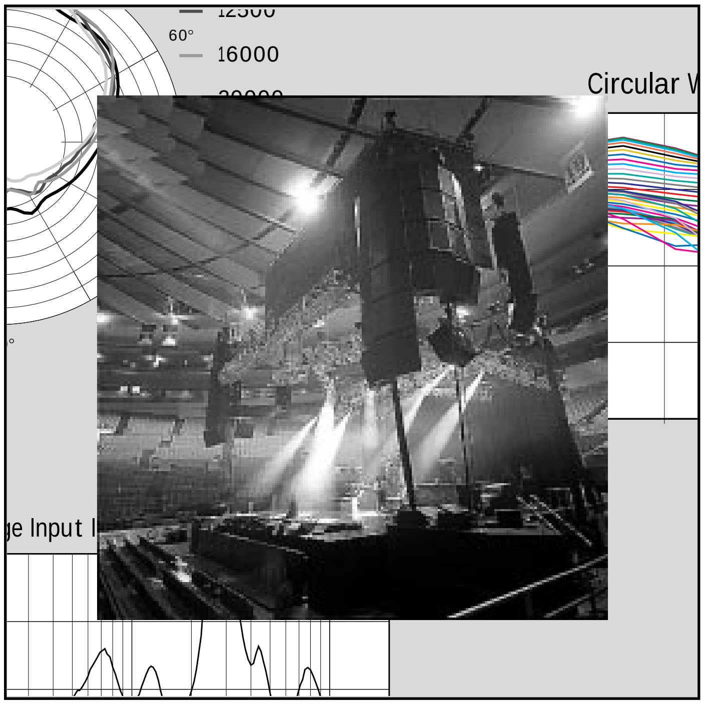

INTEGRATING PERFORMANCE & APPLICATION DATA WITH LOUDSPEAKER DESIGN CONCEPTS

An Eastern Acoustic Works Engineering White Paper

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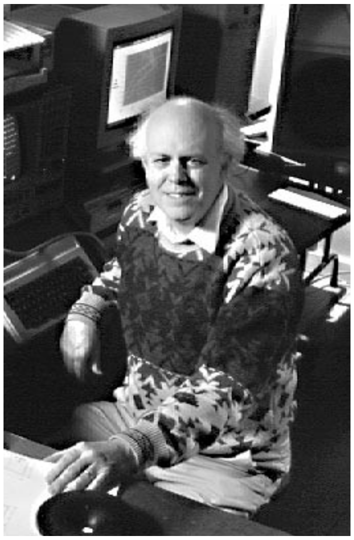
EAW ENGINEERING PRINCIPLES



Kenton Forsythe, Executive Vice President, Engineering, has developed EAW's engineering approach during two decades of research and development in professional loudspeaker system technology.

Throughout his two decades of work in professional audio, EAW's Executive Vice President, Engineering Kenton G. Forsythe has sought to improve loudspeaker system performance by developing, discovering and integrating new developments in all aspects of audio technology. Throughout his carrer, Forsythe has focused on optimizing the speaker system's total acoustic output, which determines the way it activates the room or listening area.

Because his designs are rooted in fundamental laws of physics, they have proven to be solid foundations for continuing refinement and innovation, as with the KF850E Stadium Array® Systems introduced on EAW's fifteenth anniversary in 1993.

REAL WORLD RESULTS

EAW has never pursued technology for its own sake. Instead, our engineering team has developed a design process that focuses on improving total system performance in the many "real worlds" of sound reinforcement applications. Design goals and parameters are determined at the outset by the system's intended uses. New concepts and specific innovations are only a means to achieving higher levels of performance, not ends in themselves. This approach leaves EAW engineers free to incorporate an ever-expanding range of technologies including the patent-pending ARC™ Technology acoustical filter and the digital/analog hybrid control and processing of the MX8000 Close Coupled Network Processor™.

COMPREHENSIVE EVALUATION METHODS

To maximize the value and impact of these techniques, the EAW design process integrates application requirements, listener evaluations and performance measurements into the design process. We specify power response and beamwidth consistency along with conventional parameters such as on-axis frequency response, distortion, peak and long-term SPL, efficiency, directivity, coverage consistency, etc.

Our engineering department has developed proprietary software that links advanced measurement devices such as the Brüel & Kjær 2012 Audio Analyzer with an automated turntable controlled over an IEEE 488 bus and a multi-platform network incorporating Pentium® and Power PC® based engineering workstations. This system is designed to facilitate rapid acquisition of comprehensive data sets. Workstation post-processing, analysis and display of many kinds of performance data leads to new methods of quantifying and modeling system performance. One of these is the subject of a paper recently presented at the Institute of Acoustics conference in Windermere, England by EAW Senior Design Engineer Michael Chamness.

The scope and power of our data analysis software expands with each design project. The speed of the process allows a greater number of design/evaluation/redesign stages to be completed within the project schedule. EAW engineers can see the results of their design decisions with precision and make intelligent refinements. The integration of conceptual models with actual test and measurement data allows EAW engineers to guide this iterative design process toward a close approximation of the original acoustical and mechanical performance goals, rather than a compromised version of a mathematically generated model which may or may not correspond to the real world.

We have also concentrated on gathering and using feedback from consultants, contractors, sound companies and other end users. Input from these sources helps us identify difficult design and installation problems, so that our search for new design concepts is grounded in the needs of the professional audio industry. Solving previously intractable design problems demands that we explore new approaches on the leading edge of loudspeaker system technology. Custom designs developed in response to newly identified applications and requirements often evolve into standard or special order EAW products.

Eastern Acoustic Work's engineering staff has grown from Kenton Forsythe to a diverse research and manufacturing team. Pictured below are: (back row l to r): Jeff Rocha, Design Engineer; Wayne Sjoberg, Electrical Design Draftsman; Sam Appleton, Engineering Manager; Jim Morrison, Mechanical Design Draftsman; Greg Burlingame, Design Engineer, (middle row l to r): Mike Chamness, Senior Design Engineer; Hideo Tamaki, Electrical Design Draftsperson; Kathy Lucier, Documentation Project Leader; (front): Kenton Forsythe, Engineering Vice President.

EAW
EASTERN ACOUSTIC WORKS

THREE ENGINEERING DIRECTIONS

The results of EAW's ongoing research and development efforts appear in three distinct product ranges.

Miami, Florida's Jackie Gleason Theater for the Performing Arts uses KF300's, SB528's and SB180's, FR253's, and SM202's. David W. Robb, Director of Electro-Acoustic Design at Jaffe, Holden, Scarborough Acoustics, Inc., designed the system, which was installed by Professional Sound Services of Miami.

PERFORMANCE/ENGINEERED SYSTEMS

Performance/Engineered Systems are designed for optimum results in a specific group of applications. Because of their flexibility, Performance/Engineered systems such as the Stadium Array Series are easily adapted to new uses by innovative system designers and installers. Originally developed in response to the demands of touring sound, the KF850E and other Stadium Array systems can now be found in performing arts centers, nightclubs, houses of worship and other venues.

High Definition MultiMedia Systems, including the JF and SM Series, exemplify the versatility of Performance/Engineered systems.

Virtual Array Series systems such as the KF300is and the KF650is are increasingly used by leaders in corporate audiovisual presentations and theatrical sound design. These systems are also deployed instead of the Stadium Array Series in smaller venues, or used to enhance articulation in marginal seating areas of large public spaces.

The JF Series of compact two-way high definition multimedia systems have been used successfully in houses of worship, as stage lip fill systems on large concert tours, and as distributed sound systems in sports facilities. These examples typify the way in which the applications set for any given Performance/Engineered system expands. Performance/Engineered systems are "standard" products that have set new standards of performance across the spectrum of professional sound reinforcement.

PROJECT/ENGINEERED SYSTEMS

Very large scale projects that have highly unusual requirements, such as theme park attractions and some stadiums or arenas, can pose seemingly insurmountable problems for the sound system designer. To solve those problems, leading consultants are working closely with the EAW Engineering team to define and develop *Project/Engineered Systems*.

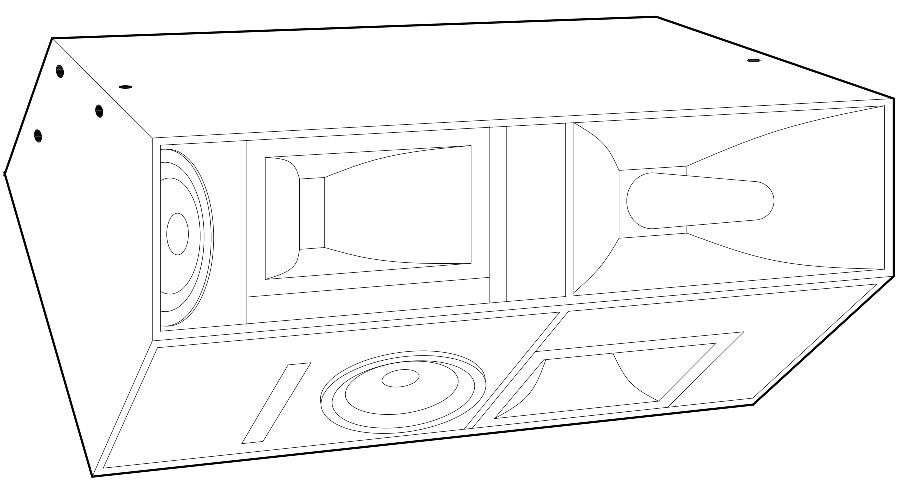
These unique systems are the ultimate examples of integrating real world data into the design process, since each one is engineered to meet the challenges of one specific venue or section of a venue. Dispersion angles, output levels, enclosure configurations and other design parameters are chosen to solve particular problems. Blueprints of the project are an integral part of the design process that produces a unique, custom-engineered loudspeaker system, capable of achieving results not attainable with any off-the-shelf product – including EAW's standard products.

APPLICATION/ENGINEERED SYSTEMS

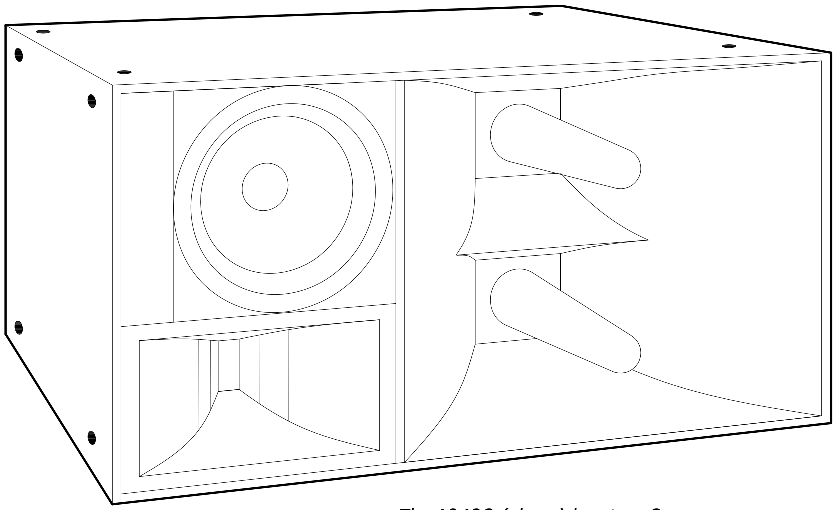
A significant number of applications also require a more specific approach than Performance/Engineered Systems can provide. Application/Engineered Systems offer the system designer a greater degree of control and flexibility, without the complexity and expense of a totally custom Project/Engineered system.

Some requirements, such as special input connections or high voltage distributed systems, can be met by special order Application/Engineered versions of Performance/Engineered products. Others, particularly large-scale projects, demand systems that are inherently more adaptable to the designer's needs. These applications are served by the evolving AS Series of Application/Engineered installation systems.

Project/Engineered system designed for a pyrotechnic spectacular at Universal Studios Florida, Orlando, Florida. The unusual downward-angled horns focus coverage on specific audience areas. Acosutic Dimensions, consultant; Signal Perfection, Ltd., contractor.

