Wideline White Paper: notes and developments

Michael Adams
Revision 2

Wideline Design Notes: (Feb. 2002)

Design objective: To design a compact system that would perform as a larger system in terms of power handling, frequency response and coverage. The primary focus is to be on the regional corporate user in ballroom situations, theaters and the myriad of small to medium size events that confront such users daily.

Coverage was to be fairly broad so as to limit the need for "side hangs or fills" when used as a main array. This broad coverage would also produce enhanced coverage when used as a center cluster, and facilitate the enclosure's usefulness as a "downfill or under hang" enclosure when used in conjunction with larger format line array systems.

The system should also be able to "stand alone" as a full range, articulate, high fidelity sound reinforcement product, able to reproduce a full gambit of musical programs without the need for additional sub woofers or bass modules. In short technical terms, it needed to be small and have "Balls". To do so would require bass response to below 60hz in a small format package.

The design should be easy to transport, assemble, use, and require a minimum of accessories to fulfill the desired needs.

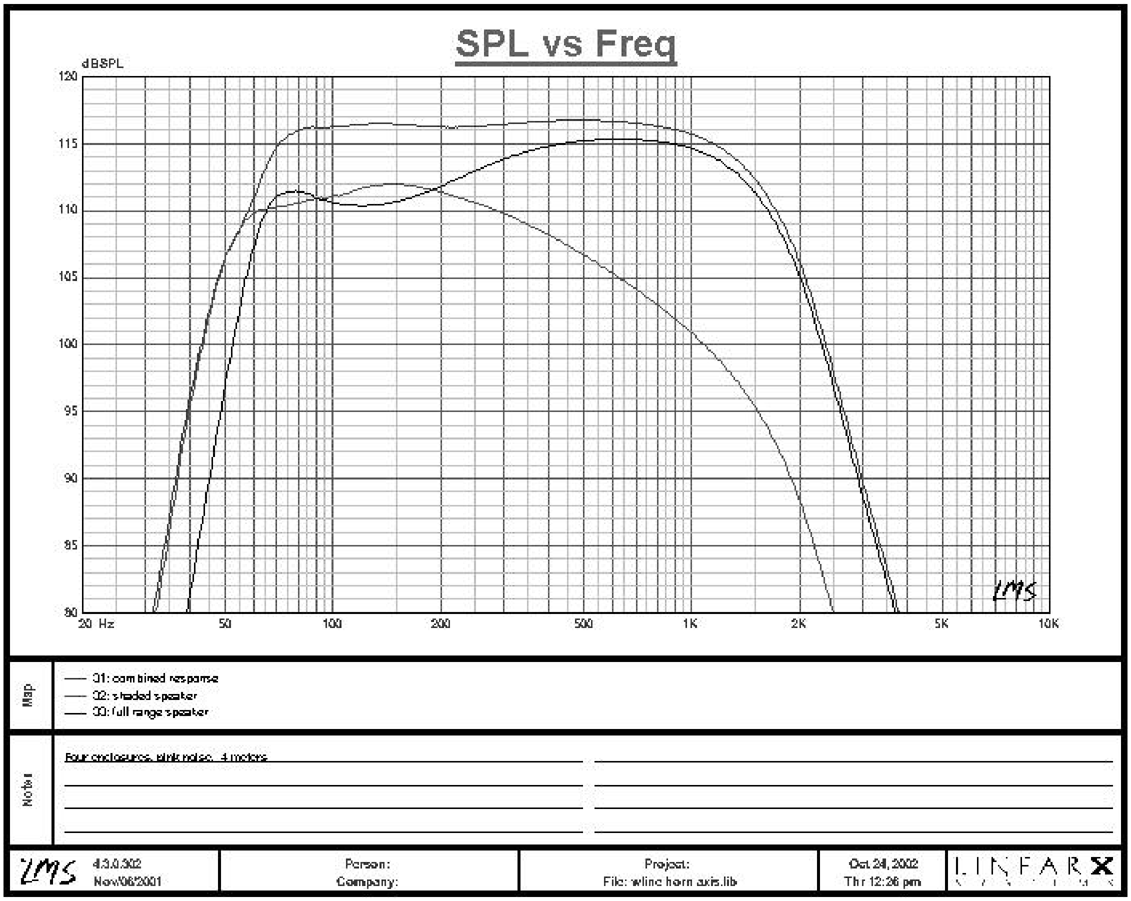
It should also be a bi-amp configuration to keep amplification to a minimum. *****

***** After much field testing, the design was altered to allow both two-way and three-way active operation.

Development:

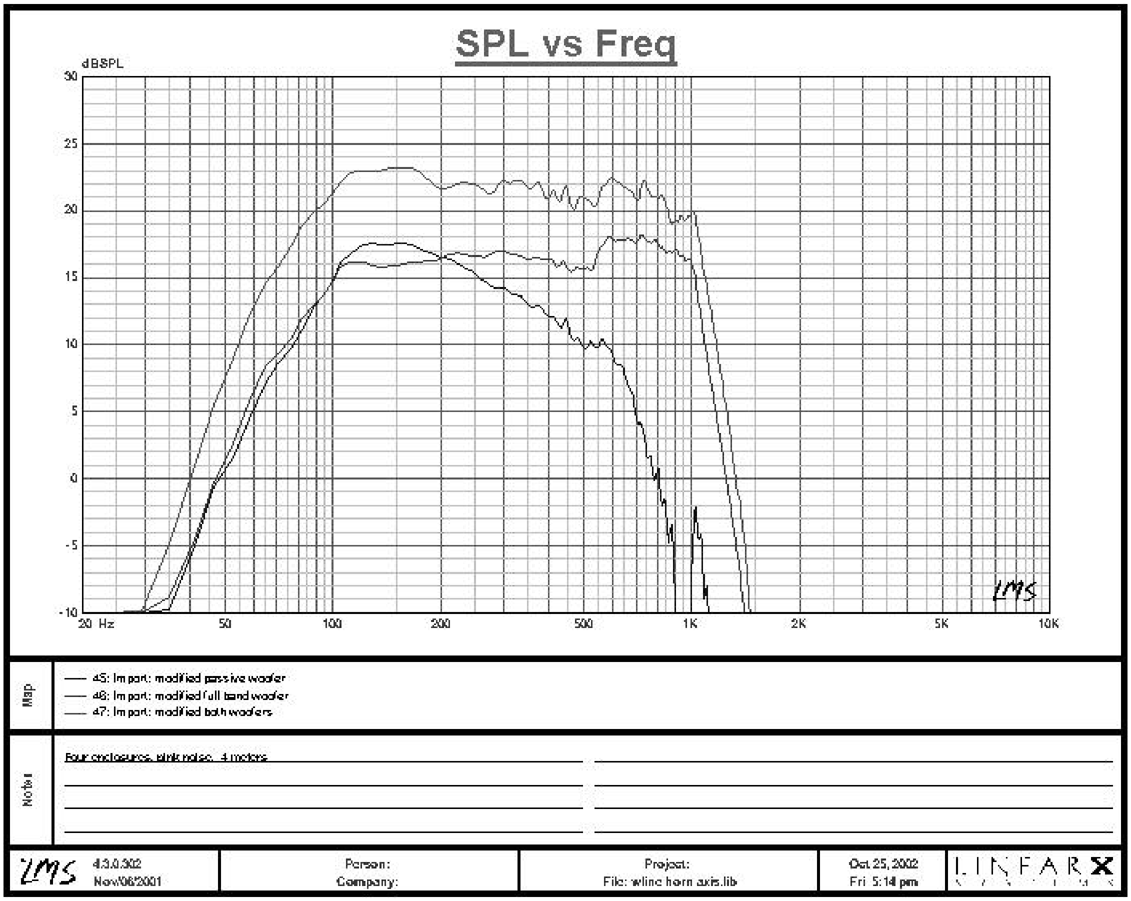
Without repeating the many dissertations on line array theory, in order to achieve both decent bass response and wide coverage in a compact enclosure, and also meet the linear array design criteria; a shaded design using two (2), ten inch (10”) loudspeakers was developed, as well as a proprietary high frequency device.

