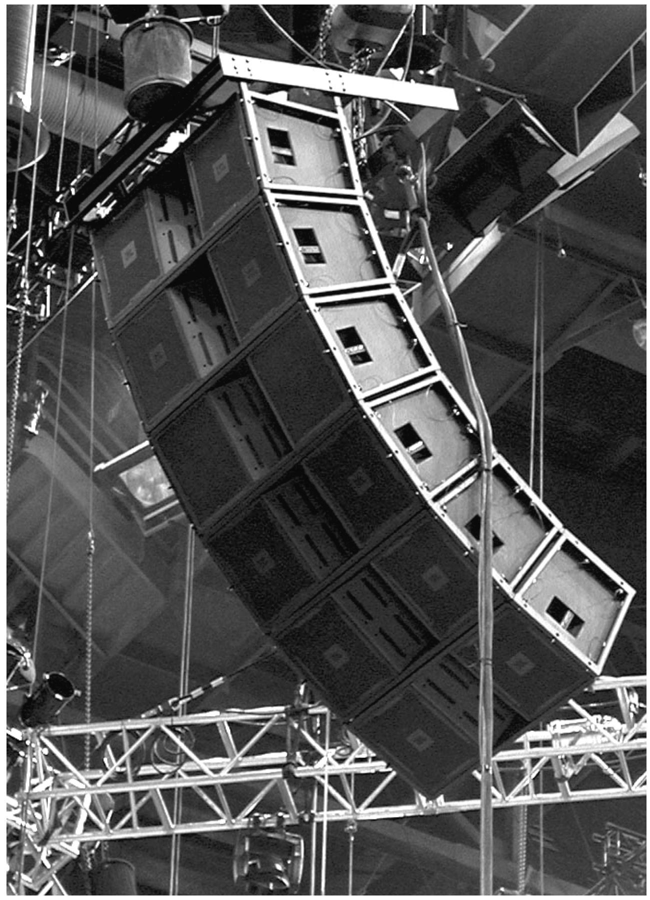


Line-Array

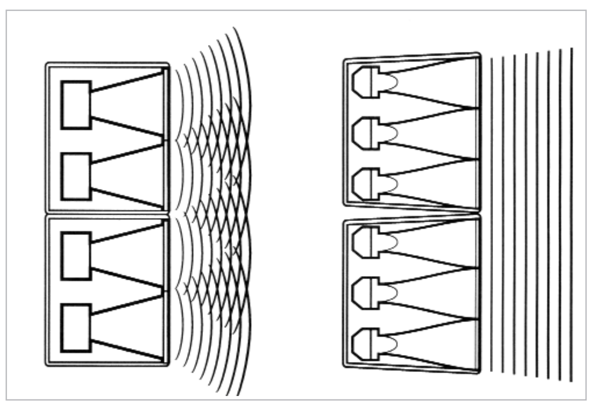
JBL VERTEC VT4889

With VerTec JBL makes its move into the Line-Array market. The first systems bearing this name were put at the disposal of the PRODUCTION PARTNER team for evaluation of sound and measurements.

The VT4889 is the first loudspeaker from the new VT-series (Vertical Technology) to be offered by JBL Pro. The Line-Array, as such, is nothing new; its method of functioning can be traced back to 1930 in relevant literature. Detailed descriptions of coverage patterns can be found in Acoustics (Beranek) from 1954 and in 1957 from Harry Olson. At the beginning of the VerTec-Array-Guide, in an historical synopsis, the reader's attention is proudly drawn to an old JBL product, the 4682, with four vertically placed 10-inch drivers and to the Clair Brothers legendary S4-System that uses this positioning for the midrange frequencies with four JBL-woofers. All historical Line-Arrays of this type work as discrete arrays of single, conventional, direct radiators or as vertical rows of horns. The problem of side lobes and interference effects are unavoidable in this discrete arrangement, caused by overlaps of individual spherical wave-fronts. More on this topic can be found in the article, 'Calculation of Line-Arrays' on page 118.

Historical Line-Arrays vs modern line sources

Modern line-arrays circumvent this problem by the dense positioning of several high-frequency drivers with special waveguides for the affected (and particularly critical) frequency



Left: Conventional System: 4 sources with spherical coverage pattern. Right: VTV4889, 6 sources that emit a coherent wavefront via JBL's Waveguides.

range above 1 kHz, in an attempt to create an even wave-front.
Only if this prerequisite is fulfilled, can these elements be positioned above each other to create a genuine line source. A continual line-array like this, otherwise found only in ribbon tweeters, radiates a wave-front in the near field in a segment form according to the horizontal opening angle of a cylindrical surface.
For deeper frequencies, with accordingly larger wavelengths, this effect is easily achieved with a simple line-up of direct radiating systems, but the distance between loudspeakers must be smaller than the wavelength. With frequencies up to 1 kHz (wavelength 34 cm) a row of conventional 8“-drivers fulfill this purpose. The low-frequency ranges are less critical, so that the high frequency range stands as the central point of a line-array. The moment the prerequisites for the emission of cylindrical wave-fronts are fulfilled, the wave-front spreads horizontally with 0-degree vertical aperture angle in the near field. The cylindrical wave-front only transforms into a spherical wave toward the end of the near field. The aperture angle in the far field depends on the length of the line source in relation to wavelength and on the transition distance from near to far field. More on the relatively simple calculation possibilities can be found in the article „Calculation of line-arrays.“ on p.118 The following formula serves as a simple guideline to calculating the expansion of the near field:

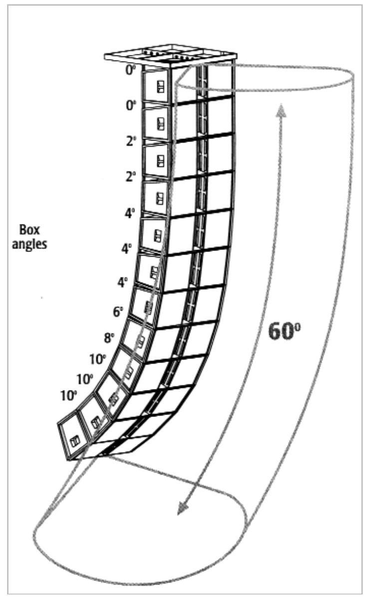
$$r_n = \frac{l^2 \cdot f}{2 \cdot 340\, {}^{m}\!/\!_{s}}$$

l in m and f in Hz

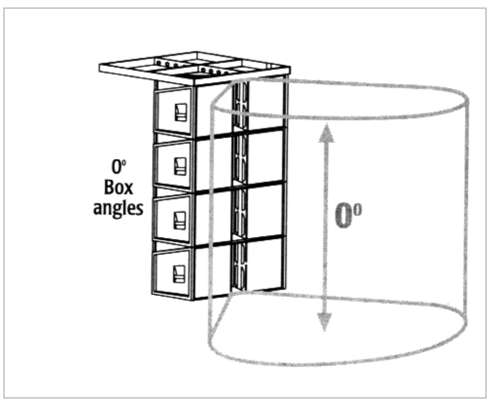
In an array measuring 4 metres in length, the transition for 10 kHz lies at 230 metres, for 1kHz at around 23 metres, for 100 Hz at 2.3 metres. Therefore high frequencies can be transmitted especially well over large distances. Energy-wasting interference effects or uncontrolled coverage patterns are only minor, thanks to the coherent wave-front of the line source. Because the wave-front expands only on one plane in the near field the total sound power emitted spreads less quickly than a spherical wave-front, meaning that the sound level reduces by 3dB per distance doubled compared to 6 dB. This effect is desirable because of the increase in air absorption at higher frequencies.

Curving

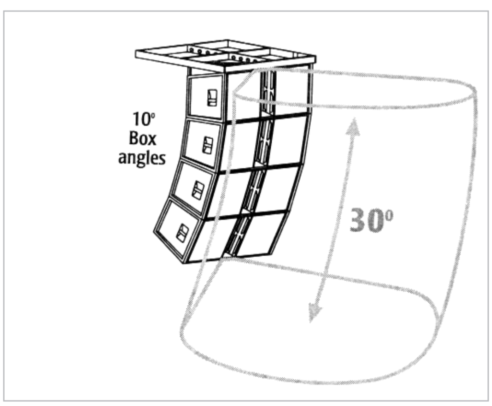
Only in rare cases would an array be used exclusively for long distances with a narrow vertical coverage angle. That’s why all systems of this type are put together from separate elements that allow a slight splay in relation to the next loudspeaker. The curving of a line-array means that even on the vertical plane a defined aperture angle is attained, that can be adjusted to the limits of the area to be covered.
Because of the trapezoid casing and a slight vertical aperture in the VerTecs wave guide, the curving is basically already integrated into the loudspeaker. This means that the otherwise unavoidable gaps in the line source caused by the curving that occurs with a purely cylindrical wave-front statement are skilfully circumvented. The VerTec allows for a maximum angle of 10 degrees from one loudspeaker to the other, that can be adjusted easily with the help of the cabinets rear hinge bars with degree markings. The corresponding figure shows an array consisting of 12 VerTec units that are curved at a baffle angle of 60 degrees in the vertical plane. All in all an array like this will have an aperture angle of 90 x 60 degrees. This raises the question of how the array compares to a classical configuration. A configuration of 2 x 3 tops each with a coverage angle of 35 x 35 degrees would theoretically cover a comparable area. For deep frequencies a cluster like this would acoustically couple, dividing the middle and high frequencies up within the area.



Near-field with cylindrical waves front using 12 VerTec-Elements with an overall opening baffle of 60 degrees.