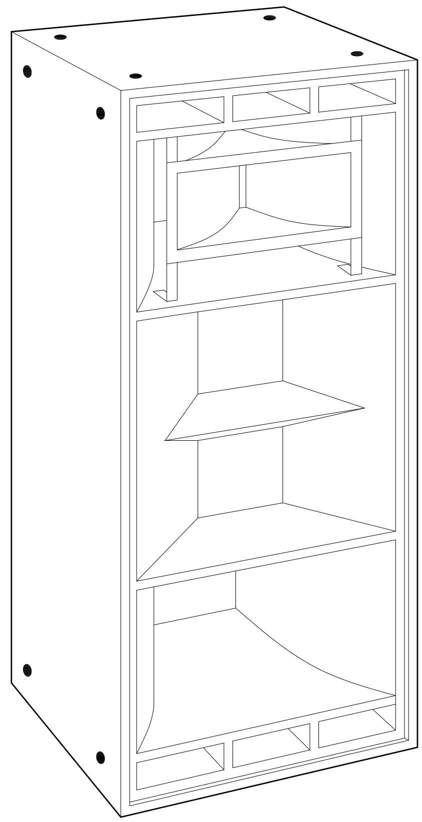


Project/Engineered dual-coverage system designed for Coors Field, Denver Colorado. Acentch, consultant; Ford Audio/Video, contractor.



The AS493 (above) is a true 3-way full-range system designed for single cabinet installations.

Wide (120° x 30°) coverage Application/Engineered system (below) includes two horn-loaded 15 inch woofers, dual 10" midrange cones on wood laminate exponential flares and a large diaphragm compression driver on a fiberglass horn.



AS Series systems are designed for wideband consistent pattern control. AS Series systems offer the designer an expanding variety of coverage patterns, output capabilities, operating bandwidths and enclosure configurations. Many AS Series systems combine the same transducers and horns in different types of enclosures. This gives the system designer greater freedom without compromising the consistent sonic character of the total installation. Rectangular enclosures facilitate single-system installations. Trapezoidal enclosures can be engineered to simplify the design and construction of horizontal or vertical arrays.

ONE DESIGN PROCESS

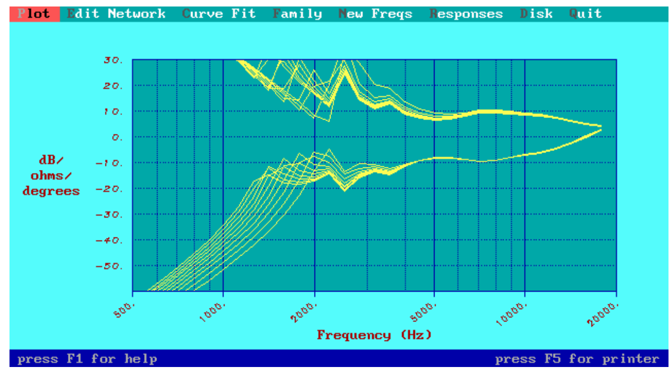
Performance/Engineered systems, Application/Engineered systems and Project/Engineered systems all emerge from the EAW design process – an approach that emphasizes the integration of objective and subjective real world feedback with theoretical models at every stage. This paper will illustrate some aspects of this process by describing a few of the products that it has produced in recent months.

COMPUTER-AIDED PASSIVE CROSSOVER DESIGN

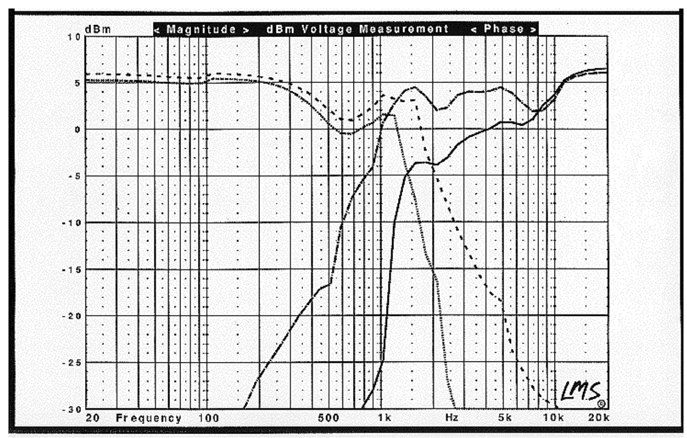
Factors such as driver and diaphragm excursion limits, distortion levels and dispersion patterns mandate the use of multi-way systems to cover the audible spectrum. Whether they involve external active electronics or passive internal networks, crossovers are a major determinant of performance vectors such as on-axis frequency response, beamwidth consistency, power response (the system's total acoustic output), impedance, reliability, power handling and more.

INTEGRATING MATHEMATICAL MODELS WITH PERFORMANCE MEASUREMENTS

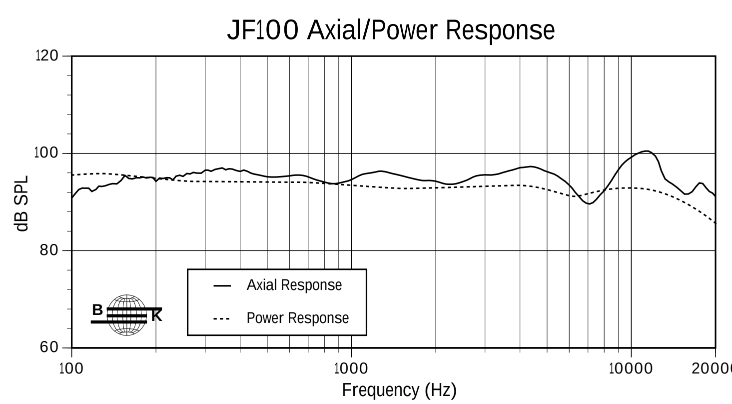
In the face of such complexity, most designers have retreated to the abstract, designing around mathematical models of electrical filters such as Linkwitz-Riley, Butterworth or Bessel Function filters. The common shortcoming of these models is that they assume a purely resistive load, ignoring the complex electrical impedance presented by the transducer as it is coupled to the air. Equations also ignore the inherently non-linear acoustic response of the driver/enclosure/



With proprietary enhancements, EAW Engineer Mike Chamness' Filter Designer software speeds comparison of alternatives and selection of optimum component values.



The network's electrical response is unorthodox but produces the optimum acoustic response from this particular driver/enclosure/waveguide system.



The final network optimizes both frequency and power response.

Michael Chamness, EAW engineer, wrote Filter Designer to facilitate crossover design. Proprietary modules written especially for EAW integrate the modeling process with our automated test and measurement capabilities.

waveguide system. Yet acoustic accuracy is the reason the crossover was designed in the first place.

ITERATIVE CROSSOVER DESIGN

At EAW, Kenton Forsythe has established a crossover design team that focuses on real world acoustic performance. He emphasizes that "It is not the electrical characteristics of the filter,

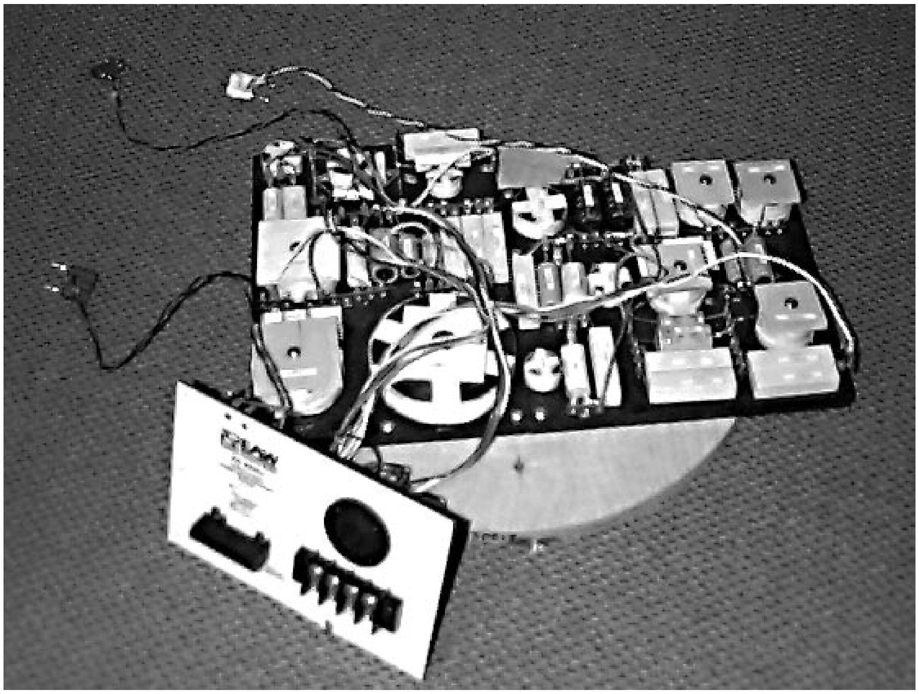
EAW passive crossovers are designed and built to handle all the power that modern amplifiers can deliver without thermal failure or measurable distortion.

but the system's acoustic transfer function that is important." Each crossover network is designed for a specific system. The goal to optimize the acoustical response of that particular system by providing coherent acoustic summing throughout the crossover region, while also maintaining a stable electrical load that can be consistently and reliably handled by today's power amplifiers.

EAW's system-specific crossover networks are far more effective than simple equation-derived designs because they take complex impedance as well as acoustic parameters such as phase and power response into account. As a result, the design process and the networks derived from it are far more complex than filter networks calculated using abstract formulas.

PROPRIETARY DESIGN SOFTWARE

To cope with the added complexity, EAW Senior Design Engineer Michael Chamness has developed proprietary enhancements for his Filter Designer software. EAW's in-house version of Filter Designer interfaces with our automated acoustical and electrical measurement systems. First, data on the frequency response, power response and complex impedance vs. frequency of the raw driver and enclosure are collected. The complex impedance and acoustical response data are then converted to a format that can be used as a component of the Filter Designer model. The



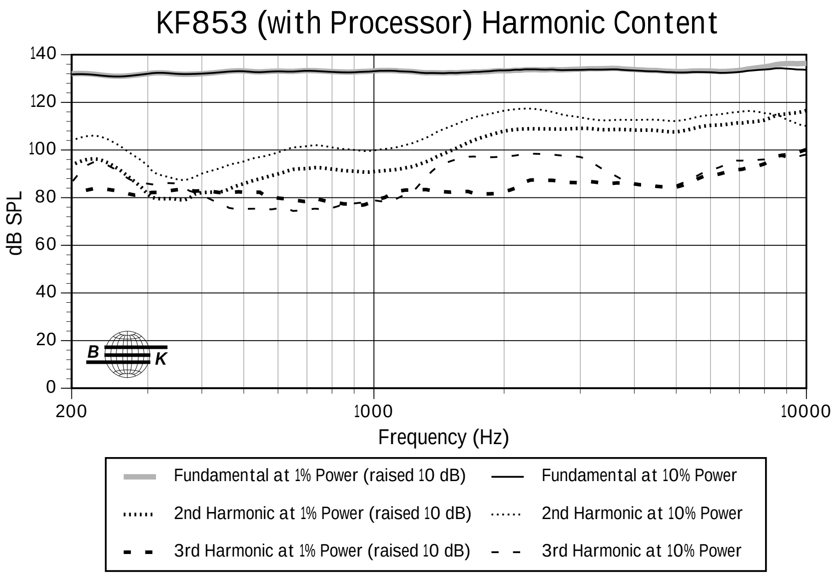
This switchable crossover for the AS300is shows the level of complexity necessary to achieve optimal acoustic response as well as maintain a stable electrical load necessary for today's power amplifiers.

software then models filters using combinations of inductors, capacitors and resistors with the empirically-derived impedance data. The projected results can be correlated with the system's measured acoustical properties.

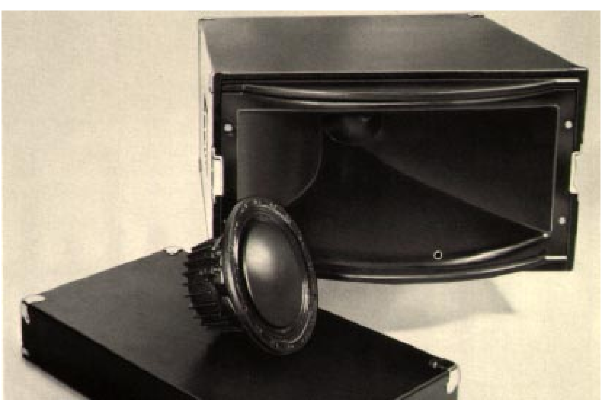
When the designer is satisfied with the software model of the filter network, it is built and the resulting crossover/driver/enclosure system is tested again. A new set of electrical and acoustical measurements are now fed back into the modeling program, which allows the designer to further optimize the network. Passive parametric-style equalization can be applied inside or outside the crossover region to optimize frequency and power responsen. The process can be repeated any number of times until the optimum combination of components and values is reached. Finally, a tolerance analysis of the network projects the effects of deviations from the nominal component values.

