AFMG
AHNERT FEISTEL MEDIA GROUP

Put your sound where it belongs: Numerical optimization of sound systems

Stefan Feistel, Bruce C. Olson, Ana M. Jaramillo
AFMG Technologies GmbH

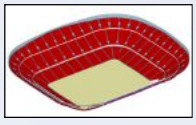
166th ASA, San Francisco, 2013

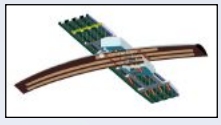
AFMG
AHNERT FEISTEL MEDIA GROUP

Sound System Design

Typical Goals:
- Complete Coverage
- High Level and Signal/Noise-Ratio
- Smooth Frequency Response
- Efficient Design
- Dynamic Range and Latency

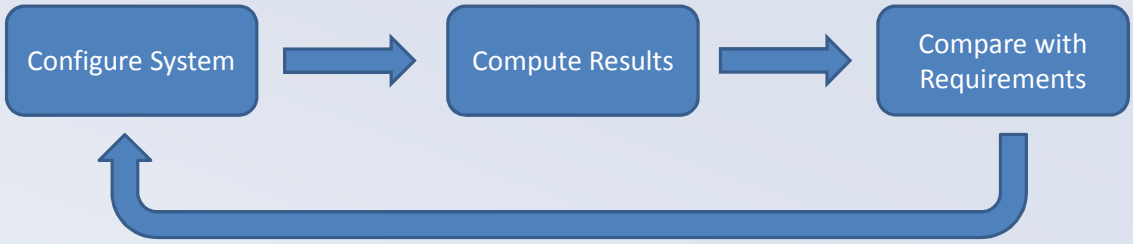
Acoustic Modeling:
- EASE, EASE Focus by AFMG





Sophisticated solutions offered by
- Portable Line Arrays
- Digitally Steered Columns

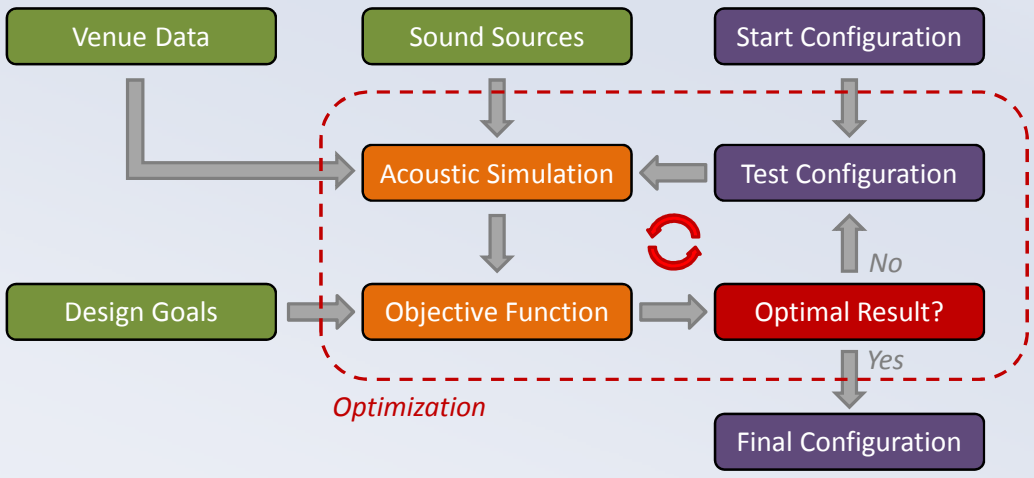
Typical Design Process



Concept of Numerical Optimization:

- Replace „trial and error" approach by automated runs
- Use design goals and user requirements to define targets, e.g. areas to be covered, smoothness, SPL, directionality
- Parameters to be varied: splay angles, delay, gain, filters

Numerical Optimization



AFMG
AHNERT FEISTEL MEDIA GROUP

Numerical Optimization

Optimization of FIR filters:

- FIR filters per array element - flexible and powerful
- But: parameter space with many dimensions and local minima
- Impossible to test all configurations („brute force")
- Different optimization algorithms possible: genetic, swarm, gradient, region contraction, …
- Goals: stability, convergence, performance => On-going research

AFMG
AHNERT FEISTEL MEDIA GROUP

Case Studies

Selection:

- Compact line array with stage exclusion (prediction)
- Line array in medium-size Hall (measurement)
- Line array in sports arena (measurement)

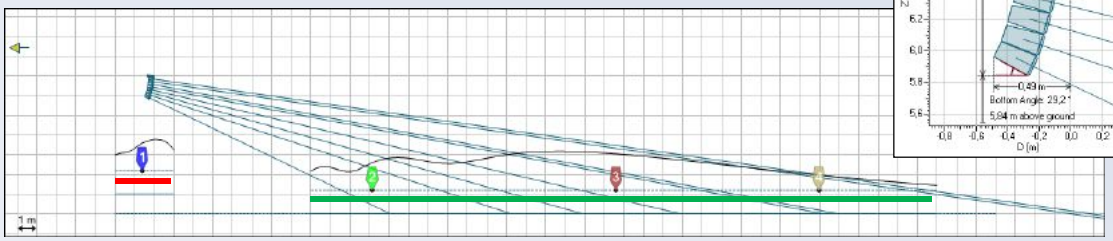
Optimized with AFMG FIRmaker

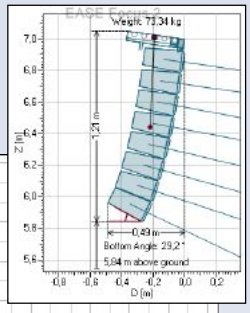
AFMG
AHNERT FEISTEL MEDIA GROUP

Compact Line Array

Setup:

- 8 Line Array Cabinets, 1x FIR Channel per Cabinet
- Main Area: Throw Distance 40 m
- Mechanically Aimed, EASE Focus Model
- Stage Area below Array to be Avoided