The shaded design allows only one 10” loudspeaker to interact with the high frequency device, maintaining directivity, while the other works in concert to reinforce the bass response. The idea of this bass assist is illustrated below.



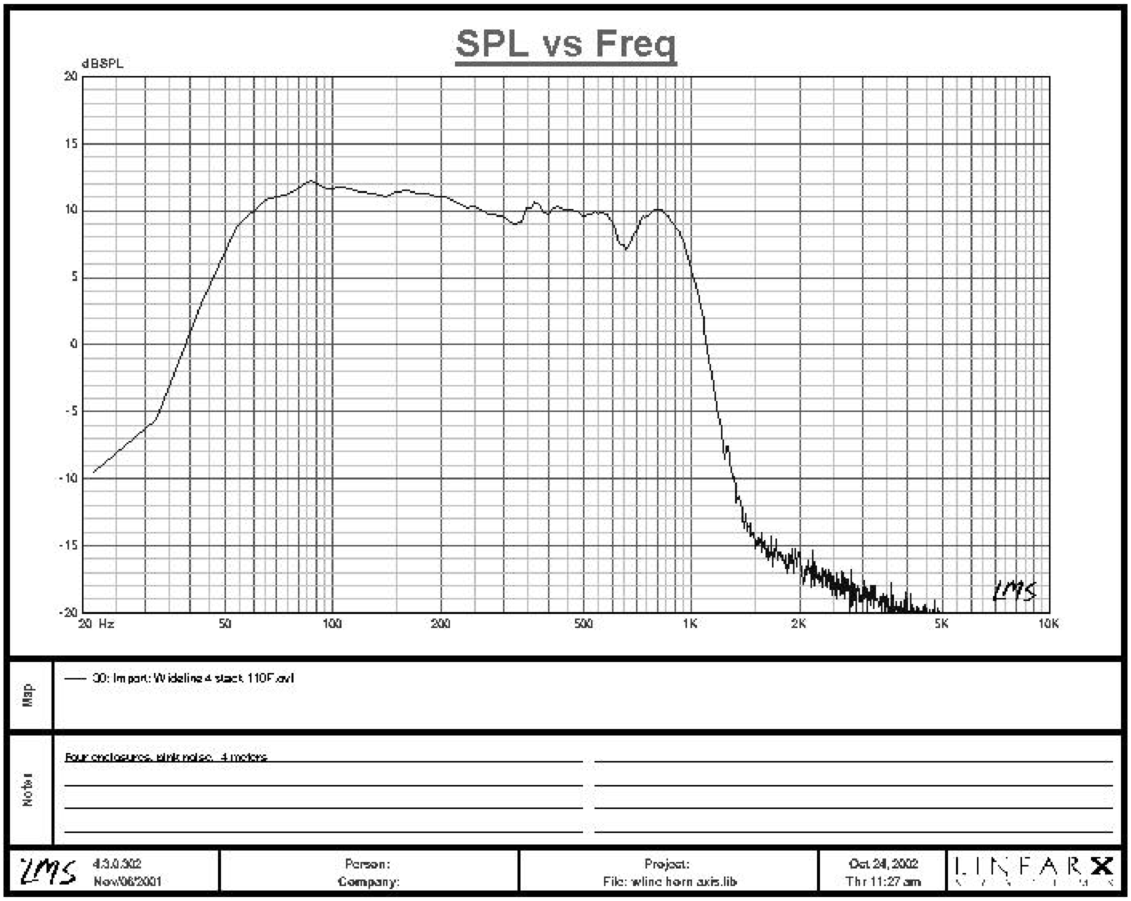
The above graph shows what is being accomplished. The graph curves 32 and 33 show the **modeled** response on axis of the two speaker elements. Curve 32 is the shaded speaker (-6dB @ 300hz in this example) and curve 33 is the full bandpass woofer (40hz – 1500hz). Each speaker is in a separate chamber, and as these elements are to be used in multiples, the low frequency is tuned for extended bass response. This causes the woofer to exhibit a rising response. The idea is to use the second shaded speaker to sum fully in the low frequency area and partially in the upper range. This would cause the rising response to be “filled in” creating a more ideal combined response. Curve 31 shows the results of the combined response.

Tests on an actual enclosure are shown in the following graph. No smoothing is applied. Scale is 1dB/div.



One can see how the combined response varies only ~1dB. A steep bandpass filter was placed at 1khz for this data acquisition.

The following graph is an actual ground plane measurement taken of a stack of four (4) enclosures in the acoustical environment known as the “parking lot”. No smoothing is applied. Scale is 1dB/division. The minor anomalies in the response are due to reflections from nearby objects.



In general one can see the bass response extends to –3dB @ ~52hz with a slight –1dB tilt toward the upper cut off frequency.

Shading:

Why not just run both speakers in the same bandpass since this is to be a two-way design and by shading it you’ve created a three-way?

The answer lies within the desired coverage angle of the system and the directivity of the two loudspeakers. A common formula for determining the directivity response of a direct radiator is:

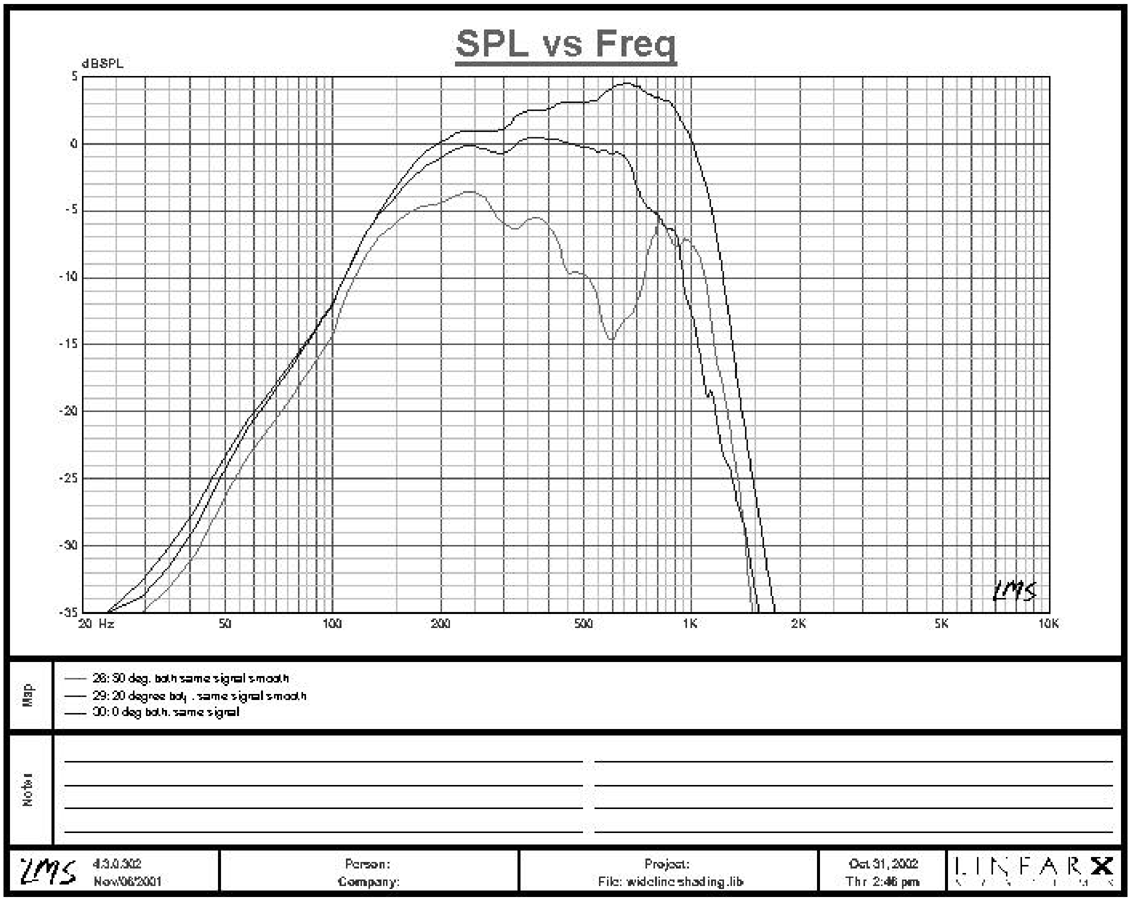
$$f_{-6dB} = {}^{0.7} / (3D * \sin Ø)$$

where: f_{-6dB} = the –6dB coverage angle, half space
D = the piston diameter in meters (m)
Ø = the coverage half-angle