Near-field with cylindrical waves front using four VerTec-elements with an overall opening baffle of 0 degrees.



Near-field with cylindrical wave front using with four VerTec-Elements with an overall opening baffle of 30 degrees.

The Advantages of the Array

In this configuration the line-array has 3 distinct advantages:

1. Because of the different splay angles the array's upper range will provide a recognizably higher density in relation to room angle, which provides a longer range to reach audience areas, situated further back. In the lower ranges the near field energy will be distributed over a wider angle. Comparable performance could only be achieved using narrow radiating horns with several planes in the upper part of the cluster with the same directional position, but this would lead to well-known effects on the aiming with side lobes and interference.
2. Loss due to interference effects is clearly minimised by using the coherent coupling in all frequency ranges of the individual units. These interference effects cannot be fully obviated even in very cleanly functioning horn systems in clusters.
3. Compared on the basis of power and range the line-array can be seen to have a clear head start on aspects like area coverage, weight and setup speed. In general one can therefore say that line-arrays have a considerable advantage in their flexible arrangement of vertical coverage patterns with adjustable range. In any case the coherent wave-front and thus the coverage is maintained from one source. An age-old wisdom in loudspeaker technology is that the larger the number of loudspeakers the larger the loss in sound quality. This can be cleverly circumvented because a line-array, despite its form always functions as a single unit. Prerequisite is of course the maintenance of the maximal splay angle of the loudspeaker boxes to each other. On the other hand the line-array doesn't offer the flexibility of horn clusters on the horizontal plane, and in certain rare situations this could be seen to be a disadvantage. VerTec elements are suitable for small to medium- sized halls, in which speakers can be suspended or stacked on stage in units of four and will provide suitable 90 x 40 degree coverage, and also for massive open-air events where extremely long ranges are possible with long line-arrays. Now to the details of the VT4889.

The Driver

JBL as manufacturer of loudspeaker systems and woofers of course grabs the chance to use drivers tailor-made for the needs of the new VT4889. A 1.5" driver (type 2435) with neodymiumium motor, 3" beryllium dome and the addition of a new patented phasing plug is used for the high-frequency range. The driver's motor is cooled with Ferro fluid in the air gap that conducts the excess heat to the metal parts quickly and with little thermal resistance. The aluminum wave-guide serves well as heat conductor for the comparatively small driver. The 8" mid-frequency drivers (Type 2250H) are also fitted with Neodymiumium magnets, with a motor with dual voice coil fitted in its air gap and a 300-Watt power rating.

At JBL one modestly asserts that this is the most powerful direct radiator mid-range loudspeaker in existence. The 8" driver works on a minute amount of volume that is completed in the assembly with a cover plate on the reverse side of the driver. For improved heat conduction the larger heat sink stands out at the back of the internal casing to avoid heat build up. With the 2255H we have a new 15" low-frequency driver also with neodymiumium motor arriving on the woofer-scene. Because of its very high performance quality this should make subwoofers obsolete for many occasions. Both 15"ers in one VerTec unit work on relatively small volume with a port tuning of around 45 Hz that should allow for real full-range usage even for music playback.

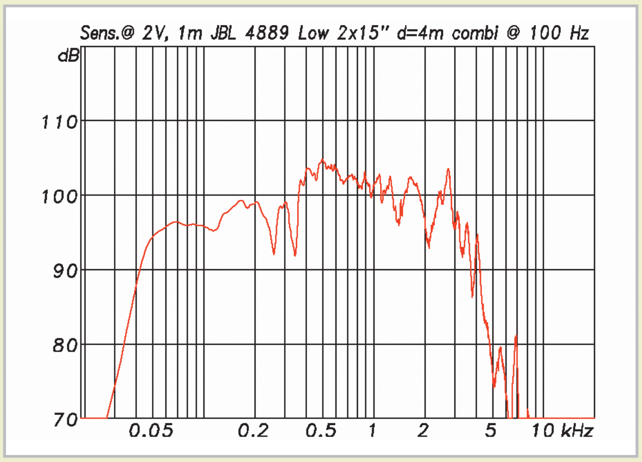
JBL really demonstrates its strengths as loudspeaker and driver manufacturer with its three new driver models creating tailor-made high-tech drivers for each different application. Last but not least the very agreeable weight of 72kg can be partially attributed to these three new driver models with their effective neodymium motors. Nevertheless, the VT4889 contains all of nine motors!

Cylindrical Wave-front Forming with Wave Former and RBI

At JBL the VerTec project team developed the "High frequency Wave Former" and the "radiation boundary integrator" (RBI) for the difficult task of wave- guiding to a cylindrical wave-front at high frequencies with short wavelengths. RBI is being registered as a patent and represents a new development in loudspeaker construction. The Waveguide takes over the difficult task of creating a coherent wave-front for the high-frequency ranges. Each of the 1.5" drivers has its own wave former that, arranged one on top of the other create the line source for the high-frequency range. Due to its lightly rounded shape the wave-front emitting from the 1,5" driver is formed in such a way as to produce an even wave emitting from the front gap.

The " radiation boundary integrator" takes over the task of bringing together the sound of all four 8" mid-range woofers and the sound from the wave former into the desired waveform. Viewed from the front, the exit gap of the wave former sits right in the middle of the RBI. The 8" mid-range system's exit gaps are positioned on the sides of the RBI. The mid-range systems cover plate improves the transition for the high-frequency range, which means there are no interruptions caused by the diaphragma. On the other hand coverage of the entire range from 200Hz to 1kHz via a small gap with high compression could be problematic.

What's interesting are the different problem-solving attempts of the different manufacturers: at L-Acoustics the mid-range membranes are integrated



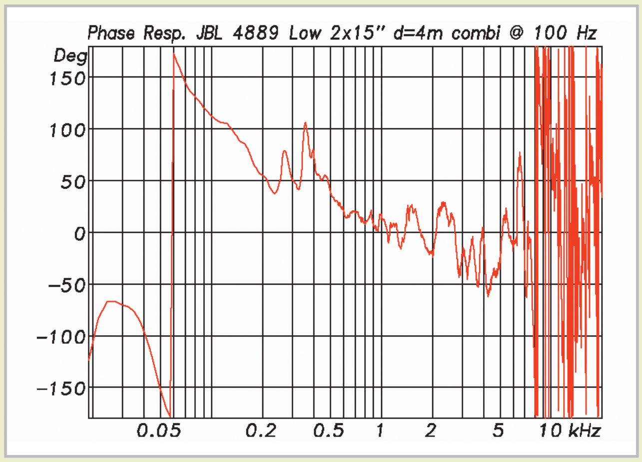
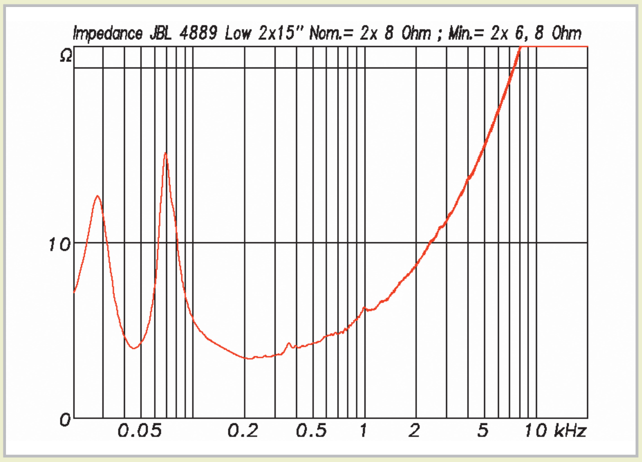


Fig. 1: Frequency response JBL VT4889 2x15" Low measured at a distance of four metres. The sensitivity of around 95 dB between 50 and 100 Hz is the equivalent of a typical 2 x 15" system. The lower transition frequency is nice and low considering the enclosure size.

Fig. 2: Phase response JBL VT4889 2x15" Low.



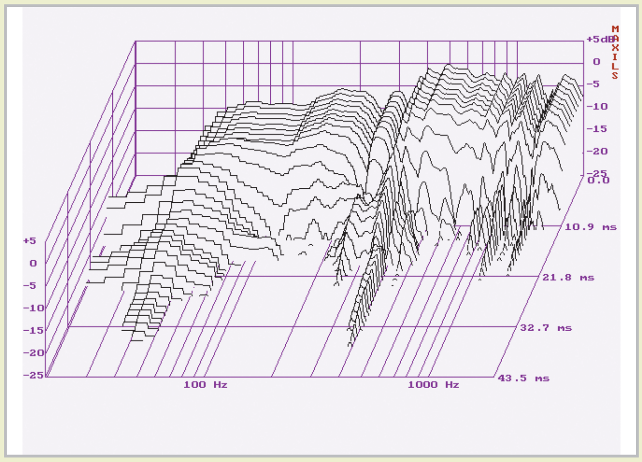
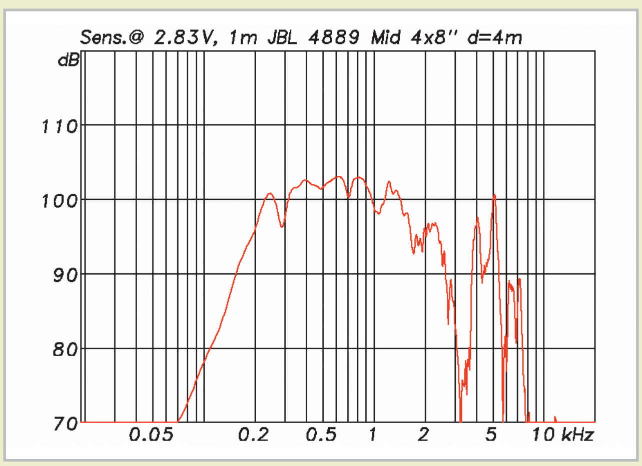


Fig. 3: Impedance curve JBL VT4889 2x15" Low; Tuning frequency at around 45 Hz.