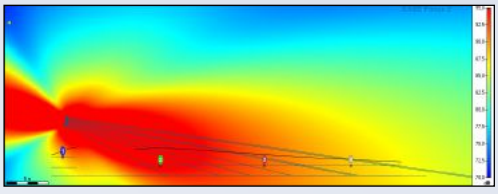


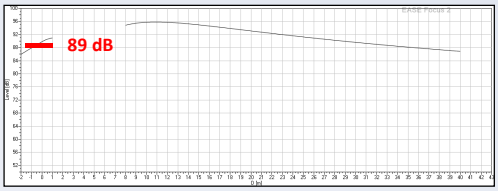
AFMG
AHNERT FEISTEL MEDIA GROUP

500 Hz Octave

No Optimization

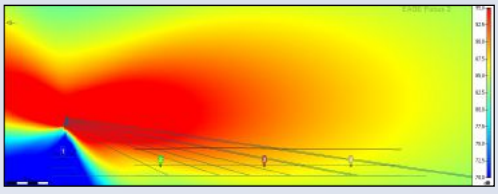
91.6 dB ± 2.9 dB

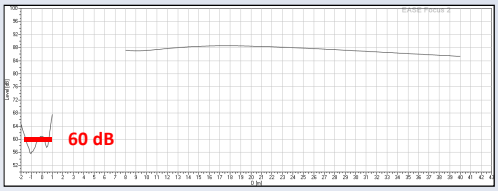




FIRmaker Optimization

87.3 dB ± 0.9 dB



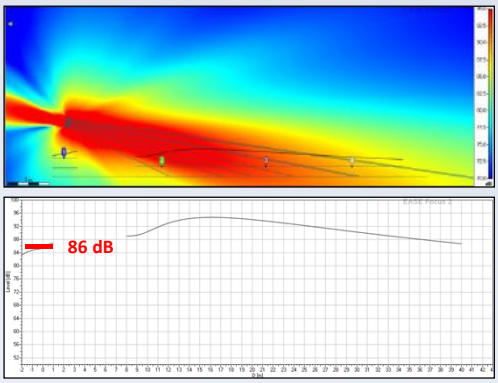


AFMG
AHNERT FEISTEL MEDIA GROUP

1000 Hz Octave

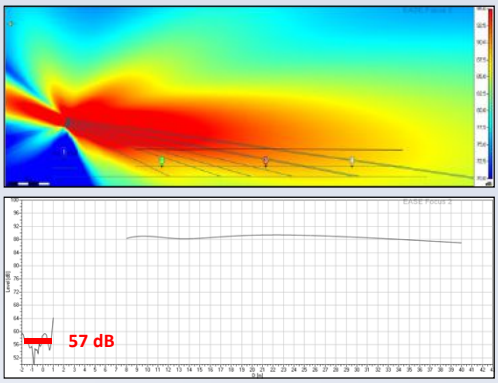
No Optimization

91.2 dB ± 2.5 dB



FIRmaker Optimization

88.4 dB ± 0.7 dB

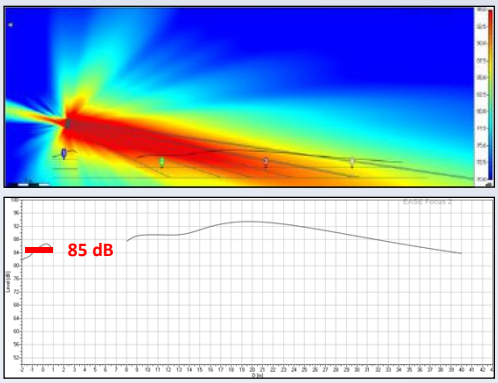


AFMG
AHNERT FEISTEL MEDIA GROUP

2000 Hz Octave

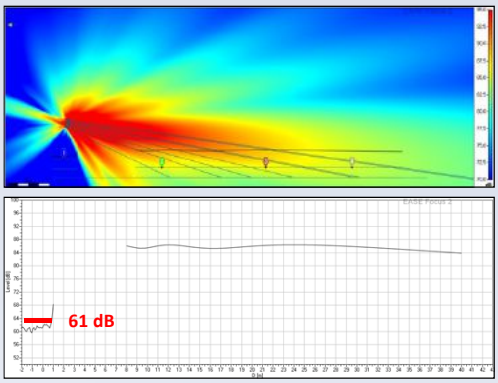
No Optimization

89.5 dB ± 2.8 dB



FIRmaker Optimization

85.4 dB ± 0.7 dB

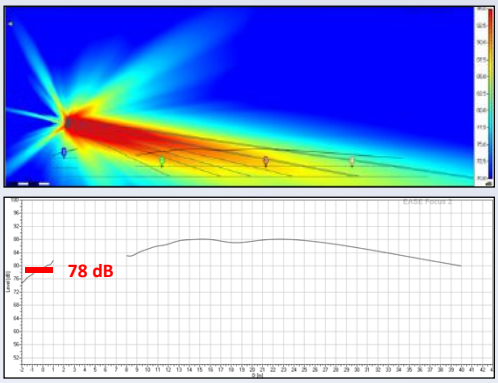


AFMG
AHNERT FEISTEL MEDIA GROUP

4000 Hz Octave

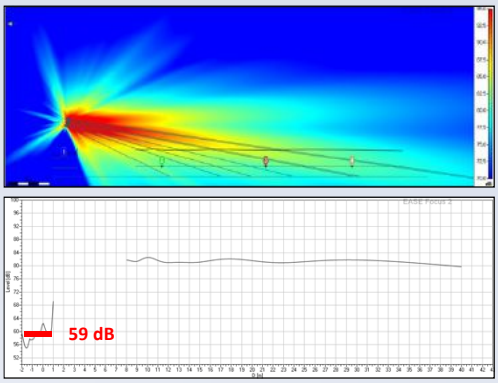
No Optimization

85.5 dB ± 2.4 dB



FIRmaker Optimization

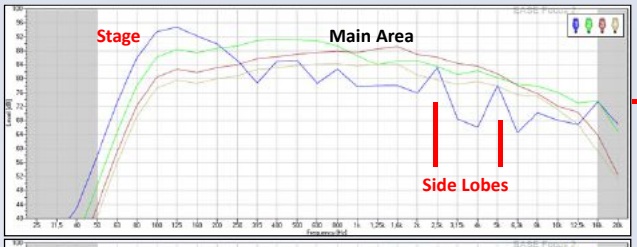
81.2 dB ± 0.3 dB



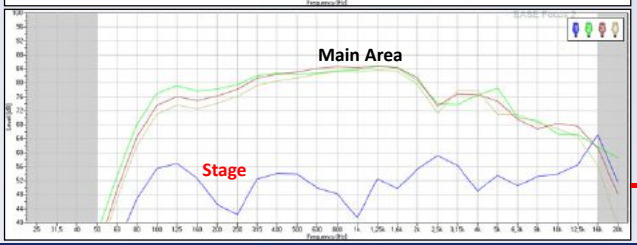
AFMG
AHNERT FEISTEL MEDIA GROUP