Our target coverage for this design is 140 degrees. By applying this formula to a single 10” loudspeaker, an upper frequency limit is reached at ~1250hz, where 140 degrees of coverage is maintained. 1250hz would be the upper limit of our crossover point. If two loudspeakers are used in concert, and are located tight together, their behavior is dependent on the center-to-center spacing of the two radiators. At frequencies below the equivalent to one-half the wavelength of the center-to-center spacing, they act as a single radiator. Above this point, they act as two separate sources and are subject to multipath interference and comb filtering. By way of example, our center-to-center spacing is 12.25”. This equates to a wavelength of ~1100hz. In order for the two 10” loudspeakers to behave as one and meet our coverage criteria, the cut off frequency would be approximately ~550hz, or one-half that equivalent center-to-center frequency wavelength. In simpler terms, if we double the radiating area, we half the coverage angle at the given frequency and must therefore, lower the upper frequency limits to maintain a given coverage angle.

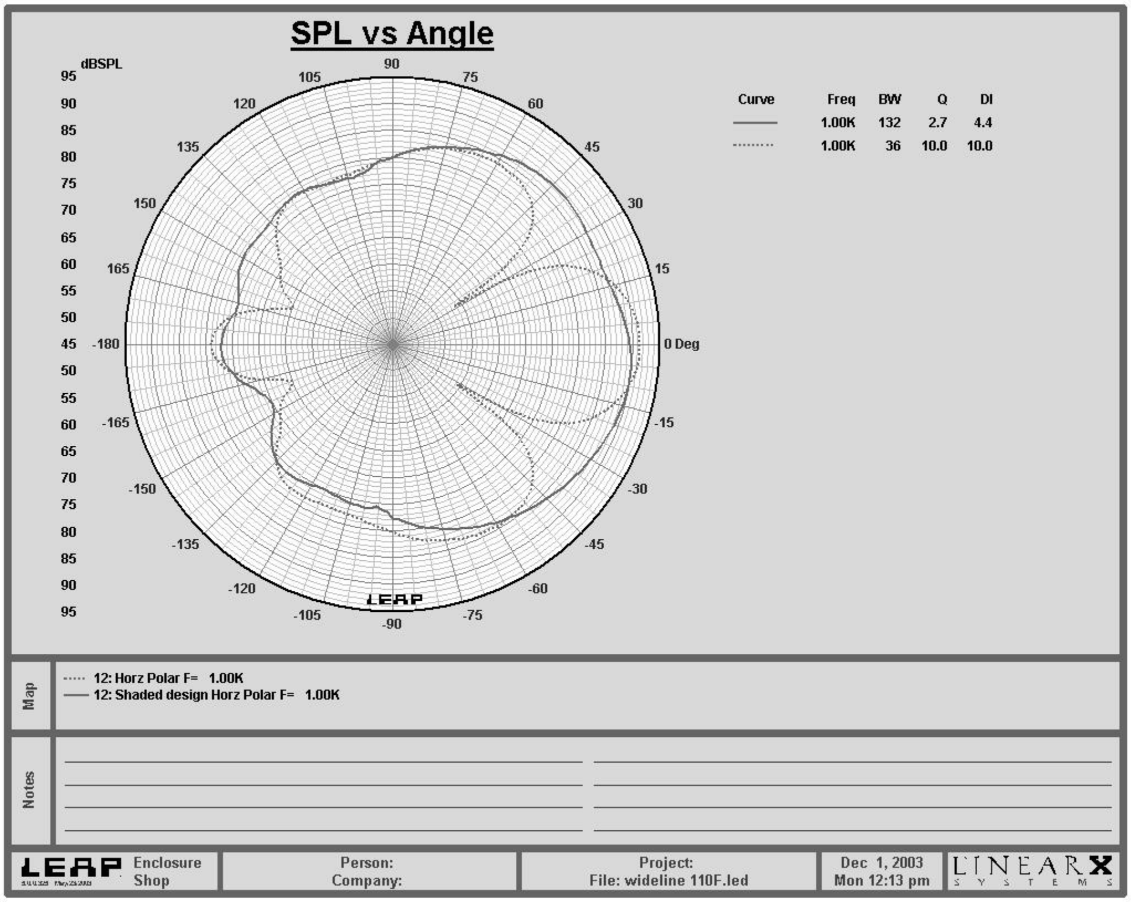
Below is an actual axis measurement of the two 10” speakers working together and the effects on the off axis response.

The following graph depicts the zero axis, -20 and –50 degree response of the non-shaded design. Both speakers are seeing the same signal to the 1000hz cut off. 1/12 octave smoothing was applied for clarification.



As you can see, the roll off is quite noticeable at 20 degrees, and at 50 degrees, the multipath interference centers at 600hz. By shading one speaker, these effects are mitigated.

The following graph shows the polar response of the shaded design vs. a non-shaded design at the 1khz crossover frequency. Though not perfect, the polar pattern of the shaded design is much smoother and without the effects of comb filtering.



Shaded design vs. non shading @ 1khz

The Low Frequency Select switch:

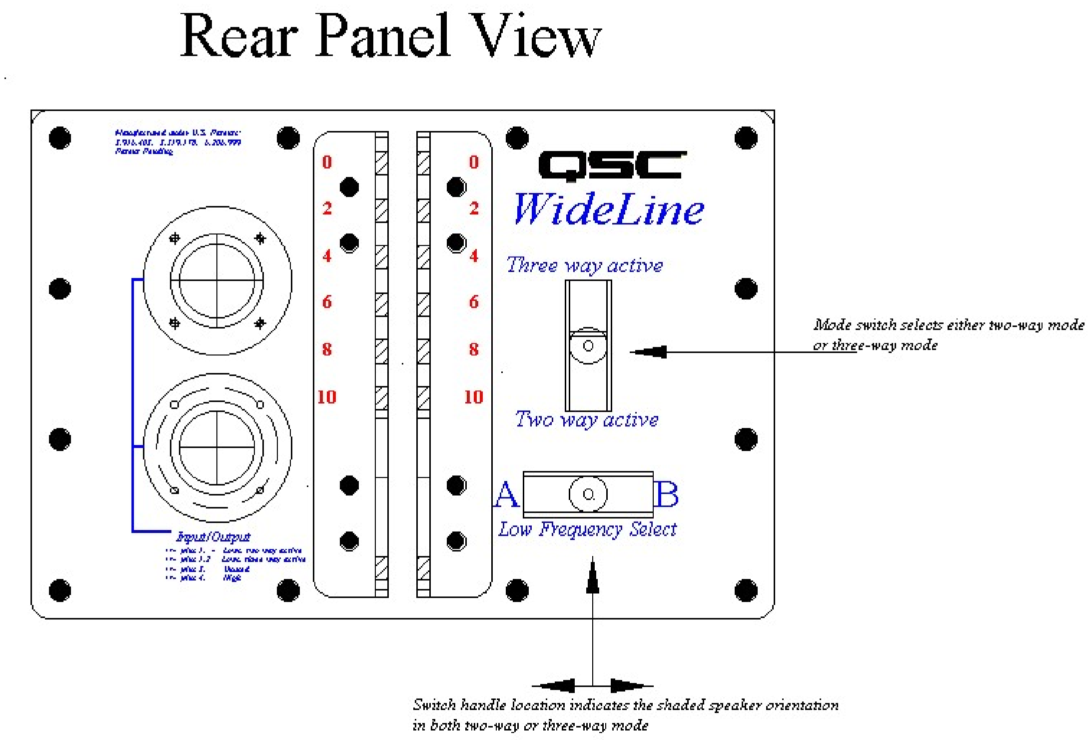
Since this is in reality, a three-way design (shaded speaker, non-shaded and high frequency), and the design specifications originally called for a two way design, the shading is accomplished through the use of a passive network. A simple –6dB per octave network, on one woofer, is all that is required. However, without making mirror image enclosures, or flipping boxes, placing the shaded speaker in the proper orientation left to right could be problematic.

