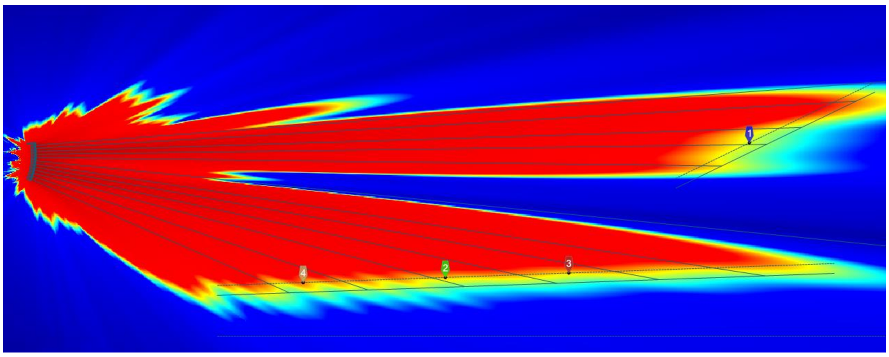
Software-Engineering | Research | Development

AFMG FIRmaker

Put Your Sound Where It Belongs!



AFMG White Paper

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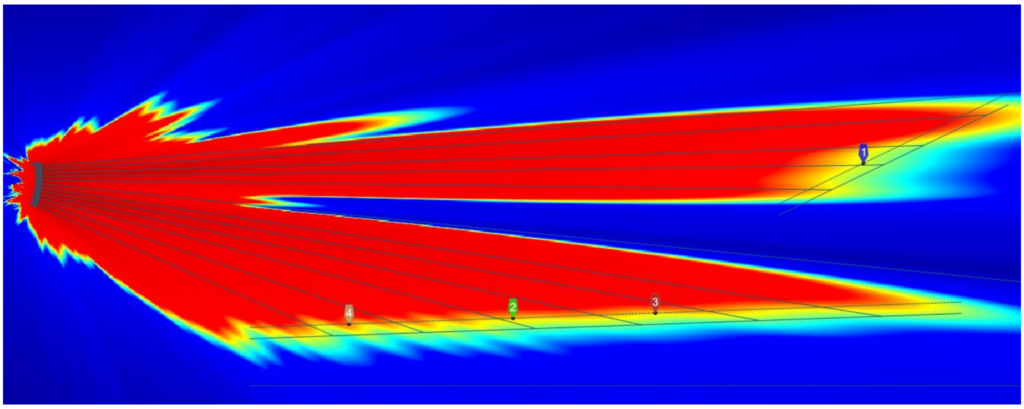
AFMG FIRmaker – Put Your Sound Where It Belongs!

Modern sound systems have not been driven to their full potential until today. AFMG's revolutionary new FIRmaker technology now combines the powers of acoustic modeling with precise system tuning and state-of-the-art DSP control. FIRmaker optimization builds the bridge to next generation sound systems, taking line arrays and steered column speakers to previously unknown performance levels.

1. Overview

Using the venue's geometry and high-resolution loudspeaker modeling data for the sound sources as input, FIRmaker computes FIR filter settings that deliver spectacularly high SPL, spectral consistency, and smooth sound coverage from the first to the last row of the audience.



FIRmaker's patent-pending algorithms can be employed universally. Concert sound applications with large-format portable line arrays will benefit from longer throw distances, unsurpassed even coverage, maximized output levels, and extremely fast setup. Digitally steered columns in acoustically challenging spaces will be boosted in their ability to deliver substantially increased SNR as well as maximum speech intelligibility.

Because it is software-only, AFMG FIRmaker works out of the box. Any DSP or amplifier platform that supports FIR signal processing can be used with FIRmaker in order to implement previously unknown audio quality for each seat. FIRmaker integration is directly supported by major manufacturers such as Lab.gruppen and Powersoft. But FIRmaker can also export FIR data to other commonly used processors and controllers - Four Audio HD2, Biamp Tesira, BSS SoundWeb, Electro-Voice IRIS-Net or Symetrix Solus to name a few.

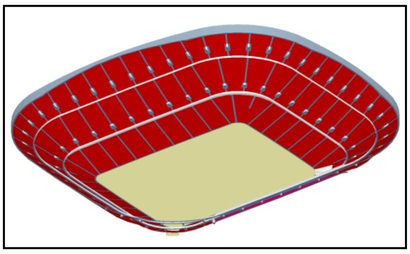
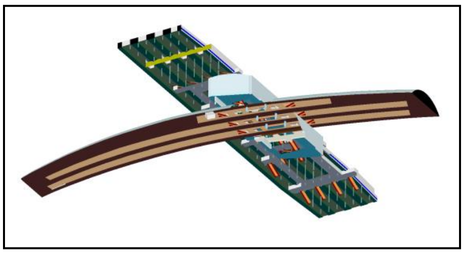
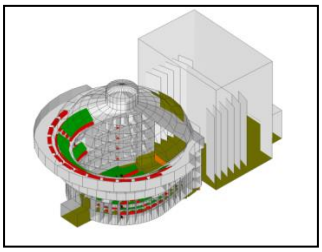
Even though this brandnew technology offers breath-taking performance improvements, AFMG FIRmaker does not necessitate purpose-designed loudspeakers. Both existing and new loudspeaker systems can be tuned with FIRmaker accurately even if using only single FIR channel per cabinet of the array. The latest version of EASE Focus 2, AFMG's award-winning modeling software, is already equipped with the new technology. Support for EASE, SysTune and EASE Evac is to come.

2. Sound System Design using Numerical Optimization

2.1. Motivation

Nowadays sound system design is a complex task, for example, when looking at indoor applications. On the one hand, contemporary architecture prefers large amounts of raw concrete, glass and steel which often results in reverberant spaces. On the other hand, recent developments in life safety regulations worldwide require high SPL and guaranteed speech intelligibility in emergency situations. Similar challenges have to be faced in concert sound and outdoor applications. Here demands for convincing musical quality as well as for a maximally large coverage area must be balanced against setup time and cost efficiency.