Frequency Response

No Optimization

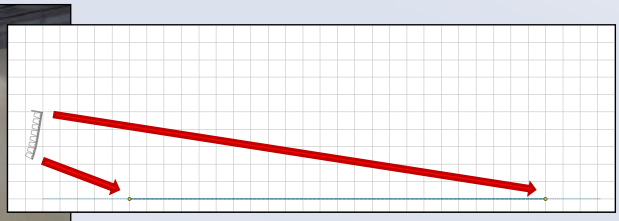


FIRmaker Optimization



AFMG
AHNERT FEISTEL MEDIA GROUP

Line Array in Medium Size Hall



Optimization:

- Smooth frequency response across the hall
- Full bandwidth 60 Hz to 16 kHz
- 1x FIR filter per Cabinet

104 measurement positions over 26 m

AFMG
AHNERT FEISTEL MEDIA GROUP

Numerical optimization of sound systems
166th ASA, San Francisco, 2013

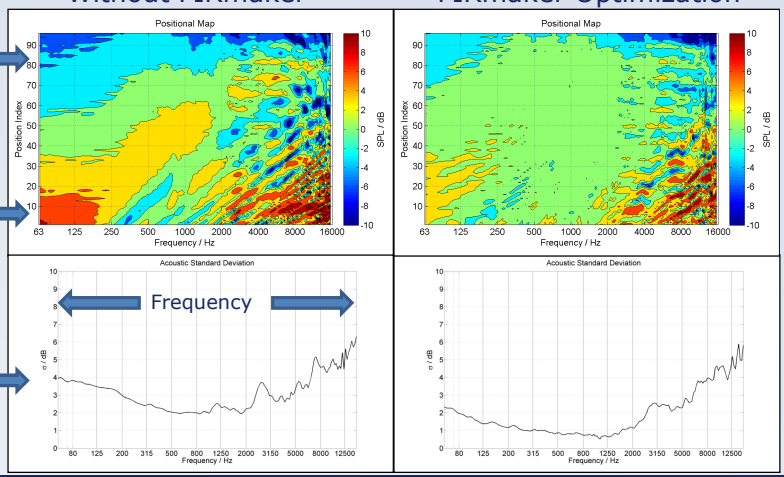
Line Array in Medium Size Hall

Without FIRmaker | FIRmaker Optimization

Back of Hall

Front of Hall

Standard Deviation across Hall



Much smoother coverage

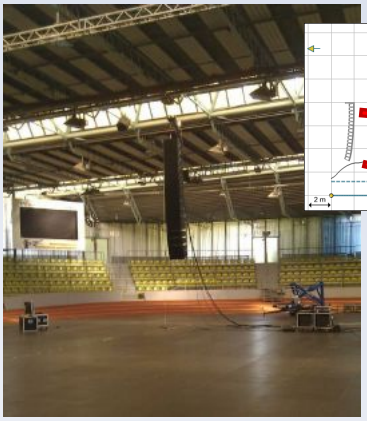
Consistent response over 25 m

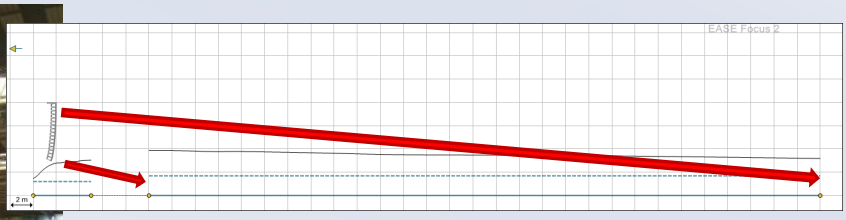
Lower standard deviation

Effective up to 8 kHz

AFMG
AHNERT FEISTEL MEDIA GROUP

Line Array in Sports Arena





Optimization:

- Smooth frequency response across the hall
- Stage area to be avoided
- Even intelligibility across hall
- Full bandwidth 60 Hz to 16 kHz
- 1x FIR per cabinet

