RLA 1 Ribbon Line Array

The unique technology behind a truly coherent line array for high fidelity professional sound systems

Introduction

Line array loudspeaker systems have recently received a high level of attention and have even become fashionable, revolutionizing the very basics of professional sound applications. Although the general concept of line arrays is not new, the contemporary incarnations of this principle represent significantly different loudspeaker systems. This new generation of line array systems aims to benefit from very specific radiation properties, exhibited by an ideal line source radiator. A line source radiator has unique and highly desirable features such as: lower SPL reduction with distance than a normal system and far superior dispersion control in the vertical plane (if the line is oriented vertically). These unique characteristics render line arrays as a separate and unique class of loudspeaker systems.

In spite of their growing popularity in professional and consumer markets, there is a definite complexity in the design and proper application of these systems. A line array that allows for maximum utilization of the benefits of a line source radiator would become a powerful and very efficient tool for the industry. However, a certain degree of misconception of some basic line array principles and specifics is still common. As a result, some of the currently marketed line array systems have quite questionable performance benefits and lower than expected sound quality.

 It must be stressed, that in addition to these misconceptions, horn loaded compression driver technology imposes certain limitations, preventing manufacturers from developing high performance line arrays with truly coherent dispersion. In order to fully benefit from the implementation of the line source concept, a line array system must incorporate transducers arranged in a continuous line that produces a coherent planar wavefront along the entire array. In order to simulate a continuous planar wavefront, a line array design must abandon the concept of simple vertical stack of compression drivers terminated with horns. This requires a radical change in horn design techniques used for decades. However, this is hardly possible due to the very principle of compression driver operation. As a solution, all current designs eventually accept various compromises and incorporate a host of extended sound conduits, phase plugs, fins and various acoustical delay devices. This, according to a manufacturers' literature, supposedly directs and squeezes sound waves into a predetermined shape, with an output wavefront which should eventually resemble a continuous line or planar radiator at the mouth of integrated horn.

The truth is, that the laws of sound propagation are much more complex than a flow of a liquid through pipes, and one can not endlessly reshape sound waves without distorting the original. All this "treatment" further complicates the transition of sound waves in such systems, producing very audible distortion. The necessity to use horn loading at high frequencies is in contradiction with the need of close spacing of midrange drivers for wide and consistent horizontal dispersion. Therefore midrange drivers in turn are also forced into various types of arrangements. In some line array designs they are hidden deep

inside the enclosure behind the high frequency section. Some use a straightforward horizontal separation. Yet other designs put them in the walls of high frequency horn flare behind narrow slots. One compromise leads to another. As a result, these line arrays exhibit little or no resemblance to a truly coherent line source system.

In reality, none of the line array systems which use midrange and high frequency drivers, loaded with complex multistage wave-shaping devices can deliver high fidelity sound and consistent coverage. Very few actually perform satisfactorily. In spite of fierce marketing battles about who's line array design approach is better, the principle compromise common to all of them remains the same, - reshaping of the original sound wavefront through essentially non-linear devices.

While other systems inevitably embrace a design which is a poor approximation of a planar line source, the RLA 1 ribbon line array system from SLS directly uses unique planar ribbon drivers (PRD 1000) which allow for nearly prefect implementation of the line source concept, proving to be the only technically feasible solution for high fidelity line array technology.

During the research and development stage of the RLA 1 design, it was recognized that there is a need for a computer program which would provide an accurate prediction of line array dispersion. The few existing "in-house" programs are either based on an oversimplified approach that limits their usefulness, and/or do not allow for simulation of the very essential near field and transition regions of a line array, but rather describe its performance based on a far field model used for common point source systems. Recognizing this need, SLS Loudspeakers developed the LASS Line Array Simulator Software program. It is an accurate software tool, which allows for simulation of line array dispersion and prediction of sound field parameters throughout the venue. LASS has been used in this paper to produce images and results for the demonstration of line array principles.

Basics of a line array system and its benefits

A line array system concept is derived from line source theory.

An ideal line source is an infinite, thin (narrow) and continuous vibrating element which radiates cylindrical waves. Such a line source has a remarkable radiation property, - its SPL level decreases inversely proportionately to the distance from the source, losing only 3dB with each doubling of the distance. A point source radiator (common loudspeakers are considered to be point source radiators) generates a spherical wave. Its SLP decreases inversely proportionately to the square of the distance from the source, losing 6 dB with each doubling of the distance.
This phenomenon can be understood, considering that expansion of a cylindrical wavefront results in a surface area gain being proportionate to increasing distance, while expansion of a spherical wavefront produces an area gain, which is proportionate to the square of the distance.

Unlike the infinite ideal line radiator, a line source with limited length has limited extension of its cylindrical wavefront zone (near field). Beyond a certain distance, the cylindrical wavefront gradually transforms into the spherical wavefront (far field) and the system

becomes a point source device. The distance, defining a border between the near and far field zones, depends on the line source length and frequency [1]. Fig.1 depicts a generalized diagram of vertical dispersion of a line source with a finite length.
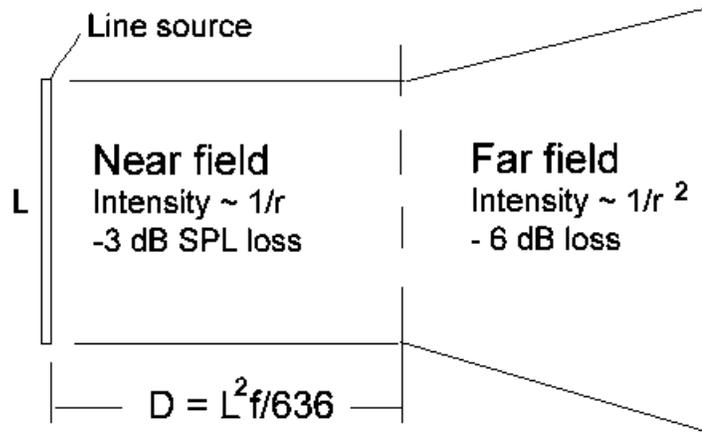

Line source

L

Near field
Intensity ~ 1/r
-3 dB SPL loss

Far field
Intensity ~ 1/r^2
- 6 dB loss

$$D = L^2 f/636$$

Fig. 1
Line array near/far field concept.
D — distance from the line to the border of the far field zone.
For 4m line array D=25m

The benefits of a line source in comparison to a point source system can be stated as follows:

- significantly smaller SPL reduction with distance allows for delivering higher sound volume levels further to the audience
- at a given sound volume level at the back of a venue (for example at 100ft, Fig.2 and Fig.3), a line source at Fig.3 will produce much smaller difference in SPL levels throughout the venue, with SPL being significantly lower in close proximity to the source (18 dB @ 1m, versus 30 dB for the point source). This provides very comfortable listening conditions without the danger of overpowering the audience in the front rows.
- cylindrical wavefront provides very controlled energy dispersion in the plane which coincides with the line source (in most applications this would be the vertical plane), resulting in excellent intelligibility even in a very reverberant environment.
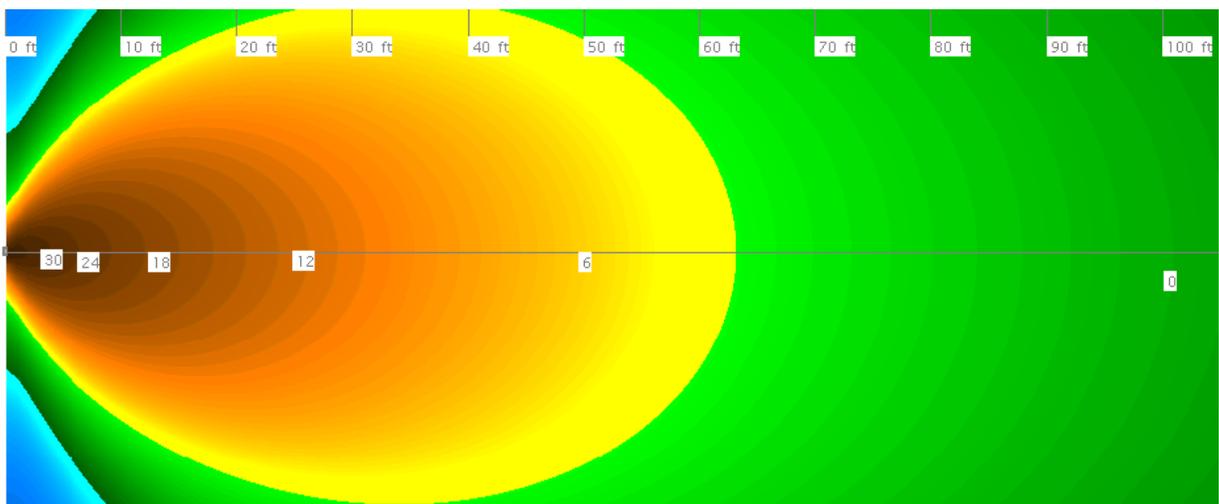