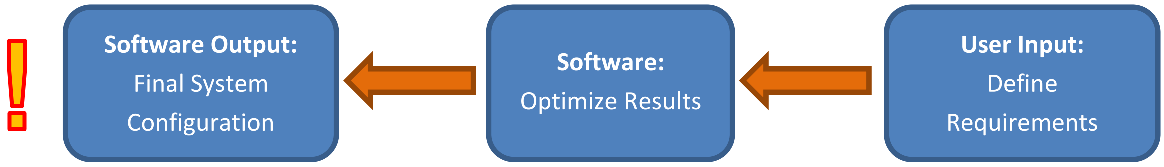
These contradicting requirements represent important aspects of any sound system in practice. For some time, modern line sources have been offering solutions with a higher level of flexibility and performance. However, with the power of this technology there comes also the challenge of correct implementation. Be it touring line arrays or digitally steered columns, the design and configuration of such advanced loudspeaker systems have become impossible without software tools that facilitate tuning as well as modeling functions.

For these reasons, acoustical simulation of sound systems is commonly used in order to predict the performance of a loudspeaker arrangement. Industry standards by AFMG, like EASE or EASE Focus, support tens of thousands of practitioners in setting up systems on an almost daily basis. A user would typically enter the geometry data of the venue and place sound sources in the virtual space. These may then be configured mechanically and electronically within the software, in a way imaging the real world. Computation subsequently delivers a variety of output data including the spatial distribution of pressure levels, received frequency responses, or acoustic figures like signal-to-noise ratio, reverberation time and speech intelligibility.

The regular design procedure usually involves several iterations of setup and configuration until the predicted performance satisfies the demands. Unfortunately, this process is time-consuming and the quality of the final result depends significantly on the experience of the user. – Clearly, it would be desirable for both indoor and outdoor applications to shorten or even avoid this “trial and error” way of designing sound systems.

One way of approaching this problem is to let the computer conduct certain iterations automatically. Given the requirements for the venue and for the loudspeaker system, one can imagine that modeling software calculates feasible configurations by itself as long as the user provides correct input data and defines the optimization priorities appropriately.

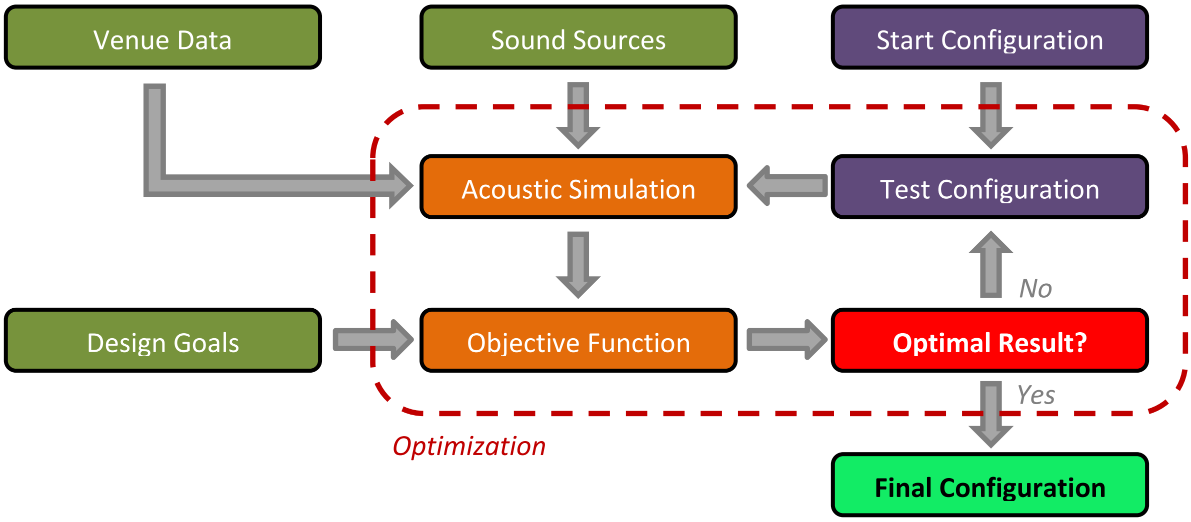


Requirements specified by the user could include the intended coverage area and target SPL values. Next to these purely technical parameters, specifications could also include quality criteria for the desired system performance. These might, for example, pose demands to the degree of smoothness that the system response should offer. Priority could be given to an even broadband SPL throughout the venue or to the linearity of the frequency response at individual listener positions.

Obviously there are various, potentially contradicting requirements for which the user would have to define priorities.

2.2. Numerical Optimization

Numerical optimization offers a feasible combination of achieving satisfying results within a limited period of time while maintaining the influence of the user on the process. *Technically spoken, the optimization algorithm takes input data, such as the geometry of the venue and the properties of the sound sources, and provides output data, that is, an optimal configuration of the loudspeaker system.* As part of the optimization process a test configuration is continually updated, the corresponding sound field is computed and then validated with respect to the goals specified by the user. When the target values are reached the final configuration is found.



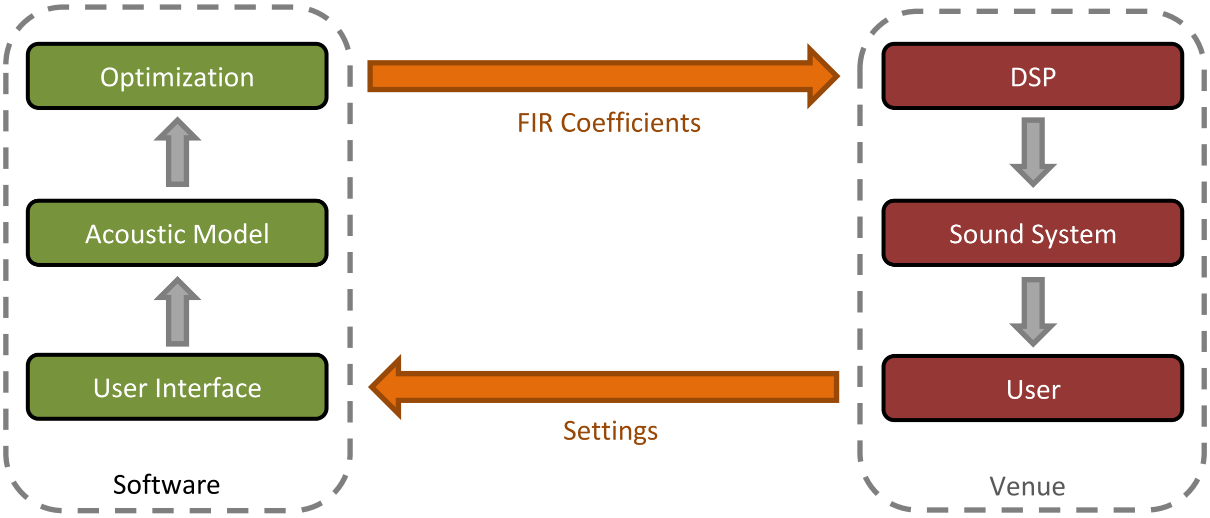
The heart of the optimization algorithm is the so-called objective function which converts all properties of the simulated sound field into a single number that measures the quality of the performance of the sound system. In the FIRmaker algorithm, the configuration that yields the highest value of the objective function is considered the best or optimal configuration.