The use of the shading switch allows either speaker component to be selected as the shaded unit (bass only). This allows one to simply orientate the switch in the desired location, for use as either house left or right, without the need to “flip” boxes. The switch has a “bat” type handle; the position will indicate which speaker is shaded. In simpler terms, the switch handle points to the side of the shaded speaker. As an added precaution, however, the flying hardware does not allow one to assemble an array with any enclosure inverted.

Design change:

After numerous events and a tour with a major artist, it was decided to add an additional switch to allow for the enclosure to be used as a three-way active system as well as in the standard two-way mode. The input connectors were changed to a pair of NL-8's to allow for the additional tri-amping scheme. A second "mode" switch was located on the rear panel to facilitate the change over from two-way to three-way active.

The low frequency select switch will function as before, but will now function in **both two-way and three-way modes.** This allows for the use of a single DSP program in three-way mode. Rather than having a separate left vs. right DSP setting to accommodate the shading, one simply needs to place the low frequency select switch in the desired location for the system orientation.

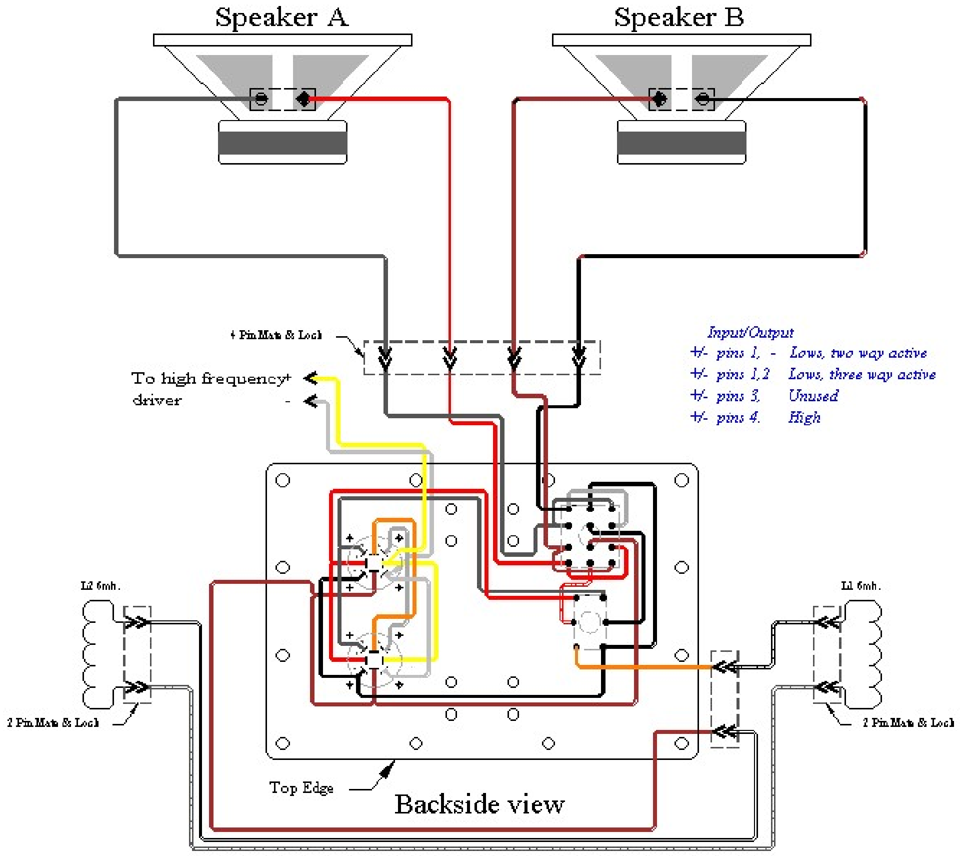


Rear panel view showing switch locations and functions.

Wideline wiring diagram:

The wiring layout inside the Wideline enclosure

In the unlikely event that a repair is necessary to the rear rigging hardware, the electrical components, or wiring of the Wideline enclosure, the rear panel can be removed from the enclosure by simply unplugging three connector blocks and the compression driver wires. The panel can then be replaced entirely or repairs can be made.



High Frequency Control:

When examining current vertical array technology and theory it has become imperative that the high frequency devices fill the vertical plane of the array element to achieve an 80% aspect ratio between the vertical height of the element and the radiating area. The wave fronts must also be planar in shape to avoid multiple source interference and achieve summation[1]. This coupling in the vertical plane serves to control the vertical wave formation to produce a well defined and seamless vertical wave front composed of individual array elements.

The challenge is to convert the single round exit of a high frequency compression driver to a tall vertical opening that achieves 140 degrees of horizontal coverage, fulfills the 80% radiating criteria and produces a planer wave. Based on the use of a diffraction slot in the ACE Model 1160, it was shown that coverage out to 160 degrees could be achieved. This was the basis for the Patent Pending, multiple aperture diffraction device used in this project.

The single high frequency driver is mounted on a device that has a wave diverter at its throat, or, input aperture. Similar wave diverters are located within the resultant “horn flares” creating multiple exits. This directs the sound waves along multiple paths of similar length. These paths are, in effect, the individual horns necessary to achieve the desired pattern control and wave sculpture. Multiple units can be arrayed vertically to extend the vertical length. In addition, horizontal coverage angles can be manipulated by adding flares to the exit aperture(s) to achieve a desired coverage angle (a common practice with diffraction slots). The design may also be adjusted for larger or smaller versions of the topology to accommodate product design considerations. In this case a 1” slot opening was sufficient to reach the coverage goals.

To verify the suitability for use as an array element, the device must produce a planar wave front and the radiating elements must fill as much of the vertical dimension as practical in order to be useful in achieving the previously stated 80% radiating factor. The accepted limits for line source behavior state that the practical upper frequency limit for which a curved source maintains the directivity response of a pure line source is limited to a curvature of no more than ¼ wavelength [2]. The formula for determining this curvature is:

$\delta = L/2 * \tan(\o/2)$ where:

δ = amount of curvature
L = the length of the source element
$\O$ = ½ the total arc angle

