of this research was the use by Dr. Heil and Prof. Urban of Fresnel analysis to understand audio interference phenomena. Utilizing theories developed in the early 1800s (to analyze optical interference) the criteria for **L-ACOUSTICS Wavefront Sculpture Technology®** was established.

4) Dr. Heil and Prof. Urban's March 1992 AES paper (preprint 3269) cites these criteria, which can be summed up in the following:
   - An assembly of sound sources arrayed with regular separation between the sources on a plane or continuous curved surface <u>is equivalent to a single sound source having the same dimensions of the total assembly *if* one or both of the following conditions are met:</u>

     a. The separation between sources (step distance, defined as the distance between acoustic centers of the adjacent sources) is smaller than half a wavelength at all frequencies over the bandwidth of operation.

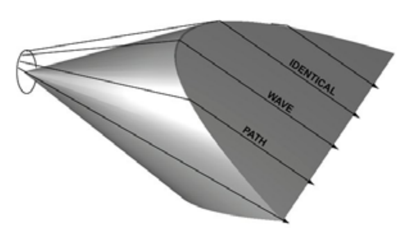
     b. The wavefront generated by the individual sources is *planar* (flat and rectangular, with constant phase across the source's output) *and* the combined surface area of the sources (the Active Radiating Factor) fills at least 80% of the target radiating surface area.



5) Line source array performance and individual loudspeaker enclosure design are tightly dictated by the physics of WST criteria.

6) Physical dimensions of loudspeakers dictate that the low- and mid-range speakers can fulfill the first criteria, but high-frequency compression drivers cannot (physically too large).

7) To couple correctly, the high-frequency section must conform to the second criterion. This led directly to the **patented DOSC waveguide**, which was the first high-frequency device capable of creating a rectangular, constant-phase planar output. Arraying DOSC devices creates a ribbon of high frequencies that act as a single acoustic device. The patented DOSC waveguide is the heart of the L-ACOUSTICS V-DOSC®, dV-DOSC®, and ARCS® systems.

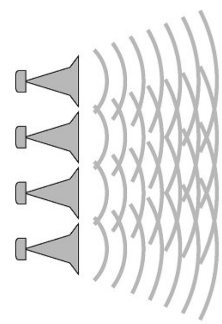


8) **The application of these concepts by L-ACOUSTICS results in a virtual single-element line-source system across the entire frequency range** that can be built and manipulated as necessary to create the desired coverage pattern.

9) With proper application of Wavefront Sculpture Technology, **the cylindrical wavefront generated by the line-source system can decrease at –3dB per doubling of distance (**as opposed to the –6dB per doubling of distance of the spherical wavefront of a traditional point-source system), resulting in much more even coverage from front to back.

Question: Can’t conical or CD horns be arrayed close enough to meet the criteria for line array coupling?

Answer: For the majority of cases, no.



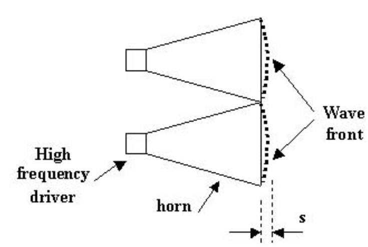
At higher frequencies, the wavelengths over the bandwidth of interest (1 kHz - 20 kHz) are simply too small for adjacent conical or CD horns configured in a vertical column to satisfy the first WST criterion, i.e., it is impossible to have the acoustic centers of sources physically spaced less than half a wavelength over their entire operating bandwidth.

When considering the second WST criterion there are two issues:

First, traditional conical and CD horns typically radiate a spherical wavefront (which appears circular in the YZ plane). As developed in the 2001 AES preprint "Wavefront Sculpture Technology", adjacent circles cannot meet the second WST Criterion at higher frequencies for the following reason:

"For the case of touching circular sound sources, the average Active Radiating Factor is λ/4 =75%. It is therefore impossible to satisfy the first WST criterion and for circular pistons the only way to avoid the secondary lobes is to specify that the maximum operating frequency be less than λ/2. In other words, the diameter of a circular piston has to be smaller than λ/2. While this is possible for frequencies lower than a few kHz it becomes impossible at higher frequencies. For example, at 16 kHz we would need touching pistons with diameters of a few millimeters

Second, the amount of wavefront curvature (in the XZ plane) has to be considered with respect to the second WST criterion. Traditional horns do not generate a flat wavefront (no matter how high the directivity) since the path lengths from the throat to the mouth are different. Again, referring to the 2001 AES preprint "Wavefront Sculpture Technology",



“The deviation from a flat wave front should be less than λ/4 at the highest operating frequency (corresponding to 5 mm at 16 kHz)"

Simple geometric calculations can provide an estimate as to how high in frequency conventional conical or CD horns will couple properly. Typically, this is approximately 6 - 8 kHz and coherent coupling over the entire high frequency operating bandwidth is not obtained. As a result, the coverage patterns from adjacent horns will overlap causing frequency- and position-dependent interference. A vertical column of conical or CD horns therefore does not meet either of the two WST criteria for coherent line-source coupling.

