LINE ARRAYS

VERSUS LINE **SOURCE** ARRAYS

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INTRODUCTION

There is a big difference between a line source array and a line array. We hope to elaborate on this throughout the course of this article following an analysis of the limitations of conventional horn-loaded systems and a description of the technology behind V-DOSC, dV-DOSC and ARCS that we term Wavefront Sculpture Technology? (WST?). WST refers to the design of a variable curvature line source array whose shape has been tailored to match the audience geometry. Essentially, it is a combination of the ability of line source arrays to generate cylindrical wavefronts plus proper focus of the system that provides even SPL distribution and 3 dB attenuation per doubling of distance.

During the summer of 1993, L-ACOUSTICS launched a new breed of sound system based on principles which had fallen into disuse since they were not considered applicable in the domain of high-end audio. What L-ACOUSTICS offered was not only a new look at these principles, but also the scientific expertise to establish the working limits of a line source. This was the origin of the WSTcoupling criteria which would eventually revolutionize the approach and future of the sound reinforcement industry.

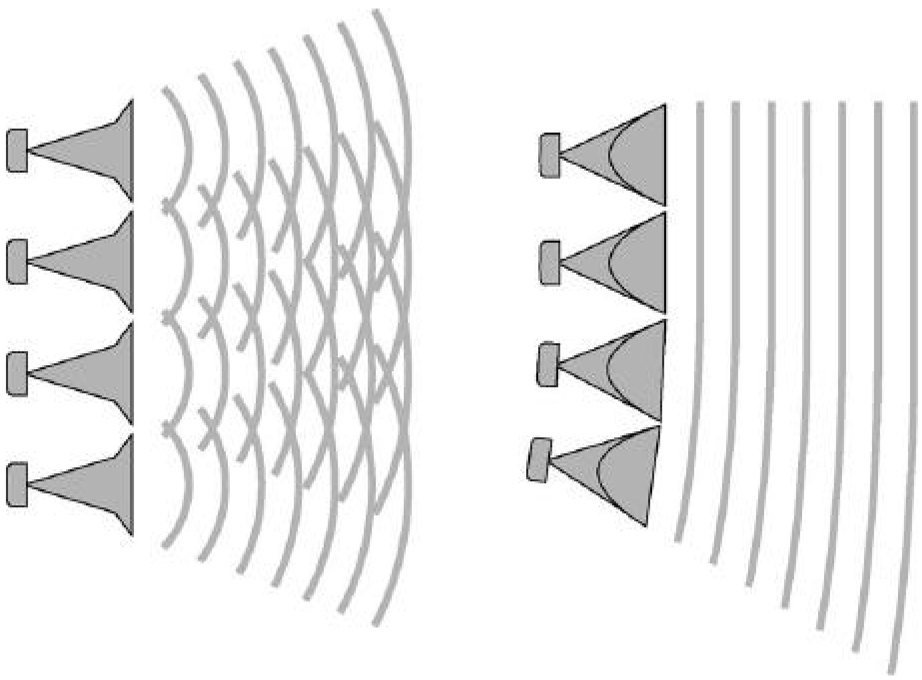
The commercial introduction of this system, however, turned out to be a delicate operation, as it put the prevailing ideas of the day into serious question. Until the advent of WST, no one had experienced a Fresnel field (near field) and a Fraunhofer field (far field). No one else was talking about the propagation of a cylindrical wavefront, the decreasing of sound pressure level by 3 dB per doubling of distance, or angular coverage in fractions of degrees. Basically, everyone was interested in the individual properties of loudspeakers, but L-ACOUSTICS introduced the idea of a collective concept associated with a group of modular speaker elements. It was an entirely new discussion, a different way of working and the results went beyond the scope of what was currently accepted in the industry. New ideas are sometimes difficult to embrace, and so we sought to find a way to slowly introduce this technology, while getting it to be progressively accepted by the major players in the pro audio field.