The precision of the performance data and the speed of the testing and modeling processes are crucial, since the design goal is real world results instead of formula-derived values. The test/design/refine/retest cycle produces a crossover that optimizes the complex balance of competing performance factors for the system's intended applications.

DESIGNING FOR MINIMAL DISTORTION



This is a plot of the harmonic content of the KF853 at 1 and 10 percent power output.The KF853 APP data will be released as an update to APP Volume 3.



An early expression of Kenton G. Forsythe's horn loaded midbass cone driver/displacement plug concept: EAW's MR-109CT, introduced c. 1978.

Any loudspeaker system intended for professional applications must be able to reproduce the full dynamic range of the source without spurious noise or distortion. Distortion is evidence of non-linearities in electro-mechanical systems, usually diaphragm and surround breakup modes. As excursion increases, so will distortion. Increasing the radiating area of the transducer will reduce excursion at low frequencies, but the added mass attenuates high frequency response.

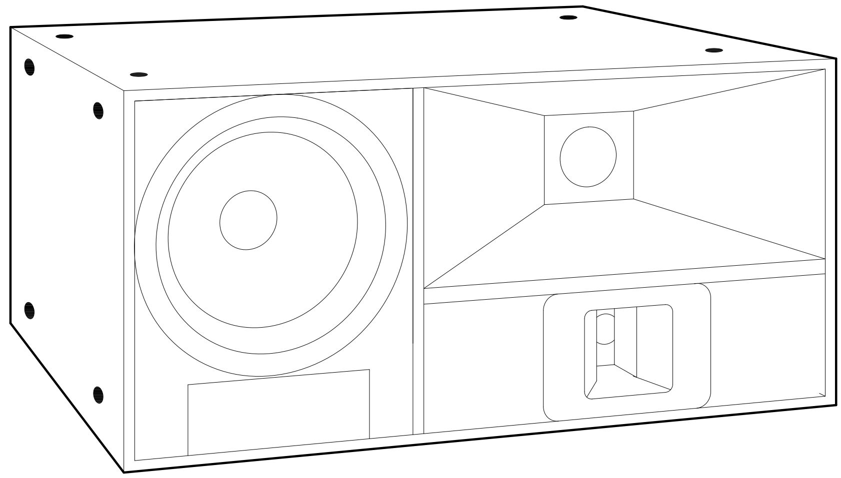
The obvious solution to this dilemma is to cross over to a significantly smaller or larger diaphragm so that usable frequency response can be extended upward or downward by a useful amount – a minimum of one and a half octaves, and a maximum of three octaves due to the requirements for low distortion and high reliability. Thus, a 3-way loudspeaker system is required for 40 Hz – 16 kHz response. The entire midrange should be covered by a single transducer.

Depending on the application, the midrange can be defined as the spectrum between 150 – 300 Hz and 1.5 – 3 kHz. It contains the fundamental frequencies and the principal overtones of most musical instruments, as well as the frequencies that determine vocal intelligibility when rated using scales such as %ALCons or RASTI. The telephone system, for instance, operated exclusively within the frequency band from 250 Hz to 2.5 kHz for many years.

Regardless of the number of crossover filters, any system with a crossover point in the midrange is fundamentally a 2-way system. The addition of subwoofers or supertweeters requires additional crossovers, but the vocal frequencies will continue to be divided between two different types of driver. Excessive distortion, radical shifts in coverage and power response, and inherently lower reliablity are the usual consequences. On the other hand, true 3-way design has forced EAW engineers to develop proprietary manufacturing and packaging technology in order to keep enclosures, and therefore arrays, compact. Optimum performance requires more complex and costly crossover networks, along with more expensive drivers and more elaborate horn construction techniques.

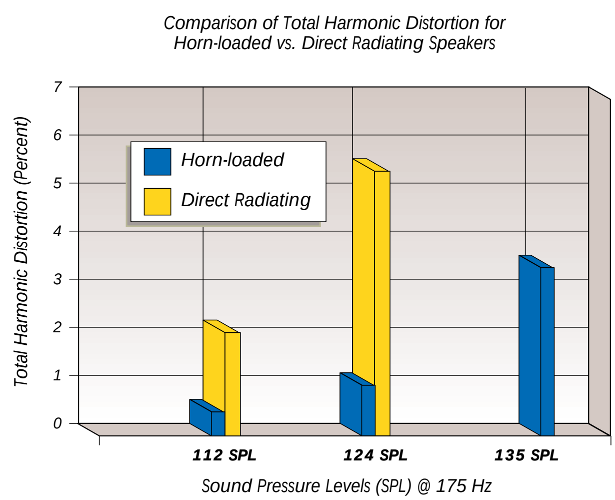
HORN LOADING REDUCES DISTORTION AT HIGH OUTPUT LEVELS

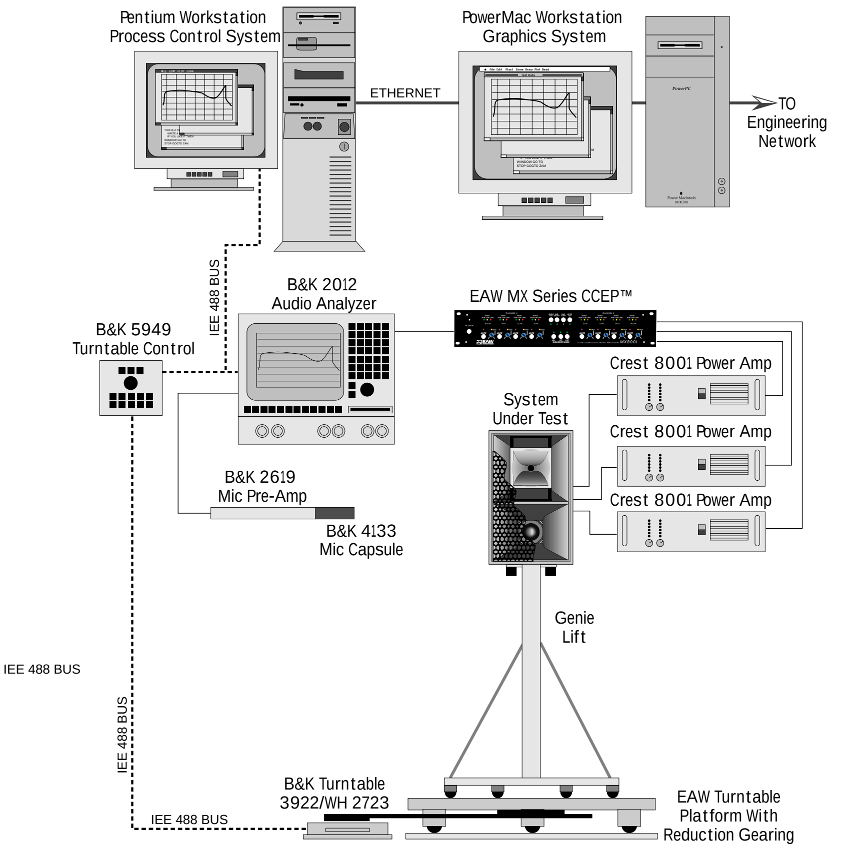
The table at left compares midbass distortion for two low-frequency systems, one a vented direct-radiating system and the other a horn-loaded design. Enclosure dimensions and drivers are identical for both systems. The superior performance of the horn-loaded system is readily apparent. The direct-radiating system's distortion is higher, and the difference increases as output level rises—at approximately 112 dB the horn-loaded system produces only 1/4 the total harmonic distortion of the direct-radiating system, but at normal operating levels of 120 dB at 1m (100 dB at 10m) and above the THD of the horn-loaded system is less than 1/6 that of the direct-radiating design. One reason for the difference is that horns provide far more efficient acoustic coupling to the air. As a result, the direct-radiating system requires eight to ten times the input power to produce the same output level as the horn-loaded system with its more efficient acoustic transfer function.



High-output low distortion arrayable systems such as the AS592 require three transducers for full range musical output and consistent pattern control.

The direct radiating system in the graph below is unable to reach the maximum SPL of the horn-loaded system, although both have identical transducers.





Above is a schematic of one of EAW's Power PC and Pentium workstation controlled loudspeaker testing suites.

Below is a view from one of the EAW's engineering laboratories of the testing hardware.The automated test and measurement system is only one of many used throughout EAW, including multiple TEF, SysID, LMS and Neutrik strip chart systems.

TESTING PROCEDURE

EAW engineers routinely collect data such as this using our Brüel & Kjær 2012 Audio Analyzer in TSR (Time Selective Response) mode. "TSR mode enables "free-field" measurements without an anechoic chamber, by rejecting the reflections from an ordinary listening room. The Type 2012 incorporates a technique that allows a useful combination of speed, accuracy, and signal/noise ratio for such measurements." (From the B&K 2012 Reference Manual, p.2.) In order to extend accurate measurements in TSR mode to the lowest audible octave, EAW has constructed a two-story test chamber at its Whitinsville, Massachusetts headquarters.

Among many other parameters, TSR mode can record the fundamental, second harmonic, and third harmonic at various power levels with speed and precision. Its test signal is a constant amplitude, linear sine sweep: The instantaneous frequency varies directly with time. When a Close Coupled Electronic Processor™ such as the MX800i is an integral part of the system being measured, the 2012's output is connected to the CCEP™ device. The resulting signal is amplified and fed to the loudspeaker system under test.

EAW's test setup allows our engineers to use a broad range of stimulus voltages. The resulting power in Watts is calculated on the basis of the test system's nominal impedance. Measurements are usually taken at a distance of 3 meters, and the results normalized to 1 meter in order to provide a standard comparison.

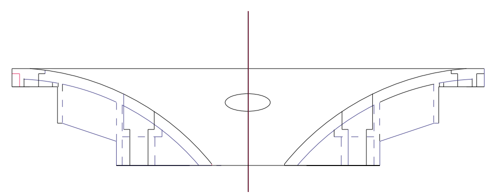
OPTIMIZING HIGH FREQUENCY HORNS THROUGH ITERATIVE DESIGN

High frequency horns are often molded from fiberglass, since the resonance of the structure and material is outside the horn's operating band. Precise driver loading in the initial section of the horn is crucial to optimum performance. For this reason, we pay particular attention to the throat area. Typical horn construction techniques require that the throat become continuously narrower. In choosing dimensions, the designer must balance the demand for constant coverage at the upper end of the device's operating band with the need for low distortion. The first goal mandates a narrow throat, the second dictates a wide one.

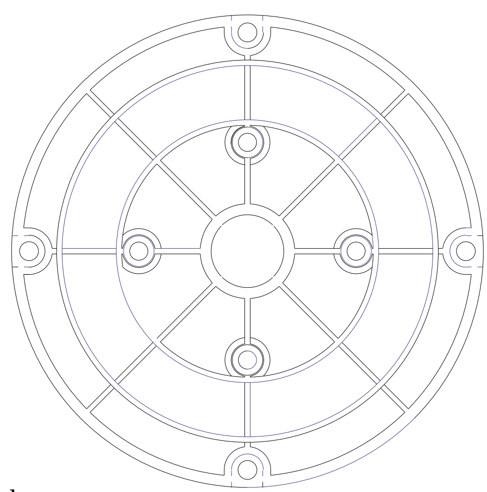
EAW engineers find this trade-off unacceptable, so our high frequency horns are formed in collapsible molds. This is a more expensive construction technique, but it allows us to produce an undercut in the initial section of the throat while still maintaining one piece construction. Coverage is consistent over a wide bandwidth, without the excessive high frequency beaming exhibited by conventional low-distortion designs.

Polar response and distortion measurements are an integral part of EAW's horn design process. Typically, a prototype of the horn will be molded in fiberglass. The horn/driver subsystem will be measured using the B&K 2012 and its motor-driven turntable, which is controlled from a Pentium workstation over an IEEE 488 bus.

JF100 wave guide prototypes. Various forms are built up using nylon, fiberglass, and clay. Test data shows the results of modifications and refinements.



SIDE CROSS-SECTION



BACK

When developing horns and other waveguides, EAW Senior Design Engineer Michael Chamness draws on years of practical experience to analyze polar data and modify prototypes.

The system is fed with a swept sine wave covering the subsystem's passband. Then the turntable is rotated 5° and the sweep is repeated. Rotating the enclosure 90° allows measurements to be taken along the vertical axis. The B&K simultaneously records amplitude, phase and other information such as harmonic distortion.

