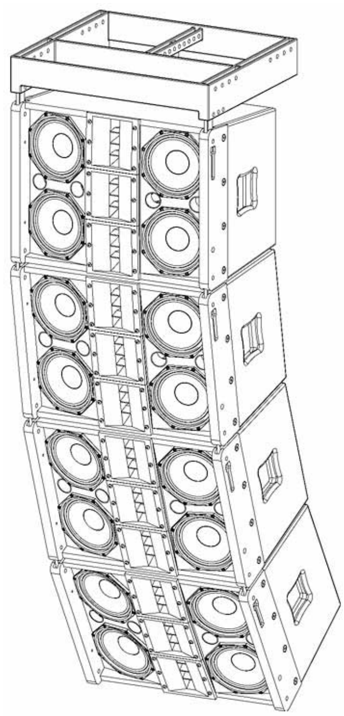
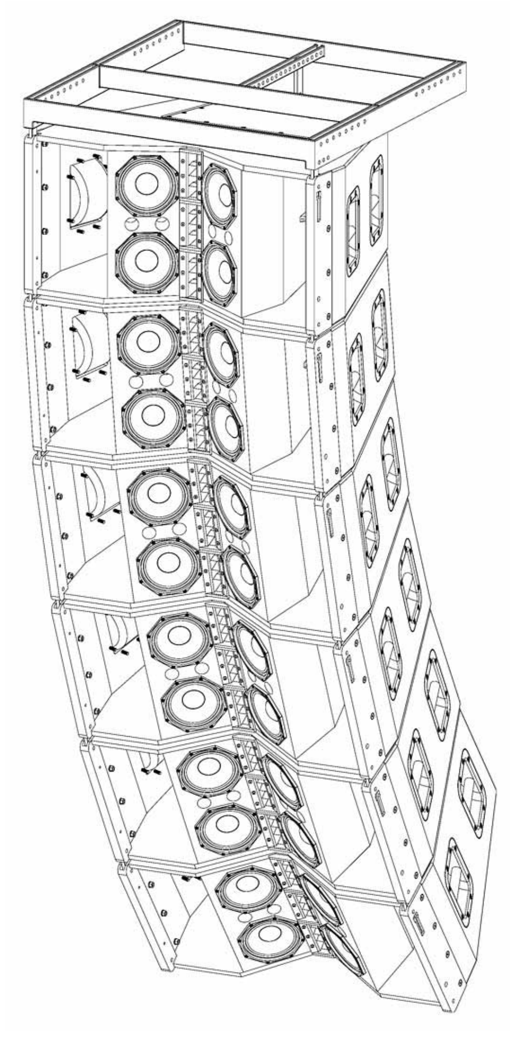
Arcline

Design Considerations
and
Practical Implications

By Rog Mogale





Arcline Design Considerations and Practical Implications

Operational Criteria

All Arcline series enclosures have been designed to fully exploit line source operational criteria and the benefits listed below.

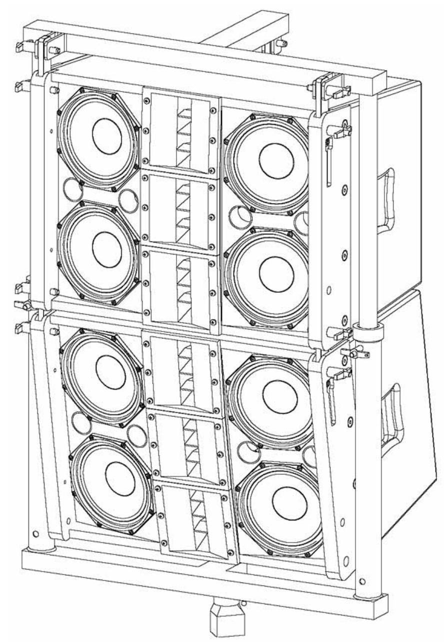
- Multiple discrete elements implemented as a single continuous source approximating a vertical cylindrical radiation pattern with constant coverage within the Fresnel near field
- Perpendicularly extending limited vertical radiation minimising floor/ceiling reflections
- Increased dynamic range and reduced distortion due to higher power handling dispersed via multiple elements in each band
- An active radiating factor >80% assuring that secondary lobe levels are no greater that 12dB down with respect to the main lobe in the far field
- A transducer centre to centre separation distance based on axial directivity analysis to maintain both constant phase front and isophase propagation implemented within a single wavelength of a devices highest operating frequency

Further techniques have also been implemented to negate some of the negative aspects inherent with line source design.