For the objective function, numerous criteria could be specified to describe the quality of a sound system in a venue. The main ones are:

- Maximum achievable SPL
- Even coverage throughout the venue
- Smooth frequency response at all listening positions
- Avoidance of sound radiation into certain parts of the room, such as reflective surfaces or stage areas
- Target values or target curves for specific acoustic figures

Besides selecting the components of the objective function and their priorities, the user also has to define the set of variable optimization parameters that establish all possible configurations of the sound system. These parameters can be splay angles between line array cabinets, delay and gain settings, location and orientation of the loudspeakers in the room, etc.

For modern line arrays and steerable columns that usually provide DSP power in abundance it seems natural to consider optimizing the filter settings for each loudspeaker. This is where AFMG FIRmaker enters the stage. *FIRmaker represents a highly sophisticated optimization algorithm that is designed for computing optimal FIR coefficients tailored to the venue.* It can be applied to any form of loudspeaker arrangement assuming that high-resolution acoustic modeling data is available for the sound sources.



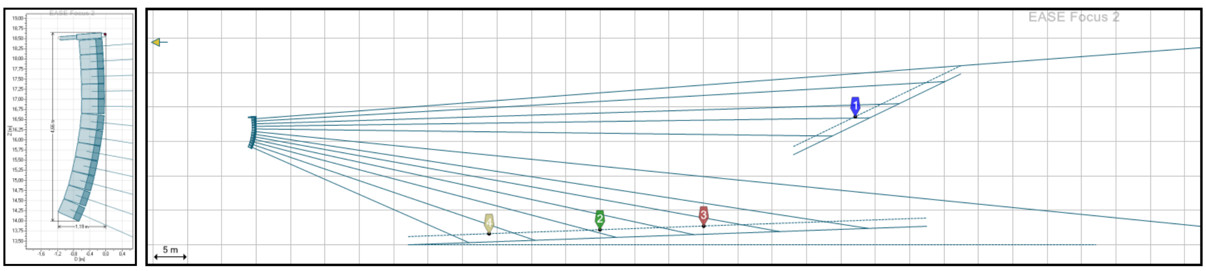
Users of AFMG FIRmaker enter data for the venue and for the loudspeakers in order to create the acoustic model. Based on the design goals specified next in the process and the limitations of the available hardware, FIRmaker then computes optimal FIR filter settings for the entire system. These can be loaded into the DSP platform in order to process audio signals played through the sound system.

3. FIRmaker Case Studies

The following case studies give an impression of how FIRmaker can be used to shape the sound field according to the layout of the venue and the priorities given by the user.

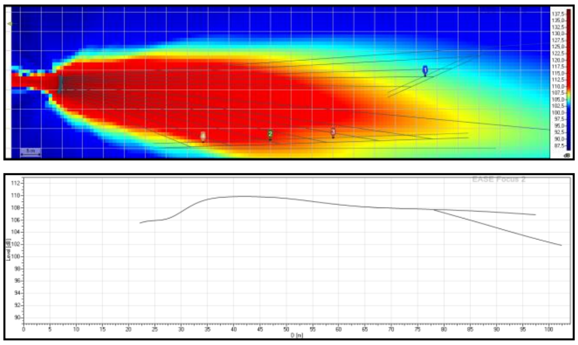
3.1. Flown Line Array

A concert line array consisting of 12 cabinets is used in a flown setup. Each cabinet is subject to a single channel of FIR processing. In this idealized, realistic venue, two audience zones have to be covered: a floor area as well as an elevated area. The throw distance is approximately 100 m. As a starting point, the system was mechanically aimed using an EASE Focus 2 model.

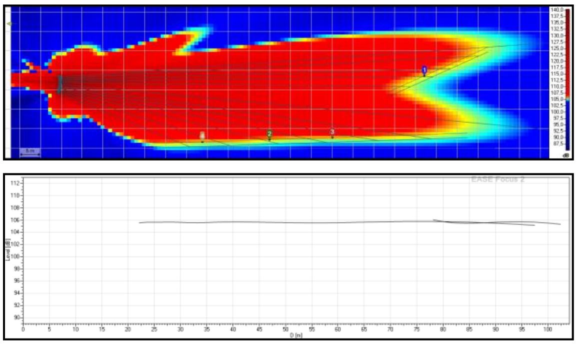


The next figures show prediction results with and without FIR filters optimized by FIRmaker. Vertical mappings as well as SPL vs. distance plots are shown for different octave bands. In all cases the optimization goal was to achieve constant level throughout the venue while keeping the average SPL. Computation times for the project have been in the range of 5 to 10 seconds.

At 500 Hz the optimized directional pattern is widened and at the same time more focused on the audience compared to the conventional configuration. The level is extremely constant as a function of distance from the array.

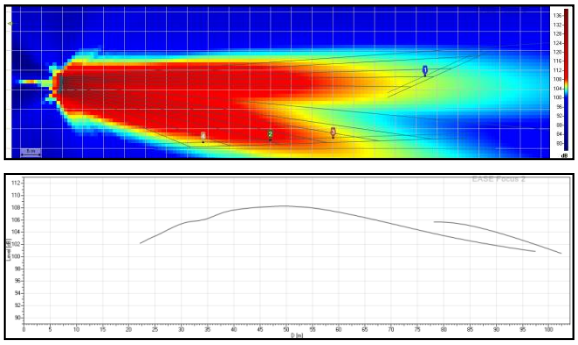


Not optimized: 107.2 dB ± 2.0 dB

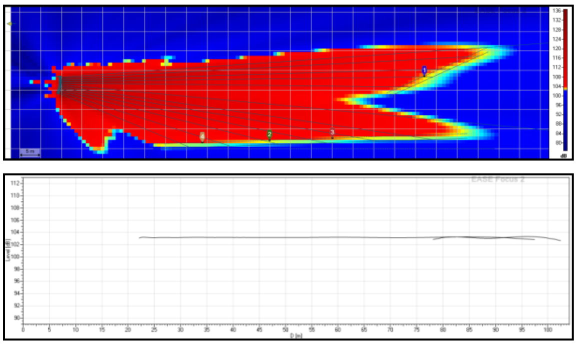


FIRmaker: 105.5 dB ± 0.2 dB

At 1000 Hz the conventional dual-beam structure is modified and enhanced by FIRmaker. The resulting SPL does not change at all going from the first to the last row. Note that a difference of 0.2 dB cannot be recognized by a normal listener.

