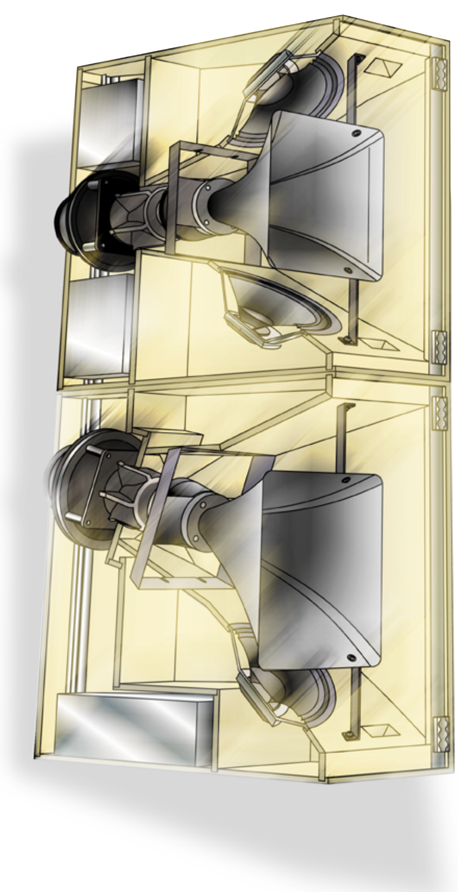
VA4

Acoustic Singularity™

An EAW Engineering Whitepaper



EAW
EASTERN ACOUSTIC WORKS

The Laws of Physics / *The Art of Listening*

Part 1: KF700 Series in Overview

System Overview: Description and Application

EAW's new KF700/VA[4] Technology Series comprises two triamplified three-way systems – the KF750 high "Q" array module and the KF755 downfill array module. The Series is optimized to create idealized arrays for both permanent and portable sound reinforcement applications demanding the highest levels of fidelity.

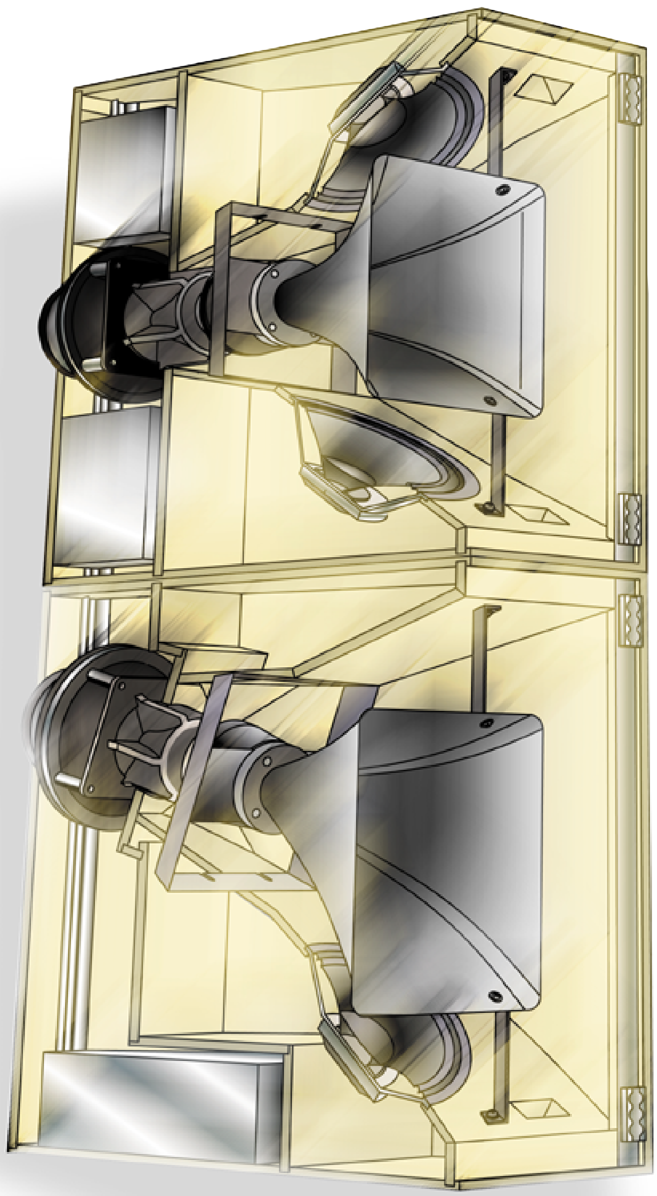


Fig. 1 – KF750 over KF755, cutaway

Its scalable nature lets the Series create arrays to cover venues of almost any size. Arrays 2 or 3 wide x 1 deep work well in small clubs while arrays 4 wide x 4 deep fill sheds and small arenas. System designers can add rows or columns of modules until their coverage and output requirements are met. In the case of larger arrays, the bottom row will often be KF755 downfill modules.