The entire process can be completed in less than half a day, enabling the horn designer to see the results of the various specified dimensions. Clay modeling is used to evaluate the impact of possible refinements to the design. In this way, the horn flare can be modified several times in a relatively short time period. The designer has the opportunity to analyze the results of any modifications almost immediately. When the horn meets specifications for coverage pattern, dispersion consistency, and other parameters, the design can be finalized and a mass-production mold fabricated.

LARGE-FORMAT MIDBASS HORNS

True 3-way design is a prerequisite for the lowest levels of distortion. A horn- loaded midrange subsystem will provide lower distortion and increased output due to its greater acoustical coupling efficiency. A cone-driven midrange system has a much lower cutoff point, again with reduced distortion. But true 3-way design alone is not enough: The concept must be executed properly. The details of driver, crossover and enclosure design must be given proper attention in order to realize all the potential benefits of true 3-way design.

Properly designed horn flares can maintain uniform coverage over a fairly wide frequency band without excessive distortion. Comparative measurements show that EAW 3-way systems produce much lower distortion in the midband, not only when compared to typical two-way and pseudo-3-way systems, but also against other true 3-way systems. Midbass horn construction is one key to this superiority.

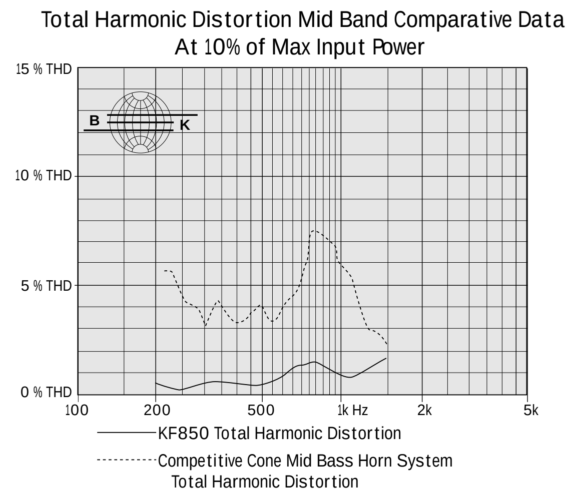
Kenton Forsythe pioneered the midbass horn flare with displacement plug in the 70's. Since that time, EAW has continued to refine this concept with advanced construction methods. While midbass and even low frequency horns can be molded from fiberglass, the resulting structure will tend to have a resonant frequency within the horn's operating band, which produces non-linear frequency and power response.

A better method of constructing large horn flares uses a wood/foam structure which resonates outside the device's passband. The reinforcing foam maximizes the acoustical rigidity of the structure. Thin wood laminates are used in the side walls to produce a complex flare.

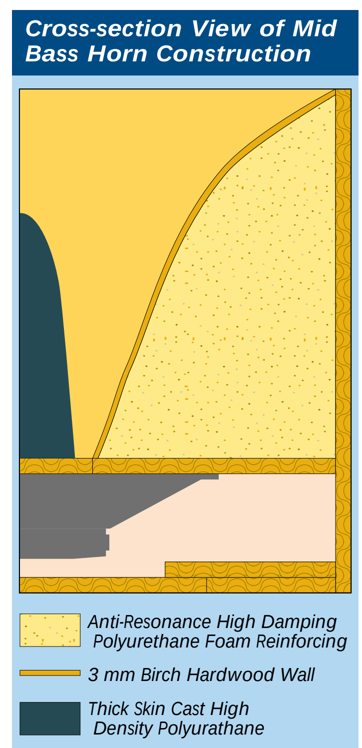
Most commercial production methods use circular cross-sections that are gross approximations of true mathematical horns. Our proprietary construction technique begins when high-precision numerically controlled routers cut the correct exponential flare into the side walls.

The surface of the horn flare is formed by bending a thin, flexible layer of multi-ply birch hardwood over a heavy birch former frame. The thin birch ply is fitted into the pre-cut track to form the sidewalls of the flare. Finally, the flare is reinforced by injecting high-density polyurethane foam into the spaces behind the walls. This maintains acoustical rigidity and damps any remaining resonances out of the structure.

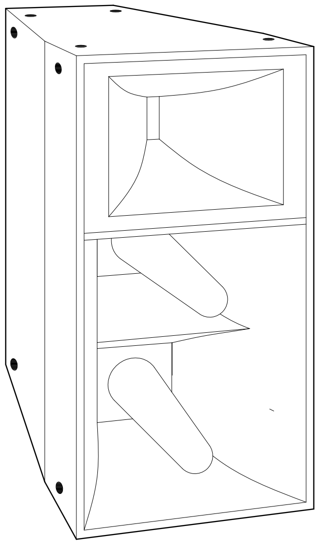
As a result of these proprietary construction methods, EAW horn flares exhibit an extremely smooth air-loaded impedance characteristic. This produces flat response over the entire operating range and eliminates the "honk" so typical of ordinary horns.



Proper execution of the true 3-way design concept minimizes distortion, even at high output levels. The KF850's total harmonic distortion is much lower than that of similar true 3-way systems.



THE AS SERIES OF APPLICATION/ ENGINEERED SYSTEMS



The Performance/Engineered MH662 Mid/High Virtual Array Module incorporates two 10 inch cones coupled to the air with a refined version of Kenton Forsythe's wood laminate exponential horn and displacement plug.

The EAW design process is applied on every scale from small studio monitors all the way up to the largest full range systems. In the AS Series, EAW engineers focused on developing systems that simplify the design and installation of permanent systems. The definition of application requirements and problems by the contractors and consultants themselves is an important part of this process. The AS Series is thus one of the prime examples of integrating real world experience with advanced design concepts.

Gerry Webber Stadium in Halle, Germany is an outstanding example of AS Series implementation.

The first and most important kind of feedback involves defining the system's performance characteristics at the outset. Array requirements such as coverage requirements and zones, an application-specific definition of “adequate” SPL, the range of operating distances, frequency response, size, weight and cost are all essential starting points for the design process. After reviewing these basic requirements for a wide range of projects, EAW engineers are developing a range of systems to meet the needs of system designers.

One common requirement of large public spaces is a sound system that focuses acoustic energy on tightly defined coverage areas. Horn loading, with large mouth sizes that provide consistent vertical and horizontal pattern control into the midbass region, is one of the keys to achieving this goal. In the lower octaves, horns and/or line arrays can be used to control dispersion.

AS Series systems are designed to combine clear vocal articulation with low distortion, full range musical reproduction. The combination of horn-loaded compression drivers and small cones with multiple high-power woofers delvers ultra-high SPL capability, controlled coverage over a wide operating bandwidth, reduced distortion, especially in the critical midband, and smooth power response.

FLEXIBLE CONFIGURATIONS

Packaging is an important part of AS Series design solutions. Arrayability is often important. The most common array configuration is a horizontal arc, but there is also a need for vertical arrays in certain stadiums and arenas. EAW engineers are also developing pre-arrayed systems that control acoustic interaction electronically, as in the MH6602 and MH6902 systems installed at th eGerry Weber Stadion in Halle, Germany. In either case, the individual array elements must be designed to work in close physical proximity to their neighbors.

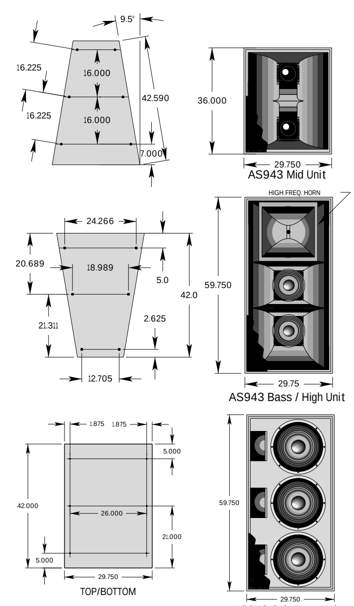
Spaces left between array elements must be filled to eliminate diffraction effects. The AS Series mounts horns within enclosures that are designed to be arrayed adjacent to each other. To contain spurious vibrations, or rear-radiating energy, EAW's proprietary cabinet and horn construction techniques fill the spaces between the flares and enclosure walls with reinforcing foam to create an acoustically rigid structure.

The enclosures may be trapezoidal with slanted sides when horizontal arrays are desired, or with slanted tops and bottoms when vertical arrays are needed. This makes installation and aiming of the cabinets virtually automatic, because the side or top and bottom angles match the coverage patterns of the horns. In smaller venues, a single system may be able to cover most of the audience area, so that a simple rectangular enclosure becomes the optimum solution.

THE AS943 ULTRA-HIGH-OUTPUT LONG THROW SYSTEM

The largest AS Series system, the AS943, was developed in response to requirements of leading theme park operators. Its extremely large ultra-long throw (40° x 20°) midbass

The MH242 ultra-long throw system is based on an ultra-high output dual 12-in mid bass subsystem. Developed for Fiesta Texas in San Antonio it evolved into today's full range AS943.



The trapezoidal KF300is enclosure has been engineered for installation in wide coverage horizontal arrays with the SB330 VA® Subwoofer.

section was originally developed as the MH242 system used in a pyrotechnic spectacular at Fiesta Texas in San Antonio. It provides tight vertical and horizontal pattern control, for true ultra-long-throw performance over an exceptionally wide operating band. The other system components bring EAW design principles to the same scale of application. Multiple drivers are combined in the high frequency section to increase output and power handling. Purpose-designed woofers, horn-loaded in multiple configurations, provide wide operating bandwidth. Because of the system's size it was necessary to package it in multiple enclosures. However, EAW engineers have designed the system to be easily installed as a functioning acoustical and structural unit.

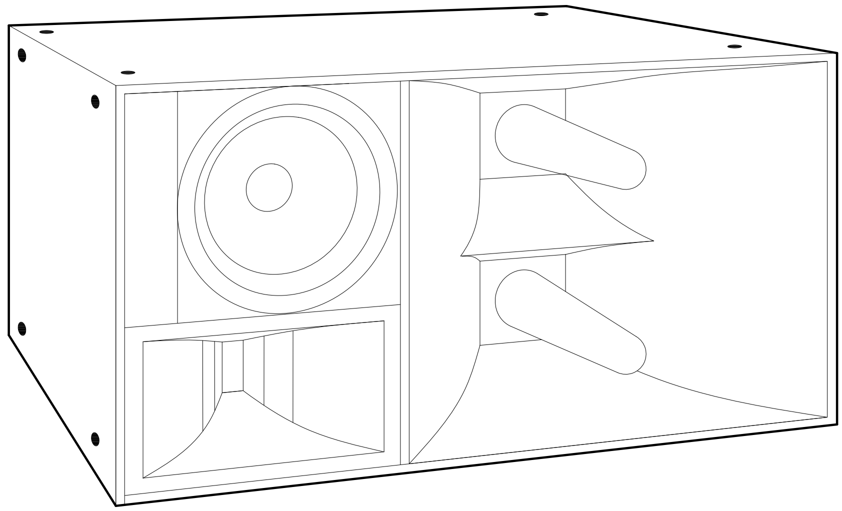
THE AS300IS MEDIUM THROW INSTALLATION SYSTEM

The smallest AS Series system, the AS300is, is designed for relatively short operating distances of approximately 7 to 25 meters. It uses the high frequency and midrange subsystems of the KF300is Virtual Array System. The differences between these two systems illustrate the way in which the EAW design process creates forms that follow real world functions.

The trapezoidal KF300is enclosure has been engineered for installation in wide coverage horizontal arrays with the SB330 VA® Subwoofer. The AS300is enclosure is rectangular, since it is intended for single installation. Since compact packaging and minimal frontal area are not as important in these applications, the AS300is is configured as a horizontal package, with a 15 inch woofer next to the midrange and high frequency subsystems. The 15 inch woofer extends low frequency response, so that the AS300is does not require a separate subwoofer in most applications. The KF300is, which is designed for minimal frontal area and "footprint," uses a 12 inch woofer underneath the two horn-loaded subsystems.