Fig.2 Point source dispersion. A 3 cone driver at 4 kHz. (SPL levels are shown in boxes on the centerline, while distance in feet is shown at the top).
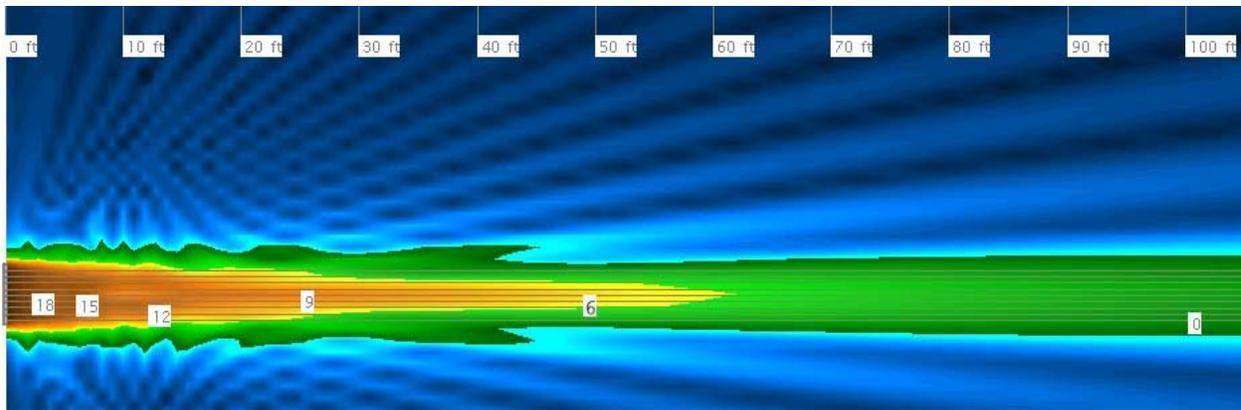
Fig.3 Line source dispersion. 55" high LS 8695 line array system at 4 kHz.

A true line array system is different from a line source in that it consists of a discrete array of transducers and has limited length. In this case, the notion of a continuous line source should be considered in the relationship between line array geometry and the wavelength of reproduced sound.

The primary question defining the proper operation of a line array is whether the array can be considered as a continuous line source over the reproduced frequency range.

Let's consider a discrete line array system as shown on Fig.4 The system consists of a number of linearly placed radiators on a length **L**. **P** is an equivalent radiating piston height (diameter for a circular piston) and **H** is a space taken by each driver or distance between driver centers.
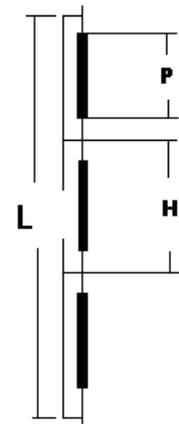
The condition that defines a discrete line array as a line source can be related to two different shapes of the radiating element. It is shown [1], that for circular drivers, proper line source behavior, or "coupling", can be achieved in a frequency range where:

H < λ, where λ is a wavelength at a given frequency.

Fig.4 Line array basic geometry

For example, to fulfill this condition at 5 kHz and above, drivers must be spaced at less than 2.67" (6.8 cm) between centers.

This is a completely unrealistic condition for a practical design.
This means that NONE of line arrays, based on a simple stack of cone drivers, can perform as a line source at high frequencies. If a line array is not properly coupled, the resulting dispersion is far from consistent and exhibits severe lobing along with significant SPL irregularities within the coverage area.

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It is also stated in [1], that only flat rectangular pistons, radiating a coherent planar wave and spaced tightly together, can be combined in a true line source system.

Comparison of existing line array design concepts with RLA 1 technology

Fig.5 shows the comparison of wavefront generation in a typical line array element (one enclosure) in the RLA 1 high frequency section, along with some other current designs which use compression drivers.
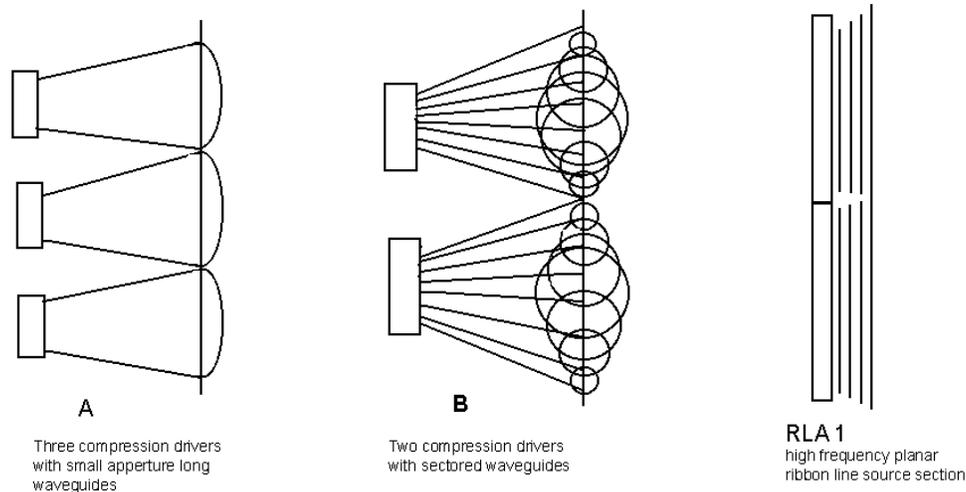

**Fig.5
High
frequency
wavefront
generation
diagram**

A
Three compression drivers
with small apperture long
waveguides

B
Two compression drivers
with sectored waveguides

RLA 1
high frequency planar
ribbon line source section

The picture shows the vertical cross-section of each design.
Design A incorporates long, small aperture waveguides and tightly spaced compression drivers in an attempt to reduce the curvature of the wavefront at the output of a vertical integrated slot. The design has its limitations, because the drivers have finite size and cannot be spaced closely enough. Very long waveguides could also produce wavefronts with lower curvature at a given output height, but the box has limited depth. Such long waveguides also introduce significant distortion in addition to the distortion inherent to compression drivers.

Design B uses another approach. Two compression drivers have sectored waveguides that supposedly generate a plane wave at the output by "slicing" a wave into thin segments and producing a line of secondary sound sources at the output. Instead, due to their different lengths, there is a progressive delay between each channel's output from center to periphery. Therefore, the combined wavefront at the output is still far from flat, having a shape of a sphere segment. Attempts are made in one similar design to introduce a progressively inverse delay from periphery to the centre in order to generate a plane wavefront. However, the only possible solution, – using fibrous materials or open cell foam, does not result in acceptable consistency. Additionally, those materials simply absorb high frequency energy.

Some other line array designs do not attempt to recreate a planar wavefront at all, and simply use a stack of horn-loaded transducers. This inevitably leads to further degradation to the coverage consistency of such arrays.

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The RLA 1 high frequency section has two coupled PRD1000 ribbon drivers which directly radiate sound with a planar coherent wavefront, ideally conforming to the requirements of the line source concept.