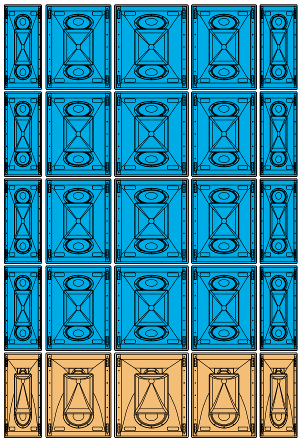
EAW engineers have minimized the size of each KF700 Series module by containing both the high and low frequency subsystems within the full-sized mid frequency horn which covers almost the entire face of each enclosure. This provides numerous advantages in both permanent installations and concert touring applications.

In both the KF750 and KF755, this mid frequency horn works with a new 10-in MF cone with integral phase plug assembly. The KF750's horn is axis symmetrical while the KF755's provides vertical coverage from 0° to -35°.

The HF subsystem of both modules loads a 2-in exit/100mm voice coil compression driver with a 35° x 35° constant directivity horn that is mounted coaxially within the MF horn. Again, the KF750's horn is axis symmetrical while the KF755's provides 0° to -35° vertical coverage.

Aside from the angle of the horns, the only component difference between the modules lies in the LF subsystem. The KF750 uses 2x 12-in woofers mounted within the upper and lower horn walls to create a dipolar array that extends vertical pattern control into the LF passband. The KF755 employs a single 12-in woofer mounted within the MF horn's lower wall.

Because the KF700 Series modules are so compact (at just 31-in tall), the arrays they create are quite small yet they produce genuinely robust output levels over the entire audio band.



Capacity: 20,000
Distance to FOH: 150 feet
Horizontal Coverage: 160°
Array Height: 13.25 ft

KF700 SERIES SYSTEMS (PER SIDE)
KF750: 5 wide *x* 4 deep
KF755: 5 wide *x* 1 deep

CONTINUOUS POWER HAND. (PER SIDE, WATTS, LF/MF/HF)
27000/10000/5000

APPROX. CONT. OUTPUT AT FOH (DB SPL, LF/MF/HF)
124/113/118

APPROXIMATE PEAK OUTPUT AT FOH (DB SPL, LF/MF/HF)
130/119/124

Fig. 2 – Array for a hypothetical arena

Lets place two hypothetical 5 wide x 5 deep arrays (one per side, bottom rows are KF755's) in a typical arena (capacity 20,000). Modeling predictions indicate continuous output at the FOH position (150 from the stage) of 118 dB/113 dB/124 dB (HF/MF/LF). These arrays would hang no more than 14 feet below their bumper bars and would weigh less than 2.5 tons each.

Recommended subwoofers for KF700 Series arrays are the KF940/BH822e dual 12-in bass horn SuperSub or the SB1000e dual 18-in subwoofer. Either will provide ample sub bass response, depending on your application. As a rule, the KF940 is optimized for very large applications where fairly large arrays (4x or larger) can be constructed.

Technology Overview: Acoustic Singularity and VA4

The KF750's Acoustic Singularity design makes it the first and only three-way array module that acts as a true point source. Since all three subsystems' acoustic centers lie along the same axis, simple signal delay creates a Unified Space/Time Origin of the entire broad band audio image.

By more tightly aligning the arrivals from multiple subsystems, the KF750 sets a new benchmark for array performance by making the reproduced audio truer to the source. Listeners will most readily notice improved clarity and impact from finite events like the crack of a snare drum.

With the HF subsystem mounted coaxially within the MF horn flare, the HF signal output can be delayed 1.24 msec synchronize it with the MF. This is a natural benefit of coaxial systems and requires only that the distance between acoustic centers be known.

While it might seem that integrating the spaced woofers would be a greater challenge, the LF subsystem's dipolar array configuration places the acoustic center for LF information exactly on the axis shared by the MF and HF subsystems. Once again, simple signal delay of 1.80 msec perfectly aligns the subsystems.

The goal of VA^4 is to extend the KF850's legendary level of horizontal array control into three-space. In terms of sound reinforcement, three-space (three dimensional space) consists of the horizontal and vertical axes as well as depth of field or "throw." As they did with the KF850, EAW engineers have achieved broadband pattern control by focusing on the mid frequency device – the single largest element in the KF700 Series.

To see how KF700 Series modules reproduce sound into three-space, EAW engineers created a entirely new audio imaging tool – topographical images that show how a given loudspeaker disperses sound into space over the full frequency range. How these are created and what they depict will be covered later in this paper.