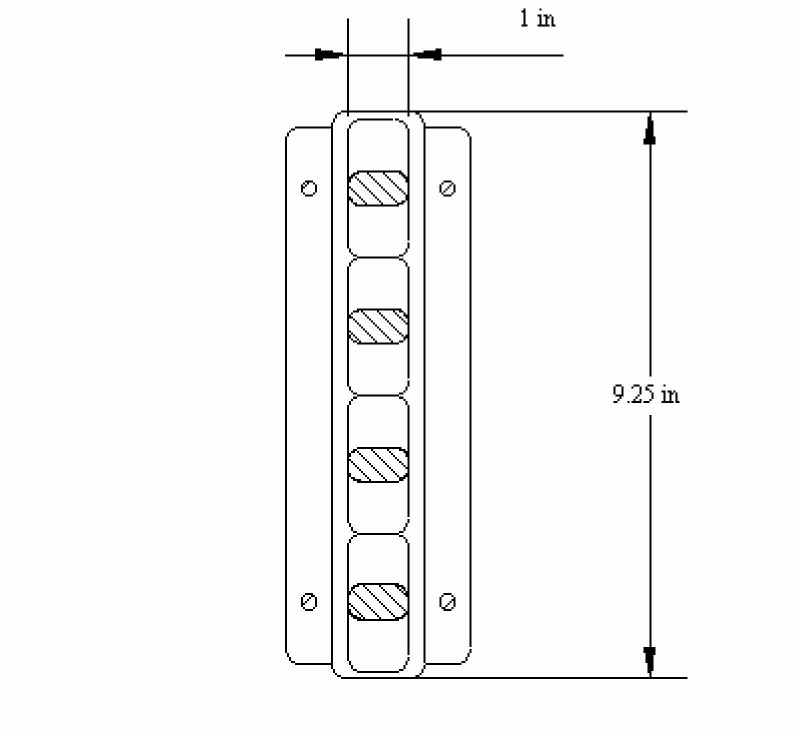
In this version of the multiple aperture device, we have a 20-degree total arc and an individual element length of 2.25”. Since the earlier paths are plane wave in nature, wave curvature is at a minimum before the exit apertures. Applying these values to the above equation yields a curvature length of .098 inches. To find the practical upper frequency limit for line source behavior, the formula would be:

$f = c/4\delta$ where:

f = upper frequency limit
c = speed of sound in inches per second
δ = calculated amount of curvature

Thus: $f = 13{,}500 / 4(.098)$
$13{,}500 / .392$
$f = 34{,}439$ Hz

This upper planar limit of 34kHz is more than adequate for use in the musical spectrum. And, as shown in the following diagram, each radiating element of the device combines to fill almost 100% of the total frontal area. Thus, allowing for practical use as a line source element.



Front view of the multiple aperture device

Total frontal area = 9.25 sq. in.
Total radiating area = 9 sq. in.

Active Radiating Factor = 97%

[1] Urban, Heil, and Bauman, "Wavefront Sculpture Technology" AES preprint #5488 2001

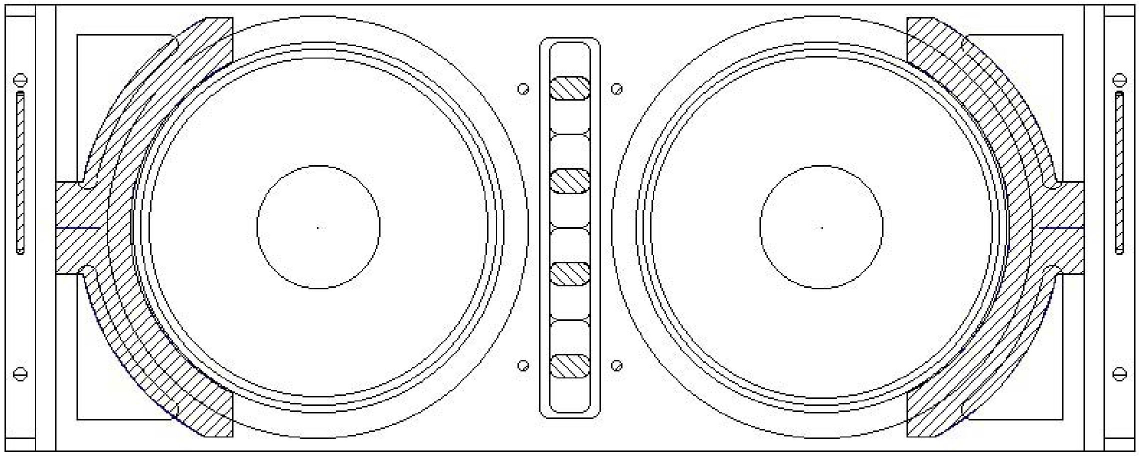
[2] Mark S. Ureda "Line Arrays: Theory and Applications" AES convention paper presented 5/2001

Speaker Baffle Treatment for the Wideline System

During developmental testing, it was discovered that there was an apparent narrowing of the high frequencies in the extreme (beyond 45 degrees) off axis regions. Investigation into the horn topology revealed nothing of significance to cause this problem, other than the fact that it is a 1" diffraction slot and as such, has some limitations with regard to dispersion. While experimenting with changes in the horn topology, it was discovered that the speaker baffle configuration was the main culprit. Destructive interference from late waveform arrivals caused a significant portion of the apparent narrowing. These late arrivals are due to reflections from the loudspeaker cone angles and their proximity to the horn exit, as well as some contribution from the side flanges of the grille frame and enclosure.

Research was done into the various types of foam materials that could be used to accomplish the task of mitigating the destructive interference. A 1" thick, 1.8lb density, polyester product was selected. This material is fairly transparent at low and low-mid frequencies, but is fully engaged at approximately 2khz and above.

A contoured foam piece was designed in CAD, and then the file transferred to a laser-cutting table. The foam "edge" treatment is attached to the grille frame and appears as shown below.



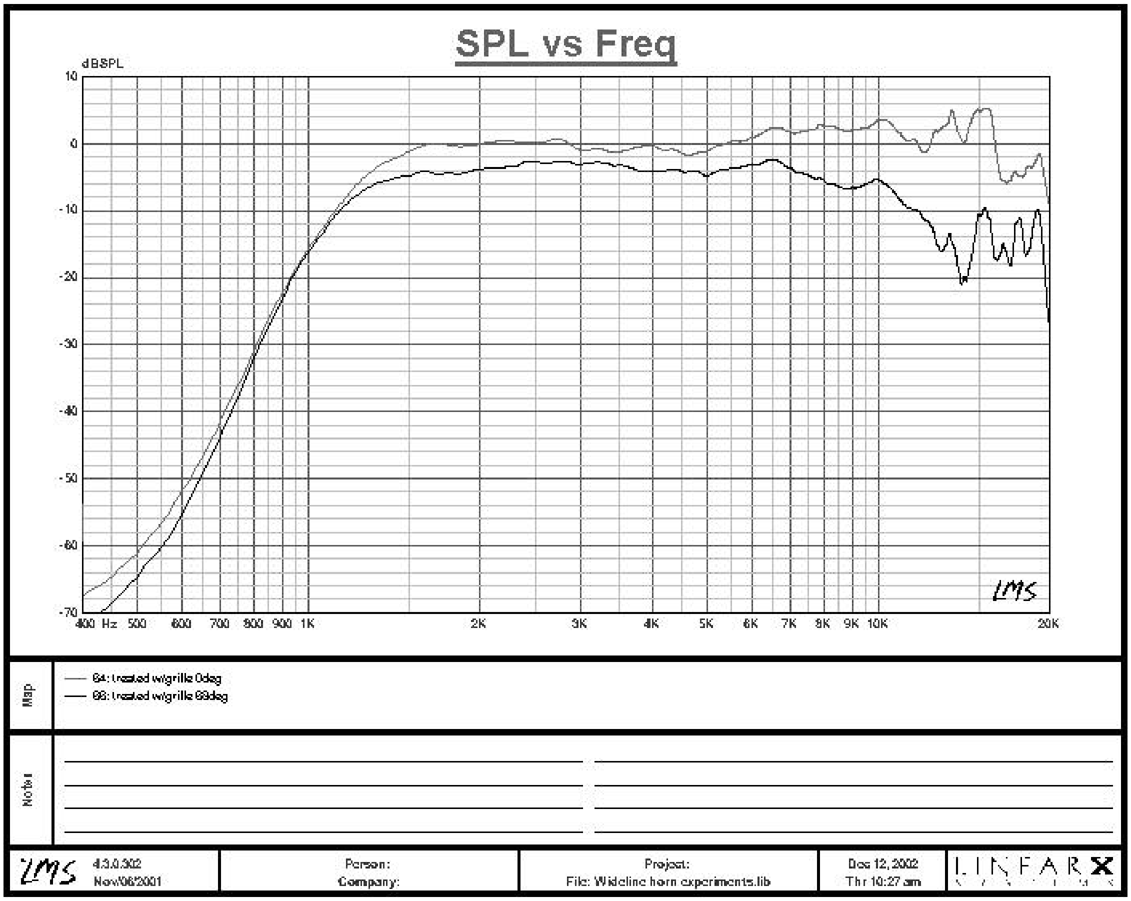
Speaker Treatment

The foam is blacked and becomes nearly invisible under the grille assembly.