In addition to superior wavefront generation, the RLA 1 has a unique but simple design solution for reproducing midrange and high frequency signals with the highest degree of coherency. It is extremely important for producing even horizontal dispersion, to have a symmetrical driver arrangement with sections having coincident axes of symmetry. This leads to the HF section being positioned between midrange drivers. On the other hand, the midrange drivers must be mounted very closely to each other to prevent the system from having narrow horizontal dispersion (beaming) at upper midrange crossover point (typically around 1-1.5 kHz). If a system is beaming in this most critical vocal range, the entire performance will be severely compromised. Line array application techniques require at least 90° nominal horizontal dispersion (at –6 dB) in order to maintain consistent coverage in wide venues. Fig.6 depicts driver arrangement techniques used in line arrays for satisfying these requirements.
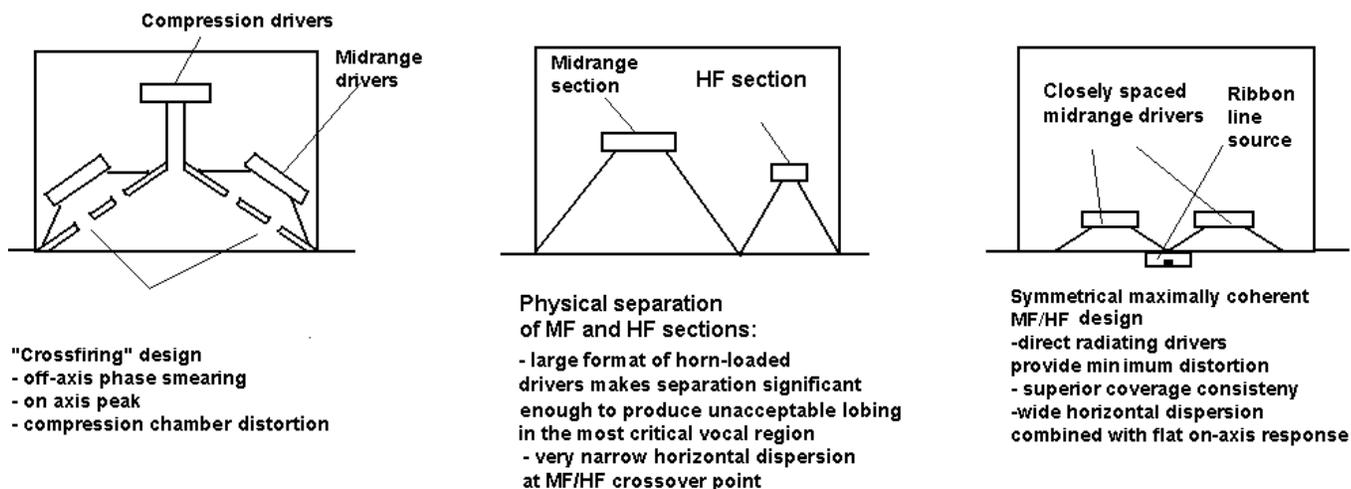

Fig.6   MF/HF arrangement in line arrays. Top view.

The picture clearly demonstrates the advantages of ribbon driver based design. The presence of the ribbon line source element in front of the midrange units creates an additional off-axis shading effect that widens dispersion at extreme angles. Direct radiation is the only acceptable concept in order to maintain low distortion and achieve high fidelity reproduction.

The RLA1 has four 6 _" midrange drivers arranged two horizontally/two vertically.
Close spacing and mutual coupling of MF drivers allow for consistent and wide dispersion and perfectly coherent radiation with the ribbon line source element.
The direct radiating ribbon line source, being only 1 _" wide, has very wide dispersion up to very high frequencies (20 kHz) which is unattainable for any other driver. This provides high quality and intelligibility of sound even at extreme off-axis locations.

Comparison of vertical coverage pattern of the RLA1 and compression driver based line array

LASS Line Array Simulator Software allows for very a vivid demonstration of the difference between ribbon line source concept and other line arrays which do not provide a coherent, flat wavefront.

Below, are images generated for the 10-element RLA1, with each element being 17" high and a 10-element line array of the same size with curved wavefronts. It has been demonstrated [2] that the effect of gaps between transducers very closely resembles the effect of curved wavefronts, when a wavelength approaches _ of the curvature. In fact, it could be geometrically illustrated, that a line array with series of curved wavefronts (Fig.5 A, B) can be modeled with an array of flat pistons with gaps between them. For this particular simulation, a line array with 75% of its radiating area (filling coefficient), was chosen.

The total height of both of these 10-element line arrays is 16.8 feet and a simulation field is extended to 150 feet. Dark lines represent hypothetical listening planes.

LASS allows for generation of SPL distribution diagrams along these planes. The particular line arrangement, depicted below, illustrates SPL coverage consistency along the "venue" on the axis of the arrays and across the coverage zone, along the line parallel to the array, at a distance 60 feet.

It is clear after observing Fig.7 and Fig.8, that the RLA1, being a truly coupled array, has far superior coverage consistency along the venue and across the vertical coverage zone. The level of ripple is significantly larger for the array with less radiating percentage or having radiating segments with curved wavefronts, such as generated by compression drivers. Such an array also has a very irregular and difficult to predict, coverage zone border with noticeable narrowing of the coverage "corridor" with distance.

Another simulation (Fig.9, Fig.10) depicts a vertical view of the same line arrays, shaped in a J-type figure, which is common for sound reinforcement applications. The simulated venue is 157 feet long and is split into three listening areas with corresponding listening lines.
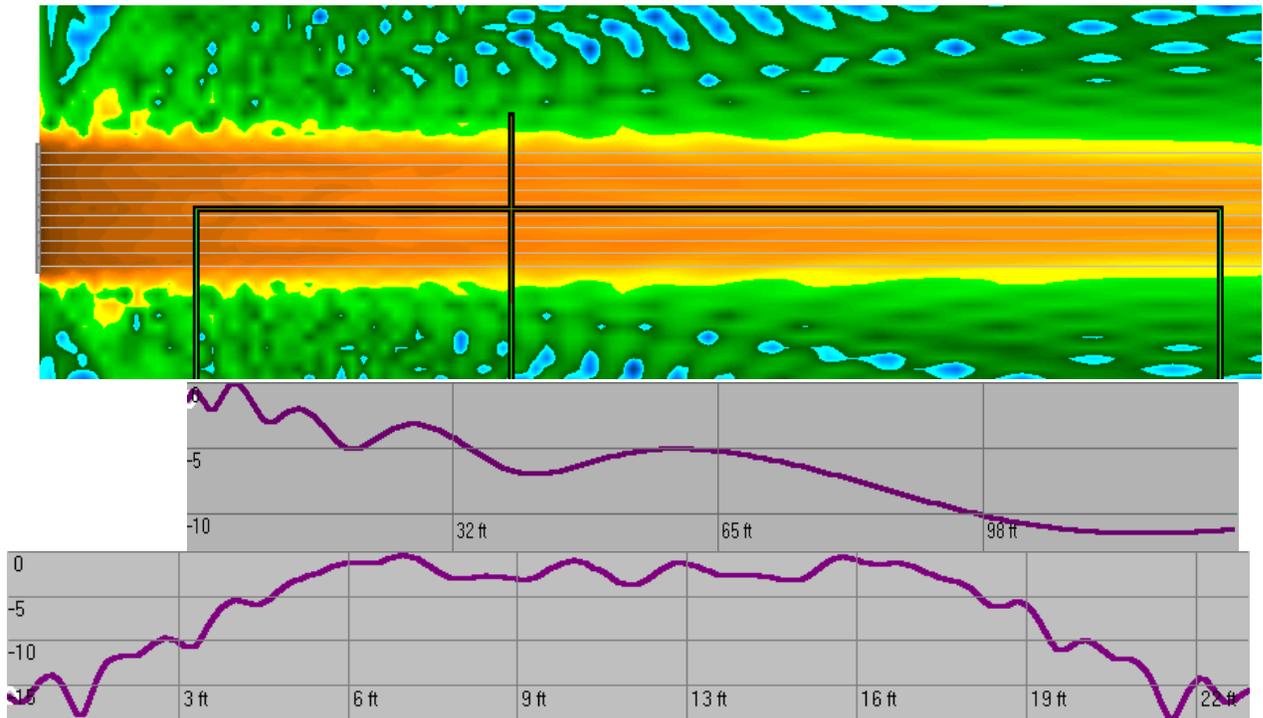
Fig.7 10-element RLA 1 line array, no splay, 4 kHz.
Top graph — SPL along the horizontal line.
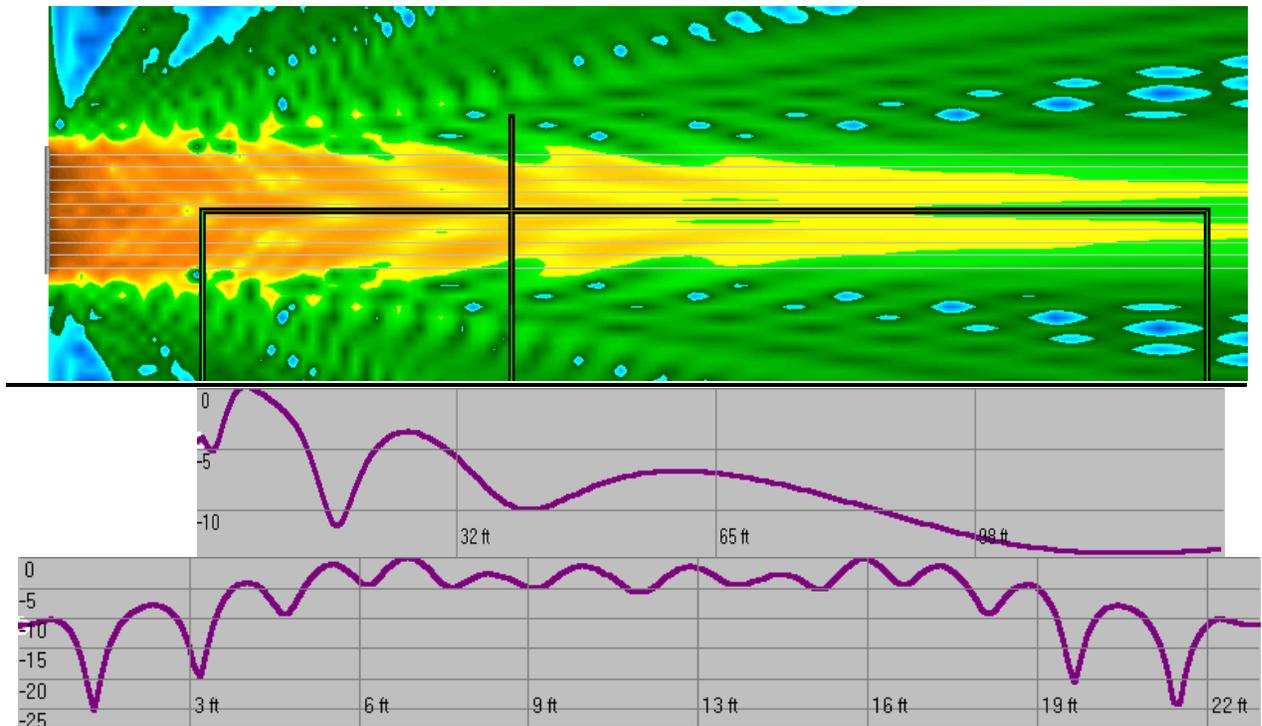**Bottom graph — SPL across the vertical line**