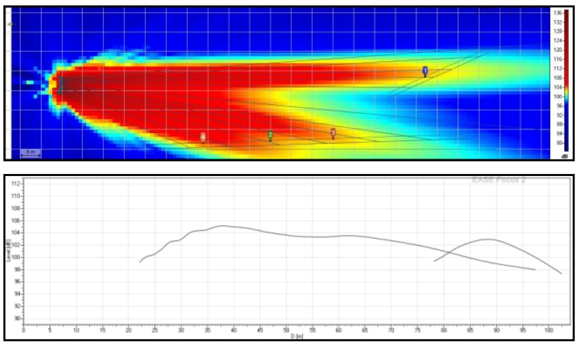


Not optimized: 104.7 dB ± 2.3 dB

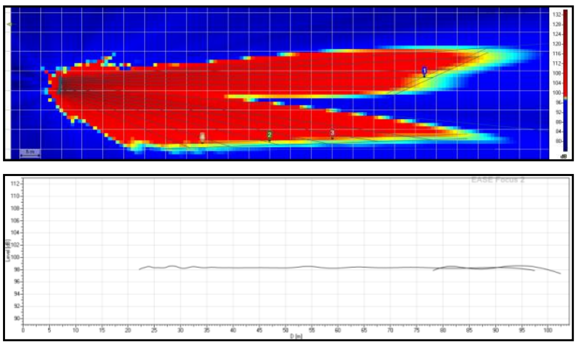


FIRmaker: 103.1 dB ± 0.2 dB

At 2000 Hz, the directional pattern of the conventional setup breaks up into multiple lobes. This results in a fairly uneven SPL distribution. FIRmaker, however, provides a flat spatial response with only a small reduction in average level.

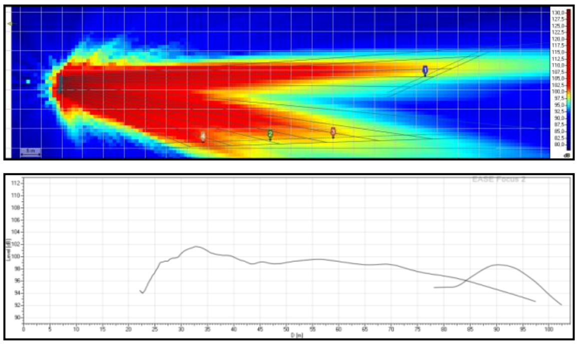


Not optimized: 101.8 dB ± 2.1 dB

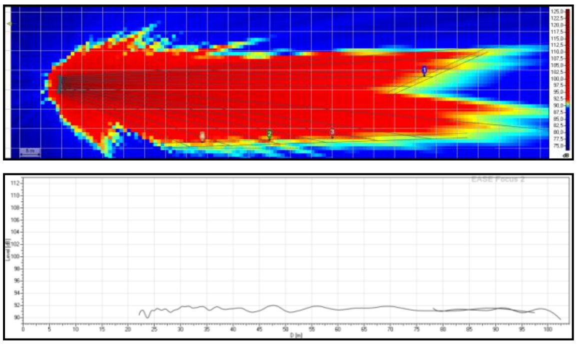


FIRmaker: 98.1 dB ± 0.3 dB

At 4000 Hz, the not-optimized line array starts losing directional control. Optimization with FIRmaker provides a much smoother course of sound pressure level as a function of distance. As a trade-off for the improvement, the overall SPL is reduced by about 6 dB.



Not optimized: 97.6 dB ± 2.4 dB

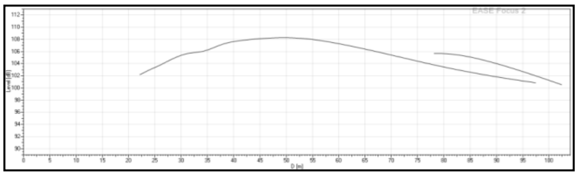


FIRmaker: 91.3 dB ± 0.4 dB

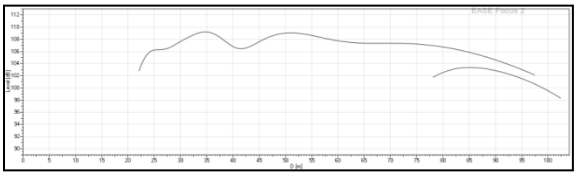
From the previous examples it can be seen clearly that FIRmaker is capable of establishing a very smooth spatial response behavior for the loudspeaker system. The standard deviation across the entire audience zone was reduced from about 2.3 dB to just about 0.3 dB at an average reduction of SPL of only 2-3 dB. It is notable that the system used in this study is already considered a professional solution on the market today.

Since FIRmaker provides user-controllable optimization criteria, a system could also be tuned for maximum SPL or different weightings between smoothness and level.

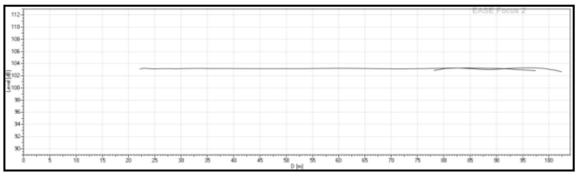
Results for different optimization priorities are shown below, for the octave band of 1000 Hz.