Fig. 4: Waterfall plot JBL VT4889 2x15" Low. First resonances occur at 260 Hz and 340 Hz.



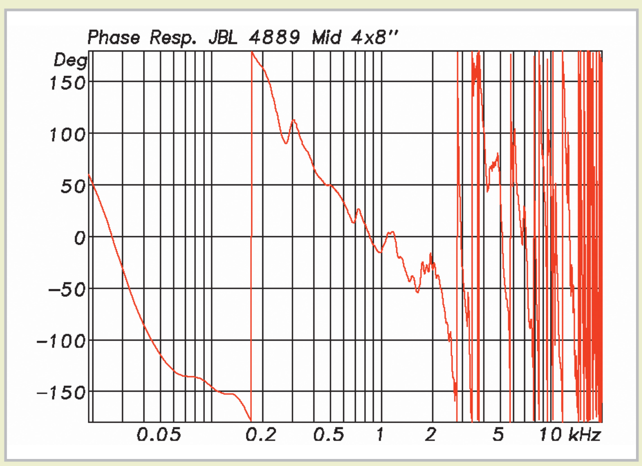
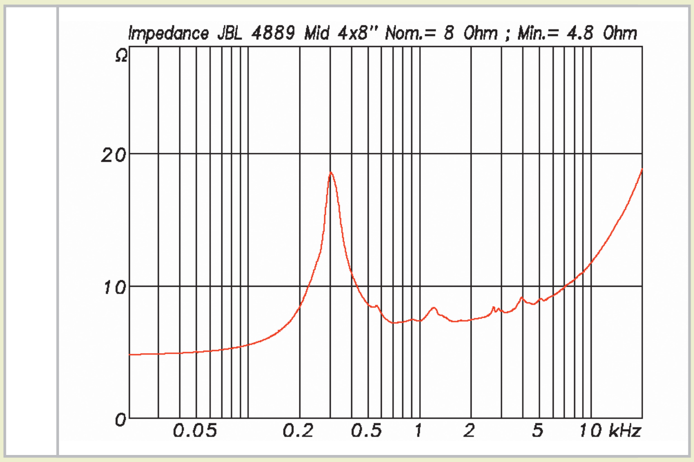


Fig. 5: Frequency response JBL VT4889 4 x 8" Mid measured at a distance of 4 metres. The sensitivity values of around 102 dB are relatively high for a direct radiator.

Fig. 6: Phase response JBL VT4889 4 x 8" Mid.



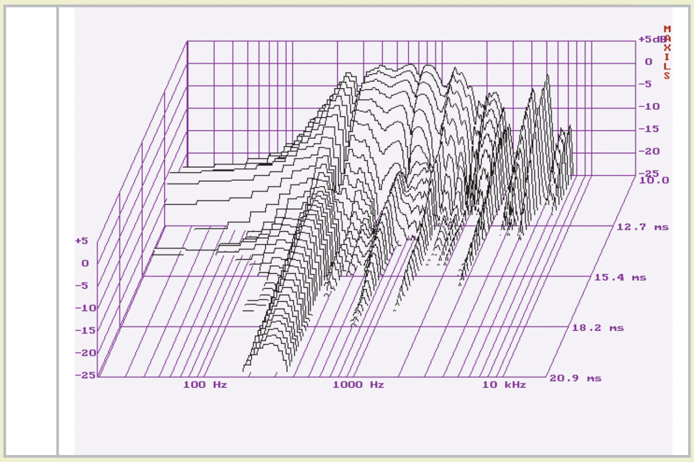
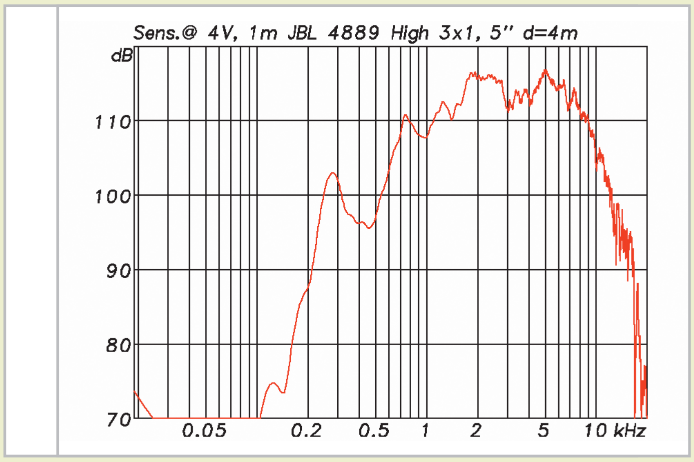


Fig. 7: Impedance curve JBL VT4889 4 x 8” Mid. The resonance frequency at around 300 Hz is very high due to the small volume.

Fig. 8: Waterfall plot JBL VT4889 4 x 8” Mid with some resonances in the working range.



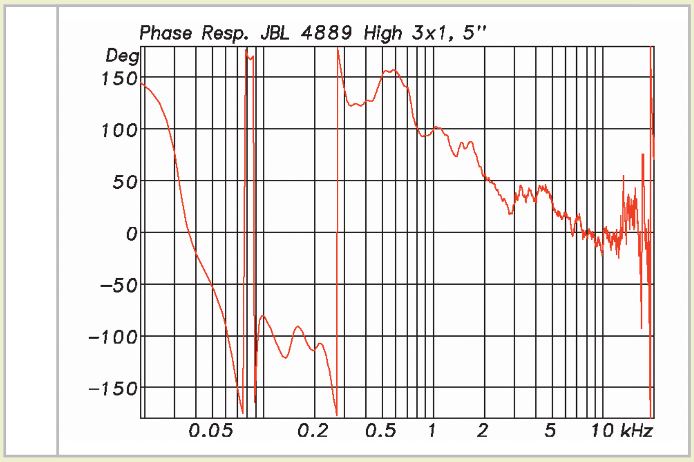
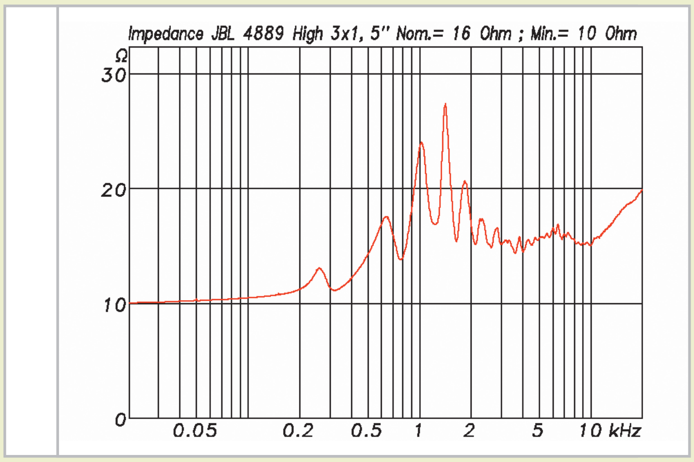


Fig. 9: Frequency response JBL VT4889 3 x 1.5” High measured at a distance of 4 metres: Very high sensitivity with a later roll off to the higher frequencies. Hardly any brake up modes at high frequencies.

Fig. 10:Phase response JBL VT4889 3 x 1.5” High.



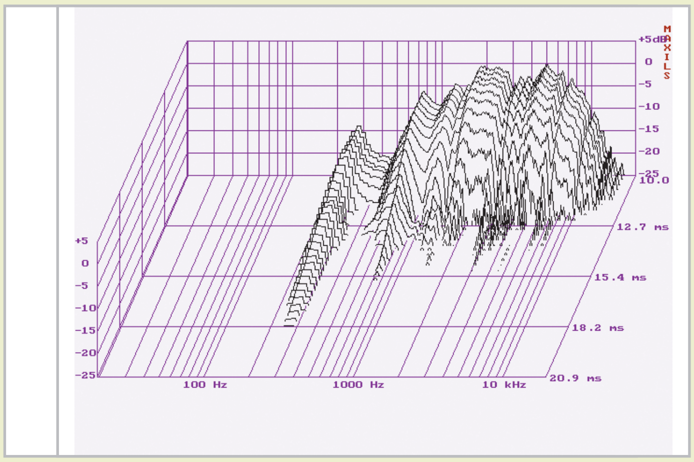


Fig. 11:Impedance curve JBL VT4889 3 x 1.5” High.

Fig. 12: Waterfall plot JBL VT4889 3 x 1.5” High.

without further ado into the high-frequency horn surface, in contrast, Electro-Voice inserts cone drivers with flat diaphragma in their X line.

Enclosure Concept

The VerTec element's trapezoid casing is made of a waterproof, lightweight composite material that contains all nine drivers. The woofers' front exits are protected from mechanical influences and rain with strong grilles and backed with foam rubber. The mid-ranger's narrow gaps are covered by a thicker layer of foam rubber and the wave-guide's sound exits get enough protection from a fine metal grille. A total of 8 integrated handles and a transport-dolly that serves simultaneously as the front-cover turn the handling of this mere 72 kg loudspeaker box into pure pleasure. The lightness of this loudspeaker is even more surprising when one considers that the casing is fitted with a permanent rigging frame, which only has to be secured with hinge bars and pins. Considering the high power-density, dimensions measuring 489 mm x 121 mm x 546 mm (H x W x D) and the weight of only 72 kg we have to be talking about a real sensation. JBL again sets the standard, when it comes to the construction of modern, lightweight loudspeakers, whilst even now other manufacturers offer loudspeakers that plague their owners with well over double the weight of a VerTec unit.