- Close HF device separation between adjacent enclosures that form a single continuous source operating to over 17,000Hz when arrayed with multiple enclosures, regardless of individual enclosure vertical tilt amounts
- Decreased response irregularities and phase degradation by applying a curved baffle arrangement with virtual common feed point to equalise sound path length discontinuities within the near field
- On board vertical tapered power feed with symmetrical shading minimising path length derived destructive interference

Arcline 6 Design Goals

Arcline 6 has been designed as a small format solution providing a wide horizontal dispersion with minimum phase degradation and high SPL capabilities from a very small enclosure. Whilst correctly arrayed point source designed enclosures can offer all of the above benefits, they can never compete on size. Multiple enclosures are always required to provide the necessary horizontal dispersion and the complexity of the rigging system has resigned their use to large scale concert and touring applications only. If all of the above criteria are to be met and employed for use in smaller applications, I can only see a line source as the practical solution. I do not base the decision on the 3dB per doubling of distance argument brought about by being within the near field of a cylindrical radiation pattern, I base the decision on the need for a wide horizontal dispersion with high SPL in a small format that requires minimal rigging. The truth is that for the type of work the Arcline 6 will get used for, a true cylindrical wavefront can only exist above midrange frequencies due to a severely truncated line length, leaving the Arcline 6 more suited to short and medium throw applications.



Two Arcline 6 in a tower winch cradle

Migration Techniques

For a 3dB reduction in SPL per doubling of distance (decreasing SPL inversely versus the distance), requires the listener be placed within the near field of a cylindrical wavefront. The distance at which a vertical cylindrical wavefront can extend this condition is a function of the length of the line versus frequency. At any given distance a longer line will allow a lower frequency to fulfil near field operating conditions.

Arcline Design Considerations and Practical Implications

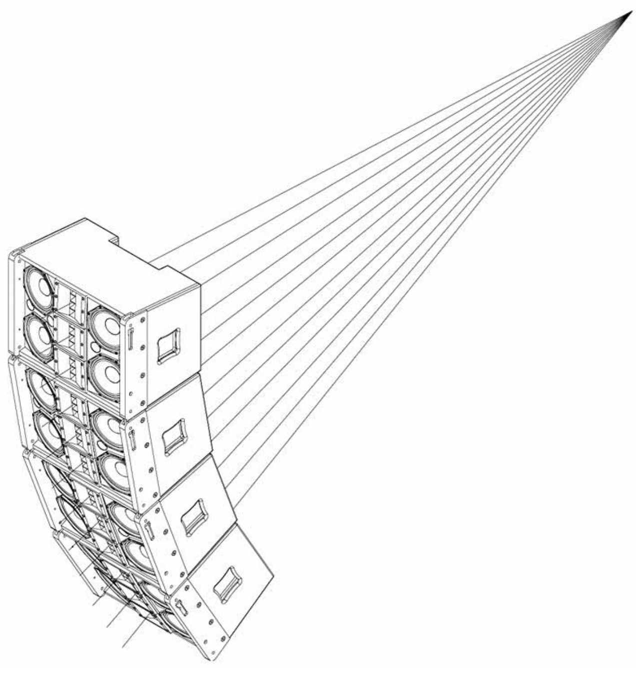
Migration Techniques Continued

At the point where the length of the line becomes too small to substantiate a perpendicularly extending vertical cylindrical radiation pattern, the wavefront transforms into a radial extending spherical radiation pattern. This point is called the transition distance and can be calculated $d = 1.5\ f\ h^2$ or from far field analysis by Ureda [1] as $d = 1.45\ f\ h^2$. After the transition point radiation migrates into the far field sound levels decrease by 6dB per doubling of distance (decreasing inversely with the square of the distance). As can be seen to gain the benefit of a 3dB reduction in SPL per doubling of distance requires the listener to be within the near field and for the line length to be suitably long enough to maintain a vertical cylindrical wavefront out to the furthest listener at the lowest frequency to be produced by the line. To satisfy these stringent goals would require a very long line and to create near field conditions out to a distance of only 10 meters (32.8 ft) down to 100Hz would require the line to be 8 meters (26.2 ft) in length. If a vertical line is used inside a room and positioned so that both the top and bottom of the array are within a single wavelength of the highest reproduced frequency to the floor/ceiling, the line can be considered to be 3 times it free space length.