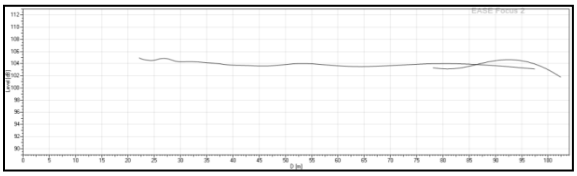
Not optimized: 104.7 dB ± 2.3 dB



High SPL: 105.5 dB ± 2.8 dB



Smooth SPL: 103.1 dB ± 0.2 dB

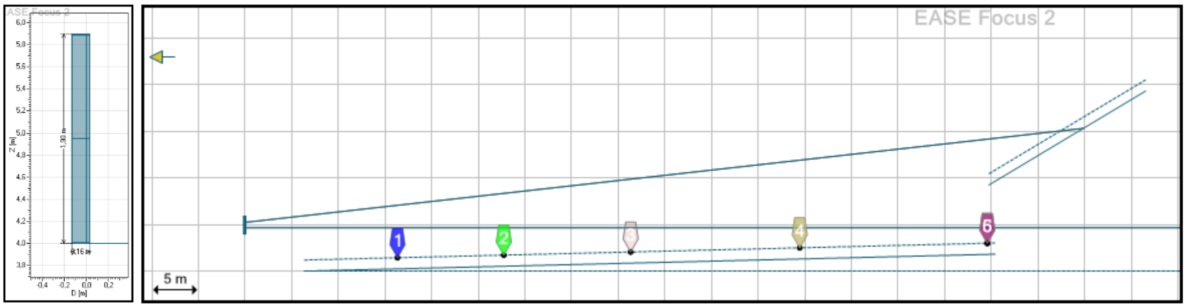


Smooth & High SPL: 103.7 dB ± 0.5 dB

Obviously FIRmaker gives the user all options to find the right compromise for his application and venue.

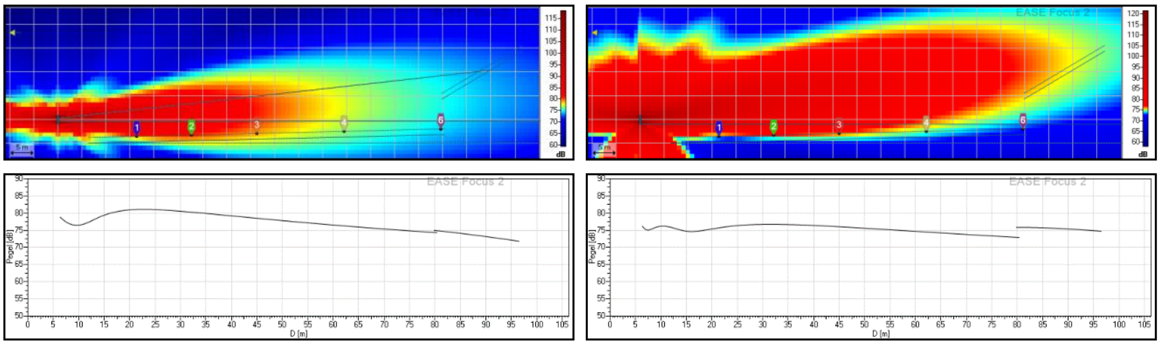
3.2. Digitally Steered Column

This example utilizes a steerable column loudspeaker in the same venue as before. The column loudspeaker is horizontally aimed. It is about 2 m tall and consists of 16 individually controlled and equally spaced transducers. A setup using conventional beam steering filters in a dual-beam configuration is compared against a setup using optimal FIR filters computed by FIRmaker.



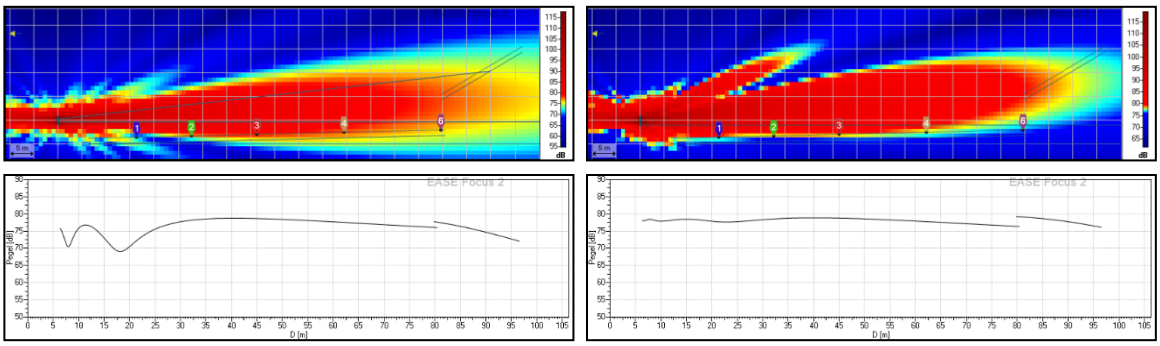
The next figures present simulation results for these two setups. Vertical mappings as well as SPL vs. distance plots are shown for different octave bands. In all cases the optimization goal was to achieve constant level throughout the venue while keeping the average SPL.

At 500 Hz the FIRmaker algorithm directs the main lobe further upward compared to the coventional setup in order to achieve a very smooth level response along the listening positions. This leads to a small overall level reduction of 1.7 dB in this case.



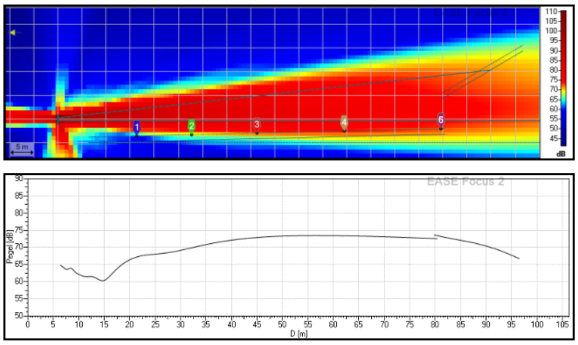
Conventional Steering: 77.0 dB ± 2.6 dB FIRmaker: 75.3 dB ± 1.0 dB

At 1000 Hz the achieved SPL can be increased in average while establishing a much smoother level distribution at the same time. Clearly, FIRmaker minimizes the side-lobe structure that would otherwise negatively affect the front rows.

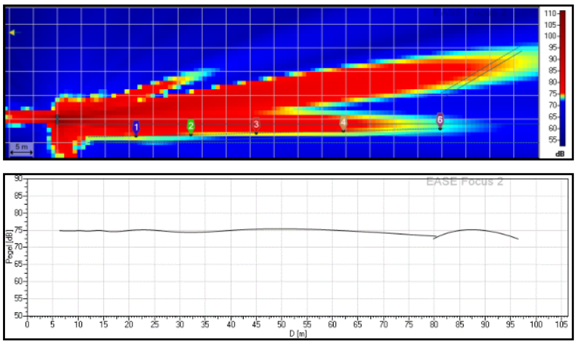


Conventional Steering: 76.3 dB ± 2.4 dB FIRmaker: 78.0 dB ± 0.8 dB

At 2000 Hz it can be recognized that the FIRmaker filters create a full dual-beam configuration where each beam covers one of the audience areas – achieving equal levels across all receiver positions. Conventional beam-steering, even with a fairly narrow beam-width setting, often does not allow for this degree of exact tailoring of the radiation pattern to the venue.