The results of this treatment are shown in the following graphs:

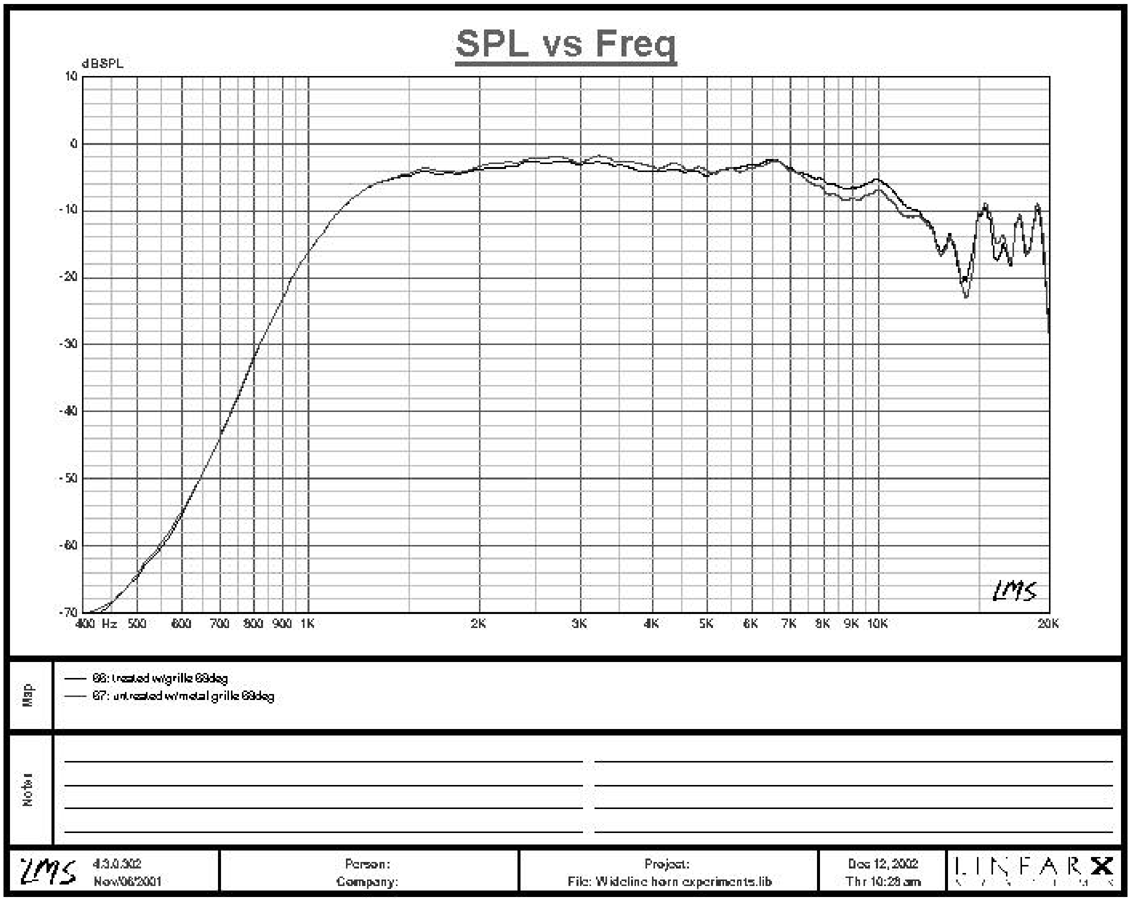
Measurement data, speaker edge treatment:

The graph below shows the on axis, and 68 degree off axis, response of the high frequency horn with the treatment and grille installed. 1/3 octave smoothing is applied along with two very narrow filters.



The 68deg. data curve maintains a +/- 2db response from the crossover region through 10khz. The grille assembly is now the determining factor in off axis performance as it causes a loss of 1dB to 1.5dB above ~ 7khz at this extreme angle.

This graph shows just the 68deg. off axis curves of the treated and untreated baffle with grille assembly installed. You can clearly see the improvements with the treatment added. A smoother midrange is complimented by a 2dB boost above 7khz.



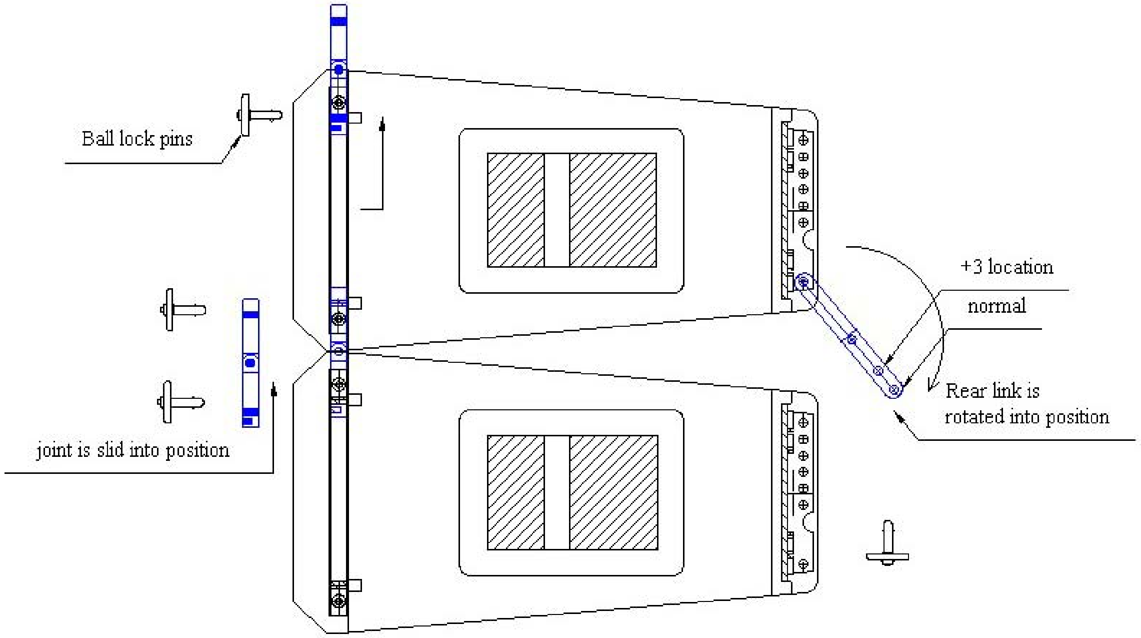
Rigging hardware:

- **Mounting and Suspension** - CAUTION: SUSPENDING SPEAKERS PRESENTS A RISK OF SERIOUS INJURY OR DEATH. PLEASE USE CAUTION TO ASSURE THAT MOUNTING SURFACES ARE CAPABLE OF SUPPORTING AT LEAST FIVE TIMES THE WEIGHT OF THE SPEAKER AND MOUNTING APPARATUS. USE ONLY LOAD RATED HARDWARE. ALWAYS CONSULT WITH A CERTIFIED PROFESSIONAL WHEN IMPLEMENTING OVERHEAD SUSPENSION.