Today, as a result of the success of our approach, some manufacturers eventually saw that they had no choice but to get in line with their version of the concept. What is distressing is to see certain companies who not only imitate beyond what is flattering, but who also are attempting to appropriate the nature and origins of our concepts for themselves. Fortunately some maintain their proprietary concepts and specifications and it is important for the consumer to understand that there is a difference between reality and marketing-speak. Our experience with V-DOSC is backed up by facts, not only promises.

WHAT'S WRONG WITH CONVENTIONAL SYSTEMS

The trend in sound reinforcement has been to increase both the actual SPL during concerts and the size of the audience to be covered. This inevitably leads to an increased number of loudspeakers since more powerful single loudspeakers would reach such sizes and weights that their transport, handling and installation would simply not be practical.

In practice, conventional horn-loaded loudspeakers are typically assembled in a fan-shaped array following the angle determined by the horizontal coverage angle of each enclosure in an attempt to reduce overlapping zones that cause destructive interference. With this type of arrangement, the maximum clarity available in one direction can only be provided by the individual enclosure facing in this direction. Attempts at "flattening the array" in order to achieve greater throw and higher sound pressure levels results in severe interference in an uncontrolled way, affecting coverage, pattern control, intelligibility and overall sound quality. Even when arrayed according to specification (the trap angle of the enclosure is always an ''optimum'' compromise since the polar response of individual horns varies with frequency), the sound waves radiated by individual loudspeakers do not couple coherently thus the conventional system approach is fundamentally flawed. Furthermore, the chaotic sound fields created by interfering sound sources waste acoustic energy, thus requiring more power than a single, coherent source would in order to achieve the same sound pressure level.



Conventional System Versus WST-Based System

WST CRITERIA

As early as 1988, a preliminary system named "DOSC" had proven the feasibility of V-DOSC. From this experimental concept, theoretical research was undertaken by Professor Marcel Urban and Dr. Christian Heil. The results of this research were presented during the 92nd AES convention in Vienna, March 1992 (preprint n°3269).
The theory that was developed defines the acoustic coupling conditions required for effectively arraying individual sound sources. Relevant parameters include: wavelength,

the shape of each source, the surface area of each source and the relative source separation.

In brief, the coupling conditions can be summarized as follows:

An assembly of individual sound sources arrayed with regular separation between the sources on a plane or curved continuous surface is equivalent to a single sound source having the same dimensions as the total assembly if one of the two following conditions is fulfilled:

1) Shape: The wavefronts generated by the individual sources are flat and the combined surface area of the sources fills at least 80% of the target surface area.

2) Frequency: The step or source separation, defined as the distance between the acoustic centers of the individual sources, is smaller than half the wavelength at all frequencies over the bandwidth of operation.
These two criteria form the basis of Wavefront Sculpture Technology™.

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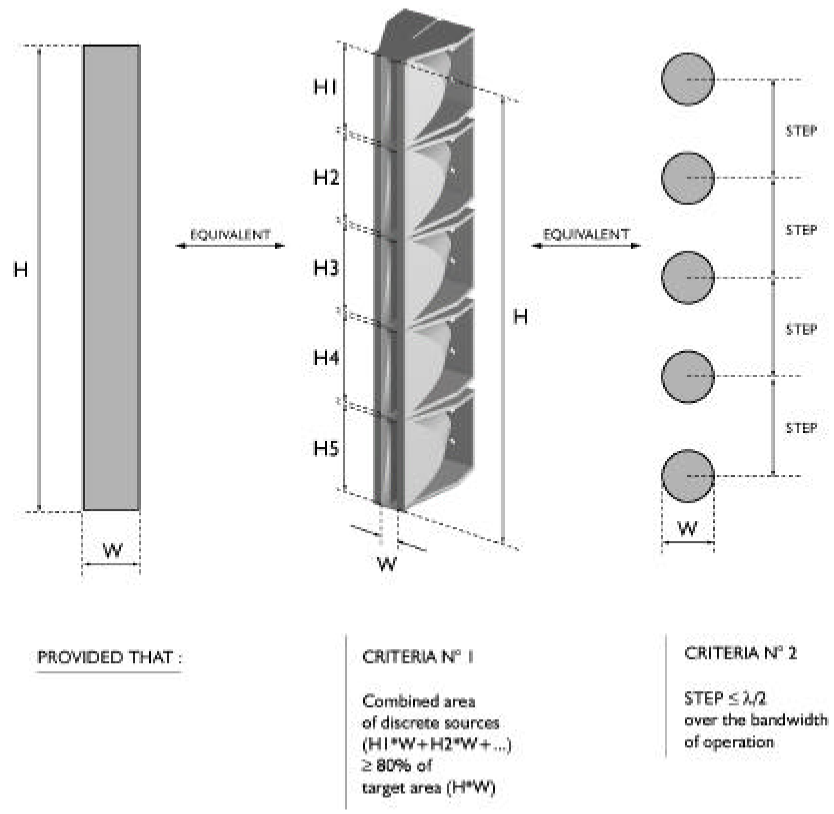