*Measurements supported by d&b audiotechnik

140 measurement positions over 70 m

AFMG
AHNERT FEISTEL MEDIA GROUP

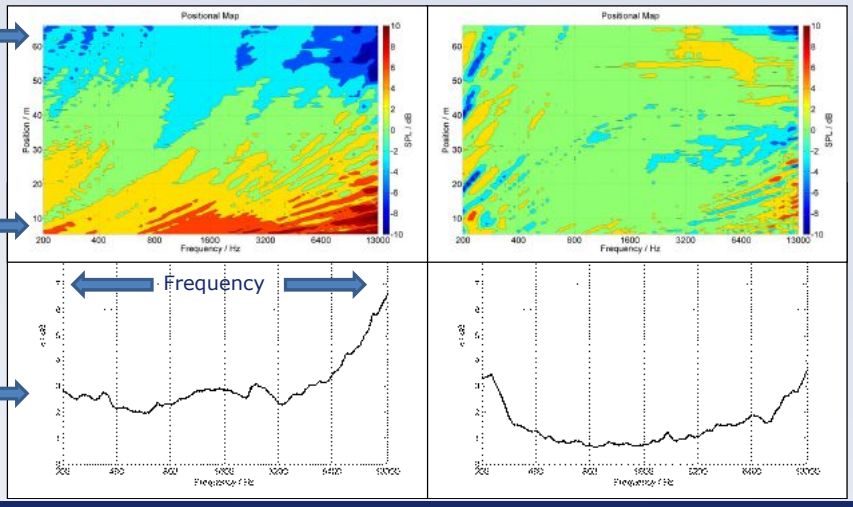
Line Array in Sports Arena

Without FIRmaker | FIRmaker Optimization

Back of Hall

Front of Hall

Standard Deviation across Hall



Smooth coverage

Consistent response over 65 m

Lower standard deviation

Effective up to 13 kHz

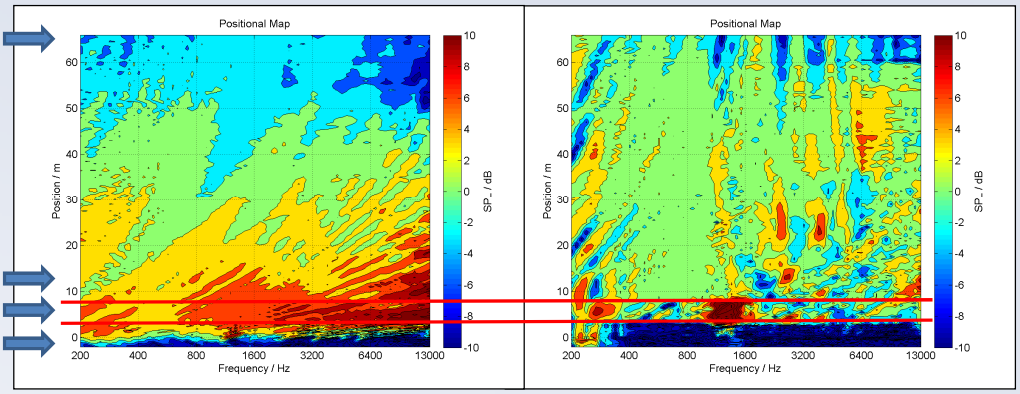
AFMG
AHNERT FEISTEL MEDIA GROUP

Numerical optimization of sound systems
166th ASA, San Francisco, 2013

Line Array in Sports Arena

SPL Reduction on Stage Area

Back Rows
Front Rows
Empty Area
Stage Area



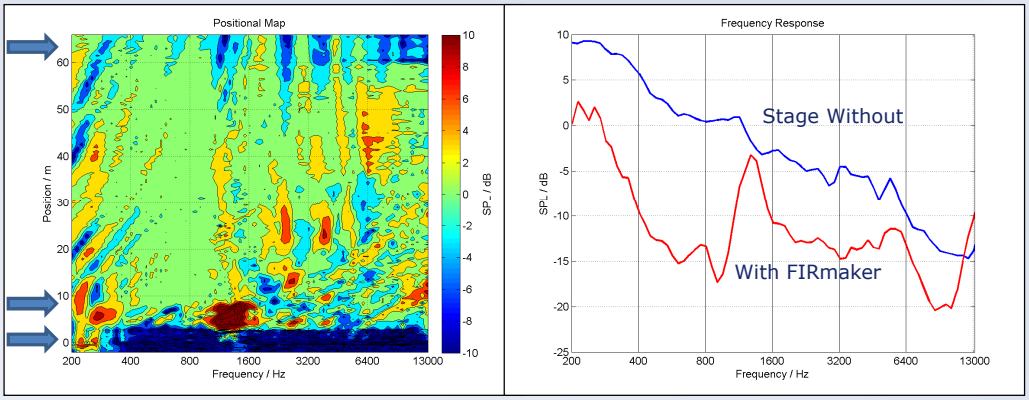
AFMG
AHNERT FEISTEL MEDIA GROUP

Numerical optimization of sound systems
166th ASA, San Francisco, 2013

Line Array in Sports Arena

Avoiding the Stage

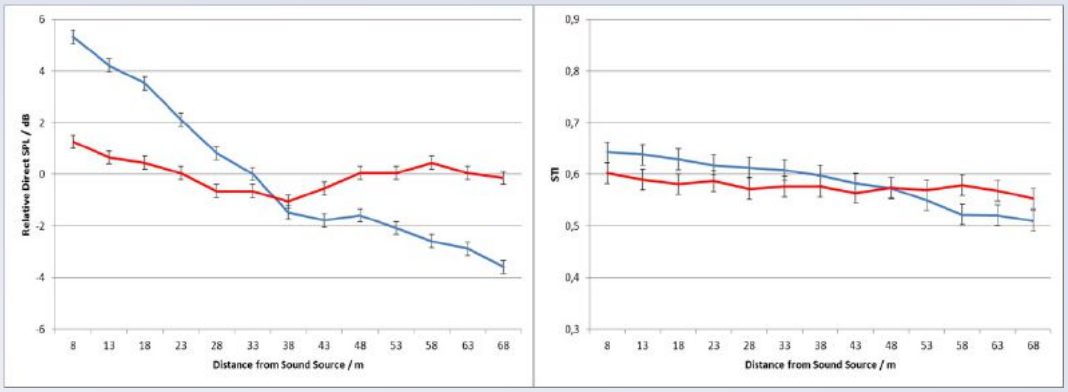
Back of Hall
Front of Hall
Stage Area



AFMG
AHNERT FEISTEL MEDIA GROUP

Line Array in Sports Arena

Improvement in SPL and STI distributions

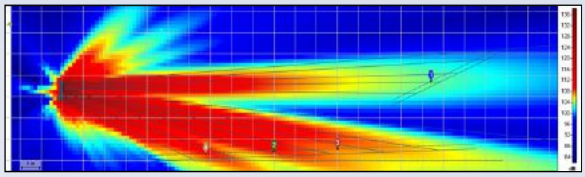


AFMG
AHNERT FEISTEL MEDIA GROUP

Technical Requirements

Requirements:

- FIR-capable controller or processor, FIR size > 250 taps (at 48 kHz)
- High-resolution GLL modeling data for loudspeaker cabinets / transducers
- DSP channels:
  - Per cabinet
  - Per transducer
  - Per group of cabinets, e.g. pairs



Limitations:

- HF: Spacing of controlled sources, mechanical accuracy, coherence
- LF: Source length, modeling accuracy (diffraction effects)
- FIR: Dynamic range, tap count, latency

Conclusions

Conclusions:

- Numerical optimization for modern sound systems, especially loudspeaker arrays (licensed by manufacturers)
  - Based on high-resolution acoustic simulation and efficient optimization algorithm
  - Critical: definition of objective function
- Offers substantially increased coverage control as well as SPL and STI improvements
- Already effective using 1 FIR channel per cabinet (mechanical arrays)
- Applicable to existing array designs and even already installed systems
- Limitations are given by array size, DSP hardware and modeling accuracy

AFMG
AHNERT FEISTEL MEDIA GROUP

Put your sound where it belongs: Numerical optimization of sound systems

Stefan Feistel, Bruce C. Olson, Ana M. Jaramillo
AFMG Technologies GmbH

166th ASA, San Francisco, 2013