From all of the above its clear that an array made with two or four Arcline 6 enclosures will not put many listeners within the near field, especially at lower frequencies. Hence the primary design goals were not those of obtaining an increase in far field sound intensities due to the 3dB reduction in SPL per doubling of distance, but were born from preserving on axis integrity whilst minimising side lobe degradation in a small enclosure size with a very wide horizontal dispersion.

As stated earlier to form a single continuous source approximating a vertical cylindrical radiation pattern, multiple discrete elements must be spaced within one wavelength ($< \lambda$) of their highest operational frequency. Many have suggested that a more stringent criteria of no more than a half wavelength ($< \lambda / 2$) spacing between sources at their highest operating frequency be implemented as this places far field nulls in the off axis response beyond $\pi/2$. But according to Ureda [1] the centre to centre spacing of circular transducers must be less than one wavelength at their highest operating frequency. This less than one wavelength criteria creates a constant phase front with comb lines appearing after one wavelength separation. Also the directivity of multiple sources in a line increases until one wavelength spacing has been reached and then starts to decrease beyond this spacing, whilst the first cancellation does not occur until a separation of two wavelengths. It is for these reasons that all circular transducers have been placed within one wavelength of their highest operating frequency. The vertical centre to centre (c-t-c) separation of Arcline 6 bass mid transducers within each enclosure is 192 mm, which equates to one wavelength at 1,795Hz. The vertical (c-t-c) separation of these transducers between adjacent enclosures in an array is 210 mm, which equates to one wavelength at 1,641Hz. The horizontal (c-t-c) separation of these transducers is 310 mm, which equates to one wavelength at 1,112Hz. As an internal crossover with high out of band rejection (< 24dB per oct) and a frequency of 900Hz is used, all criteria regarding single wavelength (c-t-c) separation have been met.

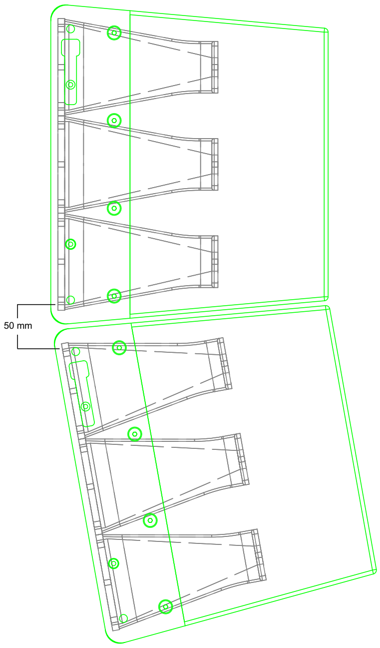
All HF devices used with Arcline enclosures are vertical slot radiators. Each device is driven from a 1" compression driver and contains path length compensation devices located within each device. The maximum deviation from any location on the throat to any location on the mouth is 5 mm, giving each HF device an upper operating bandwidth of 68,933Hz, which is far higher than the 20,000Hz upper response of the compression driver. This means each HF device can present a uniform vertical cylindrical radiation pattern out to both edges up to an upper operating frequency of more than 3 times that set by the compression drivers upper response. Each Arcline 6 enclosure contains three HF devices and the furthest edge to edge (e-t-e) separation between any two HF devices within a single enclosure is 15.6 mm, which equates to one wavelength at 22,094Hz. Again this is above the upper operating response of the compression drivers of 20,000Hz. Each Arcline 6 positions its outer most HF devices right at the edge of the enclosures front baffle, so the (e-t-e) separation of any two HF devices between adjacent enclosures is no greater than 20 mm, which equates to one wavelength at 17,233Hz. This spacing limits the upper response of a multiple line of enclosures to 17,233Hz, but I consider this a small compromise when all the other benefits of a true line source are met. The above HF device separations have also allowed for an active radiating factor well above the recommended 80% as stated by Urban, Heil and Bauman [2]. This assures that secondary lobe levels are no greater that 12dB down with respect to the main lobe in the far field. Furthermore, all components within the line are placed on an arc with a common virtual feed point, see dia 1. This greatly reduces phase anomalies and response irregularities by equalising the path lengths between the transducers and listener within the near field.