Suspension System

The VerTec's suspension system is based on the side frames on each box that allow for the linking of as many as 18 units to each other with a safety factor of 7:1. The entire weight is carried by the steel frames, without stressing the speaker enclosures in any way. As already mentioned, the splay angle can be easily adjusted via the hinge bars inserted in the frames. Assembly of the uppermost box on the rigging frame also takes place via these hinge bars and enables you to set an angle at this early stage too. Rigging frames for the VerTec are offered in two variants:

One for compact arrays, and the big version for up to 18 units. Both frames can be reversed for use on the ground for ground stacks with 4, or 6 units. Another assembly-choice is a large array with smaller sub arrays. Here a smaller frame is connected to the lower end of a large array. All in all the rigging system appears flexible and easy to use.

The assembly of an array can be completed on the ground and then step-by-step the locking pins can be pushed into the back hinge-bars whilst hoisting proceeds, to attain the desired splay angle. In more confined conditions the boxes can of course be mounted one by one without having to assemble the array in its entire length on the ground.

In the US VerTec units have been field-tested in use for the past 6 months. The units have proved their excellence and the construction principle behind the rigging system remains confirmed.

Amping

The system put to our disposal for testing by Audio Pro Heilbronn was fitted out with Crown-Amps MA5002VZ and a completely new controller dbx 480.

The entire cabling was done with Neutrik-Speakon-Connections NL8. With altogether four MA5002 as many as four VerTec units and two additional 2 x 18" subwoofers can be driven. As an alternative controller, JBL suggests the DP226 from XTA and the Omnidrive Compact 366 from BSS in its user-guide. The parameters for all three models are found with the respective systems.

Individual Measurements

Prior to our measurements of the entire system the three ways of a single VerTec unit were measured directly. Considering its small casing size the 2 x 15" woofer unit (Fig.1-4) supplies a good sensitivity of 95 dB at 2V/1m in the 50 –100Hz range, which increases to 99dB at 200Hz. The first resonance effects occur at around 260 and 40 Hz.Fittingly the 4 x 8" mid-range unit (fig.5-8) starts at 200 Hz and has a sensitivity of 102 dB in its range to around 1 kHz. Here the high resonance frequency of 300 Hz is noticeable, caused by the small volume behind the driver. At 700 Hz and 1,1 kHz there are two, somewhat smaller, resonances noticeable within the transmittable range. When considering the sensitivity of the low and mid-range sections in the VerTec one mustn't forget that one is dealing with direct radiators not with horn systems, where, with the mid-range, one can at best talk about a kind of wave-guide. The high-frequency unit with its 1.5" drivers (fig.9-12) supplies sensitivity values from 110 dB at 1 kHz, and up to 116 dB at 2 kHz, that can almost be maintained up to 8 kHz. Over and above this, the course is broken, although the first break-up modes occur at around 14 kHz. In the important high-frequency range between 4 and 8 kHz the new JBL drivers succeed in being almost 10 dB louder than comparable older models.

Figures 14 to 17 show how a VT4889 unit performs as a whole. The accompanying controller-set up in fig.13 performs a small system EQ and a strong increase in highs in order to balance the frequency response, in addition to its actual X-Over function.

Noticeable is the parametric EQ at 300 Hz in the mid-range, which brings the level up +4 dB at a point that is already resonating. The resulting frequency response is shown in fig.14 gives an all-encompassing and balanced impression, although these tests on one individual system are not yet reliable testimony.

The phase response is shown in fig.16 as minimal phase response for a three way system with passages at 4th order.

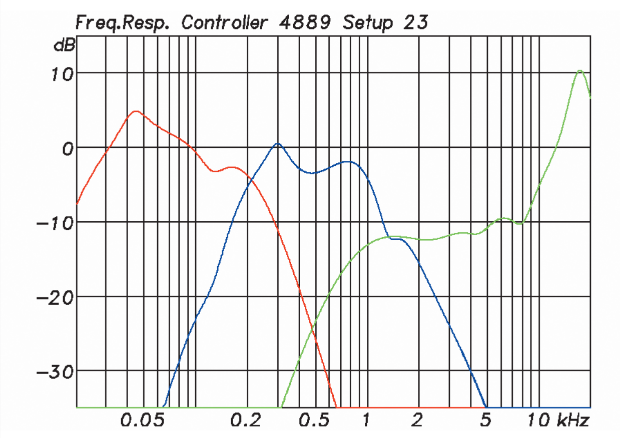


Fig. 13: Controller settings Set-up No. 23 with an unusual boost of +4 dB in the mid-range – exactly on a resonance point.

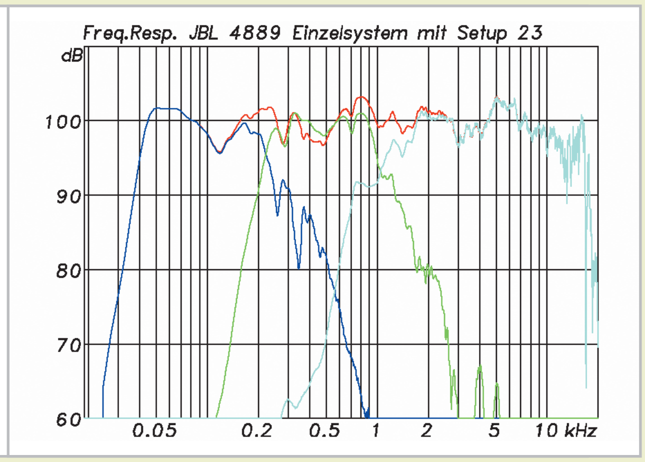


Fig. 14: Frequency response of single system JBL VT4889 at 4 metres distance with Set-up No. 23.

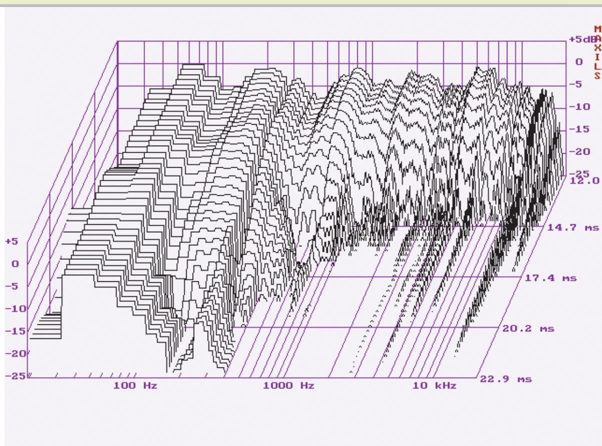


Fig. 15: Waterfall plot of single system JBL VT4889, with a strong resonance at 300 Hz.

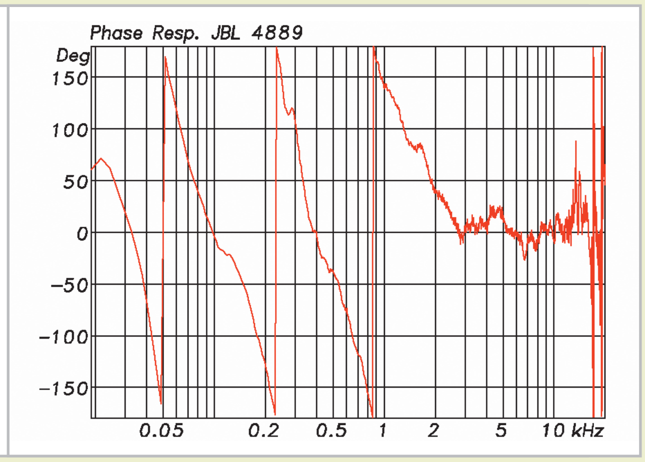


Fig. 16: Phase response of single system JBL VT4889.

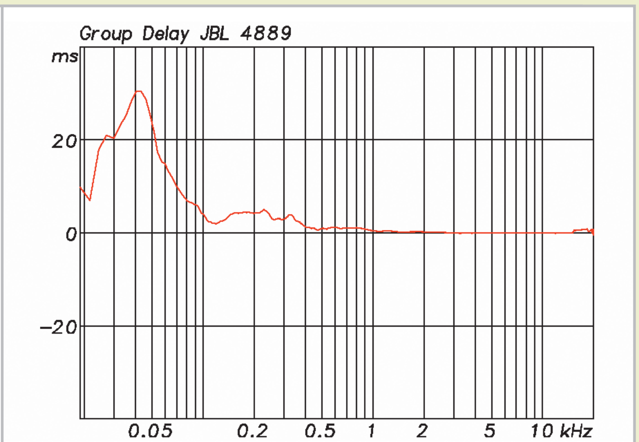


Fig. 17: Group delay of a single system JBL VT4889 with a strong increase to the lower frequencies, caused unavoidably by the high pass filter 8. Order (acoustically and electrically 4 orders each).