Wavefront Sculpture Technology Criteria

V-DOSC - THE SOLUTION

V-DOSC is the first exact embodiment of the principles of Wavefront Sculpture Technology. V-DOSC stands for "Diffuseur d'Onde Sonore Cylindrique" – in English this means Cylindrical Sound Wave Generator. The "V" in V-DOSC refers to the V-shaped acoustic lens configuration employed for the mid and high frequency sections.
V-DOSC was designed as a system consisting of identical, vertically-arrayable elements. Individual transducers are physically arranged within each enclosure so as to meet WST criteria, frequency band by frequency band, when the enclosures are arrayed together. Each element radiates a flat iso-phasic (constant phase) wavefront, allowing the overall

assembly of multiple elements to produce a single extended sound source. Since the angle of separation between adjacent elements is adjustable, the wavefront can be focused by physically shaping the array. Through successful coupling over the entire audio frequency range, V-DOSC produces a consistent wavefront over a large area with very little fluctuation in frequency response and sound pressure level.

The heart of the V-DOSC and dV-DOSC systems is the internationally patented DOSC waveguide. Essentially, the DOSC waveguide permits fulfillment of the first condition of WST for frequencies higher than 1.3 kHz, i.e., the wavefronts generated by individual DOSC waveguides are planar and their combined surface area accounts for at least 80% of the target surface area. The real key towards satisfying Criteria 1 is that the wavefronts generated by the individual components must be flat in order for the sources to couple coherently and herein lies the key difference between a line source array and a typical line array.

LINE SOURCE ARRAYS VS LINE ARRAYS

To get speakers or horn-loaded devices to couple, the components need to be located with a separation of less than half the wavelength at the highest frequency of their operating bandwidth. This is fairly easy to accomplish at mid and low frequencies but because it's physically impossible to get the acoustic centers of two HF drivers that close together, L-ACOUSTICS designed an acoustic lens which produces a flat radiating ribbon of sound, allowing the high end to couple properly. We use a conventional HF driver, but attached to that is a waveguide that manipulates the path lengths of the sound produced by the HF driver, so they all arrive at the exit point simultaneously. Under these conditions, an array of multiple drivers can satisfy the second criteria of the WST.

If you theoretically divide the circular opening of the V-DOSC compression driver into a series of infinitely small point sources and look at all the possible path lengths from the exit of the compression driver to the rectangular exit of the DOSC lens, you'll find they're all the same length. So the lens is like a time alignment plug or an acoustic transformer - it's transforming a circle into a rectangle. This lens' shape looks a little like an axe or tomahawk head, but it's actually a unique geometrical shape - it's the only shape that'll do that transformation and that's why it can be patented.

If you look at conventional horns - a conical or a constant directivity horn - just from a simple path length analysis you can see there's curvature associated with the wavefront radiated by the horn (not all the path lengths are the same from the driver to the exit of the horn). And that's at one frequency alone. Since individual polar patterns of conventional horns vary with frequency the curvature of the wavefront is also changing with frequency. So a vertical column of those horns is not going to couple in the same way as the DOSC waveguide. That's why we say a line array could be anything configured in a vertical column, but a line source array is something that's coupling properly in the high end and approximating a line source. Once we start talking about variable curvature line source arrays and matching the coverage of the system and SPL distribution to the audience geometry, then we're talking about Wavefront Sculpture Technology (WST).