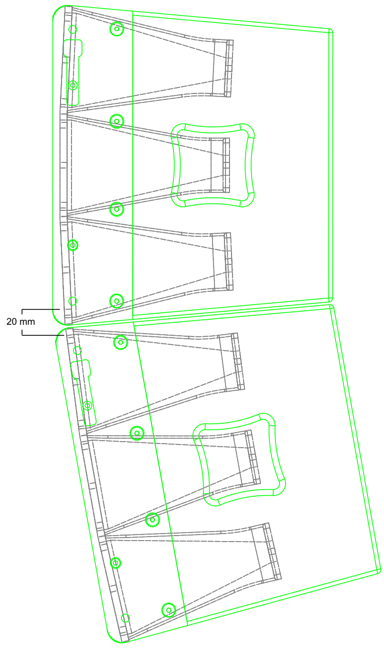
dia 1. Arcline common feed point

Arcline Design Considerations and Practical Implications

As can be seen in dia 2. many line array systems fail to form a continuous line source from their HF devices because the edge to edge distance between adjacent enclosures is too great. It only takes a separation distance of 34 mm to limit the upper HF response to 10,000Hz and there are very few systems that can even achieve a separation as close as 34 mm. Many line array manufactures push to achieve HF device (e-t-e) separation of half wavelength within each enclosure and then have a (e-t-e) separation distance between adjacent enclosures of greater than 50 mm. This totally destroys the single line concept and severely restricts the upper HF response of the whole array. It can also be responsible for a lack in HF intelligibility and extension with increased distance, which is another inherent problem with line sources that have wide adjacent enclosure separations at the front baffle. As can be seen in dia 3. Arcline negates these problems by using an HF device separation that allows a continuous source to be maintained to frequencies above 17,000Hz even when arrayed with multiple enclosures and varying amounts of vertical tilt along the line.



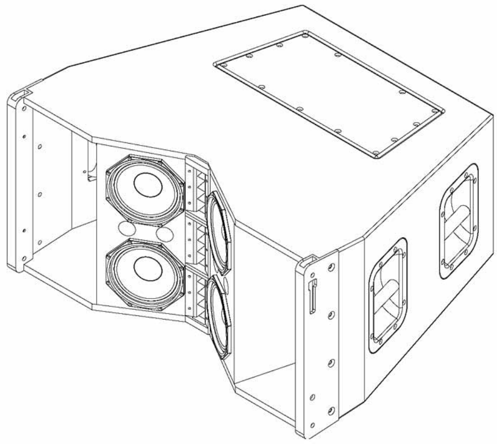
dia 2.



dia 3.

Arcline 12 Design Goals

Arcline 12 has been designed as a medium to large scale solution to sound reinforcement. The mid and HF sections have identical performance to those of its smaller brother the Arcline 6 and likewise meet all the criteria for a vertical cylindrical radiation pattern to exist.



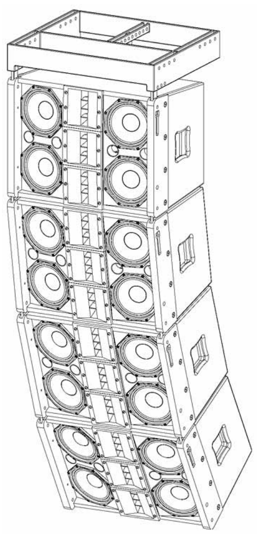
Arcline 12

The difference lies in the way the lower mid frequencies are reproduced. As can be deduced from previous pages, unless an impractically long line is created only the upper frequencies will couple to form a cylindrical radiation pattern. This means the upper (loaded) frequencies can obey a 3dB reduction in SPL per doubling of distance, whilst the lower frequencies have to obey the 6dB reduction in SPL per doubling of distance. This results in the familiar line array sound that lacks weigh in the low mid and upper bass with increasing distance. The Arcline 12 gets around this inherent problem by replacing the lower mid and upper bass section with a high efficiency horn loaded system with low directivity index and proven throw capabilities. Perceived throw is a bit of a misnomer unless a line is created that can provide a vertical cylindrical radiation pattern. Horns have traditionally been associated with throw and projection, not because they form cylindrical radiation patterns, but instead have a high efficiency/higher starting SPL and a tight controlled directivity index. The marriage of a horn loaded device reproducing frequencies below where a finite cylindrical wavefront terminates negates most of the inherent problems associated with line source systems today. A truncated line can be formed with multiple Arcline 12's without losing the vital lower mid and upper bass frequencies (100 - 400Hz).