Fig.8 10-element line array with 75% of radiating surface per element, no splay, 4 kHz.
Top graph — SPL along the horizontal line.
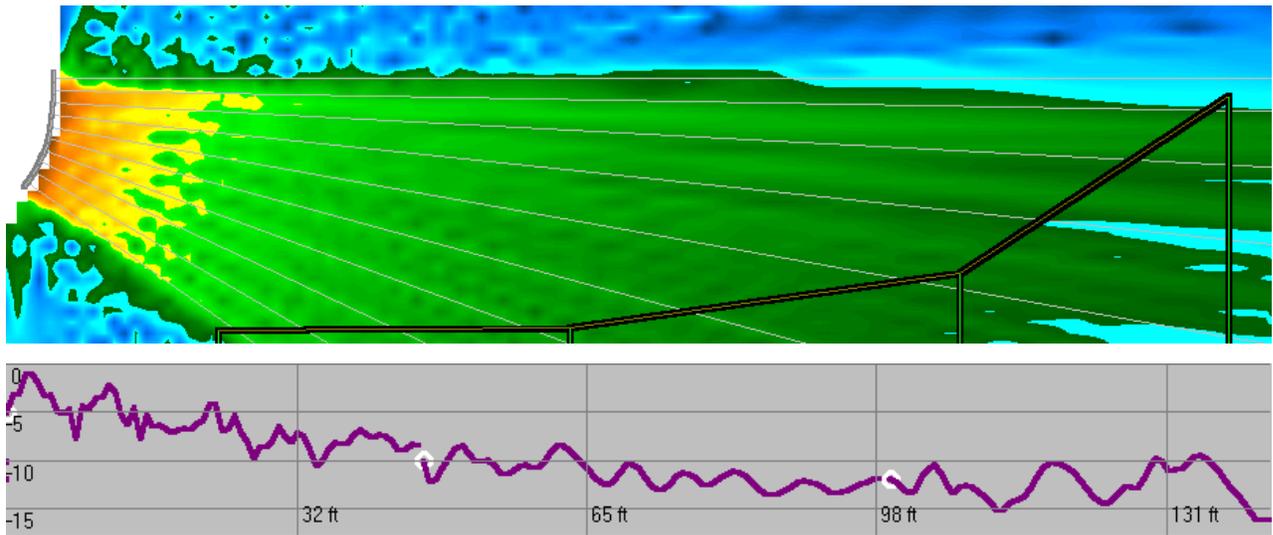**Bottom graph — SPL across the vertical line**

Fig.9 10-element RLA 1 line array, J-shaped, 8 kHz. Bottom graph — SPL along the three sections of the listening line shown at SPL distribution map above.
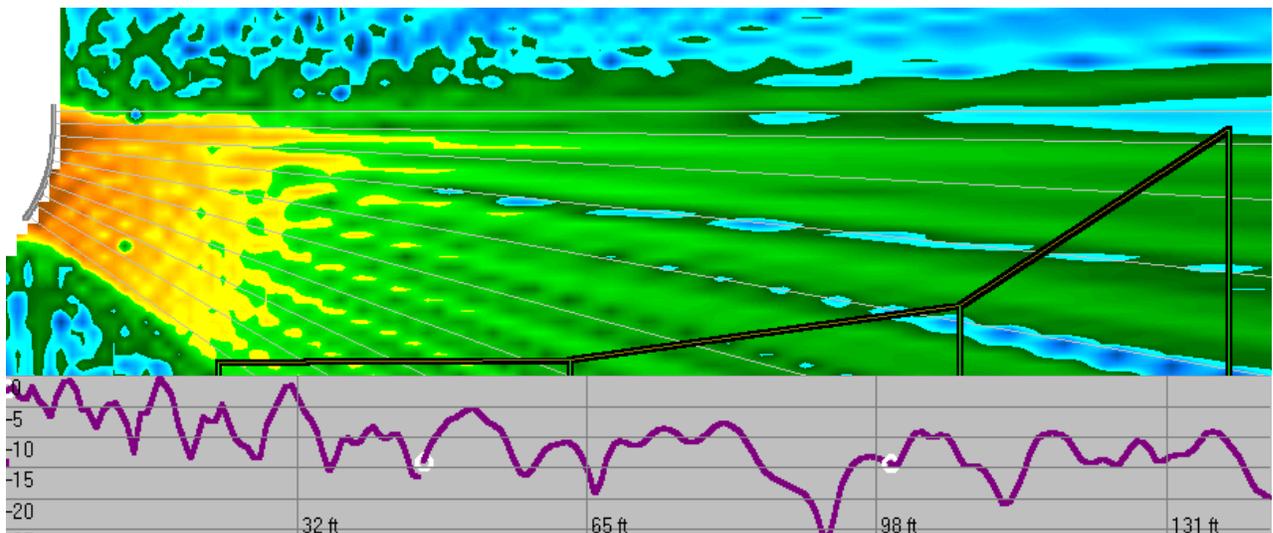

Fig.10 10-element line array with 75% of radiating surface per element, J-shaped, 8 kHz. Bottom graph — SPL across the three sections of the listening line shown at SPL distribution map above.

The RLA1, as illustrated in the above two figures, has much smoother SPL distribution along the venue and less SPL losses, while the other array exhibits significant SPL irregularity, "holes" up to 10-15 dB in level (Fig.10, bottom graph) and noticeable gradual narrowing of coverage at large distances. All signal energy above 8 kHz would have even more dramatic reduction in these areas. In a real situation such deviations would be clearly noticeable, leaving a significant portion of the audience with almost no high frequency information, and in some cases, rendering certain areas within the venue lacking in intelligibility. It is very important to preserve the overall SPL and spectral balance at each frequency throughout the coverage zone. RLA-1 provides significantly better performance and coverage predictability in comparison with other line arrays, based on compression drivers. In cases where an array is not coupled (Fig.10), the coverage zone borders are not clearly defined, with noticeable lobing, off axis "hot" spots and "holes" within the coverage zone.