To summarize, for traditional horn-loaded line array type systems, coherent summation is simply not possible at higher frequencies because the wavelength becomes progressively smaller than the physical separation between horn and driver assemblies and there is curvature associated with the wavefront radiated by the individual horns. If the amount of wavefront curvature is greater than half a wavelength then adjacent horns will not couple coherently and neither of the two WST criteria can be satisfied.

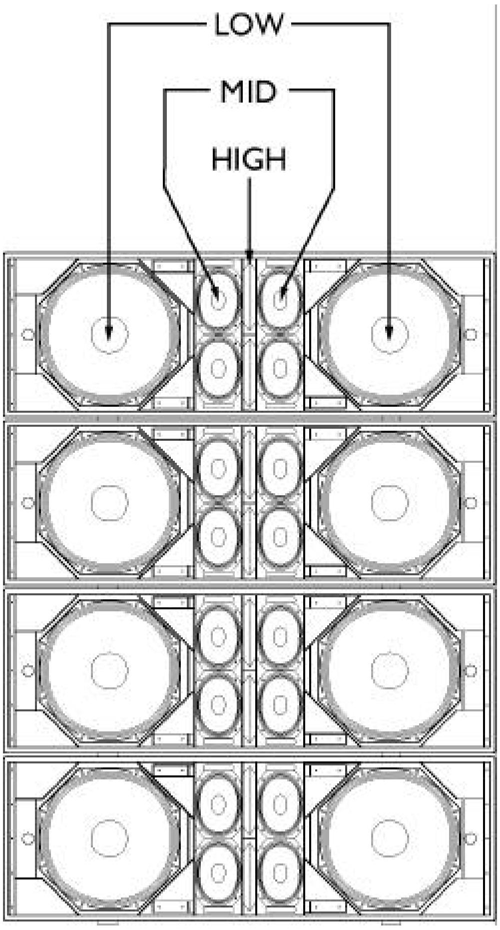
WST-BASED SYSTEM PROPERTIES

V-DOSC elements are vertically arrayed in two or four characteristic "J" shaped columns. Since elements of the array couple coherently, the enclosures are physically smaller and fewer cabinets are required in comparison with conventional systems. This makes V-DOSC very cost effective for touring sound applications where transport space and handling time means money. These properties also make V-DOSC and dV-DOSC highly effective for fixed installation where compact size combined with predictable coverage is important.

WST-based systems have 4 key benefits:

1. The first key benefit of WST is the **PREDICTABILITY OF THE WAVEFRONT'S SHAPE**.
   Horizontally, the entire V-DOSC array has the same coverage angle as a single element (90°). Vertically, the coverage is directly determined by the number of arrayed elements and the specified angle of separation between them. Given this predictability, vertical coverage can be optimized to match specific audience area requirements. A quick, user-friendly CAD spreadsheet – specifically developed for V-DOSC or dV-DOSC by L-ACOUSTICS – helps the operator to determine how to focus the wavefield so that tonal balance and sound pressure levels are evenly distributed throughout the listening area. Using this program, array design can be conveniently performed on a case-by-case basis to optimize coverage for each venue according to the specific audience layout.

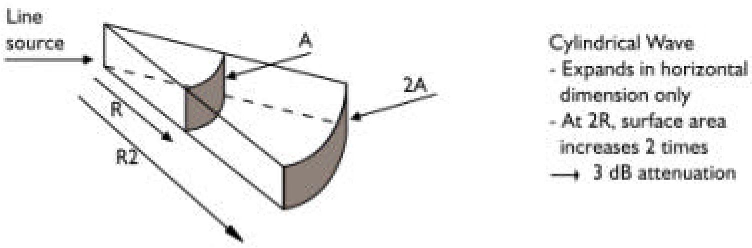
   The configuration of transducers in a V-DOSC element is symmetrical with respect to the plane of propagation of the wave, i.e., the plane bisecting the horizontal coverage angle. High frequency transducers are located in the middle, mid frequency transducers are on both sides of the high section, and low frequency transducers are laterally positioned on both ends. Such a configuration is described as having COPLANAR SYMMETRY.