VA4 Technology also goes one step beyond three-space by solving problems in the fourth dimension: Time. The KF700 Series' patent pending phase plug design solves problems of early arrivals in the upper mid frequency range by developing a more logical cone geometry.

With this design, all paths from the source (voice coil) through the cone assembly (cone, dustcap and surround) and into the horn throat are virtually identical. This subtle yet important breakthrough gives the KF750 its remarkably clear sound.

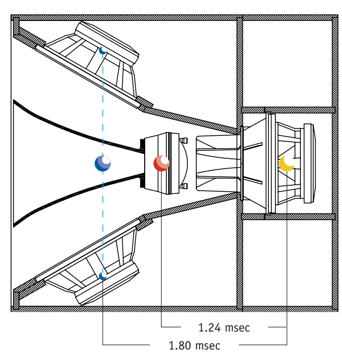


Fig. 3 – Acoustic Singularity

Part 2 – KF700 Series Technology in Detail

Professional loudspeaker systems strive to optimize performance in four areas:
• spectral (frequency range, sound quality)
• spatial (pattern control, SPL distribution, arrayability)
• temporal (unified arrivals from various subsystems)
• utilitarian (size and weight, roadworthiness, rig-ability)

Unfortunately, optimization in one area usually results in degradation elsewhere. For example, spatial performance (pattern control) can be optimized by very large horns, but the resulting enclosure's utility for portable applications will be severely degraded.

The goal of the KF700 Series was to optimize performance attributes in all areas without compromising others. Specifically, the main goals were:
• unifying arrival times within and among the subsystems
• achieving broadband pattern control in the both the vertical and horizontal planes
• creating a portable package that is smaller, lighter, more efficient and, therefore, more powerful than a KF850
• setting a new standard in audio fidelity

Optimized Mid-Frequency Sub-System: Achieving temporal coherence and spatial consistency

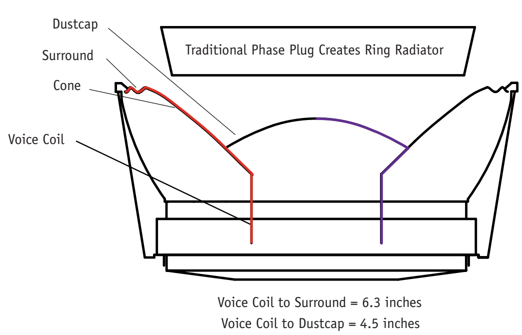
EAW has historically created true three-way professional loudspeaker systems that use a single cone transducer to reproduce the majority of the vocal region. This approach significantly reduces distortion resulting in a more natural vocal sound. But the additional subsystem has typically created compromises in the temporal and spatial domains.

In addition to the sonic difficulties associated with transitioning between subsystems in the heart of the vocal band, two-way systems suffer from higher distortion in the lower portion of the compression driver's range. In the temporal domain, however, two-way systems excel where typical three-way systems falter.

Unlike the relatively simple geometry of a compression driver's diaphragm, there is a slight but noticeable difference in the point of origin of a cone driver's dustcap, cone, and surround. Particularly in the upper midrange, these differences create a "smearing" of arrival times at the listener that degrades the clarity and impact of mid-frequency sonic events: most notably vocal reproduction. Because they are what the ear hears first, early arrivals out of the passband can affect overall fidelity even though they are substantially lower in level.

Traditionally, most manufacturers (including EAW) have asked the mid-frequency phase plug to fix the arrival smear. But because this approach treated the symptom (inconsistent arrivals at the horn throat) instead of attacking the disease (bad cone geometry), it fails. In contrast, the KF700 Series' entire mid frequency cone and phase plug assembly was designed to solve this problem at the source.

Fig. 4 – Traditional mid cone w/ phase plug, side view cutaway



The distance from a cone driver's voice coil to its dustcap is shorter than the distance from the voice coil to either the cone or surround. Therefore, the energy radiating from the dustcap most often leads the energy from the rest of the system. Traditional phase plug designs have isolated this energy and routed it through a longer path than that which faces the energy from the cone or surround. In so doing, the phase plug attempts to equalize the arrival smear.

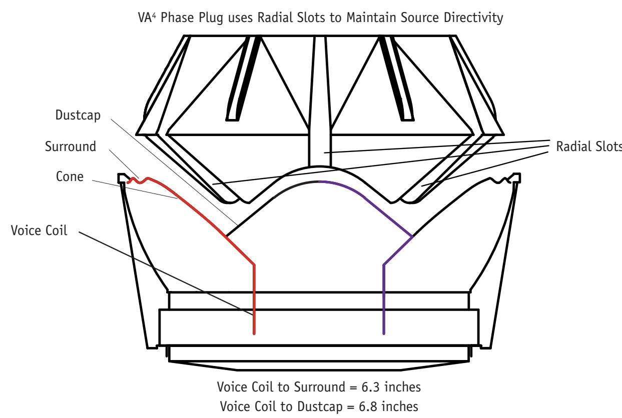
Conventional phase plug designs achieve this result by using a circular entrance and exit to the phase plug – they simply convert the output from a point source into a ring radiator. This approach has proven effective with high frequency compression drivers mostly because the simpler compression driver diaphragm geometry and shorter high frequency wavelengths create significantly smaller arrival differences that are less problematic to resolve. But because the wavelengths in the mid frequency passband are so much greater , this ring radiator solution actually creates another more serious problem.

