LINE ARRAYS

CONCEPTS AND MODELING TOOLS

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A line array is a stack of loudspeaker systems in a single line. The line is usually curved. Uncurved lines do not have desirable directional patterns for most applications.

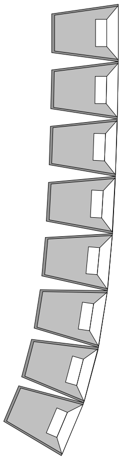

Figure 1. Line array

Most line arrays are oriented vertically, although horizontal line arrays are commonly used for subbass. For a vertical line array, the curvature and length of the array combine to determine the directional pattern of the array in the vertical plane. In contrast, directivity in the horizontal plane depends mainly on the properties of the individual loudspeaker boxes and not on the geometry of the array.

In a basic vertical line array application, two curved vertical line arrays are hung from the ceiling -- one on each side of the stage.

In more ambitious applications, additional arrays ("side arrays") may be deployed pointing offstage, to cover seats to the far left and right. This technique is normally used for large arenas.

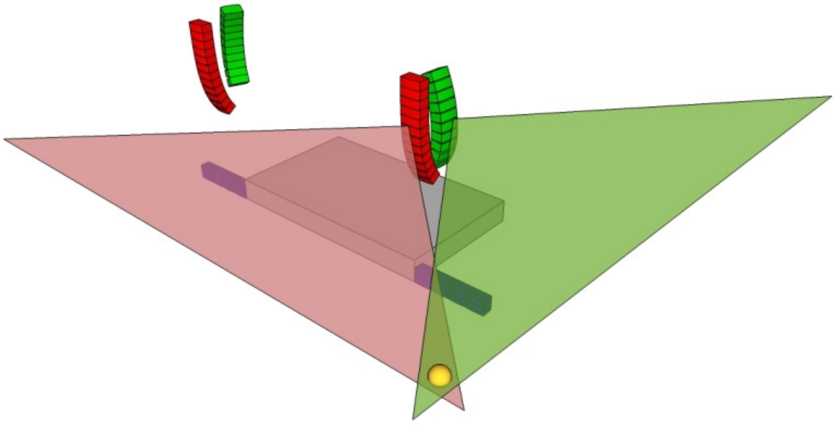

Figure 2. Line array system in arena, showing vertical front and side arrays, stage, and horizontal subwoofer arrays stacked on floor

ACOUSTICS

For a line array loudspeaker system to work properly, the sound waves it emits must be formed in a particular way so as to combine properly with the emitted sound waves of the other loudspeaker systems in the array. Simply arranging conventional loudspeakers into a line would create a line array, but one that would not work at all well over the whole frequency range.

A key element of line array design and use is the selection of what is called the "array face curve". The face curve is the line connecting the centers of the front faces of the boxes when they are configured into an array. The angle between boxes is adjustable; thus, a large variety of face curves may be constructed.

The shape and scale of the array's face curve determine its vertical directional pattern. The goal is to choose a face curve that yields a directional pattern which provides a uniform sound level at all listening positions. For this to occur, the array must compensate for distance by directing more sound to distant positions, less sound to nearer positions.

Selection of the proper set of interbox angles for a particular situation is a relatively complex task. The complexity arises mainly because sound does not behave like light -- one cannot simply point a loudspeaker like a flashlight and have its sound go only to the desired place. The directional pattern of an array is a complex function of its shape and size, and of signal frequency.

For this reason, it has become standard practice in the sound reinforcement industry to use computerized acoustical modeling tools to predict and optimize the directional properties of line arrays in situ. By using these tools properly, the sound system designer can determine the optimum array geometry specifically for the venue of interest. The resulting specification is then used to erect the array.

A brief introduction to array modeling physics is in Appendix A, below.

MECHANICS

In typical installations, a line array may weigh from 100 to 1500 kg or more, and be hung 15m or more above the venue floor. Usually, there are people underneath -- audience, performers, and/or crew. The arrays must be hung at precise heights and tilted at precise angles. In touring applications, array setup and teardown must be quite rapid - for average shows, 1.5 hours or less.

For these reasons, mechanical rigging is a significant challenge, not only because of life safety, but also in the interests of positional accuracy, setup/teardown efficiency, and general ease of use.

In this area, array design software must include functions to ensure that no array design exceeds working load limits or violates other mechanical constraints of the products involved.

SOFTWARE

Background

Commercial line array modeling software was first fielded in the late 1990's, and until recently has evolved fairly slowly. The software was typically developed by the loudspeaker manufacturers and contributed to the community at no cost. Most of it was Excel-based, usually with additional VBA functionality added.

The models used were 2D (i.e. planar) models that displayed simple XY graphs showing directivity and coverage in the vertical plane. They predicted only the direct sound field due to the line arrays, and did not take reflections, reverberation, or absorption into account.

A few more advanced 2D modelers were offered; these were standalone programs (i.e. they were not spreadsheet-based) and used more advanced graphics -- typically false-color plots of delivered sound level in the venue.

For serious acoustic design, third-party 3D modelers were (and are) offered. These modelers are not written by loudspeaker companies, are relatively complex to use, and are expensive. They are engineering software, not end-user tools. The main contenders in this category are EASE and CATTacoustic.

Today

Today, manufacturer-supplied array design software is evolving. Although many of the spreadsheet-based products (including EV's LAPS II and EVADA) are still available, many manufacturers are delivering or thinking about newer options, most of which involve 3D or quasi-3D modeling and user interfaces.