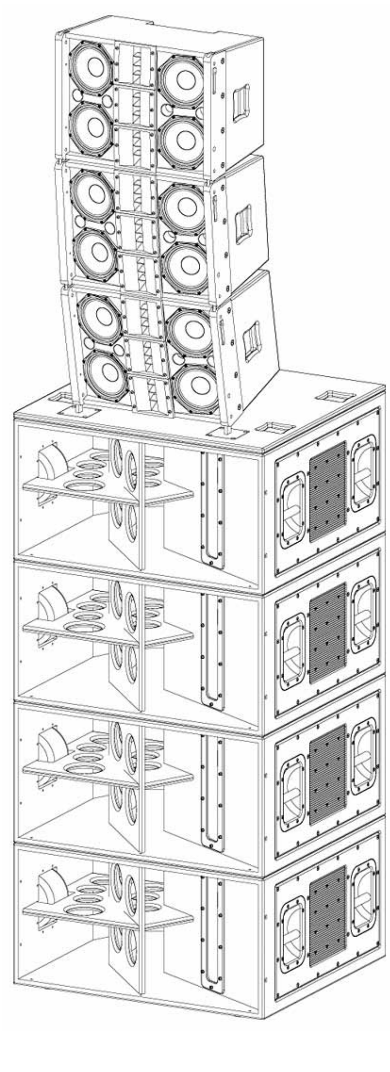
Arcline Design Considerations and Practical Implications

Practical Implications

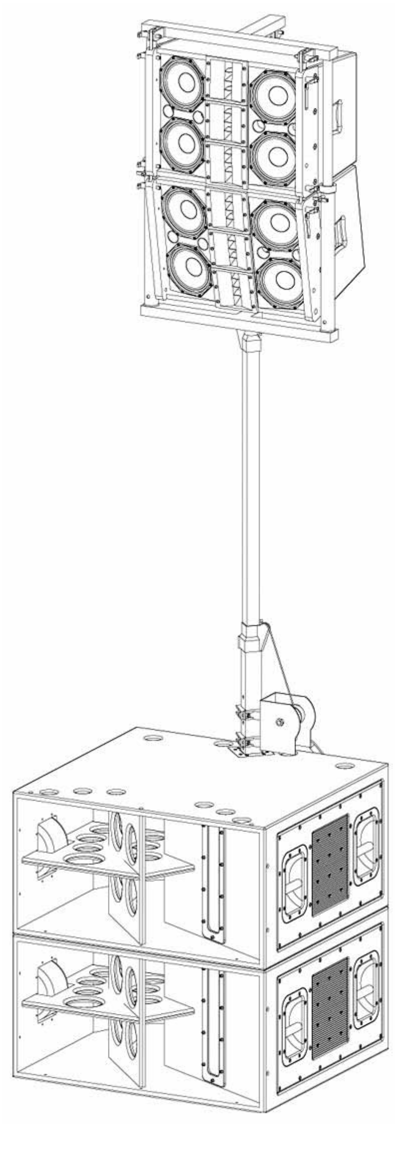
Arcline 6 can be configured in many different ways by the use of flybars, tilt boards, winch up towers and cradles. All the accessories required to allow the three main configurations can be supplied as options. These configurations include flown hangs via a flybar (dia 4.), ground stacked above Arcline X bass enclosures via a tilt board (dia 5.) and ground flown via the winch up tower system and Arcline X bass enclosures (dia 6.) With the latter configuration two Arcline X enclosures form the support for the tower that can winch up to a maximum of two Arcline 6's to a height of 3.5 meters (11.5 ft) and as the tower cradle is extendible it can suspend either a single or pair of Arcline 6 enclosures. Optional legs can also be attached the the tower to form a free standing system of two Arcline 6's for conference use etc.