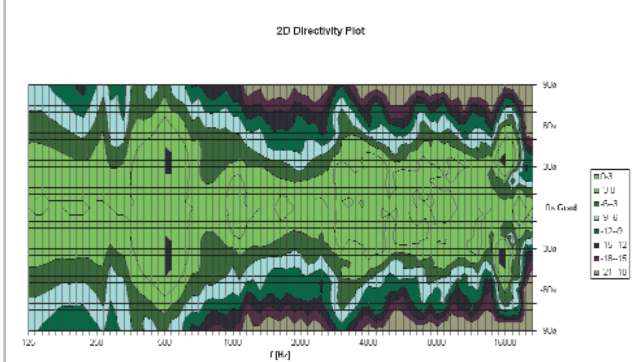


Fig. 18: Horizontal isobars shown at +/-90 degrees, measured on a single system. The transition is very smooth considering that this is a system that was primarily optimised for perfect coupling on the vertical plane.

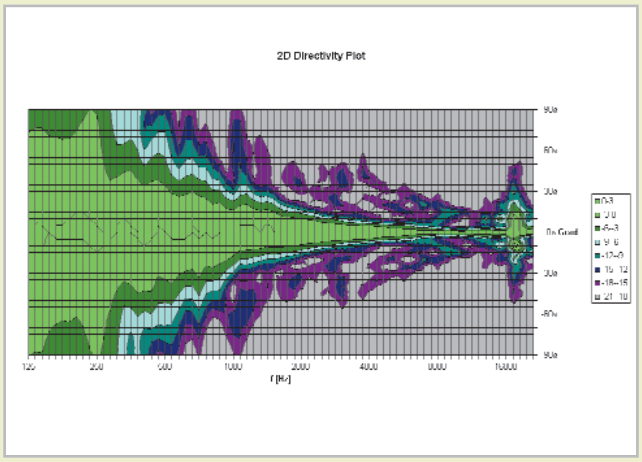


Fig. 19: Vertical isobars shown at +/-90 degrees, single system. The cylinder wave coverage causes the impression of continual constriction when measured on an orbit around the loudspeaker. This is technically correct, but the actual wave dissipation isn't rendered. (Please read the explanations to this phenomenon included in the accompanying article.) The line source works right up to 16 kHz.

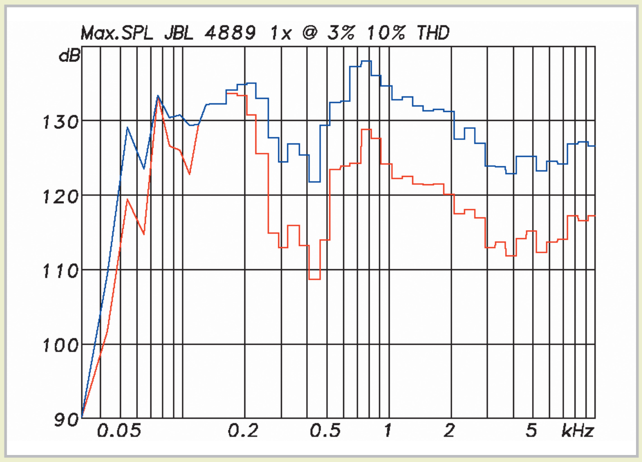


Fig. 20: Maximum SPL (at 3-%- and 10-%-threshold for the THD), measured on a single system. Measured at a distance of 4 metres, converted to 1 metre.

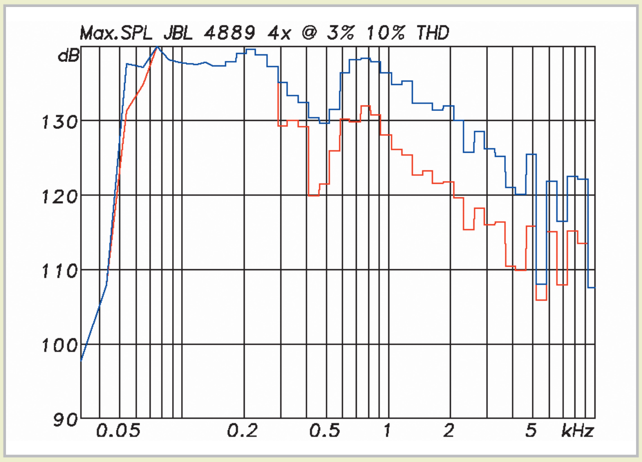


Fig. 21: Maximal SPL, this time measured on a 4-unit line-array.

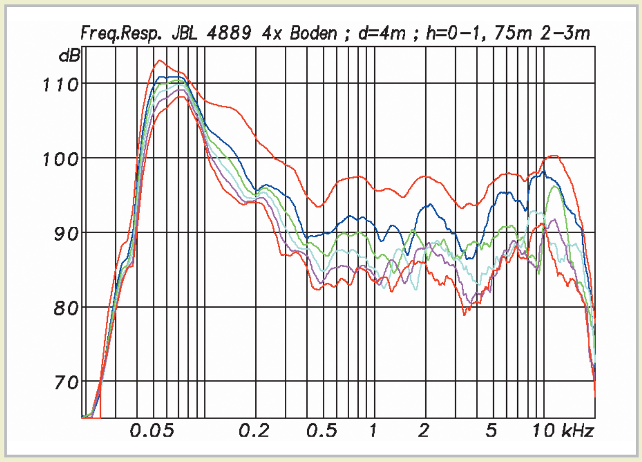


Fig. 22: Rapid drop in level beyond the cylinder wave: 4-unit line-array measured on a sound reflective floor at 4 metres distance. Measurement height: Upper red curve 1,75 metres (within the range of the cylinder wave); other curves were each 25 cm higher, beyond the cylinder wave.

15" woofer 2255H with Neodymium motor

8" mid range driver (300W) with Neodymium magnet and heat sink

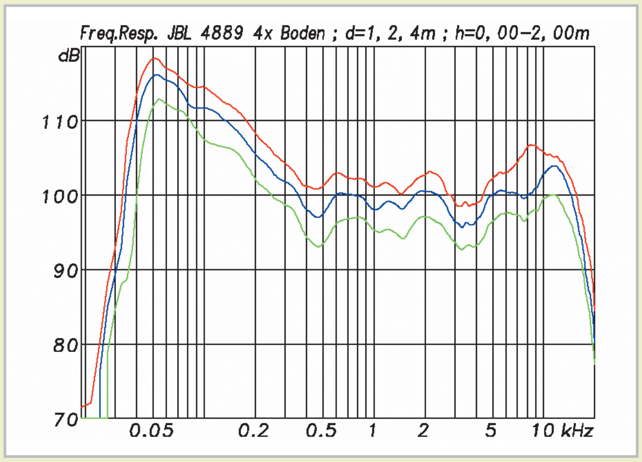


Fig. 23: Level drop of only 3 dB per distance doubled! 4-unit line-array on sound reflecting flooring measured at 1,2 and 4 metres, each averaged over 9 points at a height from 0-2 metres.

Open mid-range next to the WaveForm gap. Left shows the reverse of the 8" cover plate with affixed wave-guide and exit gaps for 8" speakers.

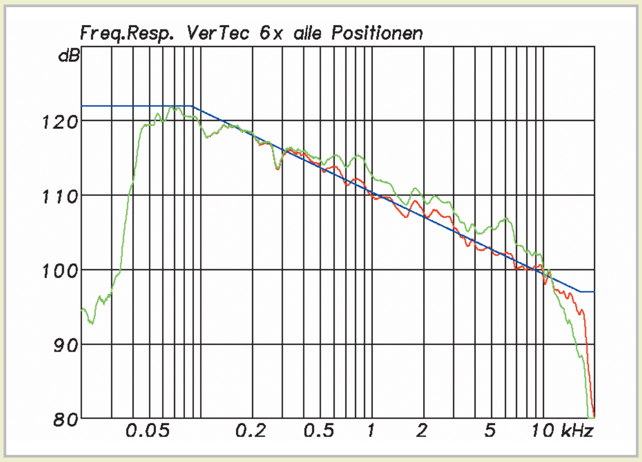


Fig. 24: Line-array in a hall, averaged over 30 points from 5-50 metres distance in the middle and outer areas of the audience area; gr = measurement without EQ; rt = measurement with EQ.

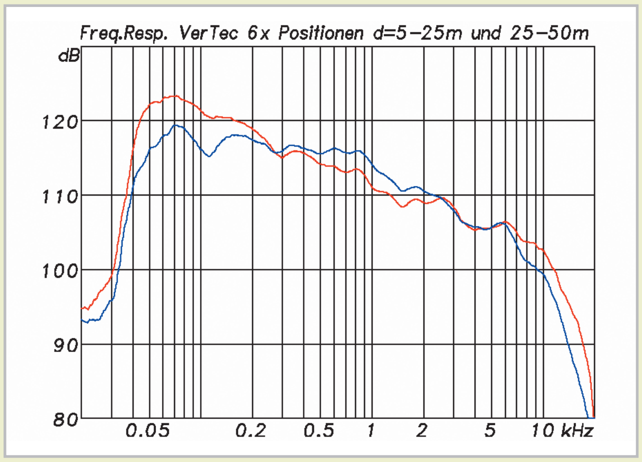
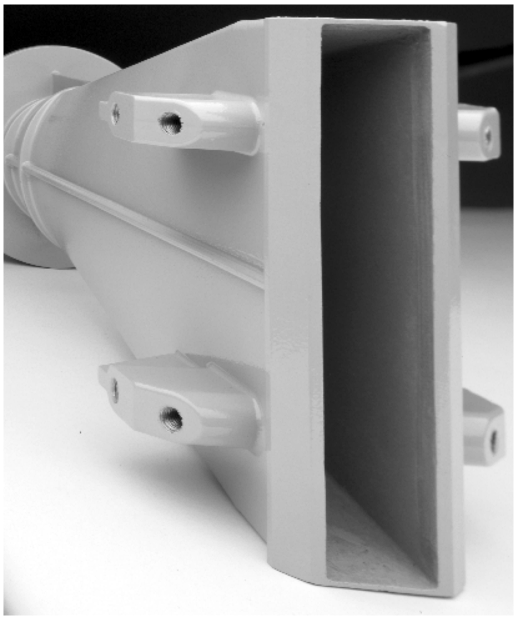


Fig. 25: 6-unit line-array in a hall, each averaged over 15 points from 5-25 metres (rt) and from 25-50 metres (bl) distance. Example of a 5,4 metres long array from a cylinder wave coverage in the near-field to a spherical wave front in the far-field.