Though the recommended maximum array is sixteen (16) enclosures, the rigging system for Wideline has been engineered to achieve a minimum of the industry standard of 5:1, with twenty-four (24) enclosures when using the large array frame. Palos Verdes Engineering has certified the mechanical calculations, and destructive tests have been performed by ATM Flyware. Weight of a twenty-four box system is only 1680lbs and the large array frame weighs 83lbs.

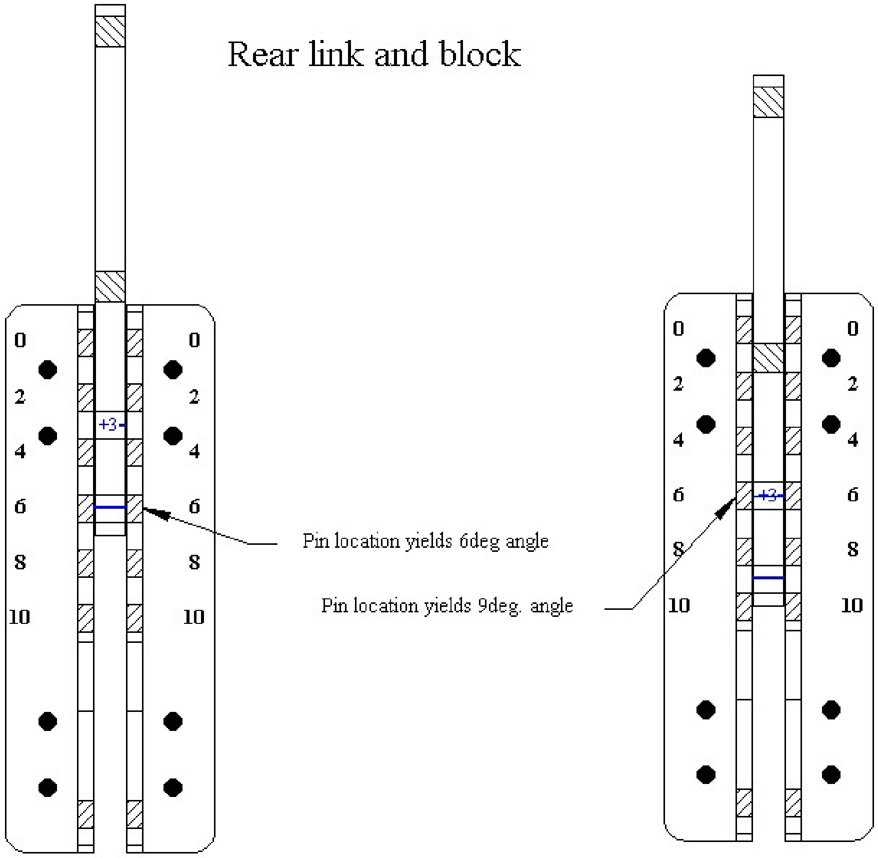
Wideline enclosures use a three-point suspension system. The system consists of front, left/right, captive articulated joints and a single rear link blade. Articulation is in two (2) degree increments using the first location on the link bar. With the use of the second location, one (1) degree increments can be reached starting at three (3) degrees. The total angular range is therefore, 0, 2, 3, 4, 5, 6, 7, 8, 9, and 10 degrees. All pieces and locking pins remain with the enclosures. No ancillary items are needed to fly the enclosures from the Wideline grid.

Operation:
The front captive joint is slid from its housing and pinned into position using the provided locking pin. The exposed end of the articulated joint is inserted into the receiver tube located on the adjacent enclosure and locked into position by a locking pin. This is repeated for each side of the enclosure. The rear link blade is rotated into position and pinned at the chosen degree increment.



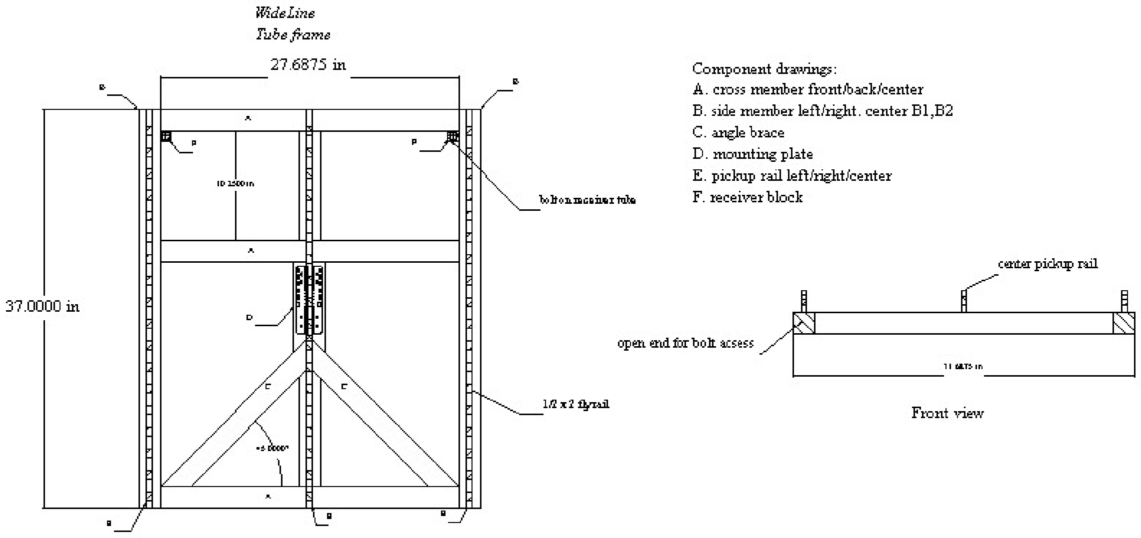
Rigging Hardware

As can be seen in the illustration below, by using the first pin location on the link arm, a normalized setting in 2-degree increments is achieved. When the "+3" location is used an additional 3 degrees are added to the "normalized" location. By way of example, when the first link arm location is used in the 6-degree block location, a splay of 6° is achieved. However, when one uses the "+3" link location in the same 6° block location, the total angle is now 9° (6° plus 3°). In this manner 1-degree increments can be had starting with 3° (0 ° block location and +3° link arm location).



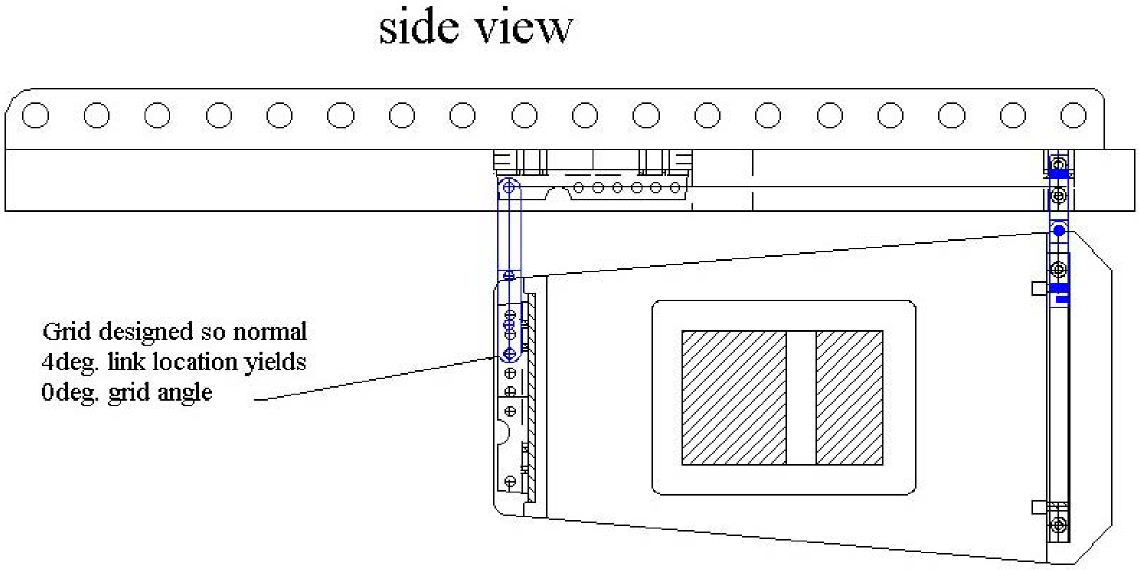
There are two (2) array frames available for the Wideline system. The large frame is used for flying a typical four (4) to sixteen (16)-box array. A smaller, more compact and easier to handle frame is available for use as a small array, four (4) or less, stacking or fly grid. This grid will easily sit on deck stacked bass enclosures or it can be used at those smaller events to fly clusters from the stage trusses. The larger grid may also be inverted and used to stack up to six (6) or more enclosures.