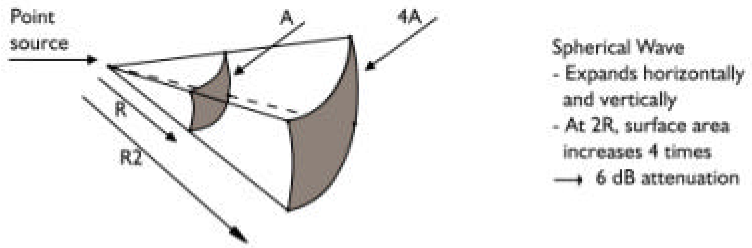


Coplanar symmetry is the cylindrical domain equivalent of the coaxial arrangement for individual (spherical) sources. Essentially, coplanar symmetry allows for homogeneous coverage of the sound field at any listening angle over the V-DOSC array's 90° horizontal coverage window. Coplanar symmetry also eliminates off-axis acoustic cancellations at crossover frequencies so that polar lobbing is not an issue. Psycho-acoustically, coplanar symmetry is largely responsible for the exceptional stereo imaging properties that are characteristic of V-DOSC. Any line array which doesn't have coplanar symmetry won't enjoy that sort of uniformity.

The 90 degree horizontal coverage is independent of the number of vertically arrayed elements and is very stable from 630Hz to 18kHz. In fact, if you looked at individual polar patterns of a V-DOSC element you'd find that each frequency plot would virtually overlay each other. So we take an average of the individual polar plots and re-plot the data on a linear scale (which we call an iso-contour or constant SPL contour) so that we can look at the coverage of two left/right arrays and get an idea of the stereo imaging from the amount of overlap between them. We can play around with the pan of the two arrays to get a bigger or smaller stereo zone. But bear in mind, these are the -6dB contours, so even if you're over to one side actually on axis to one of the arrays (and not inside the overlap stereo zone), you're still getting energy from the other array at a reduced level. And, because you've got two extremely coherent sources, you've got a good chance of getting decent stereo imaging. In fact, most people say the impression is of sitting in front of near field monitors. Another trick to provide even more of the audience with a stereo image is to introduce off stage fill arrays. With four arrays we can cross pan L/R, so you have stereo imaging for more of the audience while also increasing the overall horizontal coverage of the entire system.

2. Another significant benefit of V-DOSC is the fact that **THE SYSTEM EFFECTIVELY EXTENDS THE NEAR FIELD REGION AT HIGHER FREQUENCIES**.
   For flat V-DOSC arrays, this results in a 3 dB reduction in SPL with doubling of distance as opposed to the 6 dB reduction that is typical of conventional systems. This property arises due to the physics of cylindrical waves versus spherical waves.





This means that V-DOSC should not be evaluated in terms of the classical "$ / kilowatt"-ratio, i.e., due to it's ability to perform Wavefront Sculpture, V-DOSC has different attenuation properties than conventional systems. Comparing SPL predictions according to standard calculations is not meaningful since V-DOSC produces a combination of cylindrical and spherical wavefront propagation that must be evaluated using specific calculations. For this reason, L-ACOUSTICS is working actively with developers of modeling softwares to develop proprietary modeling capability for WST systems as a complement to our proprietary ARRAY CAD spreadsheet.

3. Apart from these two first benefits, the WST-based systems also generate the **DECREASING OF SOUND PRESSURE LEVEL BY 3DB PER DOUBLING OF THE DISTANCE**:
   When variable curvature V-DOSC arrays are employed there is a combination of cylindrical and spherical propagation. This combined propagation, together with the actual shape of the audience allows the wavefield to be focused so that tonal balance and sound pressure levels are evenly distributed throughout the listening area.

Although pure cylindrical wave propagation is not always in effect, 3 dB reduction with doubling of distance can still be obtained along with extension of the near field.