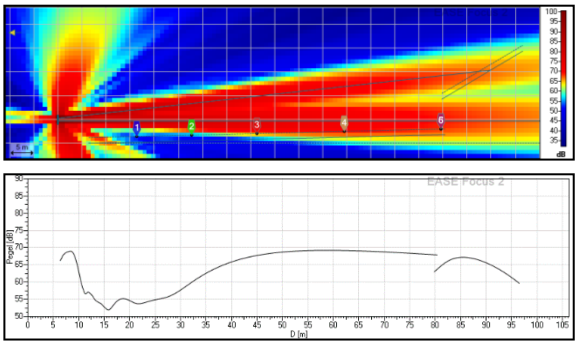


Conventional Steering: 70.3 dB ± 3.8 dB

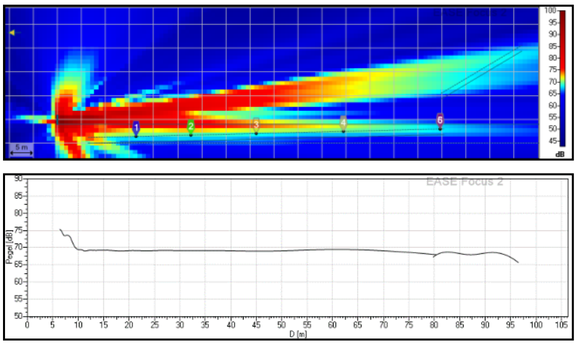


FIRmaker: 74.6 dB ± 0.7 dB

At 4000 Hz the conventional steering approach provides enough resolution to assign a separate beam to each audience zone. However, this goes along with major side lobes in the near field of the system. The FIRmaker solution offers both a substantially increased overall level as well as a very flat spatial response.



Conventional Steering: 64.1 dB ± 5.4 dB



FIRmaker: 68.9 dB ± 1.1 dB

Looking at the full set of octave bands, FIRmaker provides both measurably increased SPL throughout the audience as well as an extremely flat response of level versus distance.

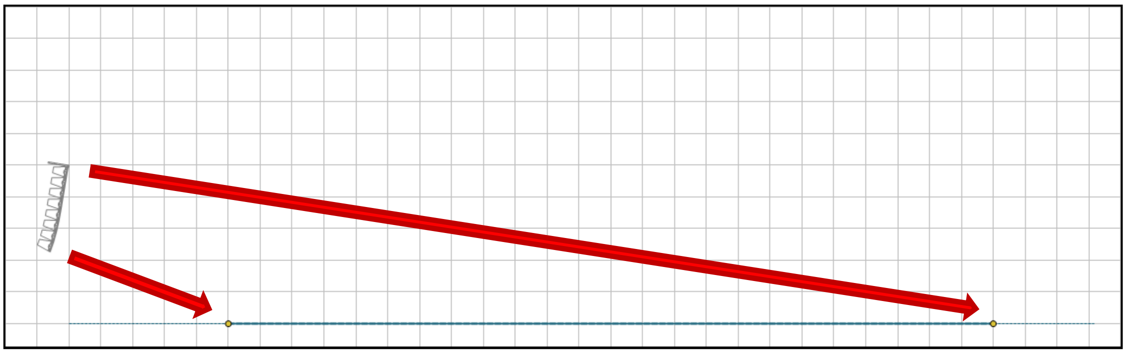
Even though further extensive tuning of the conventional setup might provide slightly better results, it is obvious that FIRmaker delivers a completely different quality regarding the radiated sound field. It is also noteworthy that FIRmaker results are available within seconds without the need for manually adjusting any beams.

4. Validation Measurements

The performance of FIRmaker's algorithms has been confirmed in numerous field measurements, including highly detailed tests in an anechoic chamber, in a large-scale setup as well as in several smaller setups. Two representative results will be discussed in the following sections.

4.1. Flown Line Array in Medium-Size Hall

The test setup consists of a flown line array with eight two-way cabinets. Single-channel FIR processing was applied to each cabinet using an HD2 FIR controller by Four Audio. Ground-plane measurements were taken along the axis of the array. A total of 104 positions over a distance of 26 m were covered, horizontally starting 5 m in front of the array.

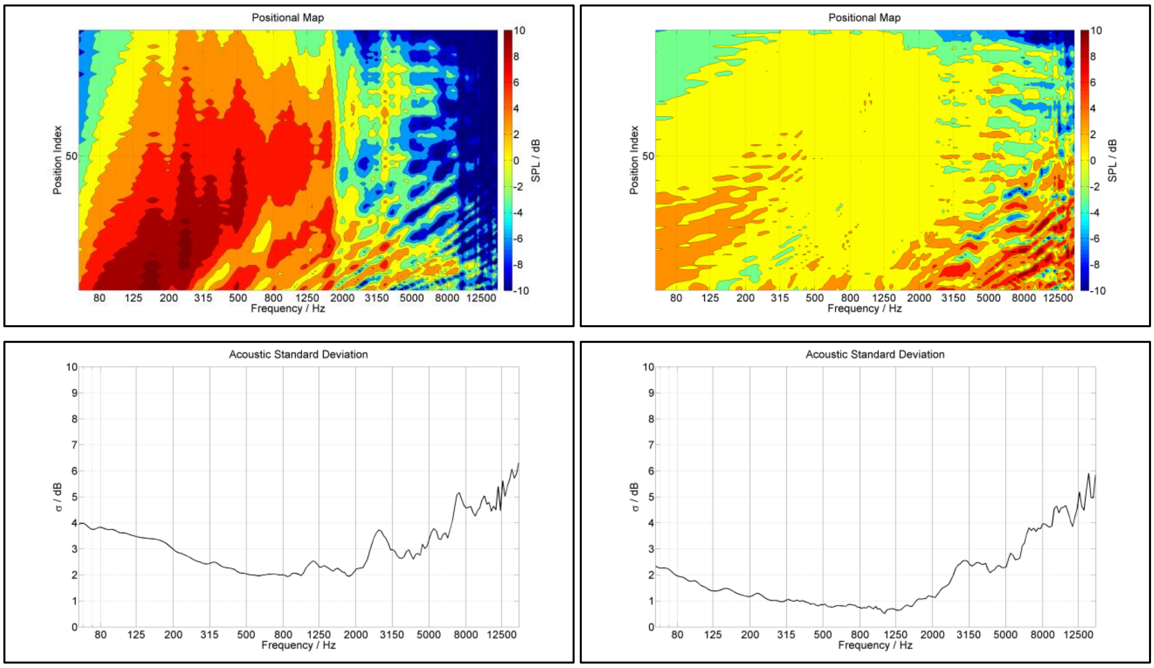


The primary optimization goal was to achieve a smooth frequency response across the hall. The system was optimized for the full audio range of 60 Hz to 16 kHz.