A ring radiator exhibits a more dramatic narrowing of beamwidth with increasing frequency than a cone transducer. When the mid frequency device becomes a ring radiator, its directivity narrows too greatly with increasing frequency to the point where it no longer fills the bell of the horn.

This is a problem that virtually all horn-loaded mid or midbass systems suffer from, including systems that are highly regarded in the professional community such as JBL's HLA, Meyer's MSL-4 and MSL-6 as well as our own KF850. As a result all of these systems exhibit acceptable low/mid coupling, but the mid/high energy does not cover from box to box, leaving upper mid holes in the frequency response on the seams of an array.

The KF750 mid/phase plug assembly approaches the problem in a different way. It attacks the problem at the source. The cone transducer's temporal smear is corrected by precisely aligning the cone/dustcap/surround geometry to maintain temporal unity. The distance to the dustcap is slightly longer to compensate for differences in material density.

Fig. 5 – Traditional mid cone w/ phase plug, side view cutaway



The phase plug, whose geometry is matched to the cone, then serves to leave this unity intact. Expanding radial slots within a compressing frame lower the mechanical reactance of the load facing the transducer without modifying the directivity associated with the source. This allows for faithful reproduction of upper mid frequencies without any narrowing of beamwidth.

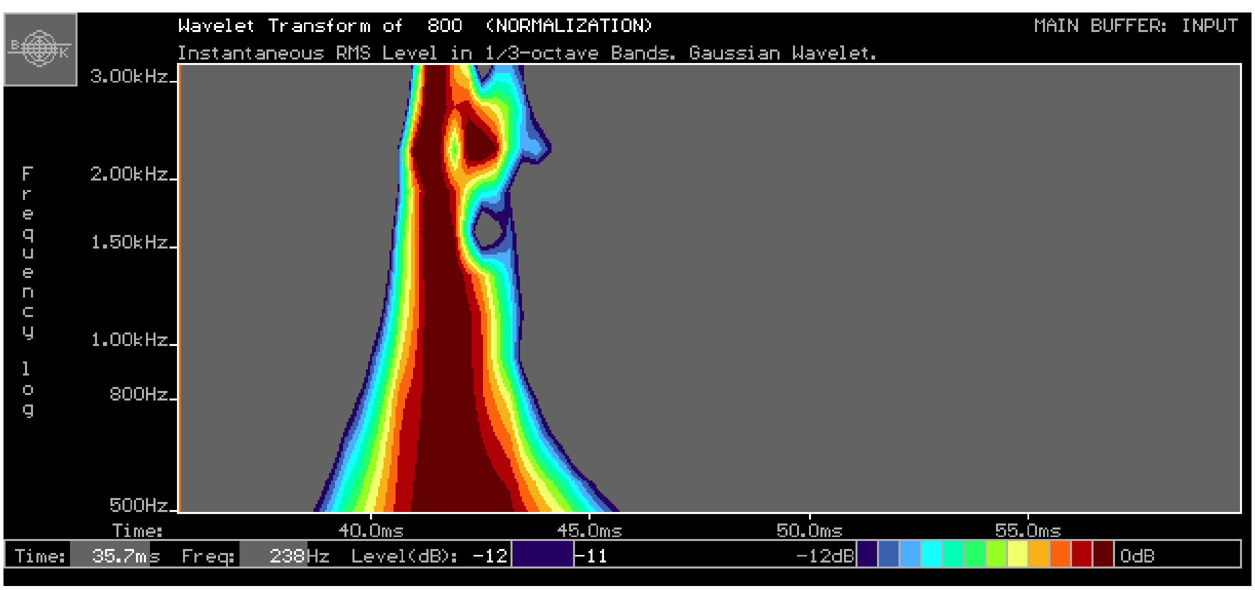


Fig. 6 – KF850 midrange cone wavelet

The wavelets (figs. 6 & 7) illustrate the difference between old and new mid-frequency cone/phase plug technologies. These wavelets represent data gathered at 1 meter from devices mounted in a pseudo-infinite baffle wall. The vertical axis indicates frequency, the horizontal indicates time, and color indicates dB SPL with each color change indicating a 1 dB drop in level.