dia 4. flown system



dia 5. ground stacked system

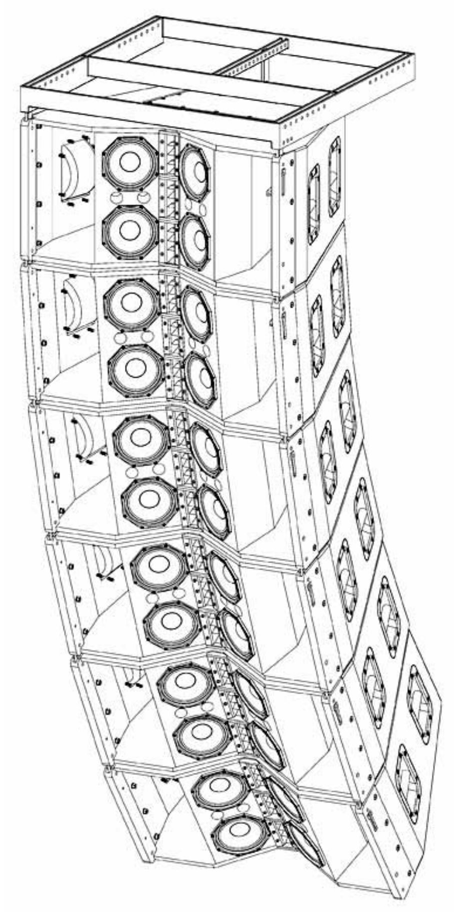


dia 6. ground flown system

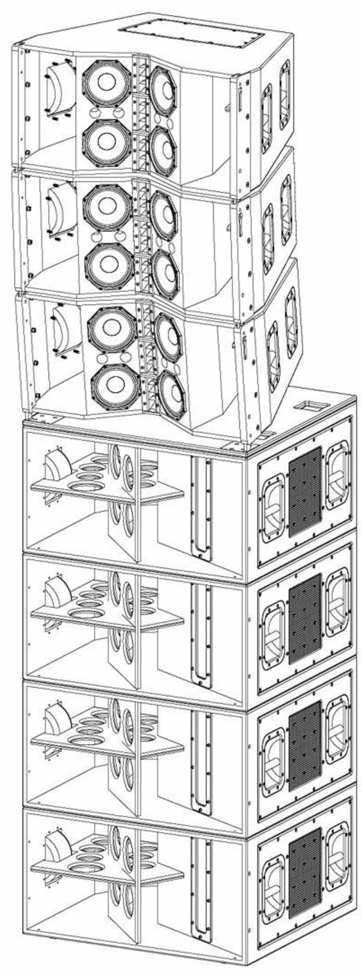
Arcline Design Considerations and Practical Implications

Practical Implications

Arcline 12 can also be configured in many different ways by the use of flybars and tilt boards. All the accessories required to allow the main configurations can be supplied as options. These configurations include flown hangs via a flybar (dia 7.) and ground stacked above Arcline X bass enclosures via a tilt board (dia 8.)



dia 7. flown system



dia 8. ground stacked system

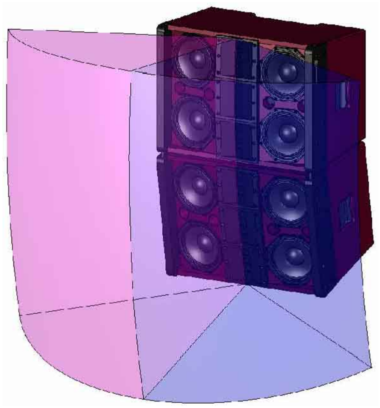
A typical ground stacked system for larger applications could comprise of 16 Arcline X and 8 Arcline 6's. This would be configured as 8 Arcline X's and 4 Arcline 6's per stack. The component count for such a system would be, 32 x 15" horn loaded woofers, 32 x 6.5" midrange drivers and 24 x 1" compression drivers with a total input power of 32Kw RMS. The system would be capable of producing peaks of just over 150dB at 1 meter with a -3dB point of 38Hz. As the total cubic volume of the system is so small, such a system would only require the use of a transit size van for transportation.

System setup times with Arcline can be incredibly quick and in timed trials it took 2 men just 12 minutes to unload and set up the complete system mentioned above. For applications that require a system to cover a greater distance, the 4 Arcline 6's in the above system could be replaced with 3 Arcline 12's per side.

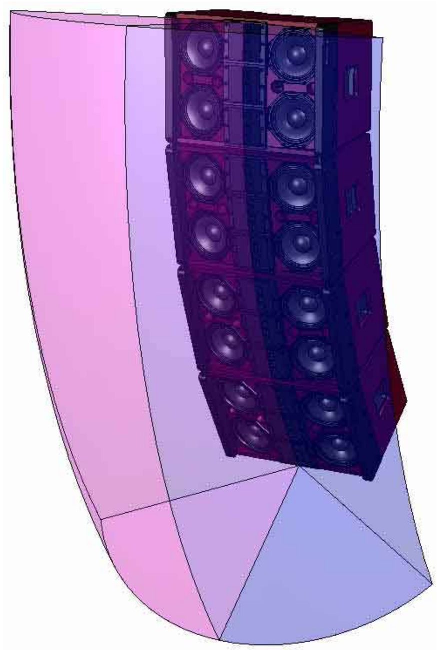
Arcline Design Considerations and Practical Implications