The following plots illustrate the results of applying FIRmaker to a conventional line array setup. The two top graphs show the Positional Map of the arrangement, that is, the color-coded frequency response for each location.

- Within the plot, positions close to the array are found on the bottom while positions on the far end of the hall are at the top of the plot.
- Displayed from left to right horizontally is the frequency response at the corresponding position from 60 Hz at the left to 16 kHz on the right.
- The level at each position and for each frequency is displayed by color.

The color scale is the same for both graphs, yellow equates to ±1 dB variation, green/blue and orange/red indicate greater deviations from the mean. Obviously, the unoptimized setup displays a comparably large amount of variation both with respect to distance from the array as well as with respect to frequency. The setup optimized with FIRmaker shows only very small variation for the largest part of the frequency spectrum and coverage area. Except for the high frequencies in the proximity of the array the overall behavior is extremely well-controlled and homogeneous.



Without Optimization — With FIRmaker Optimization

The second pair of graphs, displayed below the colored Positional Maps, illustrates the corresponding spatial standard deviations. This shows the statistical spread of the frequency responses measured at individual positions. The smaller the spatial standard deviation the more uniform is the sound coverage.

Evidently, in the relevant range of 60 Hz to about 8 kHz, substantial improvements can be recognized. In particular between 100 Hz and 4 kHz where optimization can be applied most effectively for this setup, the standard deviation is approximately halved, from clearly audible 2 to 4 dB down to only 1 to 2 dB. In fact, the variation of the mid-range level between 400 Hz and

2.5 kHz is already within the uncertainty of measurement. Several experienced listeners were not able to recognize these variations during the accompanying listening tests.

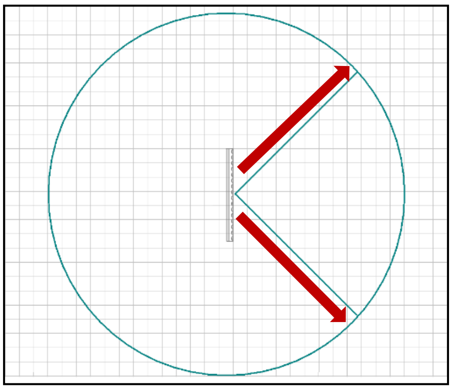
This detailed measurement illustrates that on the one hand FIRmaker results are able to improve the performance of a conventional setup in a dramatic way. On the other hand they also demonstrate that the accuracy of the underlying sound system computer model is extremely high, since the implemented FIR filters have been computed only based on modeling data.

This confirms the approach of optimization by acoustical simulation as a whole.

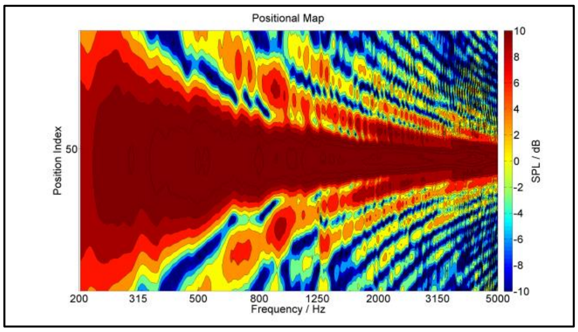
4.2. Digitally Steered Column on Rotator

The second test employs a column loudspeaker that consists of 16 equally spaced, individually controlled transducers over a length of about 2 m. In this case the optimization goal was to change the raw beam of the vertical loudspeaker array in a way that an opening angle of ±45° is covered evenly and frequency-independent.

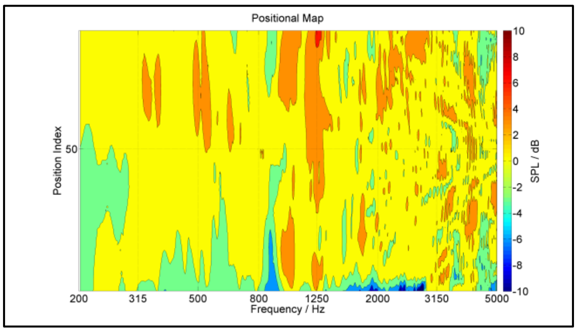
Measurements were taken on the full vertical circle of 360°, in steps of 1°. This measurement series was supported by Anselm Goertz / Four Audio and conducted in the anechoic chamber of the ITA Aachen, Germany.



The measurement results are shown as a Positional Map where the vertical axis covers the angular range of -45° (bottom) to +45° (top). The horizontal axis corresponds to the frequency range of 200 Hz to 5000 Hz in which the optimization was active. The color scale is the same for both graphs, yellow equates to ±1 dB variation, green/blue and orange/red indicate greater deviations from the mean.

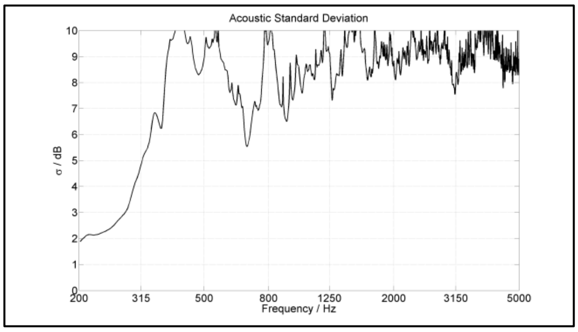


Without Steering

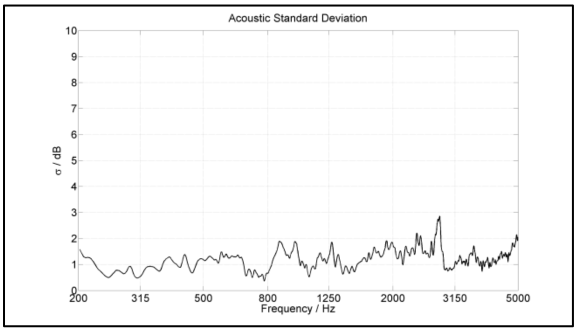


With FIRmaker Optimization

The only softly structured, areal appearance of the optimized plot immediately demonstrates that FIRmaker optimization allows widening the beam accurately and without any side effects, thus achieving high spectral uniformity at the same time.