THE CJ563 LONG THROW INSTALLATION SYSTEM

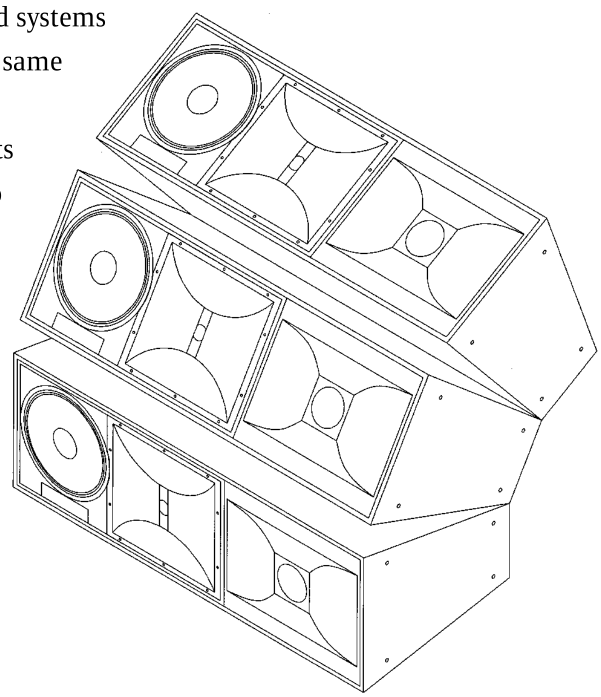
In between these two extremes are systems such as the CJ563. This three-way full range installation system is a vertically arrayable system that provides 60° x 40° coverage. It is similar in concept to the horizontally arrayable MH662 Mid/High Virtual Array Module, although the packaging requirements of a vertically arrayable system have dictated modifications to the high frequency horn. Both systems share certain components, such as dual 10 inch midrange cones. In the CJ563, these are coupled to the air with Kenton Forsythe's midbass horn flare and displacement plug using a flare similar to that used in the MH662. The high frequency section is a large diaphragm compression driver and a fiberglass horn. To speed installation, EAW engineers have designed the CJ563 as an integrated three-way full range system. The horizontla packaging creates a line array of vented 15 inch woofers, for better vertical pattern control. The The MH662 is designed for horiztonal arrays with separate BH or BV Low Frequency Virtual Array Modules.



The AS 493 is designed for single system installations.

AN EVOLVING RANGE SHAPED BY REAL WORLD REQUIREMENTS

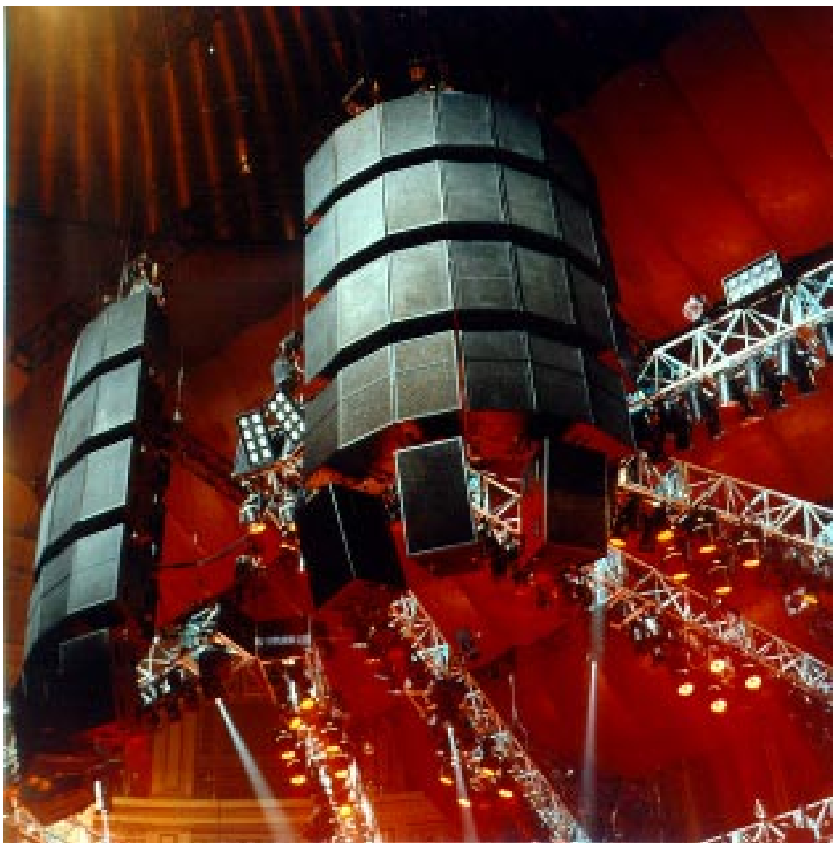
The AS Series concept is based on a range of pre-engineered systems. This range is continually evolving. Existing AS Series systems have been defined by the needs of specific projects. EAW Engineering will continue to develop AS Series configurations and systems in this way. At the same time, we invite leading consultants and contractors to participate in the definition of AS Series systems, based on the factors outlined above such as coverage angles, SPL capabilities, etc.



The CJ561 is designed to form vertical arrays.

THE STADIUM ARRAY SERIES

EAW engineers are already applying many of the techniques developed in the AS Series to the evolution of the next generation of portable Stadium Array Series touring concert sound systems.



Concert Sound of London, England arrayed KF1000's, BH852's and KF850's for Eric Clapton's 100th concert in the Royal Albert Hall.

CONTINUAL DEVELOPMENT

Since its introduction in 1986, Virtual Array Technology has aimed to provide a total solution to the problems of touring concert sound reinforcement. The original VA systems, the KF850 Full Range Stadium Array System, the SB850 Subwoofer System and the MX800 Close Coupled Electronic Processor, have undergone continual refinement and development. Because the designs respect fundamental laws of acoustical physics, these systems have been able to maintain their position on the forefront of high output, low distortion, arrayable loudspeaker systems. One example is the KF850E introduced last year.

E TECHNOLOGY

Although the KF850E looks like its predecessors, many key elements of the system have been revised and improved. The new CD5002 high frequency driver developed for this system reduces distortion at high frequencies by using ferrofluid to damp internal cavity resonances. As a result, the KF850E has a smoother top end than previous versions. The magnetic topology and cone of the new KF850E's 15 inch woofer are optimized for horn loading. A vented magnet structure increases the flow of cooling air through the voice coil and enhances long term reliability. In conjunction with a modified bass horn flare, the new woofer delivers tighter low frequencies with more punch.

The KF850E also includes EAW's patent-pending Acoustic Refraction Control™ device. Mounting the high frequency horn/driver in the woofer cavity is one of the major packaging innovations of the Stadium Array Series, and imitated by other manufacturers. Unfortunately, the compression driver's output refracts around the edges of the horn flare and is reflected out of the woofer cavity, smearing transient response and causing comb filtering. EAW engineers have developed ARC™ Technology to absorb this refracted/reflected high frequency energy. The ARC device is an acoustical filter that is mounted inside the woofer cavity. Since it operates above the woofer's crossover frequency, it enhances rolloff outside the woofer's operating band, and attenuates cone distortion harmonics that cannot be eliminated by external active or internal passive filter networks.

THE VIRTUAL ARRAY TECHNOLOGY ASSOCIATION

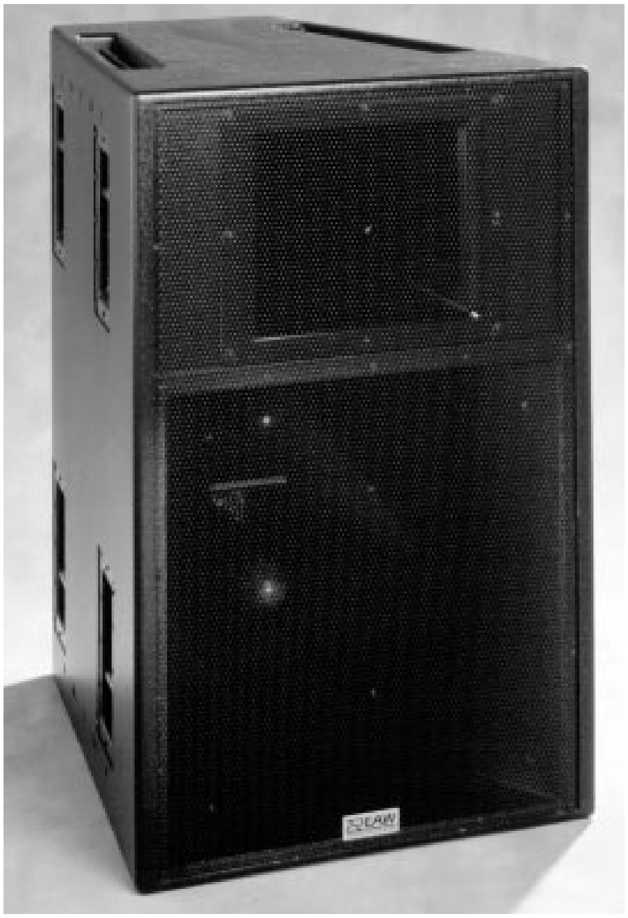
As part of its development program, EAW established the Virtual Array Technology Association of Stadium Array System owners. VATA members have been influential in the development of new "array building blocks" such as the KF852i Mid/High Stadium Array System and the BH852 Low Frequency Stadium Array System. Both systems are identical in size and shape to the KF850E, so that they can be arrayed with the same degree of simplicity.

The KF850E upgrade kit can be retrofitted to every KF850 system, including the original KF850 introduced in 1986. It advances the world touring standard with the latest developments in transducer and crossover technology.

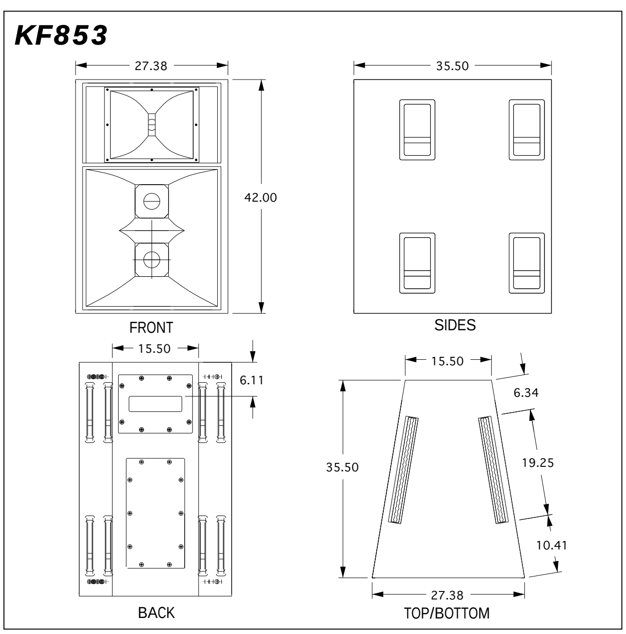
The KF852i includes two horn-loaded 10 inch midrange cones and an advanced high output large diaphragm compression driver and horn. Essentially, it is two KF850 mid/high subsystems in one enclosure. The BH852 incorporates two horn-loaded 15 inch woofers – a pair of KF850E low frequency subsystems.

Acoustically coupling identical subsystems provides a greater degree of vertical pattern control in the midrange and midbass frequencies. In addition, separating the KF850E's components into two separate enclosures gives experienced system operators greater flexibility in

Virtual Array™
TECHNOLOGY



The new KF853 High Q Stadium Array System was developed to provide true long throw performance. Its enclosure has the same side angles as all other Stadium Array systems, but it is six inches longer than the KF850/KF852/BH852/SB850 enclosure.



tailoring arrays and segments of arrays for specific venues and events. For instance, additional KF852's can be used to enhance intelligibility for speech-driven events. Conversely, extra BH852's can add the low end punch demanded by certain types of popular music.

THE KF853 HIGH Q STADIUM ARRAY SYSTEM

Many VATA companies have grown along with the Stadium Array Series itself. Their client rosters include world class concert artists, from symphony orchestras to heavy metal bands. As the demand for systems to fill the largest indoor arenas, domed or outdoor stadiums and festival sites grows, VATA companies have worked with EAW engineers to define new Stadium Array systems for these applications.

The problem areas in very large venues are the upper rows of seats. 300 to 400 feet from the stage and the main clusters, these seats are closest to highly reflective concrete or steel walls and ceilings. The reverberant field weakens intelligi-bility and in extreme cases makes it hard to perceive musical rhythm and melody. Atmospheric attenuation of high frequencies over long distances exacerbates the problem. The solution requires a true long throw system, able to project direct sound and especially midrange and high frequencies over long distances. In order to overcome the reverberant field created in stadiums and arenas, the ideal long throw device would have 30° x 40° dispersion. To provide consistent intelligibility and even coverage, such a device would maintain effective pattern control throughout the midrange and high frequencies.