Figure 6 represents data obtained from a conventional KF850 style midrange transducer. Particular attention should be paid to the upper midrange above 1 kHz. Note that the energy at the top of the passband centered around 2.1 kHz is slightly leading the rest of the broadband energy and also remains considerable after.

This difference of microseconds is difficult to observe without precision measurements, but the phenomenon is quite audible. The resulting reproduction would take a finite sonic event (a snare drum's rim shot, for example) and reproduce it over a longer period of time than it had actually taken. The source has been compromised and the events' clarity and impact degraded. With the harmonics leading and/or lagging the fundamental tone, the timbral quality of the acoustic event is lost.

Figure 7 results from an identical measurement taken on a new KF750 style mid-range transducer. Needless

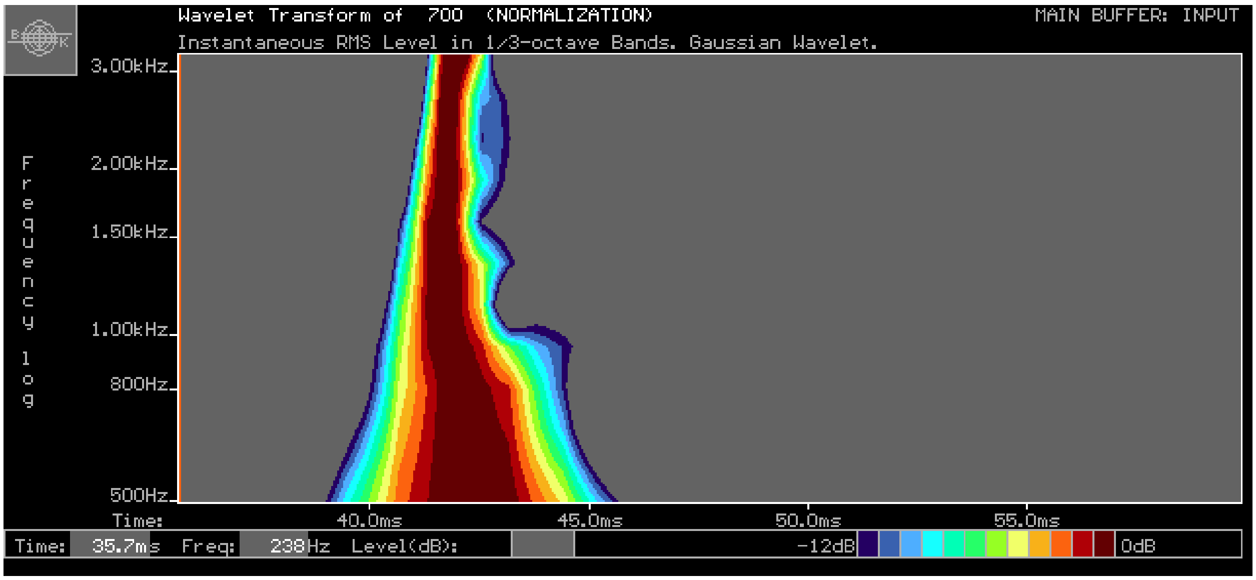


Fig. 7 – KF750 midrange cone wavelet

to say, the temporal inconsistencies have been eliminated through the implementation of a more logical transducer geometry.

In the end, the mid-frequency sub-system of the KF700 Series exhibits the temporal clarity of a compression driver alone (as in a two-way system) and the natural low distortion sonic reproduction of a cone transducer (as in an EAW three-way system) while removing crossover transitions from the vocal region and maintaining the spatial performance required for broad band constant directivity.

Optimized System Directivity:
Consistent Pattern Control From a Compact Enclosure

In order to guarantee effective arrayability, a system must exhibit consistent broadband pattern control. If a device is said to be 35° it must consistently maintain a 35° pattern over a very broad frequency range. If a discontinuity exists then either an excessively wide pattern at some frequency will cause destructive interference or an excessively narrow pattern will result in magnitude holes between boxes in an array.

In order to eliminate beamwidth discontinuities through crossover transitions, each horn must be large enough to control its maximum defined wavelength. Typically, this means that all horns must be big.

At low frequencies, pattern control is difficult no matter what the approach. If horn-loading is desired, the horns would have to be mammoth. However, EAW's Dipolar Array™ Technology dictates that separated devices operated over an appropriate bandwidth can exhibit pattern control in a given plane.

The KF750 was designed to be a 35° x 35° system. Once the optimal crossover points had been determined, it was easy to figure that a 13-in high HF horn, 26-in MF high horn and woofers spaced 23.5-in were required to achieve the system's pattern control goal. Stacked one atop the other, this would yield a nearly 6 foot tall enclosure, which is absolutely unacceptable. Thus the co-axial mid/high section with mid flare enclosing the low frequency section was developed resulting in an optimized system that is only 31-in tall.