Arcline Dispersion Angles

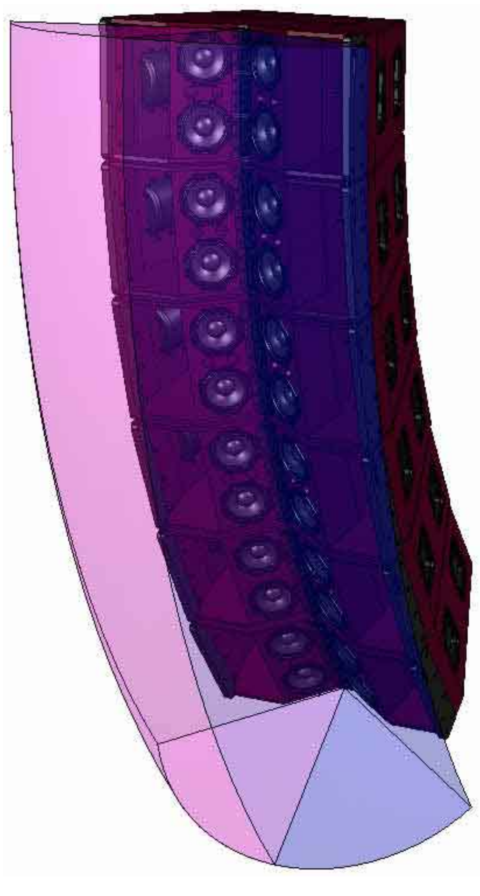
Both Arcline 6 and Arcline 12 share a 120 degree horizontal dispersion pattern (-6dB points). Arcline 6 features a 12 degree vertical dispersion, requiring fewer enclosures to provide adequate coverage in the vertical plane. Whereas Arcline 12 features a 7 degree vertical dispersion per enclosure, allowing longer lines to be created for higher SPL's with increased long distance coverage. Dia 9. depicts the radiation pattern in both horizontal and vertical planes from two Arcline 6 enclosures with the maximum tilt applied between adjacent enclosures, whilst dia 10. depicts the radiation pattern from four Arcline 6 enclosures with maximum tilt between adjacent enclosures. Dia 11 depicts the radiation pattern in both horizontal and vertical planes from a hang of four Arcline 12 enclosures with maximum tilt between adjacent enclosures and dia 12. depicts the radiation pattern from a hang of six Arcline 12 enclosures with maximum tilt between adjacent enclosures.



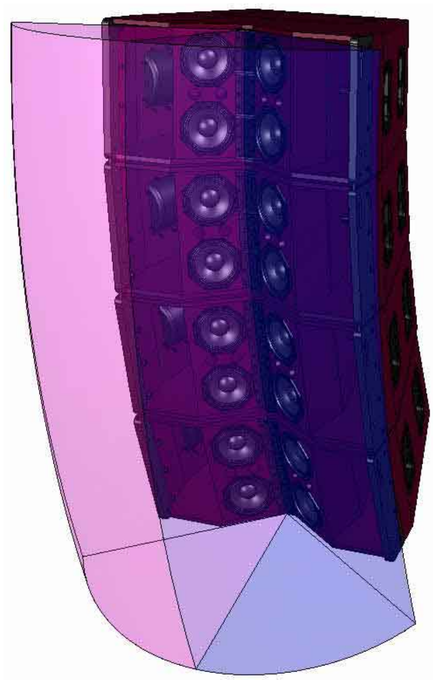
dia 9. 120 h x 24 v



dia 10. 120 h x 48 v



dia 12. 120 h x 42 v



dia 11. 120 h x 28 v

Arcline Design Considerations and Practical Implications

References

[1] M. Ureda, “Line Arrays: Theory and Applications”, presented at the 110th AES Convention, Amsterdam, May 12-15,2001.

[2] M. Urban, C. Heil,and P. Bauman, “Wavefront Sculpture Technology”, presented at the 111th AES Convention, New York, September 21-24, 2001.

Arcline technical specifications, frequency measurement data and polar plots are available at the Void website

www.voidaudio.com

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