The leader in this area is L-Acoustics, the French company that fielded line arrays fist, in the mid-1990's. The new L-Acoustics modeler, called "Soundvision", offers an attractive 3D interface with clever features for quick sketching of typical venue shapes, an evolving database of pre-entered dimensions for well-known venues, and other features. We do not know if Soundvision contains a true 3D modeler (we suspect it may not), but it is nevertheless an appealing product.

In a departure from previous practice, Soundvision is not free. However, the price is not high --125€ one-time.

Another development is the emergence of OEM-friendly third-party modelers. Software Design Ahnert (SDA) now offers EASE Focus, a generic line array modeler that can be customized to accommodate different product lines. EASE Focus is a 2D modeler with a relatively attractive interface that is still evolving. It offers convenient compatibility features with EASE (another SDA product), the full-function engineering modeler mentioned above.

An emerging question for end-user array design software is that of **platform**. To date, array design software has been offered for Windows and (sometimes) Macintosh platforms. However, with the emergence of high-quality PDA and tablet platforms, it will not be long before users will want hand-held modelers -- particularly in the touring market.

LAPS II and EVADA

In the current market, EV's LAPS II and EVADA stand as relatively well-evolved products, but are obviously aging. Acoustically, their 2D modeling is accurate, and they do a good job of supporting the acoustical and mechanical properties of all EV line array product families. However, their user interfaces are not particularly attractive, and their general level of interactivity is primitive by today's standards. Other than adding support for new products, it will not be practical to evolve the current LAPS II and EVADA products much more.

Appendix A: Array Acoustics and Modeling

We calculate the sound pressure produced by a line array at a given listening point.

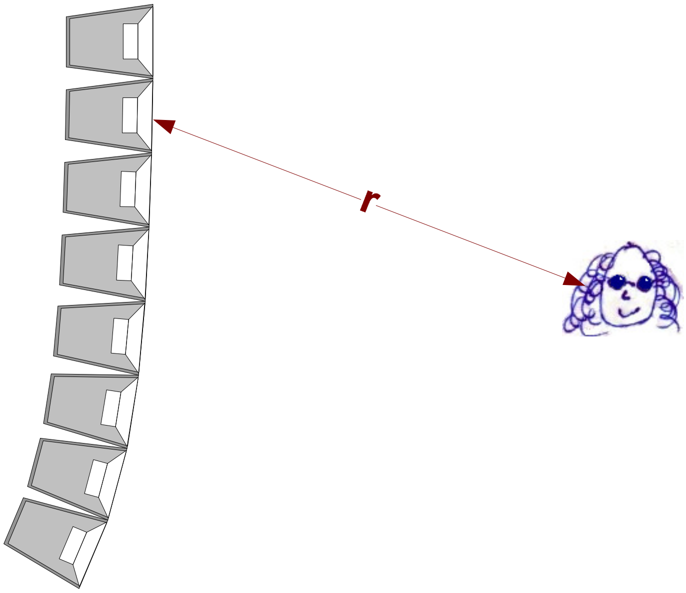

Figure 3. Sound pressure at listening point

The pressure is given by the following formula:

$$p \propto \sum_i \frac{s_i e^{-ikr_i}}{r_i}$$

where

p = total complex sound pressure at given listening point

e = base of natural logarithms = 2.71828...

$i = \sqrt{-1}$

$k = \frac{2\pi}{\lambda}$ (λ = wavelength = $\frac{\text{speed of sound}}{\text{frequency}}$)

s_i = complex amplitude of sound output of i^{th} point on face curve

r_i = distance from i^{th} point on face curve to listener

Summation is for all points on array face curve.
Number of points on face curve is chosen so that adjacent points are less than $\lambda/4$ at the highest frequency of interest. For f = 20kHz, this value is approximately 0.35".

As long as the face curve points are correctly specified, this formula is accurate for all array sizes and curvatures, and for all listening positions. In fact, it is accurate for any sound source that can be characterized by a collection of closely-spaced points.

This is a relatively simple formula. The main challenges for writers of modeling software are:

1. Ensuring that the face curve array is correctly specified. A major hurdle in this respect is the inclusion of cabinet effects. Cabinet effects can be characterized by adding additional points to the face curve array. These points need to have particular amplitudes and phases that are not easy to compute. Most simple modelers ignore cabinet effects. The primary effect of doing so is that the model results will be inaccurate for radiation angles that are far off axis (e.g. behind the array).
2. Computing this formula by brute force in 3D for all potential listening points in the venue is too compute-intensive for ordinary hardware. In 2D, the problem is tractable, but in 3D, more sophisticated algorithms are required to achieve acceptable compute times on normal personal computer hardware.

EV LAPS II and EVADA are brute-force 2D modelers that ignore cabinet effects.

We do not know how competitive programs operate, but we believe that LAPS II's modeling is at least as accurate as any of the other programs of its type.

Another modeling approach is taken by such programs as Meyer MAPP. This approach uses measured directional pattern and frequency response data (aka "balloon" data because of the way it's often plotted using 3D polar graphs) for the individual boxes of the line array. In use, the user describes to the modeler how the boxes are arranged in the array, and the modeler simply adds up the balloon data for all the boxes, taking care to account for phase and amplitude changes caused by the respective position of each box. This method can be quite accurate, but it is compute-intensive. Meyer says they collect 1 gigabyte of balloon data per loudspeaker model, and the summation is done on a small supercomputer of some kind, on the network.