Essentially, the entire KF750 system is contained within the mid frequency horn bell. As a result, the acoustic origins of all of the sub-systems lie upon a single line. Simple delay generates a condition whereby all of the devices originate from a single point in space at a single point in time. The KF750 is the first three-way system to act as a true point source, further enhancing the temporal clarity and impact of any sonic event.

Fig. 8 – KF750 Horizontal

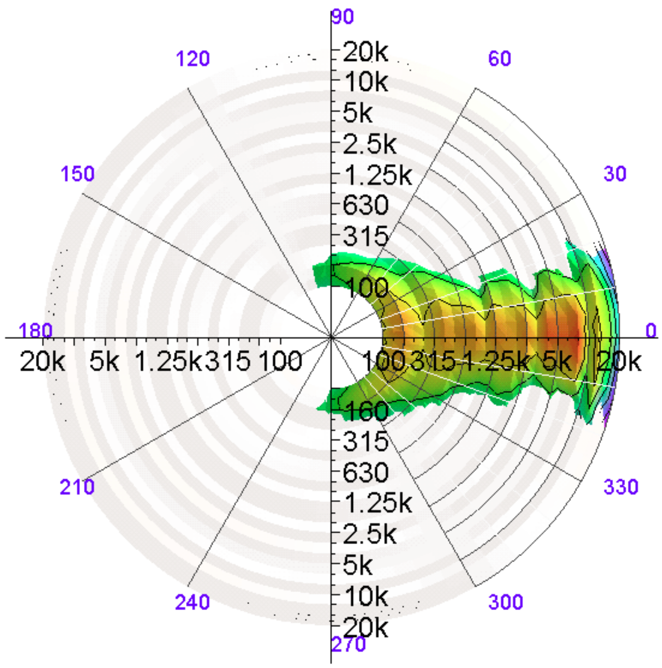
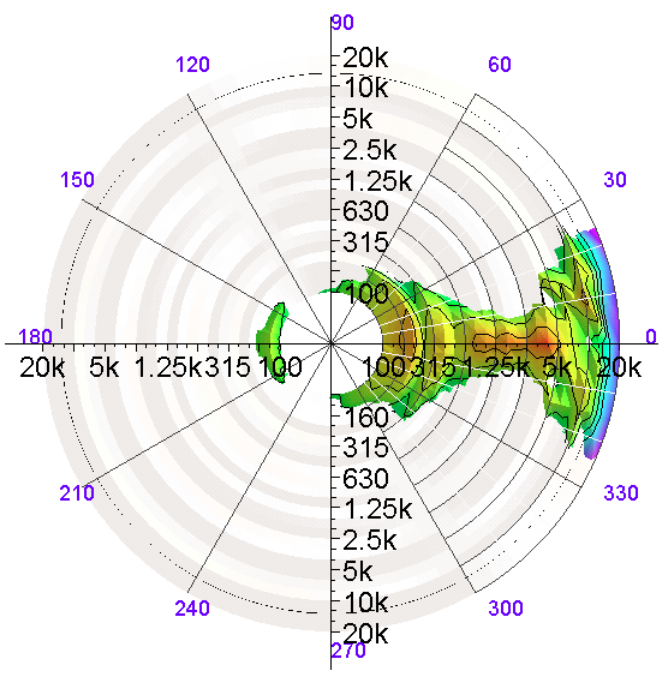


Fig. 9 – Competitive Product, Horizontal



While other highly regarded systems make attempts to approach this goal, none succeeds. For example, EAW's KF850, the Renkus-Heinz Co-Entrant system, EV's X-Array and most other single enclosure three-way systems reduce their subsystem origins to a single line. Line array systems such as the V-DOSC or our own KF860 can only reduce their subsystem origins to a single plane. None succeeds in reducing origins to a single point. Except the KF750.

The large format horns employed in this compact system yield remarkable spatial results. As a result of loading the woofers within the mid frequency horn, the 35° coverage pattern is consistent throughout the mid frequency passband in the horizontal plane. The Dipolar Array loading maintains control well into the low frequency passband in the vertical plane.

As part of the KF700 Series development process we have created a new data visualization tool which allows us to view all of the horizontal or vertical polar data gathered for a given product in one illustration. The graph is generated in cylindrical coordinates. The axial response is measured and plotted along the 0° radius of a cylinder with distance to the center of the cylinder representing frequency and height within the cylinder representing dB SPL. The loudspeaker is rotated 5° and new data are gathered and plotted along the 5° radius. The process is continued until the entire spatial output has been gathered.