Because of the quite drastic high pass filtering of altogether 8th orders a steep ascent of up to 30 ms at 40 Hz for the group delay to low frequencies occurs. This compromise is unavoidable in order to protect the woofer from excessive over-steering.

Array Measurements

After individual measurements a line-array consisting of 4 elements was set up on the reflective floor of a sound proofed half room. With upright assembly a rigging frame was dispensed with, in order to attain a good ground coupling. Acoustically the array mirrors itself on the almost perfectly reflecting granite flooring, so that virtually an array of 8 units with 4 metres in length is produced. The measurement distance was also 4 metres so that for frequencies down to 170 Hz it should have been possible to prove a cylindrical
wave-front character. The upper red curve in fig. 22 shows the averaged curve of tests in 25 cm steps from the floor to a height of 1,75 metres at a distance of 4 metres from the array.
The curve is determined by a strong bass boost because of the acoustic coupling of the loudspeakers at low frequencies, so that the level rises there by about 12 dB. Above 300 Hz the linear frequency response remain constant, where all units appear to emit a coherent wave-front. The other curves



Each of the three 1.5” drivers 2435 has it’s own Waveguide.

were also measured at 4 metres from the array.

The curve is determined by a strong bass boost because of the acoustic coupling of the loudspeakers at low frequencies, so that tyhe level rises there by about 12 db. Above 300 Hz the linear frequency response remain constant, where all units appear to emit a coherent wave-front. The other curves were measured at 4 metres distance with increasing height over the expansion of the array. For the entire frequency range above 100 Hz the level begins to drop off severely, even a mere couple of centimetres outside the cylindrical wave-front. A second set is shown in fig. 23 where measurements are taken at a distance of one, two and four metres from the array at respectively 9 points from the centre to the edge.

As is easy to discern, the level drops a mere 3 dB with the doubling of distance, as opposed to 6 dB, which can be considered further proof that the line-array can be seen as a cylinder wave-front radiator in its function.

Distinctive Characteristics of Directivity

Because of the special line-array and cylinder-wave characteristics a directivity measurement has need of a few reservations and explanations. A measurement of polar or isobar curves on a turntable has as precondition that the wave form is spherical. With line-arrays this, at least in the vertical plane, is not given. More information on this can be found in the article “Line-array Calculations” on page 120.

However, the horizontal measurements of a single unit, for the VerTec, as shown in fig.18, shows a completely accurate picture of all variants that are constituents of this unit. The VerTec is specified by JBL with a nominal 90 degrees for the horizontal plane, which, according to fig.18 can generally be fulfilled. Certain irregularities like expansion at 500 Hz and constriction at 2 kHz have to be seen under the aspect that this is no optimised horn but rather a wave guide that was developed primarily for the creation of a line source on the vertical plane. All in all considering the difficult preconditions across the entire frequency range a very balanced pattern is achieved that, thanks to the external arrangement of both woofers, stretches right up into the 125 Hz region. Directivity is excellent even at high frequencies where no constrictions occur and the full 90 degrees are held.

In a second measurement set a single VerTec unit was tested on the turntable on the vertical plane, with the above named reservations taken into consideration. The measurement at a circle of four metres distance from the loudspeaker should have the effect that the frequency range with cylinder wave characteristics should reduce the directivity to an extremely narrow range. This effect can only be observed in a single element, and that, as expected, only at high frequencies, as seen in fig. 19. At lower frequencies the coverage pattern steadily transforms into a spherical form with reduced directivity for deeper frequencies. Despite this the measurement (fig. 19) serves to assess the wave-front coherence at high frequencies. If the wave-front broke up, disrupting the principle of line source, this could be seen as a deviation from the needlepoint-shaped path in the isobar-diagram. With VerTec this effect first kicks in at about 16 kHz; proof of the good function of the wave-guide. Because of the size and weight of the VerTec it wasn’t possible to test several systems together on the turntable, as was done with the d-VDOSC.

Determination of maximal SPL

The customary procedure of a Maximal-SPL-Test is to choose the measurement distance according to the size of the loudspeaker-with large loudspeakers a minimum of 4 metres, where the sound pressure levels are then converted into a distance of one metre. The conversion factor here is +12dB (factor 4). This formula has no relevance for a cylindrical wave emission; in this case +-3dB per distance doubled or halved would apply. As yet this poses no great mathematical problem. The problem starts when in measurements for lower frequencies the wave emission is spherical (6 dB apply) and for the mid- and high frequency ranges cylindrical (3 dB).The transition between these areas is floating. The measurements in fig.21 took place on a quadruple (4) array in free field conditions at a distance of four metres on sound-reflective flooring. (acoustical mirroring of the array). The transition frequencies for cylindrical wave emission in this configuration is at around 170 Hz. For a single unit under the same conditions, as in fig.20, the transition frequency stands at around 2.7 kHz.

As can be seen from these two measurement sets, the systems couple well in the low and mid-ranges, with the maximum level rising to 9 dB in average. For lower frequencies this effect can be attributed to the acoustic coupling of the woofer, whereas for the mid-range section, the cylindrical wave emission is primarily responsible for the rise in sound level. In the working range of the high-frequency driver above 1 kHz the curves for one or four stacked units are pretty similar, because stacking only makes the cylinder wave-front higher, not louder. On the contrary, in some cases the sound level even drops off slightly with four elements, compared to a single unit, which is probably caused by unavoidable interference effects. Overall only one weak-spot, affecting the curves between 300 and 600 Hz, is revealed. This could be the result of compression effects at the narrow gaps at the front of the midrange systems.

Listening Evaluation

Input panel

Rigging-frame.

Shortly after the arrival of the first systems in Heilbronn a test set-up with the VerTec Systems was made possible on the initiative of the Crystal Sound Company. This took place in the Karlruhe Europa-Halle. An array of six suspended on the ceiling served as central cluster and could be operated with or without additional HLA-Subwoofers, as desired. As is usual at such happenings, the event turned into an impromptu meet for the German audio-scene and there was plenty to discuss. The general opinion was that the rather petite-looking unit of six VerTec systems had enormous level reserves to offer, which effortlessly filled the entire depth of the hall of around 60 metres. Special praise was given to the almost unbelievable bass-level, which caused one to involuntarily wonder whether or not the subwoofers had been turned on. With the factory tuning the very restrained highs were noticeable; they had to be boosted with an additionally looped-in EQ in order to achieve a balanced sound from the FOH point at a distance of around 50 metres. Getting closer to the array on the middle axis from the FOH point, one couldn't avoid noticing light tonal variances. However, these had already been predicted by the line-array calculator. The variances probably resulted in the transitional frequencies from the array near field into far field, which are strongly dependent on distance. This has to be accepted as a condition of acoustic principles. One mustn't forget that the VerTec is in its early stages when it comes to collecting data and experience, and in the near future new methods will be developed to optimise coverage patterns. The user can rest assured that with a company of renown like JBL, one isn't left alone in this area.

When the system is driven to its limits, the limits are first noticeable in the low-mids, which is also confirmed by the measurements . Overall the performance was a great success, which was reflected by the sale of 32 systems each to the Crystal Sound Company and Sirius.

Additionally the hall was used to conduct a series of measurements that are summarised in fig. 24 and 25. Figure 24 shows a green averaged curve consisting of 30 test points spread over the entire audience area. 6-second sweep signals were used for measurements, to make sure the entire room was included. In addition to the direct sound the curve also shows the complete reverbant and/or diffuse field in the area, which is significantly effected by the directivity of the loudspeakers. Equalisation of a curve like this promises to be much harder than a direct wave-equalisation, where one is "only" concerned with ensuring a The hypothetical blue curve was considered only as guideline for the EQ-Tuning of the VerTec in the Europa Halle. The resulting EQ curve is shown in red. Naturally the obtained EQ-settings used here have no general validity due to the fact that the room is included. Two further interesting curves resulting from the same measuring method are shown in fig.25 where the red curve was averaged on the first half of the test points and the blue curve on the rear half. The sound levels are similar in both areas, only the low end reduces less with increased distance and the air absorption is still slightly present. Without cylindrical wave emission for high frequencies the sound level drop would have been stronger for the high frequencies. All in all the frequency response is pretty balanced even without EQ, so that a dream-curve can be attained with minor adjustments.

At this point a special thanks goes out to Carsten Peter from Audio Heilbronn and Hanns Hommen from the Crystal Sound Company for the smooth execution of tests and listening evaluations.