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Comparison of the results generated by LASS and actual measurements of the 8–element RLA1 array with and without splay between elements

The LASS is a sophisticated CAD tool which allows the user to design an optimal line array layout with a minimum of necessary array elements for specific coverage requirements.

In order to assess the performance of the LASS program and the RLA1 ribbon line array, a series of ground plane measurements were made at a distance of 66 feet (20m). It is necessary to stress that using polar diagrams in their common definition for assessing line array dispersion does not make sense.

A polar diagram is valid when the distance from a microphone to a DUT (device under test) is much larger than the size of the DUT and the point of observation is located in the far field. With line arrays extending up to 10 meters in size and their near field extending up to hundreds of meters at HF, it is a practical impossibility to measure a true polar diagram of a line array. Therefore, polar measurements presented by some manufacturers, provide little meaningful information and may be confusing.

Fig. 11 demonstrates the discrepancy between line array polar diagrams. If we were able to measure polar diagrams of a 3 m long line source at 5, 50 and 500 meters we would observe different polar diagrams for different distances.

Therefore, a line array dispersion diagram, observed along the array's length (in the simplest case this would be vertical dispersion) is a particular characteristic for a particular distance. In other words, if one wants to be accurate, one must consider line array dispersion for each specific distance.
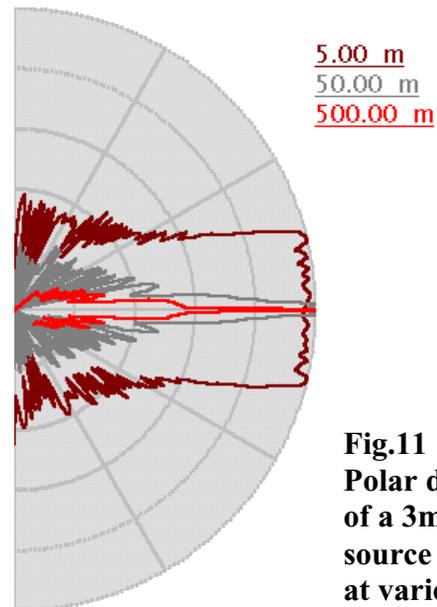

5.00 m
50.00 m
500.00 m

Fig.11 Polar diagrams of a 3m line source at 12kHz, at various distances.

Let's define a **measurement line** (see Fig.12). For meaningful description of line array dispersion at a certain distance, SPL level should be measured along the polygonal line, each segment of which is parallel and equidistant to the corresponding line array element's front panel. The measurement line is straight if the array is straight, or it could be constructed from angled segments corresponding to splayed boxes. In the latter case, each measurement line segment N' must be parallel to corresponding frontal plane of array element N, so that the measurement line is a scaled copy of the array frontal line. Vertex points between segments must be coincident with median lines between splayed boxes. During measurements, a microphone is placed on the measurement line and moved incrementally from its one end point to the other.
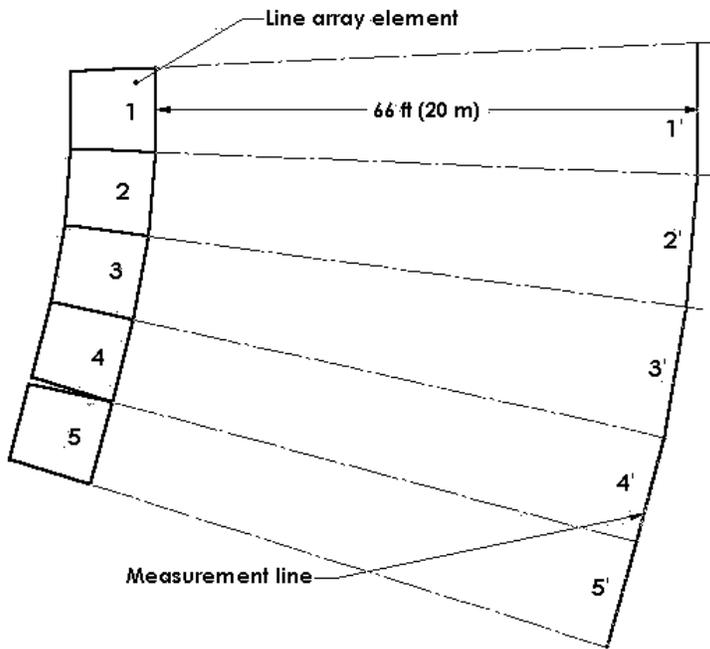
LASS allows for quick and accurate calculation of line array vertical dispersion.

Below is a series of measured and calculated graphs of the RLA 1 ribbon line array. All measurements and calculations where performed for the 8-element RLA1 at a distance of 66 feet (20m). The RLA1 3D dispersion waterfall was measured prior to constructing 2D plots and comparing the results with computer simulated plots.

Fig. 12   A general example of a measurement line geometry.

RLA1 8 boxes
4/18/2002 11:07:36 AM   SLS
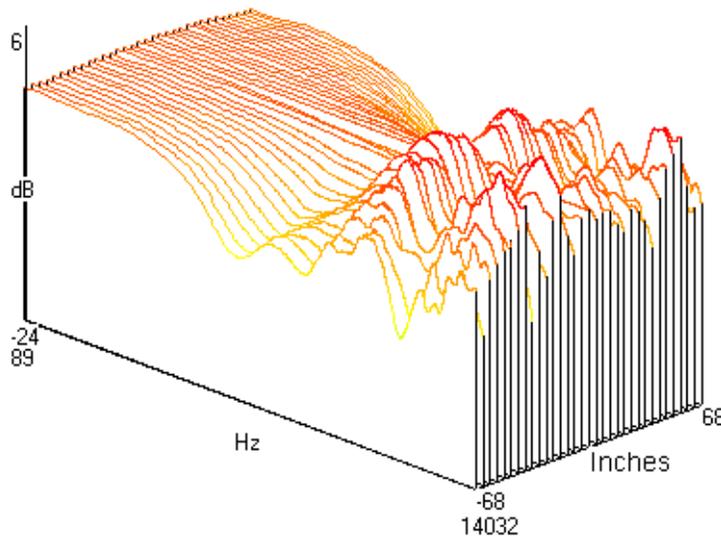8 boxes, straight line, measured at 20 meters
33 sweeps with 4.25'' steps

Fig. 13
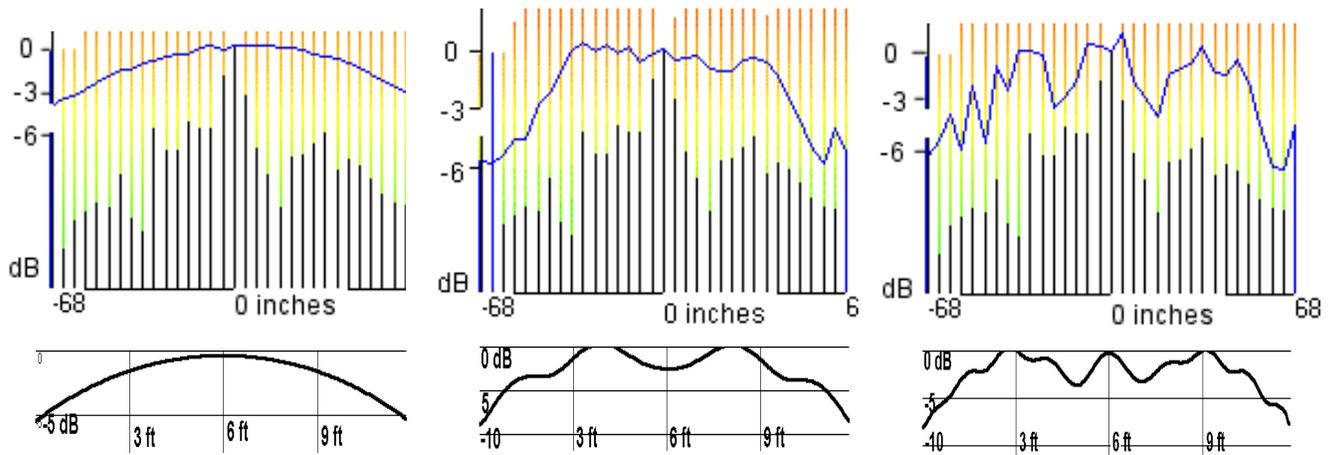**8-element RLA1, 3D dispersion diagram measured along the measurement line, 0° splay, 66ft.**