A surface is then created which connects all measured data points. The -6 dB point from the highest output at any frequency is then plotted as a secondary surface within the image. The intersection of the two plots represents the beamwidth of the system. The program creates a full 3D image which can be rotated and examined to determine the spatial location and frequency content of any problem areas that might affect system performance.

Fig. 10 – KF750 Vertical

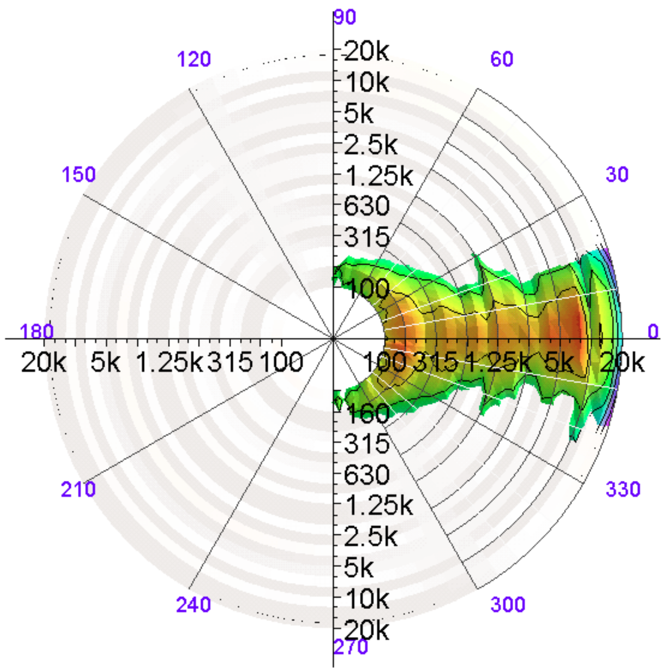
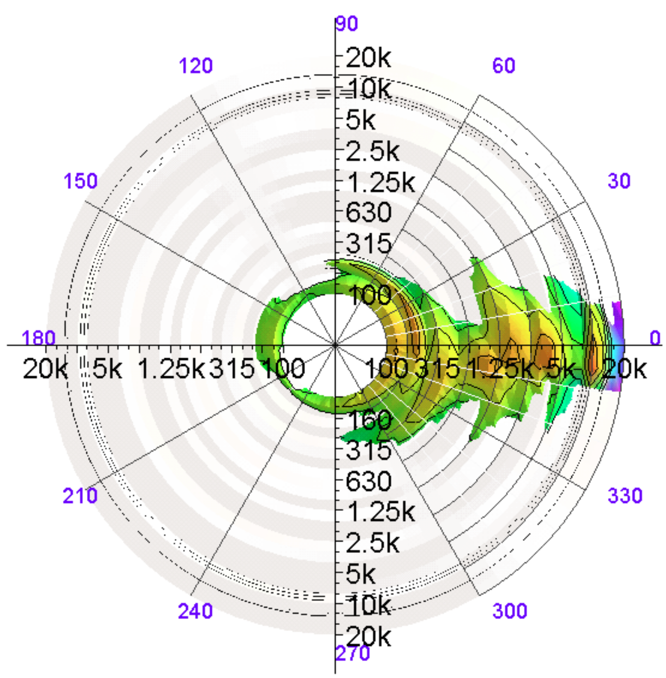


Fig. 11 – Competitive Product, Vertical



This new tool will dramatically demonstrate the effectiveness of the KF750 vs. a well regarded competitive product.All care was taken to acquire the most accurate data for each loudspeaker system.

Figure 8, illustrating the KF750's horizontal topographical plot, demonstrate the KF750's exceptional, broadband pattern control. Even at the low end, the KF750 benefits from the LF loading inside the mid flare to maintain reasonably high directivity. All of the energy remains focused within a 35° included angle with minimal deviation from those bounds.

Given these data, performance of an array into three space would require only a simple parametric equalization adjustment to compensate for low/mid coupling and provide the user with optimal array performance.

Figure 9 shows that the competitive product is also high Q, but much less consistent broadband. In fact at the low end, we can see the beneficial effect of the horn-loaded mid bass transducer to maintain high Q and focus the low end, but note the LF spill from the back of the system that was not at all apparent in the KF750 data.

Additionally, note that this product undershoots it's target beamwidth of 30° and then flares out dramatically above 3 kHz. We might assume that this narrowing at the top of the mid frequency passband results from the ring radiator phase plug design discussed above. This system exhibits good control of the beam throughout most of the pass band, but will encounter difficulty above 3 kHz when arrayed horizontally.

In figure 10, showing the KF750's vertical pattern, once again we note broadband uniformity. At the mid/high crossover point we see one minor compromise that results from an attempt to preserve utility. In order to gain a more favorable truck pack, we settled on a height of 31-in. Essentially, the slightly vertically undersized HF horn exhibits a minor increase in beamwidth just above the crossover transition. On the whole, the vertical topographical image is remarkably similar to that from the horizontal plane.