Conclusion

JBL steps into the suddenly fiercely competitive market of line-arrays. Just as with the last large scale sound system from JBL, the HLA, all high-tech guns have been drawn: In order to create the VT4889 Element the most advanced drivers have been used, an innovative enclosure has been developed that is light and solid, together with a special wave former and the RBI Technology. Despite its modest size the box is unreservedly suitable as full-range system and delivers a clean horizontal directivity performance. Clustered vertically the principle of a coherent wave-front to create cylinder waves works very well - right up to 16 kHz. Overall it is a technically perfect product as one has come to expect from manufacturers like JBL. It is not just the audio quality of the VerTec, but rather the combination of this with the extremely light and easy to handle enclosures and the ingenious suspension system, which should be decisive on the world market for this product. In summary, the VerTec line-array has, in relation to its size and weight, a very high power density, is flexible and easy to use and despite the rather high costs makes good economic sense for the user.

[1] Text and Measurements
Anselm Goertz
Photos:A.Goertz, JBL, Archive

Calculation of line-arrays

In its classical form a line-array is made up of a series of individual radiators. Each of these sources radiates a wave with a spherical front that then overlaps in the sound-field. It should be differentiated between the near-field and the far-field of such an arrangement, as its transition at a distance depends on the relationship between the wavelength and the length of the radiation arrangement. An easy formula calculates this distance as:

$$r_n = \frac{l^2 \cdot f}{2 \cdot 340\,{}^{m}\!/_{s}}$$

l in m and f in Hz

Length 1 stands here for the overall length of n single elements that have a certain distance d from each other. For the far-field the following formula results for the directivity of such a line-array:

$$R(\alpha) = \frac{1}{n} \left| \frac{\sin\left(\frac{\pi}{c} \cdot l \cdot f \cdot \sin\alpha\right)}{\sin\left(\frac{1}{n} \cdot \frac{\pi}{c} \cdot l \cdot f \cdot \sin\alpha\right)} \right|$$

The two illustrations show the directivity behaviour of the radiation arrangement. For the individual radiators a simplified spherical characteristic is assumed. The four curves represent the averaged directivity behaviour for the 1 kHz and 2 kHz octave and the three accompanying thirds. A two metre long row consisting of ten sources at a distance of 20cm from each other was used for the calculation.

For the 2 kHz octave the directivity increases as expected and the main maximum narrows compared to the 1 kHz octave. Interesting about these illustrations is the appearance of strong side lobes in the 2 kHz octave, where there was nothing to be seen in the 1 kHz illustration. This is due to the transgression of the critical frequency, whose wave length equals the distance between two of the line-arrays sources. For the chosen distance of 20cm the critical frequency lies at 1700 Hz. Above this frequency a line-array starts to create distinct side lobes from discrete sources and is therefore unsuitable for controlled coverage. With further increasing frequency the number of side lobes increase and they move in toward the main maximum. This effect occurs as a matter of course with all line-arrays with discrete sources even when these consist of high Q horns. The directivity calculated based on spherical radiators overlaps the directivity of a single system.

If a line-array is assembled out of normal horn systems, as it is presently often done, then the narrow coverage behaviour in the main maximum on an axis is obtained, but the distinct side lobes are only repressed within the capabilities of a single horn, which usually leads to compromising results.

Modern line-arrays like the V-DOSC, VerTec or X-line differentiate themselves from the previously discussed discrete line-array through their “genuine” cylinder wave characteristic, that can be produced over the entire frequency range with only one line source, which is not possible with discrete radiators.

A line source means that a continual infinite length and evenly radiating source is produced. These line sources radiate a cylinder shaped wave-front, that, due to the infinite expansion of the line irrespective of the distance, maintain their expansion shape.

In reality there are some restrictions and reservations to be made. Because of the finite length of a real line source the wave expansion area has to be divided into near- and far-field. The formula for the transition equals that of the discrete array. However there are differences in the formula for the directivity function of the line-arrays far-field, that acts as real line source of the length 1. The following polar diagrams show the resulting polars, again for the 1 kHz and the 2 kHz octave.

The shape of the main maximum on the middle axis of 0 degrees is identical to a discrete array. The difference here is that side lobes don’t occur.

$$R(\alpha) = \frac{\sin\left(\frac{\pi}{c} \cdot l \cdot f \cdot \sin\alpha\right)}{\frac{\pi}{c} \cdot l \cdot f \cdot \sin\alpha}$$

In summary it can be said that a discrete line-array consisting of individual sources below the critical frequencies behave similarly to a genuine line source.

Significant differences occur only above the critical frequency, where the undesirable side lobes occur. The art of creating a line-array suitable for the entire audio-range lies in creating a coherent wave-front not only for low and mid-ranges, but for the high frequency ranges too. For the low frequencies this is no problem with the alignment of the drivers in a straight line. As our example showed, for frequencies up to around 1500 Hz, normal 8” drivers in a close arrangement are perfectly adequate. This is exactly how it is done in all well-known line-array systems: each box contains one or two 8” drivers as close to one another as possible. With a cross-over frequency between 1000 and 1500 Hz to the high-frequency driver this is on the safe side. For the high frequencies it isn’t enough to merely stack the drivers above each other, because the sources would separate and cause side lobes. In order to accomplish this coherent wave-front with “ normal drivers” wave guides are used, that, depending on the manufacturer are variously called Waveguide (JBL), Hydra (EV) or Wave-Front Sculpture Technology (L-acoustics).

When evaluating the coverage patterns of the far-field the wave-front spreads in a spherical shape, even for a line radiator. For a 5.4 metre long line radiator this means r>43 metres at 1 kHz, and accordingly at 100 Hz r>4.3 metres. In the near field however, the wave-front takes a similar form to a cylindrical wave with the useful attribute that the sound pressure level reduces by 3 dB when distance is doubled rather than 6 dB. For the calculation of the opening angle of the main maximum in the far field an additional small formula comes into play that the 6 dB opening angle of the main maximums BW-6dB can be calculated as:

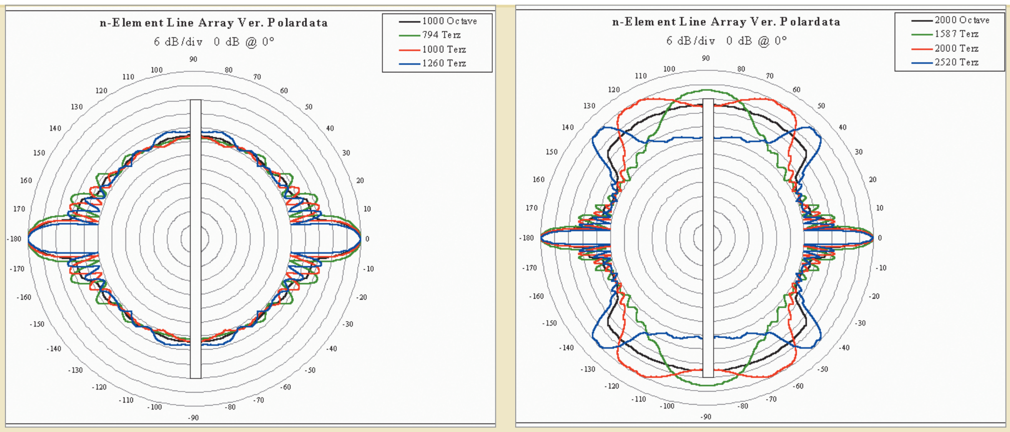
$$BW_{-6dB} \approx 2 \cdot \sin^{-1}\left(\frac{1.9 \cdot \lambda}{L \cdot \pi}\right)$$

For an example with 5.4 metres in length that would be about 4.4 degrees at 1 kHz.

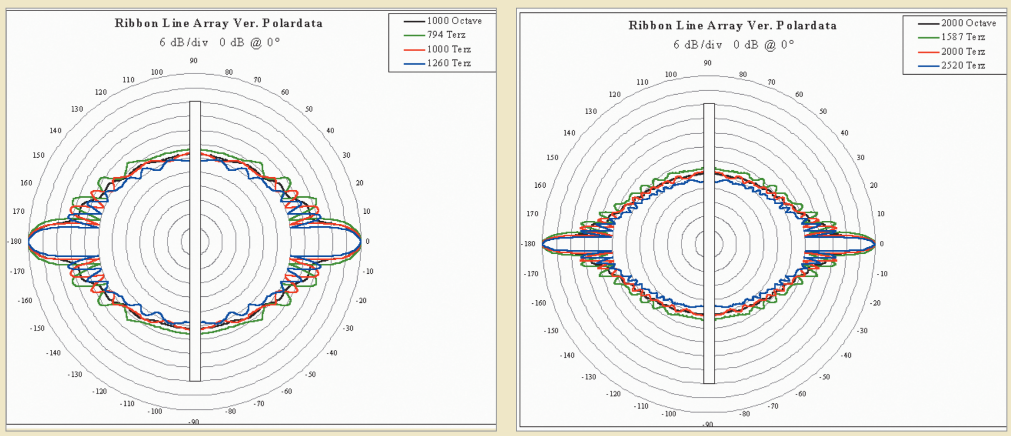
So much as to the theory of line sources, that in part were already explained in 1930 in a publication of the JASA. The large ribbon-tweeters like the Z-line from Sonus (see the 3/2000 issue of our sister publication for media technology PROFESSIONAL SYSTEM) fulfil the requirements of a line source with coherent wave-front over the entire audio-frequency range in near-to perfection.

In order to make a light curving of the line-array possible, to cover a larger area the line-arrays consisting of small units have to be capable of graduation without the wave-front breaking open. Trapezoid casing and a small vertical opening gap in the individual unit supports this application.

A.G.



Directivity behaviour of a line-array from discrete spherical radiators below (first figure) and above (second figure) the critical frequency, the wavelength which corresponds to the distance between two sources.