Fig. 14 8-element RLA1, no splay. Measured vertical dispersion — top graphs. Calculated vertical dispersion — bottom graphs. Left — 500 Hz, center — 2.5 kHz, right — 5 kHz.
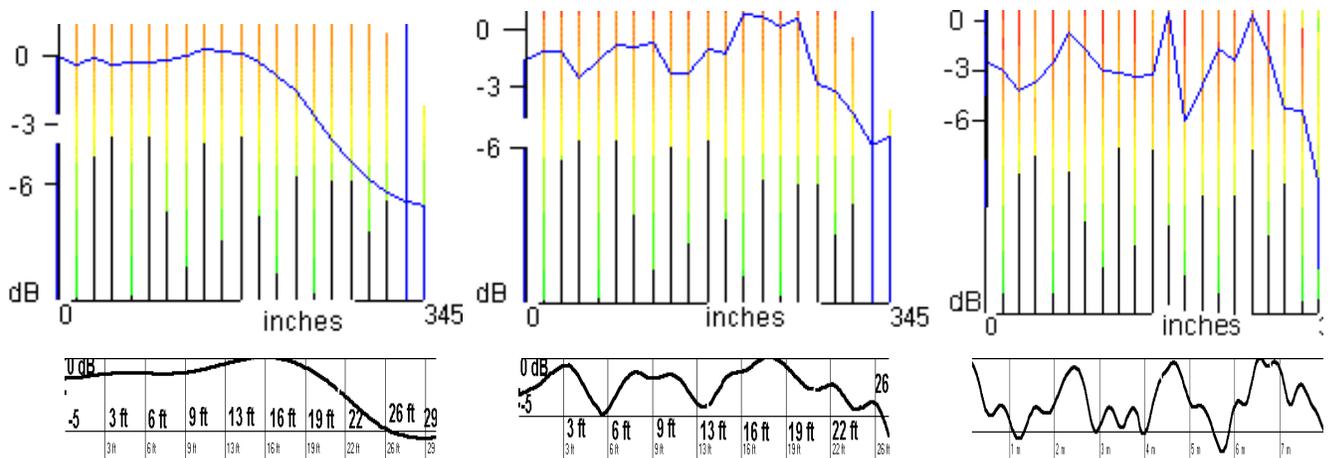

Fig. 15 RLA1, elements splayed at 5°between each other. Measured vertical dispersion — top graphs. RLA1 calculated vertical dispersion — bottom graphs. Left — 500 Hz, center — 2.5 kHz right — 5 kHz.

A strong correlation of results is evident in all instances, including the similar SPL deviations. Furthermore, the RLA1 dispersion is remarkably consistent within the coverage area, being – 6 dB at the borders and very smooth inside the array coverage zone (Fig.14). The maximum SPL deviation inside the main portion of the coverage is less than ± 3 dB at 5 kHz, even when the RLA1 elements are splayed at 5° (Fig.15).

In a coupled array, vertical dispersion is defined by the array's geometrical dimensions and the elements' splay. A coupled line array creates a "corridor" of sound between the end points, if it operates as a line source. It is a misconception that a line array has the vertical dispersion larger than 0°. In practice, a coupled line array has 0° vertical dispersion. The SPL drops approximately by -6dB at the ends of the projected "corridor", with very steep SPL reduction away from the coverage zone.

Fig.16 and Fig.17 depict a family of normalized (to the central on-axis microphone position) frequency response curves for each of the above 8-element RLA1 line arrays.

RLA1 8 boxes
4/18/2002 11:07:36 AM   SLS
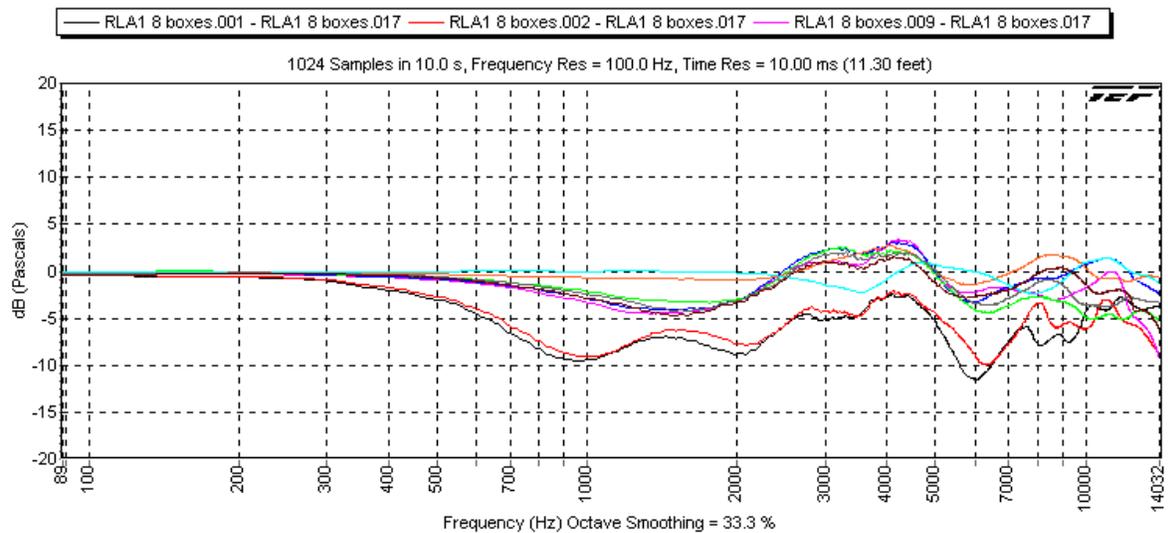8 boxes, straight line, measured at 20 meters□□33 sweeps with 4.25" steps

RLA1 8 boxes.001 - RLA1 8 boxes.017 — RLA1 8 boxes.002 - RLA1 8 boxes.017 — RLA1 8 boxes.009 - RLA1 8 boxes.017

1024 Samples in 10.0 s, Frequency Res = 100.0 Hz, Time Res = 10.00 ms (11.30 feet)

Fig. 16 8-element RLA1, 0° splay. Family of frequency response curves measured along the measurement line (across the coverage area) at 66ft.

RLA1 8 boxes curved 5deg
4/18/2002 3:30:34 PM   SLS
8 boxes, 5deg, measured at 20 meters□□21 sweeps with 17.25" steps

RLA1 8 boxes splayed 5deg.001 - RLA1 8 boxes splayed 5deg.002

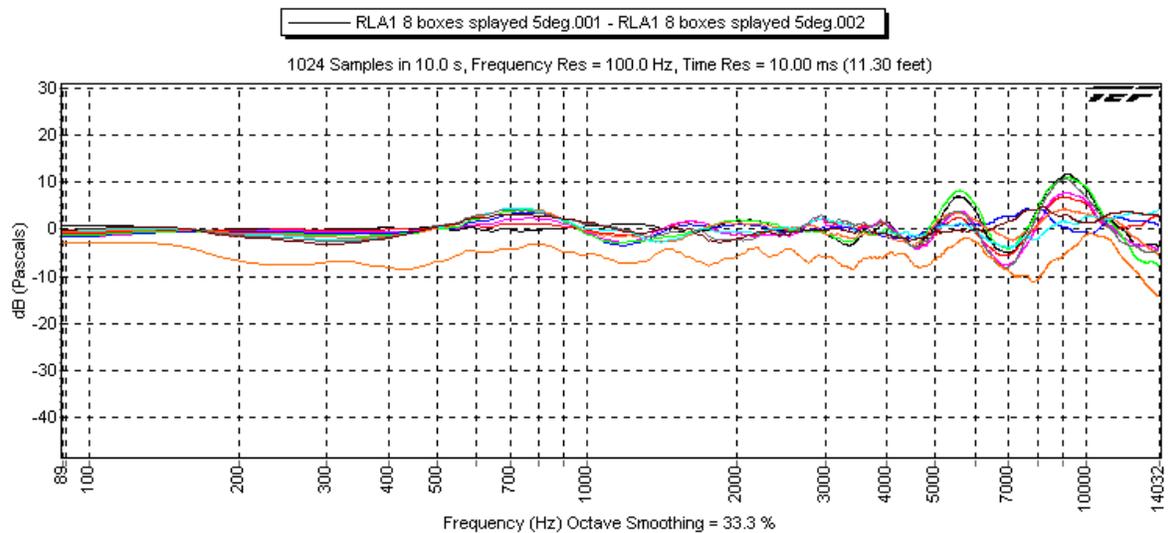1024 Samples in 10.0 s, Frequency Res = 100.0 Hz, Time Res = 10.00 ms (11.30 feet)

Fig. 17 8-element RLA1, 5° splay between elements. Family of frequency response curves measured along the measurement line (across the coverage area) at 66ft.