The patented DOSC waveguide meets the 80% rule and presents a planar wavefront with constant time-aligned path lengths for all frequencies being emitted by the device.

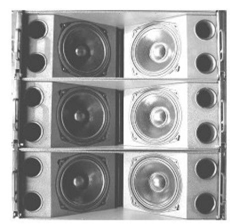
Question: What's so different about the "near-field" aspect of line arrays?

Answer: An interesting benefit of line source arrays is the extension of near-field performance. The immediate result is much more presence from the system, as the direct to reverberant ratio is increased. In addition, as mentioned above, SPL decreases at half the rate as traditional spherical wavefronts, since the cylindrical wavefront expands only in one plane. Instead of being dictated by inverse square law attenuation (SPL decreases by 6dB over doubling of distance), the near field of a properly designed line-source array decreases at 3dB per doubling of distance. Traditional systems radiate a spherical wavefront (constantly expanding both horizontally and vertically), while line-source arrays radiate a cylindrical pattern (constantly expanding in only one plane). The transition from near field to far field (where inverse square law applies) is dictated by frequency and the number of units in the array, and can be easily predicted.

What extended near-field coverage means practically is **coverage is much more even from the front of the coverage area to the back**. Therefore, the folks up front won't need to be blasted in order to present sufficient SPL to the folks in the back of the coverage pattern. **Spectral balance is also preserved with distance**, since mid- and high-frequency cylindrical attenuation properties help offset air absorption losses.

Question: Why are components in V-DOSC and dV-DOSC mirror imaged?

Answer: The L-ACOUSTICS innovation of coplanar arrangement of drivers in both V-DOSC and dV-DOSC cabinets **reduces off-axis lobing** at crossover frequencies, resulting in even, predictable horizontal coverage. In effect, the coplanar arrangement emulates the performance of coaxially loaded spherically radiating devices. The benefits of coaxially mounted drivers are also illustrated in other products in the L-ACOUSTICS line.



Question: Line-arrays get beamy at higher frequencies. Is this a problem?

Answer: The trick is to control the coverage of the system's wavefront by bending the array over the entire frequency band, without affecting the full-frequency single-source performance of the system. L-ACOUSTICS' **Wavefront Sculpture Technology was the first successful modern implementation of full frequency coverage manipulation for line source systems**, a direct result of the development of the patented DOSC waveguide and extensive experience with pattern control.

Projecting high frequencies over long distances has traditionally been a problem, since these frequencies attenuate dramatically due to air loss over distance. The traditional approach has been to use multiple high-frequency horns and drivers in order to compensate for the spectral imbalance created by this loss. However, this approach has inherent problems, as indicated above. By utilizing the performance characteristics achieved with the extended near-field (due to the full-frequency cylindrical coverage pattern created by DOSC-based systems), more high frequency energy is available. This translates to more consistent spectral balance over long distances than traditional system designs (as noted above).

Question: Anybody can build a line array - what's so special about L-ACOUSTICS?

Answer: The physics involved with building a line array have been known for decades. **L-ACOUSTICS was the first to develop both the criteria required for successful full-frequency implementation, and the devices necessary to deliver a broad frequency-response solution,** so that **the entire system acts as a single acoustic source**. This was defined and implemented as L-ACOUSTICS **Wavefront Sculpture Technology (WST).** The first line-source array element design based on WST criteria, V-DOSC, set the standard in line-source array performance. While anyone can assemble an array of acoustic devices in a column, the challenge is assembling an array of sources that act acoustically as a single device over the entire frequency band. L-ACOUSTICS has more experience with this than any other major manufacturer. In addition, L-ACOUSTICS' ARRAY software allows array performance to be accurately modeled and the coverage accurately predicted.

To Conclude…

The benefits of line source array systems are apparent to many, as evidenced by the number of major manufacturers who have jumped on the bandwagon recently. The even, predictable coverage pattern provides an efficient, clean solution to today's system designers. The performance of the V-DOSC system has benefited concertgoers for many years. Paying attention to the physics, time coherency, phase coherency, and reliable design tools are all elements of every product within the L-ACOUSTICS product line. Products now include the industry-standard V-DOSC, dV-DOSC, and ARCS systems, a variety of subwoofer systems, and 8", 12" and 15" two-way systems utilizing coaxially mounted compression drivers.

There is a reason touring professionals worldwide specify L-ACOUSTICS systems. Hear why, and call us for additional information.