For comparison: Directivity behaviour in a continual line-array with coherent wave-front, for the two frequency ranges shown above, for discrete line-arrays.

Line-array Calculator

The manufacturers of line-arrays are presently in a difficult situation in that the simulation programmes like EASE or Ulysses that are on the market aren't suitable for their new loudspeakers. Despite the abundance of loudspeaker libraries and the programmes wide use these components cannot be found. This is connected, not with the unwillingness of the manufacturers, but with the characteristics of the line-array, which is incompatible with the functions of the simulation programme. Basically the simulation programmes assume a spherical wave-front from their acoustic sources, which ideally shows a directivity where distance is irrelevant. In normal loudspeakers this is largely true, so that a directivity balloon measured at 4 metres will also be valid at 10 and 20 metres. This prerequisite is fulfilled if one is positioned in the far field of a source. With "normal" loudspeakers 4 metres is adequate for all frequencies in the audio range.A simple formula calculates the distance for the end of the far field as forementioned as:

$$r_n = \frac{l^2 \cdot f}{2 \cdot 340\,{}^{m}\!/_{s}}$$

l in m and f in Hz

Length 1 is the largest expansion of the radiator in one direction, which equals the diameter of the direct radiators diaphragm. The transition from near to far field shouldn't be visualised as a gap or point, but as a continual transition from a near field with local minima and maxima and a far field with a continuous 1/r level decrease. For the calculation of a balloon one should therefore be well into the far field and choose a test distance greater than:

$$r_f = \frac{l^2 \cdot f}{340\,{}^{m}\!/_{s}}$$

For a 4 metre long line-array this would mean a distance of 47 metres at 1 kHz, for 5 kHz as much as 235 metres. Only beyond this distance would the classical simulation programmes produce useable results for a line-array. In contrast, the near field and the transition area are much more complicated.

Problematic Balloon Data

Staying with the demonstration method of balloon-data for a line-array one would have to test a whole series of balloons for different distances and the simulation program would have to calculate the point of impact and then calculate the distance from the source, only to then apply this data to the balloon suitable for that distance. All in all a very complicated process, made even more so by the fact that the balloon-data would have to be determined for all the line-arrays various configurations, so that this kind of calculation for freely configurable line-arrays like V-DOSC, VerTec or X-Line doesn't make much sense.

An alternative method is the discretion of the array into such small elements that in a complex calculation like this, they replicate the line-array functions exactly.

The elements mustn't be added as clusters, but instead, have to be added together minutely, source by source. To attain correct results for the upper 8-kHz-octave, the discretion has to take place in intervals smaller than the wavelength of the highest frequency to be tested. For the 8 kHz octave this would mean around 3 cm. Accordingly a 4 metres line-array would consist of at least 133 single elements. Calculation work increases considerably, but this method allows any configuration or curve angle to be calculated on the basis of a single set of data. All that be needed would be a convenient way of entering the line-arrays data into the simulation program. The testing of this kind of calculation of a line-array in a simulation program has yet to be done; the newest test results will be published at a later date.

Special Array Calculator

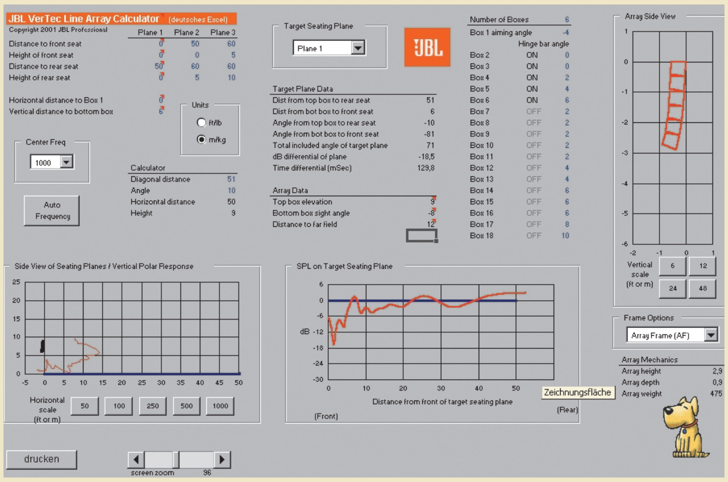
To supply the user with an immediately applicable calculation tool the loudspeaker manufacturers offer their own programs to calculate the pure direct coverage patterns of a line-array. For the VerTec there's a line-array calculator that works on excel. It requires Excel 95 or later with activated VBA Add-in.

Up to three audience areas and a line-array with up to 18 VerTec units can be entered in an intuitive fashion on an user-friendly screen. The calculation occurs solely on a vertical plane in a room and shows the polar diagram of the complete array and the sound pressure level in one third octave intervals. Even on slower PC's the curve appears almost without any delay as soon as the frequency is chosen, so that an overview is immediately possible. Calculations are only taken from the far field perspective; therefore nothing can be said on the topic of short distances.

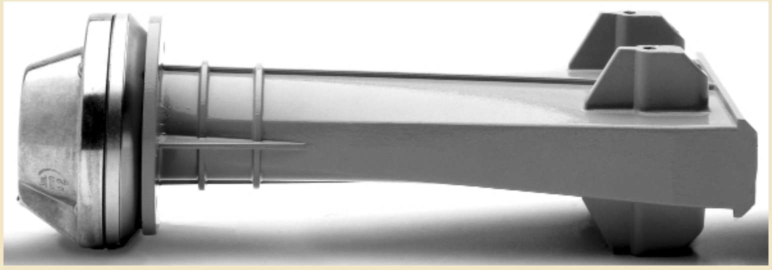
Also, the sound level results are only relative to each individual representation and so no comparison can be made of absolute sound levels in the audience area.

Comparison of the results of line-array calculators with their measurements

suggests that the Excel routine works with a model of n-elements where each element has the vertical directivity of a single VerTec element and is included in the calculation with an angle-offset the size of the set-up angle. This method serves as a good compromise for a quick overview, without great emphasis on accuracy.
Parallel to the acoustical data the calculator gives other useful information about weight and dimensions of the array and its set up angle. Overall the LAC (Line-Array-Calculator) is a useful tool on location and in the planning stages of an installation. Near field effects and the actual cylinder wave expansion are not taken into account here. For exact calculations, with consideration of the acoustic environment, implementation in of the well-known simulation programs should be done as soon as possible. The trend is growing toward line-arrays and now almost all loudspeaker manufacturers are jumping on this French band-wagon. Software manufacturers are well aware of this development and everywhere work is getting underway and speedy updates are promised. Nothing, however, has been said about the way in which the calculation of line-arrays will be implemented. A.G.



The LAC screen in Excel with settings for a 6-unit array for listening evaluation in the Karlsruhe Europa Halle. Near-field effects and the actual cylinder-wave expansion are not taken into account by LAC.



Three of these drivers with Waveguides on top of each other create a coherent wave-front for the line-source.

Horizontal Coverage of Line-Arrays

Line-arrays from the big manufacturers on the market are at the moment all specified with horizontal opening-angles between 70 and 120 degrees. This scale is practical for many applications, especially with the combination of different systems, for example 90 degree modules at the top and 120 degree units at the bottom of the array, in order to attain a certain adaptability. Despite this, there will always be situations where larger angles are needed. For a central cluster above the stage of a wide audience area 180 degrees would be sometimes desirable. For the opposite extreme, coverage of a long, narrow area, a substantially narrower horizontal angle with increased sensitivity on axis is desirable.

Generally questions arise as to variation-possibilities and the possibility of assembling the line-arrays horizontally in clusters.
Under this aspect we find a classical construction in the line-arrays of V-DOSC or VerTec, with external positioned direct-radiating woofers and coaxial mid to high range arrangements. The horn function in a horizontal plane is realized with simple linear planes, that also serve as sound wall for the mid-range driver. With Electro-Voice we find a different arrangement in the X-Line. The high-frequency driver is built in separately and the woofer and mid range driver are arranged coaxial. The woofers are designed here as flat-membrane loudspeakers to keep the horn area as linear as possible. In the VerTec the mid-range drivers are covered with slit covers for the same reason.
These simple horn functions or wave-guides are necessary due to the necessary vertically closed arrangement of the paths in a line-array.

A clean and narrow coverage pattern of, for example, 40 degrees over a wide frequency range is difficult to attain with this kind of horn. Especially in the low- mid range strong expansions of the coverage angle would be caused, comparable to the behavior of a narrowly radiating horn with a direct radiator. By adding the loudspeakers to a tight cluster, parts of the area would be covered by single horns for the high frequencies. For the lower frequencies a smooth transition to an allover radiator would be attained by the acoustic coupling of the close proximity of the drivers or horn openings. For typical line-array systems this is hardly possible because the arrangement of the individual paths doesn’t allow for a clean acoustic coupling. For two VerTec lines rigged next to each other the centrally arranged mid-high units that cover the frequency area from around 2000 Hz up, would lie so far apart that interference would occur, even if the line-array would be perfectly straight aligned. An alternative to the symmetrical set-up of a VerTec or V-DOSC could be the solution offered by Electro-Voice with the X-Line, where the high frequency horn positioned on the side next to the coaxial low mid arrangement allows for a symmetrical mirror-like arrangement of two lines rigged next to each other. More to this probably in our 6/2001 issue after detailed measurements of the at this point still slightly modified X-Line.

In the JBL and L-Acoustics handbooks it is advised not to cluster several lines, but rather to rig them spaced at a larger distance around the stage area. A.G.

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