Psycho-acoustically, near field extension allows one to walk a considerable distance from a V-DOSC system with only a small difference in SPL due to the system's unconventional attenuation rate. Effectively, more of the audience experiences near field listening, enjoying higher fidelity, improved stereo imaging and exceptional clarity. Subjectively, the loudspeakers seem much closer and the sound is ''in your face''. Image localization is towards the action on stage - not the loudspeaker arrays. Practically, this extension of the near field means that extreme sound pressure levels are not required close to the system in order to provide acceptable SPLs further back in the audience - this is a highly desirable property that also results in reduced potential for hearing loss for both audiences and engineers.

Near field extension, combined with the precision and predictability of V-DOSC coverage is also effective in "pushing back" the barriers of the critical distance in highly reverberant spaces (critical distance is defined as the distance where the energy of the direct sound is equal to the reverberant energy). In many situations, it is extremely important to keep energy off the roof, for example in outdoor sheds, amphitheaters, and arenas. If we can excite less of the reverberant energy in the room and focus more energy on the audience, we can effectively move back the critical distance in a given room. Given the well-defined vertical coverage of V-DOSC, the advantages of WST become immediately obvious when working in difficult rooms.

4. The last benefit… but not the least is the **HIGH DEGREE OF SPL REJECTION** that is obtained outside of the defined wavefield. Nominally as high as 20 dB, this permits the installation of a V-DOSC array behind or above microphones with exceptionally high feedback immunity. Monitor engineers enjoy working with V-DOSC FOH systems since there is very little backwave on stage - even at lower frequencies due to the coplanar symmetric arrangement and the vertical line array configuration of the low section.

High SPL rejection outside of the defined coverage region also makes V-DOSC an excellent solution in situations where environmental noise control is an issue, for example, in situations where outdoor venues are located close to residential areas.

THE V-DOSC NETWORK

L-ACOUSTICS opted for a measured distribution of the V-DOSC system within the rental market, with particular emphasis on education and technical support. The V-DOSC Network was built up bit-by-bit, adding a few new members each year. The companies that purchased V-DOSC systems were welcomed by L-ACOUSTICS and Cox Audio Engineering for their capability to integrate and assimilate new technologies, for the quality of their staff, and for their high degree of representation within the rental market. Today, the V-DOSC Network is a force of more than 60 suppliers of highly specialized services, who are market leaders among the best in their field, and are located all across the globe. Together they form an extremely structured, organized and well-trained Network which offers more than 2,500 interchangeable V-DOSC cabinets.

Rental companies don't invest in new technology for the sake of a manufacturer - they make a strategic technological choice that offers the greatest overall return on their investment. The Network is about having the appropriate partners in their respective market segments, who are able to stimulate and respond to demand as it arises. Indeed, a large part of the success of V-DOSC can be attributed to the Network organization.

Another important contributing factor to the acceptance of V-DOSC and WST is the focus on training of specialized personnel to operate this technologically sophisticated system. But sophisticated doesn't necessarily mean complicated. When we're dealing with directivity that is accurate to a fraction of a degree, as well as a radically different way of working both in the near field and the far field, it's important to be able to rely on competent people who are not only aware of such technology, but who have also experienced and mastered it. So we place great emphasis on Certified V-DOSC

Engineers (CVE) Training Seminars, which are an important source of scientifically tested information regarding the set-up and operation of the system. Once these operators have been taught how to use the tools that we put at their disposal, operating a V-DOSC system is actually quite simple.

IN CONCLUSION

The introduction of V-DOSC seven years ago started the current trend towards line arrays in the industry and V-DOSC remains the benchmark that others are measured by. During the past 7 years, the V-DOSC system didn't wait to evolve: every year we put forward developments that are the result of the enormous diversity of operations that the system is subjected to. Be it in amplification, processing, construction quality, variety of presets, technical support, modeling tools or rigging, the current vintage contains many enhancements when compared to the original 1993 version. These improvements – undoubtedly – constitute a significant advantage over emerging line array systems.

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