With these requirements established, the design process could begin. The first challenge was to fit these horns into an enclosure that would maintain the array format established by the original KF850 Full Range Stadium Array System and expanded with the KF852i Mid/High and BH852 Low Frequency systems. Of course, the new Stadium Array system would also have to fit into a standard semi trailer: Otherwise it would be useless for touring concert sound.

DESIGN SOLUTION

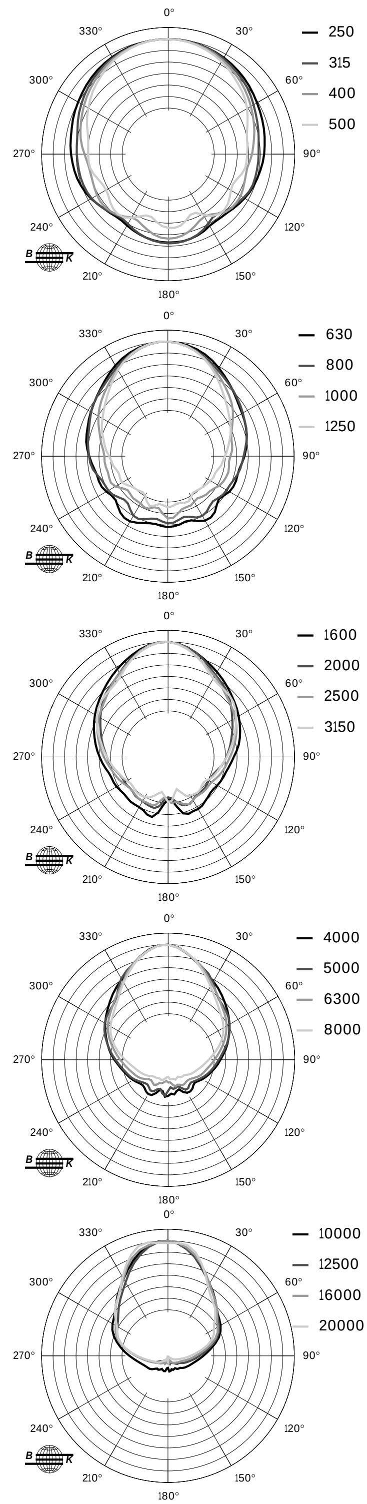
Kenton Forsythe's solution is the new KF853 High Q Stadium Array System. Its enclosure has the same side angles as all other Stadium Array systems, but it is six inches longer than the KF850/KF852/BH852/SB850 enclosure. The all-metal hanging structure is centered within the enclosure, so that the fly track lengths and angles will mate precisely with other Stadium Array systems. This enclosure is the largest that would fit into a standard semi trailer side by side with two rows of other Stadium Array systems.

The extra length has been used to create larger midrange and high frequency horns. The added depth was necessary to accommodate longer horns with 40° x 30° flares. The extra frontal area allows larger mouth sizes for extended operating bandwidth. These horns were developed using the iterative process described above. Test results of the final designs show them to be outstandingly effective at maintaining consistent dispersion and smooth power response throughout the KF853's operating range.

To maintain consistent sonic character with other Stadium Array Series systems, the KF853 uses the same 10 inch cone midrange drivers. Thanks to the efficient acoustic transfer function of the larger midrange horn, these drivers reach unprecedented output levels.

The KF853's large diaphragm compression driver is completely new. This proprietary 2 inch exit device has a massive magnet structure that provides exceptional efficiency: the KF853 is measured at 117 dB SPL for a 1 Watt input at 1 meter.

Because of the added enclosure depth, time alignment of the high frequency and midrange drivers



These horizontal polar graphs from the EAW APP Technical Documentation give a good picture of the 40 degree horizontal coverage angle of the new KF853 High Q Stadium Array System.

In Texas Stadium, Spectrum Sound owner Ken Porter hung KF853's as the top row of a large Stadium Array System incorporating KF852's and BH852's as well as KF850's.

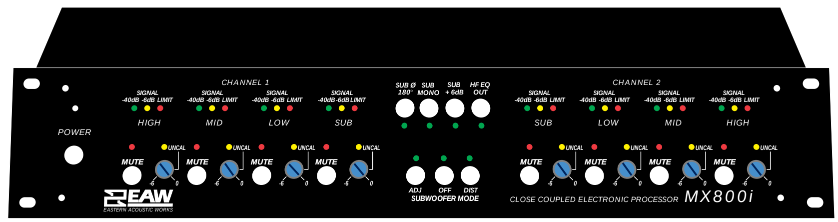
with other Stadium Array Series systems is necessary for optimum array performance. The new MX8000 Close Coupled Network Processor™ includes digital delay lines on each of its four frequency bands. Ultra fine 5.208 microsecond resolution allows the MX8000 to correct driver alignment to 1/16th inch.

Both processors take advantage of the compression driver's additional high frequency energy to compensate for the effects of atmospheric attenuation. High frequency equalization sections have been optimized at the factory to compensate for high frequency air loss and provide flat response at distances in excess of 100 feet.

Production prototypes of the KF853 have been tested in the field by Spectrum Sound of Nashville, Tennessee. The first venue to experience the long throw impact of the new Stadium Array Series system was Texas Stadium, home of the Dallas Cowboys. The event was a gathering of over 50,000 memebers of the Promise Keepers, a nationwide Christian men's organization. Spectrum Sound owner Ken Porter hung the KF853's as the top row of a large Stadium Array System incorporating KF852's and BH852's as well as KF850's. Additional Stadium Array systems were stacked stage left and stage right to cover the seats set up on the playing field, which was protected by plywood sheets.

Since the stage was set up in one end zone, the KF853's were aimed at seats at the extreme far end of the stadium. Listening tests showed that the actual performance of the new High-Q Stadium Array System is accurately predicted by the polar plots and other measurements gathered in EAW's engineering facility.

CLOSE COUPLED SIGNAL PROCESSING



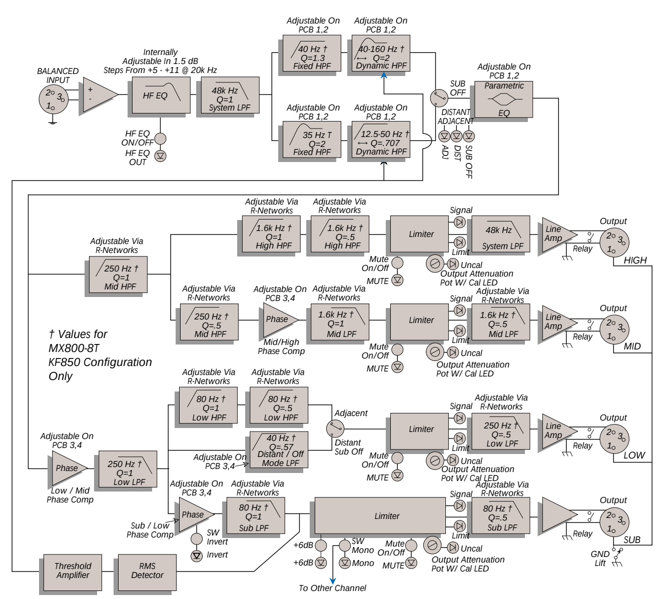
The MX800i is EAW's 4-way analog Close Coupled Electronic Processing™ unit.

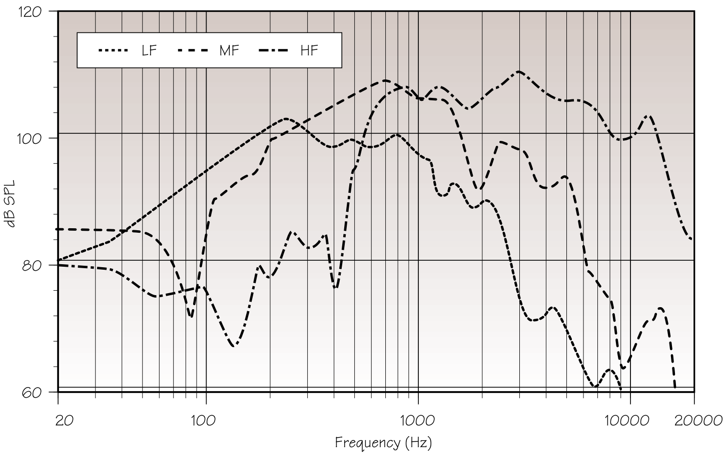
Integrated active electronics have been a key ingredient of Virtual Array Technology since its inception. However, Kenton Forsythe's use of electronics differs substantially from the typical "processed" loudspeaker system. EAW engineering practice does not accept signal processing as an acceptable solution to basic flaws in the electromechanical and acoustical elements of the loudspeaker system. Therefore, EAW processors do not use dynamic effects to provide driver protection. Instead, electronics are integrated into the total loudspeaker system as a way of maximizing its performance. Whenever possible, EAW systems are designed to function with or without active electronics, and to deliver superb performance in either operating mode. One benefit of this approach is that the tonal balance of EAW systems remains consistent at all operating levels.

EAW loudspeaker systems integrate active electronics with internal passive networks and acoustical filters. As in other aspects of loudspeaker design, EAW engineers use test and measurement throughout the design process. The relevant data is much the same as that used in the design of internal passive filter networks. Active electronic processors make it easier to add gain in specific frequency bands when necessary. Because the processor drives the power amplifiers, the reactive impedance presented by the loudspeaker system itself is not a factor. Still, the task of balancing and integrating a multitude of signal processing functions to optimize performance of the total system is a complex one.

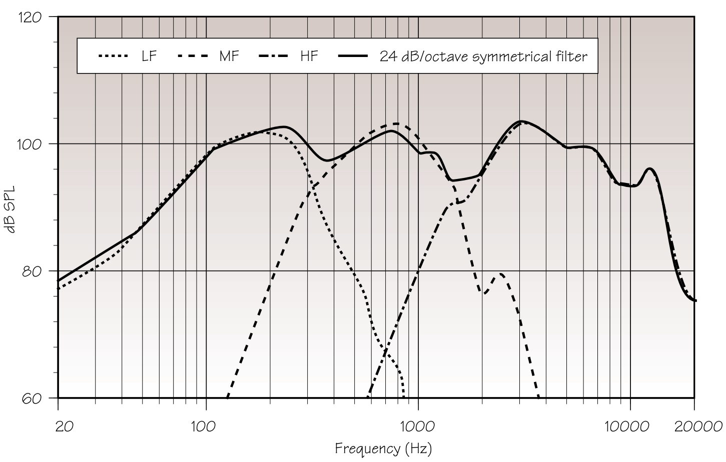
The MX800i, for instance, is a four-way stereo crossover. Each fourth order filter network

This block diagram shows the MX880i's general schematic layout.

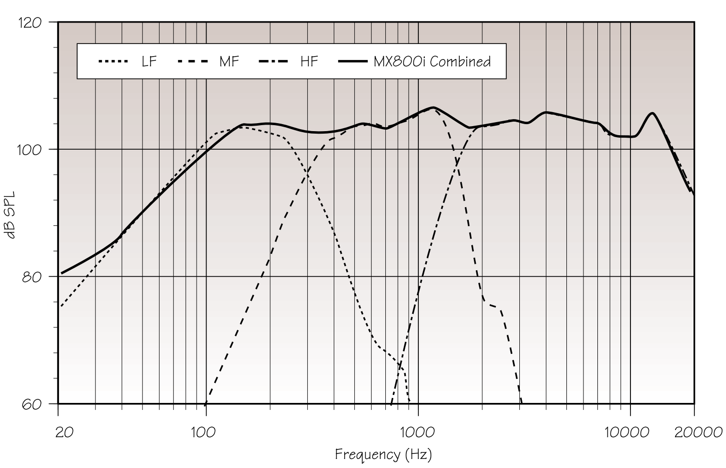




Raw driver response is anything but smooth:The crossover must integrate the three curves.

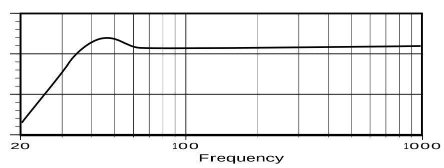


Mathematically correct filters produce uneven frequency response.

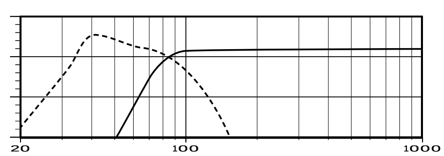


Complex asymmetrical filters are required to achieve the most accurate final results.