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The straight RLA1 (0° splay) demonstrates very good coverage consistency ± 4dB throughout the entire measured spectrum. The two bottom lines indicate the border (-6dB) of the array's coverage zone, coinciding with the ends of the measurement line. The 8–element RLA-1 dispersion control starts from 500Hz. Below 500 Hz the array gradually loses its line source properties and begins to resemble a point source device below 200Hz.

The RLA1, consisting of 8 splayed elements, has a significantly lower point of dispersion control, down to 200 Hz, due to the larger size of the array's frontal line dimension. The lowest curve on the graph indicates the end point of the coverage zone. The response is remarkably consistent and smooth within the main portion of the coverage up to 5 kHz, with some deviations above this point.

Fig.18 depicts another interesting and very useful relationship: the difference between measured frequency response of the straight RLA1 and the curved RLA1 with 5° splay between each element. The microphone was placed in the middle of the coverage zone, on symmetry axis, at 66 feet (20m). When elements of the array are splayed, the output is significantly lower than the output of the same array with no splay between boxes. An average - 8dB loss above the dispersion control point of 200Hz is the result of spreading the energy over much wider coverage zone. This result points to the fact that straight and splayed line arrays will have a different spectral balance and may have to be equalized differently.

The LASS program allows for frequency response prediction throughout a venue with a reference point having equalized response. Normally, the reference point is set at FOH (front of house) mixing position.

RLA1 8 boxes curved 5deg
4/18/2002 3:30:34 PM   SLS
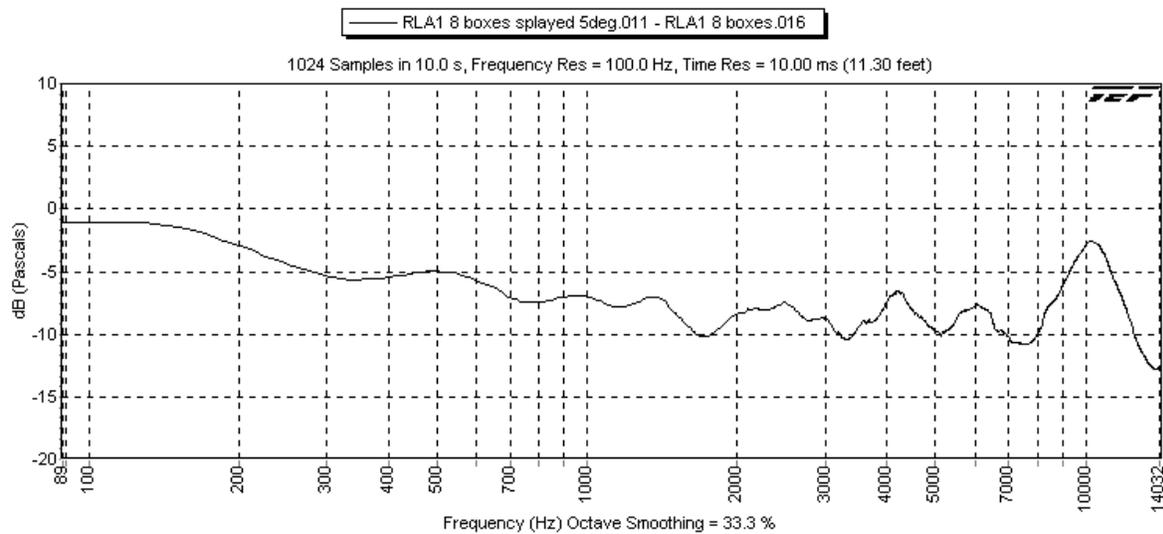8 boxes, 5deg, measured at 20 meters□ □21 sweeps with 17.25" steps

Fig. 18   SPL difference between straight (0° splay) and curved (5° splay between elements) 8-element RLA1 line array.

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J –type versus "progressive splay" line arrays

While some applications and venues could be generally divided into certain typical categories it seems more appropriate to provide a system designer with comprehensive and flexible parameters configuration tool rather than create fixed set of parameters for a discrete number of line array geometries with their dedicated DSP settings.

Extensive research during the RLA/1 development proved that even small, seemingly insignificant changes in array or venue geometry parameters may lead to noticeable improvement or degradation of coverage consistency. It was also found that line array SPL balance changes with distance, therefore any DSP processing that attempts to compensate for distance dependant deviations is useful only in a limited space and may be even detrimental to other areas of the venue.

Instead of relying on predetermined geometry/DSP configurations it is more beneficial to optimize system geometry for a particular venue using the LASS program. Such an approach eliminates the need for extensive use of DSP processing and may result in a line array with fewer cabinets. This not only improves sound quality, but more importantly, provides a much more reliable system with less hardware and shorter rigging time.

The LASS program allows for quick and vivid display of performance parameters, such as SPL curves along the listening lines. Using a comprehensive iterative process, it is easy to design the optimum line array system for a given application.

As an example, two RLA/1 line array configurations were simulated for a particular venue. Fig.19 shows these two arrays, consisting of12 elements: the array on the left is commonly referred to as a J-type array, the array on the right is what we will call a progressive splay array. There is no standard definition for each of these types.
We assume that the J-type array is an array having a vertical portion without a splay between elements, which at a certain point is connected with a curved portion, with a certain

curvature and thus certain splay angles between each of the elements.
An array with a progressive splay has progressively increasing splay angles between elements or segments of elements without a straight vertical segment.
The venue has three seating areas (three listening planes), with the furthest point being 200 feet away and 40 feet high. Fig. 20 shows simulated coverage of the J-type array and correspondent SPL distribution along the listening planes at 2 kHz.
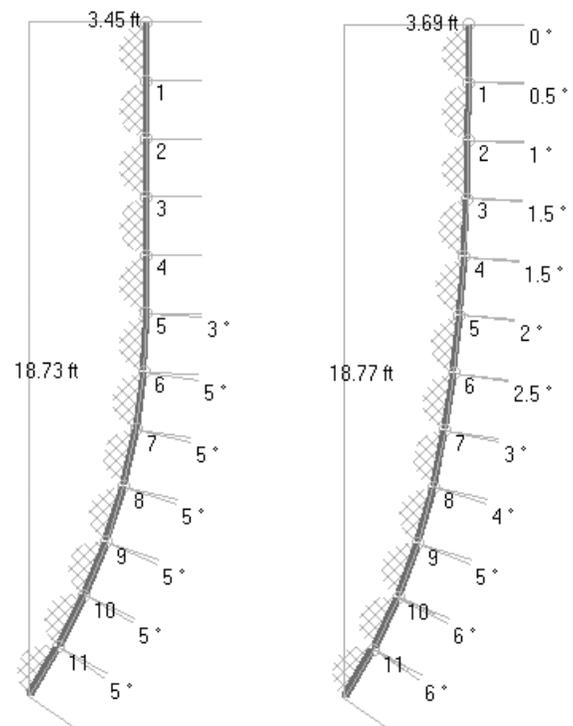

Fig. 19 Line array geometry examples: J-type - left, progressive splay — right.