Figure 11 demonstrates the dramatic impact of undersized horns particularly when coupled with larger cone transducers. The midbass devices exhibit a sharp decline in vertical beam as they approach the crossover point, again attributable to the phase plug design.

Once into the high frequency horns, the data balloons out to beyond 70°. This situation is created by the vertically small high frequency horns which are employed in the system. The beamwidth then collapses again as the HF horns begin to exhibit control, but the actual beamwidth never quite reaches the target of 25°.

These characteristics are impossible to correct for in an array. The dramatic midrange spill from enclosure to enclosure vertically will set up a great deal of destructive interference which can not be corrected. The best one could hope is to deal with the comb filtering and to equalize to the nominal acoustic output.

System Utility: Smaller, Lighter, Easier to Use

System utility is a driving force behind the development of all EAW product for both touring and installation markets, and the KF700 Series is no exception.

At the outset, the development plan called for a single-enclosure three-way system that was inherently scalable. The system also needed to be easily arrayable in virtually any configuration. This would enable users to construct KF700 Series arrays for virtually any venue type, from a small nightclub to a stadium, as quickly and easily as they now do with the KF850 Series.

At the same time, the systems needed to be smaller, lighter and more powerful than the KF850 with a rigging system that was as simple, if not more so.

Again, these goals have been reached and even surpassed.

The Series was designed such that a dead hung array of properly configured KF750's and KF755's can provide a remarkably consistent sound field through a given venue, in both the vertical and horizontal planes.

Critical listening tests have proven that KF750's flat, consistent power response allows its off-axis energy to provide nearfield coverage in situations where the use of KF755's is not desired. And with the KF755's full frequency range coverage, it can act as a stand alone system in applications requiring that coverage pattern.

In terms of total output and ultimate system utility, the KF700 Series' superiority is best demonstrated by comparing the KF700 vs. KF850 arrays that would be required for a typical venue.We've chosen to use Boston's FleetCenter, a large NHL/NBA-type arena with a capacity of around 20,000.

A typical KF850 Series array for a touring popular music concert at FleetCenter would consist of 7 wide by 4 deep KF850's above 1 row of 7 KF855's. The loudspeakers of one such clusters alone would weigh 8800 pounds and the cluster would be 19.5 feet in height.

By contrast, the more focused and efficient KF750 allow the KF700 Series array to comprise only 5 wide by 4 deep KF750's plus 1 row of 5 KF755's. This array (Figure 2) would provide 4 dB more output than the KF850 rig while weighing 4000 pounds less (roughly 45%) and hanging 6.25 feet shorter (around 33%).

Should one desire extremely high total system output, a 35-enclosure KF700 Series array could be created. Rather than hanging 7 wide by 5 deep like the KF850 Series array, it would hang in a 5 wide by 7 deep configuration with the bottom row being KF755's. This system's output would exceed the KF850 Series array by 8 dB while remaining 2000 pounds lighter and 1 foot shorter overall.

But output level is not all that a good touring loudspeaker system should provide. It needs to pack, unpack, fly, strike and pack again with minimal effort and at minimal cost.

The KF750 weighs in at only 190 lb. compared to a KF850's 260 lb. The 31-in height was specifically chosen such that a suitable pallet would allow for the stacking of three high into a standard truck. The overall dimensions were selected to ensure an effective truck pack.

The rigging was developed such that the external hardware count is minimal and all external hardware is cost effective. The rigging was also developed to eliminate hands between cabs during load-in or strike – simple fly clips attached front and back allow for easy array assembly.

Because KF700 Series system was developed with a dedicated full range downfill module, virtually all arrays will be dead hung. In rare cases where downfill is required but KF755's are not available, the rigging will also accommodate a vertical splay allowing KF750's to provide downfill coverage.

A System For The Future: Upgrades and Patents

Both modules of the KF700 Series were designed such that an integrated amplifier version can be produced with the same basic construction as the unpowered version - only the systems' back chambers need be replaced. Two 4-pin quick disconnects allow users to upgrade from unpowered enclosures to powered enclosures in a matter of a few minutes. This modular design also permits future upgrades to accommodate planned advances such as integrated DSP and remote monitoring capabilities.

We have focused our design efforts for the KF700 Series on simplicity and ease of operation in all areas from powering and processing to rigging and truck pack while optimizing acoustical performance without compromising any other area. By so doing, the Series created represents an important new benchmark in portable loudspeaker technology.

Patents are pending on the new midrange frequency cone geometry; the KF750 acoustic transformer (phase plug); the integration of dipole LF transducers into the midrange frequency horn; and the calculation of the optimal ratio between LF transducer spacing and midrange horn mouth height.

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