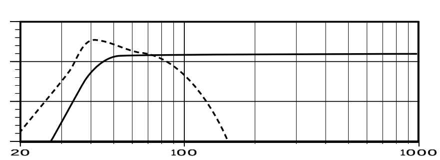
consists of two second order filters, which can be separately adjusted to produce a complex filter slope that compensates for the acoustical response of the transducer and waveguide or enclosure. Other functions include peak limiting on each frequency band, parametric equalization, CD horn EQ, allpass phase compensation filters, and low frequency excursion control. The subwoofer section can function in three modes.



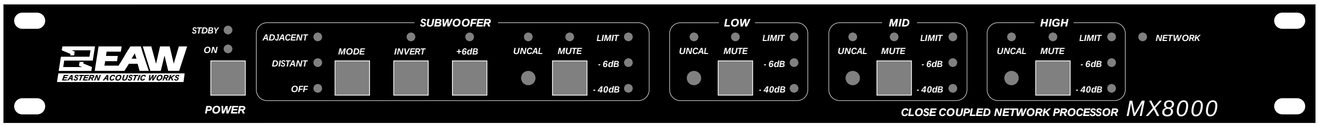
OFF optimizes the step-dwon low frequency equalization for three-way operation without subwoofers.



ADJacent provides true four-way operation with low frequency enhancement, for use when sub-woofers are in close proximity to the main system.



DIStant mode creates a three-way system plus subwoofer, for use when subwoofers are stacked on the



The MX8000 is the first dedicated speaker processor to incorporate network audio control capability.

ground while the rest of the system is flown.

To optimize all of these parameters for a specific system (with or without associated subwoofer), EAW engineers rely on the iterative process described in the opening section of this paper. Acoustic data on frequency response, distortion and phase are used as the basis for processor configuration, which is accomplished by substituting component values on plug-in daughterboards. Changing the configuration, or adjusting any parameter other than the individual limiter thresholds, requires removing the unit from the processing rack and taking off its top cover. This mechanical security helps protect the integrity of the carefully calibrated factory settings.

MX300i and MX200i processors are as sophisiticated and complex and the MX800i, although they have fewer frequency bands. CCEP processors provide operator feedback via front panel LEDs that indicate signal level, limiter status and gain calibration for each frequency band, as well as system status parameters such as Power On and Subwoofer Mode. In order to see and use the front panel, the operator must have the processor near the mixing console. Therefore the output sections of the MX800i, MX300i and MX200i are designed to drive long lengths of cable with minimal signal degradation. Their extremely low 10 Ohm output impedance maximizes Common Mode Rejection Ratio (CMRR) at the amplifier input. Signal and chassis grounds are tied through a capacitative network to protect the CCEP unit’s circuitry (see Appendix A for more information).

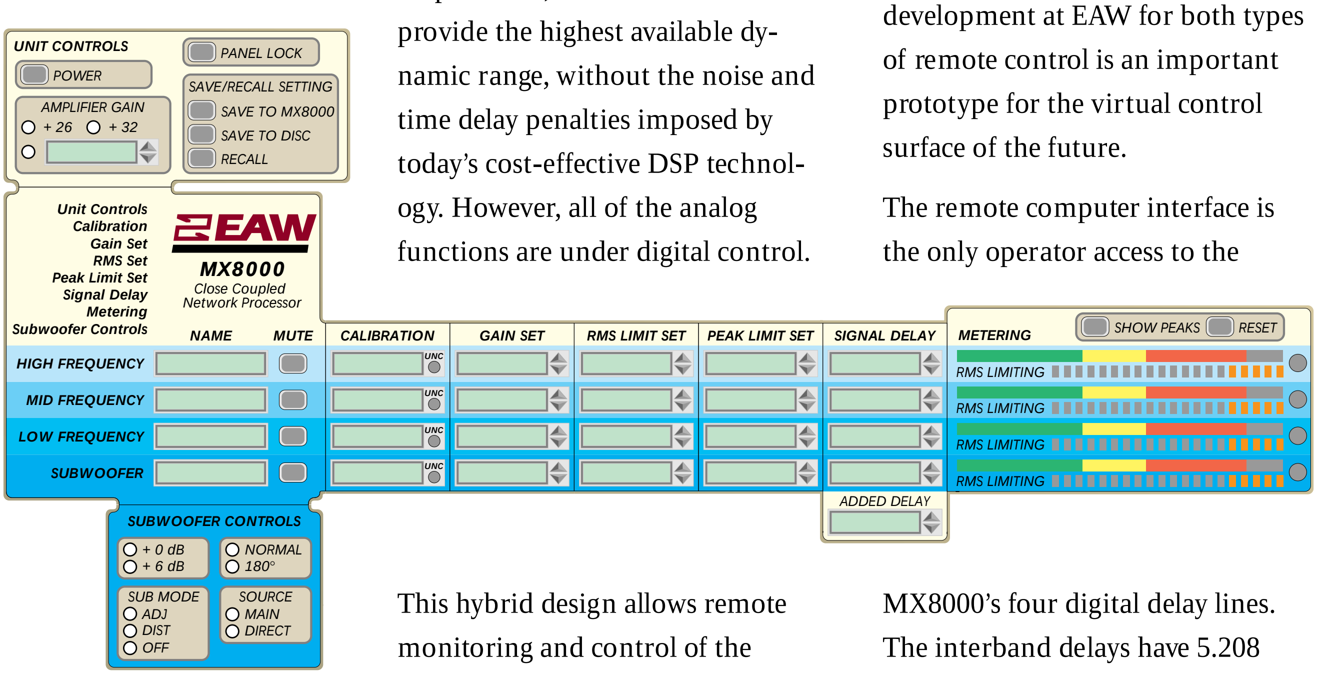
A NEW GENERATION OF CLOSE COUPLED PROCESSORS

The new MX8000 is the first dedicated loudspeaker processor to incorporate network audio control capability. EAW engineers have developed this added level of functionality in order to provide more complete information to the operator, and more control to expert system designers and operators.

The MX8000 includes all of the MX800i functions outlined above, and more. Each

Greg Burlingame, Design Engineer, is the MX8000 Project Leader. The advanced user interface of the MX8000 allows for unprecedented network processor control.

The MX8000 Network Interface is a leading edge graphic user interface designed specifically for audio processor control. The central control section contains controls which expand out the subsection controls. Once parameters have been set the controls can be collapsed so that only desired controls and metering are visible.



frequency band on the MX8000 has both peak and RMS limiters. The peak limiters are normally set to prevent amplifier clipping. The RMS limiters can be calibrated to prevent thermal failure of cone or compression drivers, once their long term current limits are known.

The MX8000's limiters, crossover filters and equalizers use analog op amp circuits, which continue to provide the highest available dynamic range, without the noise and time delay penalties imposed by today's cost-effective DSP technology. However, all of the analog functions are under digital control.

level of network interface. The Lone Wolf MediaLink chip or RS232 chip handles network communications and housekeeping chores. An internal microprocessor translates MediaLink messages into control vectors for the MX8000's signal processing functions, and converts information on operating status for network transmission. The advanced user interface are now under development at EAW for both types of remote control is an important prototype for the virtual control surface of the future.

The remote computer interface is the only operator access to the

This hybrid design allows remote monitoring and control of the MX8000 from a personal computer.

Two plug in cards are currently available for remote monitoring and control of the MX8000. The first is an RS232 serial port. The second is a proprietary version of Lone Wolf Corporation's MediaLink interface, developed by THAT Corporation. In order to provide the necessary data throughput for the MX8000's many functions and control, THAT Corporation has developed a higher

MX8000's four digital delay lines. The interband delays have 5.208 microsecond resolution, equivalent to roughly 1/16th inch, for driver time alignment within an enclosure. Maximum delay time of 341 milliseconds allows the operator to control the arrival time of the system's output: potential uses include synchronization of remote loudspeaker systems for large events or installations. Levels of password security allow the system operator or designer to completely disable to front panel. At the same time, the entire unit can be monitored, controlled or even reconfigured from the remote computer, provided the operator knows the appropriate passwords. Network-controllable MX8000's will function equally well in the amplifier rack backstage, or in the processor rack at the mix position.

The network interface will provide meters for limiter status, along with indicators for limiter calibration status, delay settings, subwoofer modes and other parameters such as master threshold settings. The master threshold control has been simplified, with factory presets for Crown MacroTech and Crest Professional Series power amplifiers. A third user-adjustable master threshold setting is preset at the factory for QSC EX Series amplifiers.

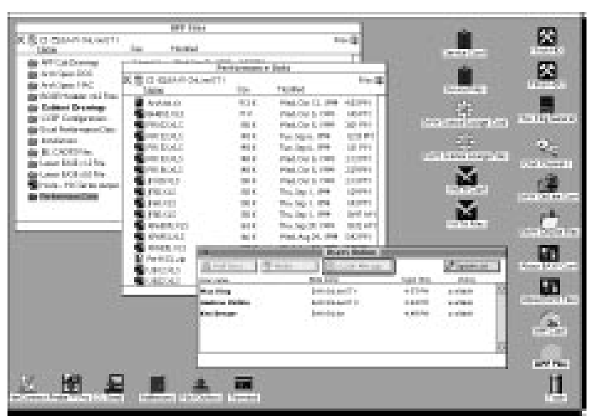
A NEW LEVEL OF SYSTEM INTEGRATION

The MX8000 is the first device to connect the loudspeaker system with comprehensive audio networks. Its network control and communication capabilities will allow the MX8000 to be fully functional as part of the virtual control surface of the future. EAW engineers see the potential to integrate the entire audio system into one multifunctional device, monitored and controlled from a single interface, as one of the most important and exciting aspects of network audio control. Automated control and variable but precisely repeatable preset parameters are inherent in digital control technology. They will almost certainly raise the minimum standard of acceptable operation for sound systems in all types of public spaces.

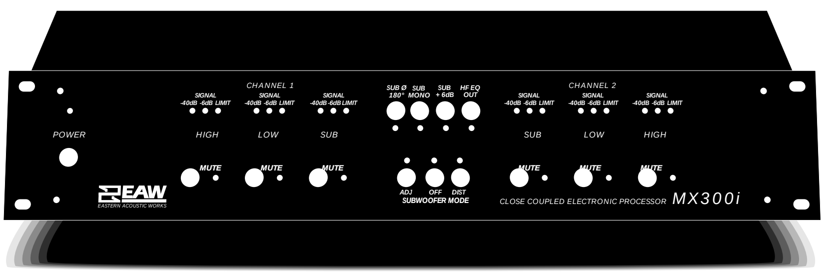
However, there are limits on the extent to which automation can be successfully integrated into a performance without compromising the spontaneity and improvisational freedom that make an event truly "live." The skills and talent of a trained and experienced operator will always be required to reach the highest levels of performance and create for the live audience a genuinely unique and memorable moment. The ultimate potential of network audio control, therefore, is to put a more intelligent, flexible and responsive system into the operator's hands. When mechanics are no longer a limiting factor on the mixer's creativity, talent and taste, the audio network will have achieved its promise.

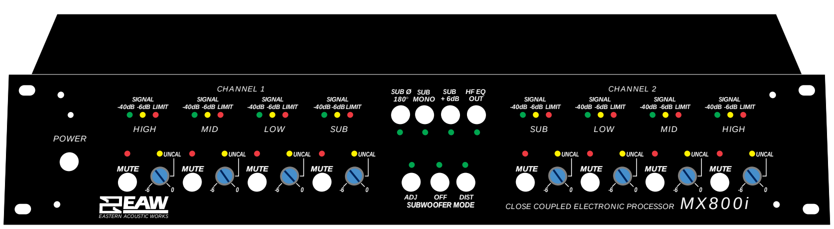
LONE WOLF™

EAW OnLine is EAW's interactive computer bulletin board. All CCEP and CCNP configurations are available for downloading, 24 hours a day.



APPENDIX A: INTERFACING MX SERIES PROCESSORS





EAW MX Series signal processors use industry-standard XLR input and output connectors. N.B. Pin 2 is “hot” at the inputs and outputs. In many live sound applications, MX Series processors will be part of the “processing rack” at the mix position, connected to the power amp racks backstage via a long snake.