A strong upper lobe is evident, resulting in higher SPL at the back seats. Then there is a large seating area below, between 65 ft and 164 ft (distance from the first row), with SPL down to – 15 dB relatively to the normalized highest level in the venue at about 10 feet (4th of 5th row). The array with progressive splay angles exhibits much better coverage consistency (Fig.21). By splaying the upper elements at very small increasing angle and evenly dispersing sound energy to the lower seats it is possible to create smoother, more consistent SPL coverage with higher average levels throughout the venue. The resulting system provides remarkably consistent coverage at only –10 dB SPL in mentioned 65ft-164 ft area and beyond up to the farthest seats, yielding total +/-5 dB SPL deviation throughout the entire venue.

It is worth noting that both systems have the same number of elements and the same total vertical coverage angle. Hardly any "level shading" or other DSP processing (except the common crossing and leveling of the drivers within each element) is necessary for such a system. The true line array performance capabilities of the RLA/1 combined with power and accuracy of the LASS program, makes such remarkable results possible.
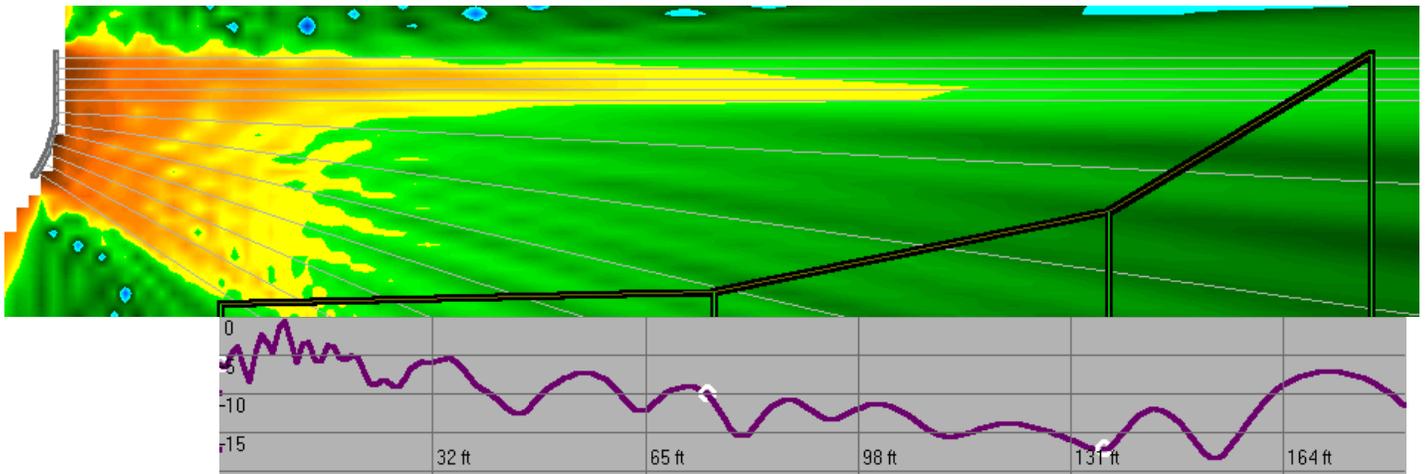

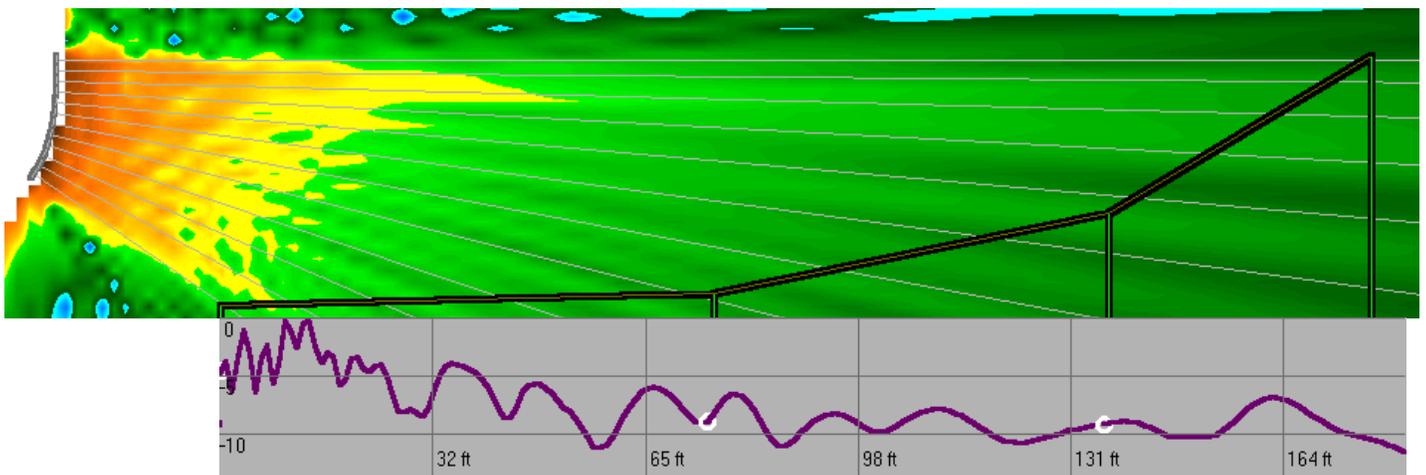**Fig.20 Coverage of the RLA/1 array in J-type configuration at 2 kHz.**

Fig.21 Coverage of the RLA/1 array in progressive splay configuration at 2 kHz.

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Conclusions

Based on the LASS program simulation, measurement data and analysis of various line array design concepts, the following conclusions can be stated that:

1. Implementation of compression drivers in line array systems, where a coherent planar wavefront is necessary to achieve line source performance, imposes significant design difficulties and results in compromising the acoustical parameters of such a system.

2. The PRD 1000 planar ribbon driver allows for elegant line array design solutions and provides a means for achieving consistent line source properties and wide symmetrical horizontal dispersion over a wide frequency range.

3. The RLA1 ribbon line array system, based on the PRD1000 driver, demonstrates far superior performance over line arrays based on conventional compression driver design.
   The RLA1 provides:
   - much better coverage consistency, SPL deviation along the RLA1 coverage area is significantly lower, without   pronounced SPL peaks and dips and areas with dramatic loss of high frequency energy, inherent to other line arrays.
   - easily predictable coverage zone borderlines
   - lower SPL loss with distance, within the coverage zone
   - effective elimination of lobing and comb-filtering

4. The vertical polar diagram, as commonly defined, is not applicable to line arrays, since it is valid, only if measured in a system's far field.
    A line array's dispersion diagram, observed along the array's length (in the simplest case this would be vertical dispersion) is a specific characteristic for a specific distance. If measured, it is only valid for the distance at which the test was performed. A dispersion diagram should be measured along the polygonal measurement line defined above, not around the circle as for polars.

5. A line array's vertical dispersion has an infinite three-dimensional characteristic, which depends on distance. It cannot be fully described by measurement data. It can only be modeled with the help of such programs as the LASS, using mathematical means, allowing for a near-field numerical simulation accounting for the distance from each element and cannot be modeled by other programs that use measured polar diagrams or far-field modeling only.

6. The LASS Line Array Simulator Software is a powerful program for easy and quick prediction of line array dispersion in the vertical plane (or horizontal plane if the array is positioned accordingly). The results of simulation closely correlate with actual measurements of the RLA1 line array. The comparison of simulated and measured data also proves that the RLA1 possesses a coherent planar wavefront, as assumed in LASS, and demonstrates line source behavior over a wide frequency range. Line arrays based on compression drivers, can be modeled by introducing gaps between radiators with a certain filling coefficient.

7. Line arrays with progressive splay angles can exhibit more consistent coverage and higher average SPL than J-type arrays. The LASS provides an accurate tool for prediction of the optimum angle increase ratio for such arrays.

8. Further development of the LASS program should be oriented on solving a 3D line array's dispersion problem. The simplest way would be adding a fixed horizontal dispersion characteristic of one element, as specified by manufacturer, and generating a 3D directivity balloon by expanding the program into the 3D domain. The ultimate solution though, and the only method feasible for accurate prediction, is the combination of LASS simulation data in vertical plane with measured data of one array element in the horizontal plane.
Using interpolation techniques and both types of data, it would be possible to generate a directivity balloon, which would be the closest approximation to a real system.

References

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[2] Ureda M., Line Arrays: Theory and Applications, AES Convention Paper 5304 Presented at the 110th AES Convention, May12-15, 2001, Amsterdam, The Netherlands