Wideline Large Array Frame:



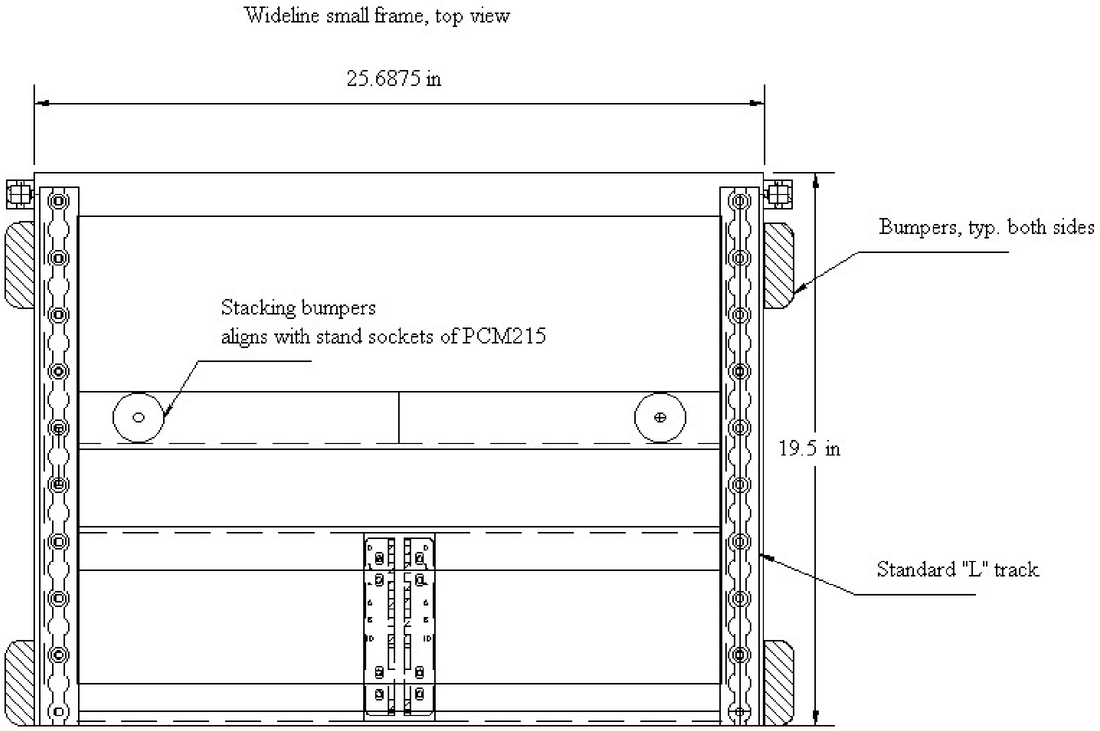
The three pick up rails allow for any number of rigging solutions to fit the most demanding venues. The rails are drilled for industry standard 5/8” shackles.

Wideline large array frame side view:



The grid allows for up or down angle options for use with either stacking or flying. The 4° “normal” locations on the link system will yield a net 0° vertical inclination.

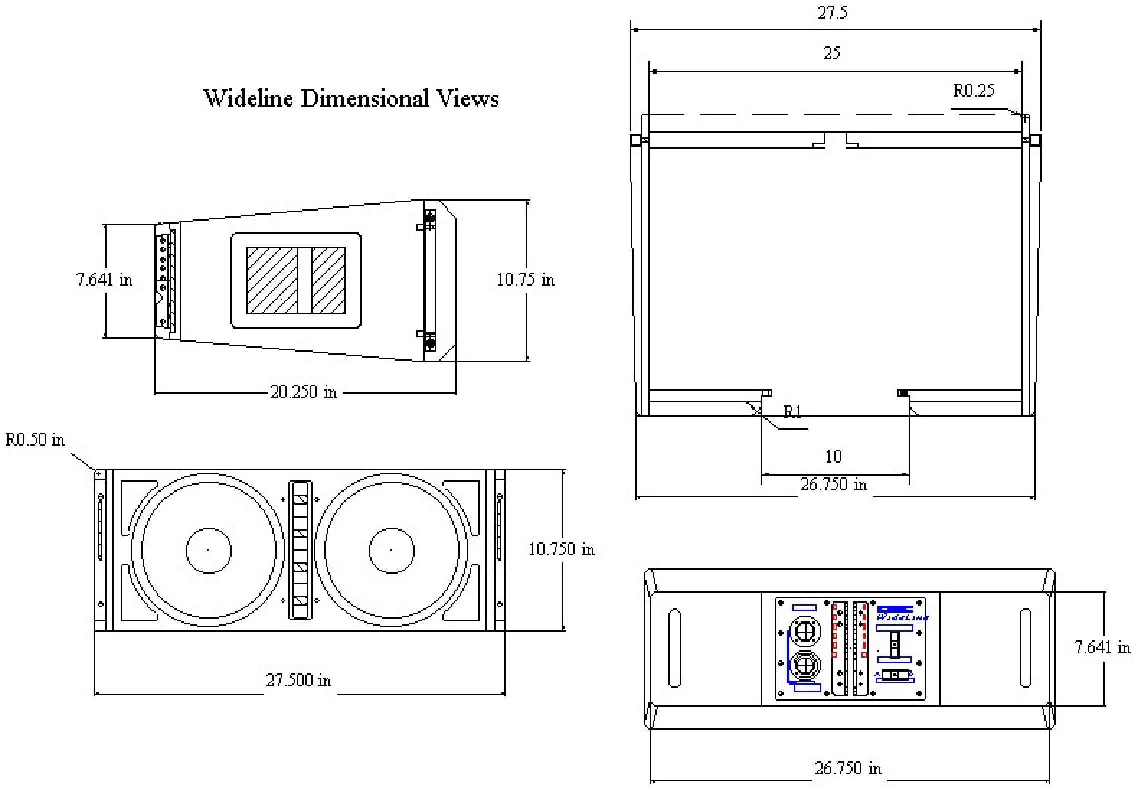
The Wideline small array frame:



The small frame will easily handle four enclosures and will interface with the QSC PCM215 powered sub-woofer in both a stacked or flown configuration.

System specifications: (Preliminary)

Configuration:	Three-way / active two-way or full three-way active
Frequency Response:	55Hz – 18KHz (+/- 3dB)
Sensitivity:	97dB (2.83v @ 1m)
Nominal coverage:	
Horizontal:	140deg.
Vertical:	Dependant on number of elements used
Nominal Impedance:	8 ohms, low frequency 16 ohms high frequency
Components:	
Low Frequency Transducers:	(2) 10” long excursion, high power, 3”v.c. 16 ohm, 380w rms each
High Frequency Transducer:	1.4” exit, 16 ohm neodymium compression driver mounted on proprietary wave transformer, power handling 80w rms
Enclosure:	
Type:	Bass reflex, trapezoidal
Material:	Composite laminate
Finish:	Black texture coat
Grille:	Powder-coated steel
Connectors:	(2) NL8
Attachment points:	Self contained rigging configuration
Weight:	70lbs, 31.8kg
Dimensions	10.75” H x 27.5”W x 20.25”D



Wideline Dimensional Views