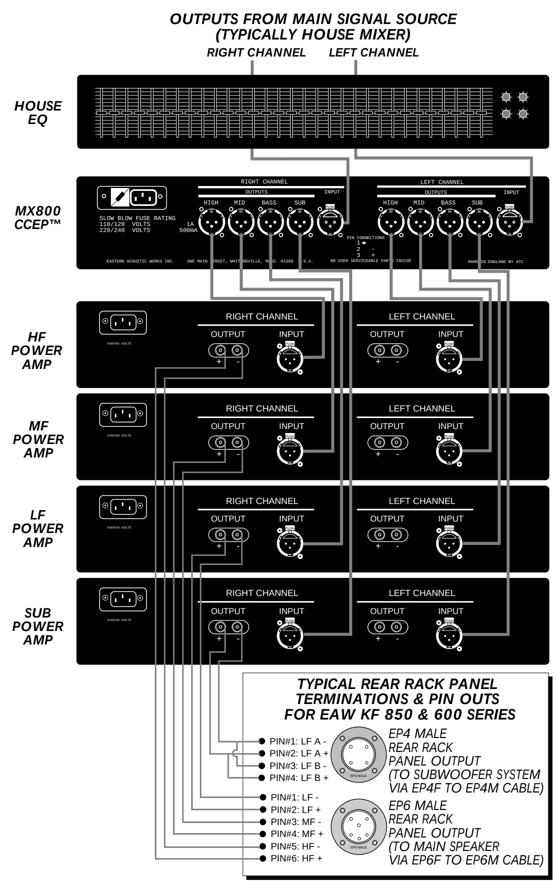
The MX Series output stage has been engineered for the best possible performance in this application. It uses a single-ended unbalanced circuit that is optimized for driving large capacitative loads (long cables) without becoming unstable. It is also designed to drive typical amplifier inputs without any loss in common-mode rejection capability.

The common-mode rejection ratio is usually expressed in dB: It is a measure of the input circuit’s ability to filter out signals that are common to both the left and right channels (such as 60 Hz hum induced by AC lines) from those that are different at both inputs (such as music). A key factor in maintaining CMRR performance is the ratio between the output impedance of the MX Series processor and the input impedance of the amplifier.

The output impedance of the MX Series processors is only 10 Ohms, while a typical amplifier has an input impedance of at least 10,000 Ohms. Using the 1:1000 impedance ratio as an example, we could calculate a “worst case” CMRR of 66 dB. By comparison, tolerance errors caused by building the input stage with 1% resistors can reduce CMRR to 34 dB. Even when .1% resistors are used, the CMRR can fall as low as 54 dB. Of course, if input impedance is higher than 10 kOhms, the effect of the MX Series processor’s output impedance would be even less.

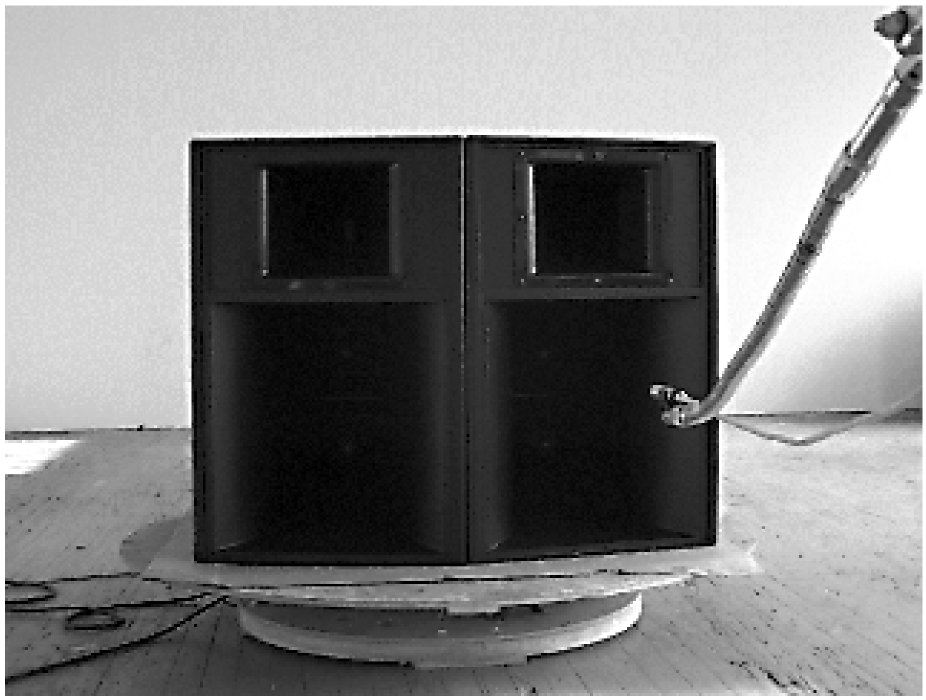
The unbalanced MX Series output stage does not provide protection against the large current s that can flow through ground loops, but an electronically balanced output offers no more protection against these dangers. To protect the unit’s circuitry, we have placed a network of capacitors between the signal ground (Pin 1) and chassis ground. Only RF frequencies can pass through this capacitor network. The rear panel Ground Lift switch disconnects Pin 1 from signal ground, preventing ground loops when the cable shield is connected to Pin 1 at both ends. The only operational disadvantage of the MX Series output stage is that if you intend to drive an unbalanced input stage, you cannot arbitrarily connect either Pin 2 or Pin 3 to Pin 1 (ground): You must ground Pin 3.

This output stage is safe, quiet and reliable under all normal operating conditions. In extreme situations involving huge differences in ground potential between the processing rack and the amp rack (for instance, if each rack is powered by a separate generator with its own floating ground potential) isolation transformers may be required. If the difference in chassis ground potentials is large enough to require an isolation transformer, it would overwhelm a balanced output stage as easily as the MX Series unbalanced output stage. In sum, a balanced output stage would offer no advantages in performance or protection over an unbalanced output stage. It would add nothing to the MX Series processor but cost.

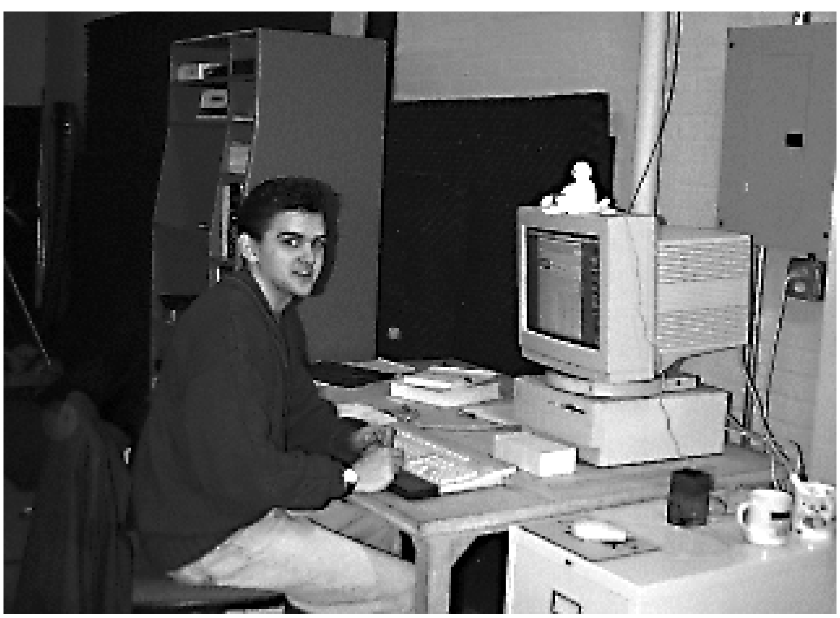


APPENDIX B: KF853 2-CABINET ARRAY TEST DATA

A pair of KF853's on the automated turntable. The performance measurements from this test are included here.

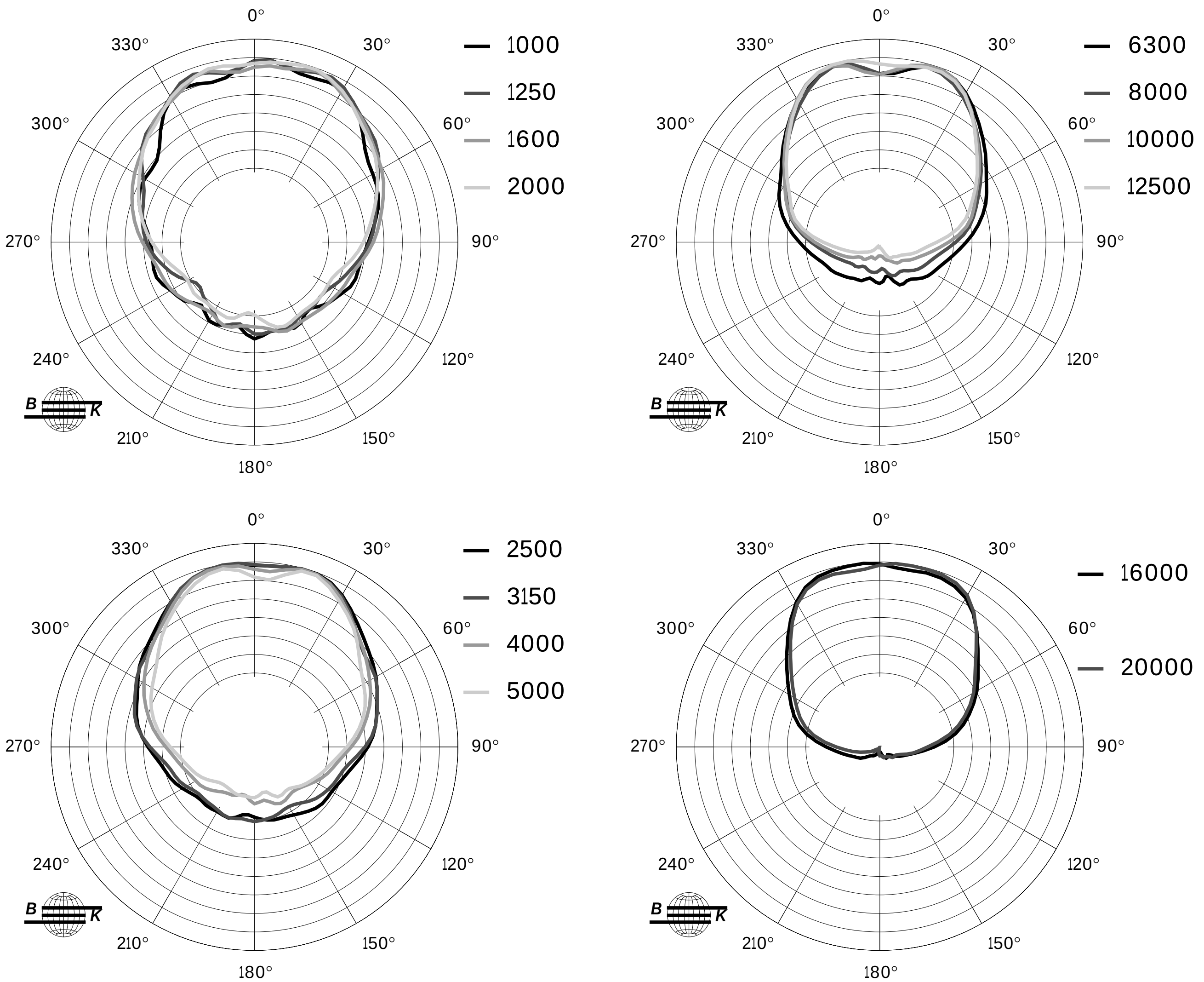


Jeffrey Rocha, EAW Design Engineer.

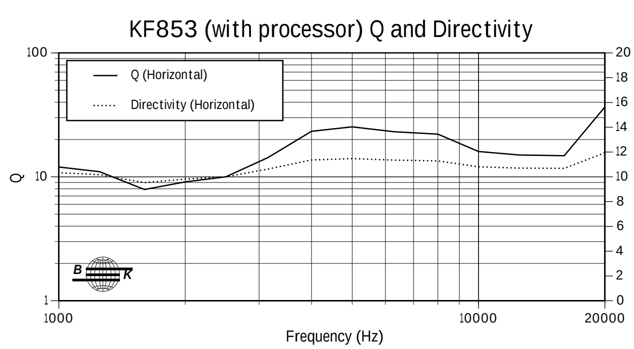


At press time (November 3, 1994) a preliminary series of performance data was measured on a 2-cabinet KF853 array by Jeffrey Rocha, EAW Design Engineer. The array performance of this cabinet is displayed on the following page.

KF853 2-ARRAY 1/3 OCTAVE HORIZONTAL POLARS



KF853 Q & DIRECTIVITY



KF853 BEAMWIDTH