Without Steering



With FIRmaker Optimization

The second pair of plots shows the standard deviation over the selected opening angle of ±45°. Obviously, FIRmaker establishes a high spatial consistency. The variation is within 1 to 2 dB for almost the complete angular and frequency ranges.

Investigation of the full 360° vertical directivity pattern reveals that beyond the angle of ±45° the radiation level is greatly reduced and side lobes are largely suppressed especially below the aliasing frequency of the array. The main lobe at the backside of the array is slightly widened as one has to expect due to the symmetry of the setup.

5. Implementing FIRmaker in Sound Systems

Utilizing FIRmaker optimized sound system solutions and offering these benefits to customers and users requires a few crucial prerequisites from a loudspeaker manufacturer:

- High-resolution EASE GLL modeling data for the loudspeakers in use.
- A FIR-enabled processor, amplifier or controller with a separate FIR filter channel per cabinet or transducer.
- A FIRmaker manufacturer license.

Initially, FIRmaker will be available to EASE Focus 2 licensees only.

5.1. Supported DSP Platforms for FIR Processing

Based on input data describing venue and sound sources, AFMG FIRmaker computes optimal filter transfer functions that can be automatically converted to FIR filters. It is therefore essential for implementing FIRmaker to have FIR processing capabilities available in the signal chain of the sound system.

FIRmaker optimization can be applied on a variety of levels, e.g. to single transducers in a column loudspeaker or to individual cabinets in a touring line array. With a trade-off to the accuracy of results even groups of cabinets, such as pairs in a large-format line array, could be combined, saving amplifiers and FIR filter channels. For each of the desired output channels a separate FIR-processing channel is needed.

FIR filters can be implemented in a standalone FIR-processing unit, e.g. the HD2 by Four Audio, as part of the signal processing performed by the loudspeaker manufacturer's system controller, or they can be integrated into the DSP unit of the amplifier.

The achievable optimization results depend on the tap count offered by the DSPs in use. Field tests with AFMG FIRmaker as well as simulation models indicate that a FIR size of 256 coefficients or more is necessary in order to reproduce the target filter transfer function to a satisfying degree.

Currently, AFMG FIRmaker development is directly supported by the following manufacturers of high-end audio products:

- Four Audio: HD2
- Powersoft: K series amplifiers, DSP4 boards
- Lab.gruppen: PLM series

AFMG has validated and confirmed interface compatibility with the above platforms.

Beyond that, FIRmaker calculated filters can also be exported in a variety of formats including standard text files (CSV) and common audio files (WAV). These formats can be loaded into a large range of DSP-based units such as:

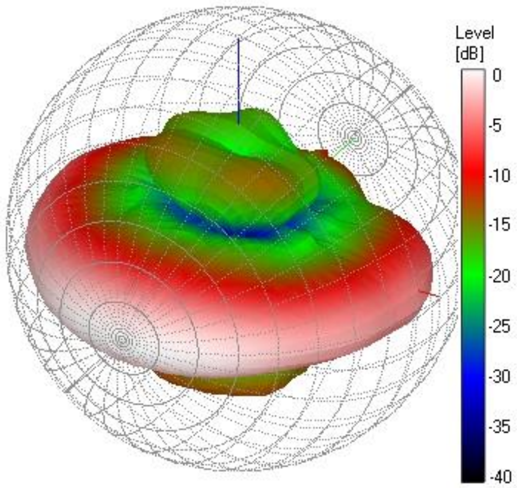
- Biamp Tesira
- BSS Soundweb
- Electro-Voice IRIS-Net
- Symetrix Solus

Further DSP and amplifier platforms are being integrated. Manufacturers interested in integration options are welcome to contact AFMG directly.

5.2. High-Resolution Loudspeaker Modeling Data

AFMG FIRmaker derives its revolutionary optimization results from the highly accurate EASE acoustic modeling engine. It combines the experience and know-how of more than 30 years of research and development with the precision of the award-winning GLL loudspeaker data format.

To achieve quality results with FIRmaker it is imperative that for all loudspeakers, transducers, and other sound sources high-resolution modeling data is available. These data must conform to AFMG's published recommendations for data resolution and measurement conditions.



5.3. Licensing AFMG FIRmaker

Launched at ProLight+Sound 2013, FIRmaker will at first be available as an add-on module for the EASE Focus 2 modeling program. The licensing system is simply described:

- To unlock FIRmaker optimization of loudspeaker systems within EASE Focus 2 a FIRmaker *manufacturer license* has to be acquired by the manufacturer of the system. One such license will be valid for all loudspeakers of the same brand.
- Configuring systems, that is, generating FIR filters in the field or updating existing installations by third parties requires a separate FIRmaker *generator license* for each company performing filter generation and for the loudspeaker brand to be optimized.
- Designing and modeling systems without creating FIR output data requires authorized loudspeaker files only and will remain to be free of charge in EASE Focus 2 for end users.
- The FIRmaker module will also be integrated in upcoming versions of AFMG software, such as EASE, SysTune or EASE Evac.

At this point, AFMG will provide generator licenses only through licensed loudspeaker manufacturers in order to ensure a high-quality system approach and professional support for the new technology.

6. Outlook

AFMG FIRmaker takes contemporary sound systems to an unseen level of performance and audio quality. It builds the bridge to the next generation of loudspeaker systems which will be powered by FIR filters tailored to the venue and based on high-resolution acoustic simulation.

It is unique to AFMG FIRmaker that optimization can be applied to new as well as existing systems – out of the box. FIRmaker does not require purpose-designed line arrays in order to achieve a significant boost in SPL and sound coverage.

Only AFMG FIRmaker offers the weather-proven, award-winning EASE modeling engine implemented in numerous, recognized software packages and employed by tens of thousands of users in their daily work.

Because of AFMG's key position in the pro-audio industry and its vast network of customers, partners as well as loudspeaker and DSP companies, AFMG is the natural partner for implementing sound system optimization technology.

Together with innovation leaders such as Powersoft, Lab.gruppen, or Four Audio, AFMG can rapidly bring the full power of FIRmaker to the world of professional audio. Designers, technicians, and engineers will be overwhelmed by the new possibilities. Forward-thinking loudspeaker companies like beta tester K-array already recognized FIRmaker as the *game-changer* that will soon sort the wheat from the chaff.

Join the next generation! – Put your sound where it belongs!

Please contact us for more information.

7. Contact Data

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