Measurements and Simulation Data for Loudspeaker Systems

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TRIUS
Audiocenter Day
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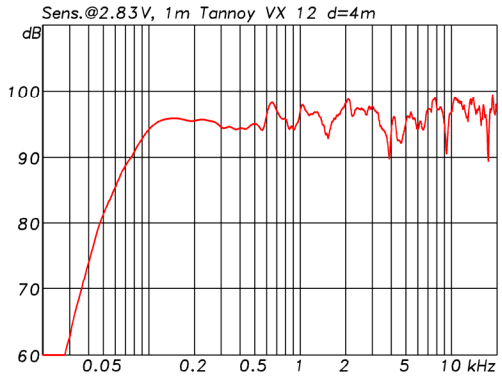
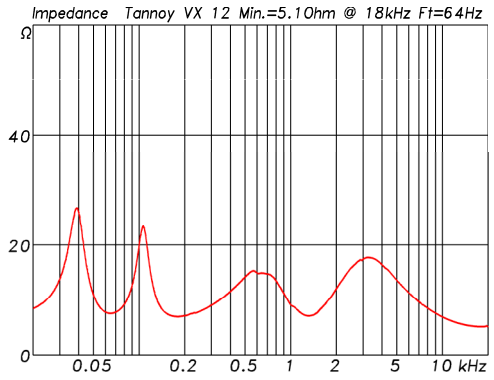
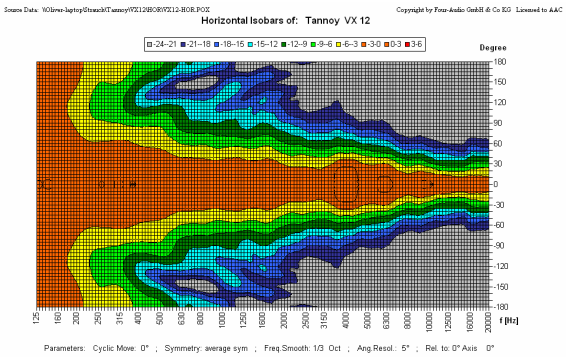
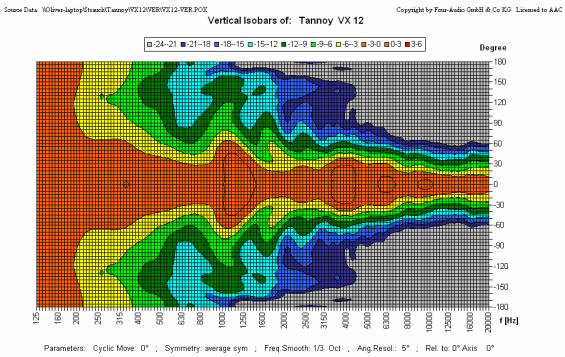
Typical Speaker Data



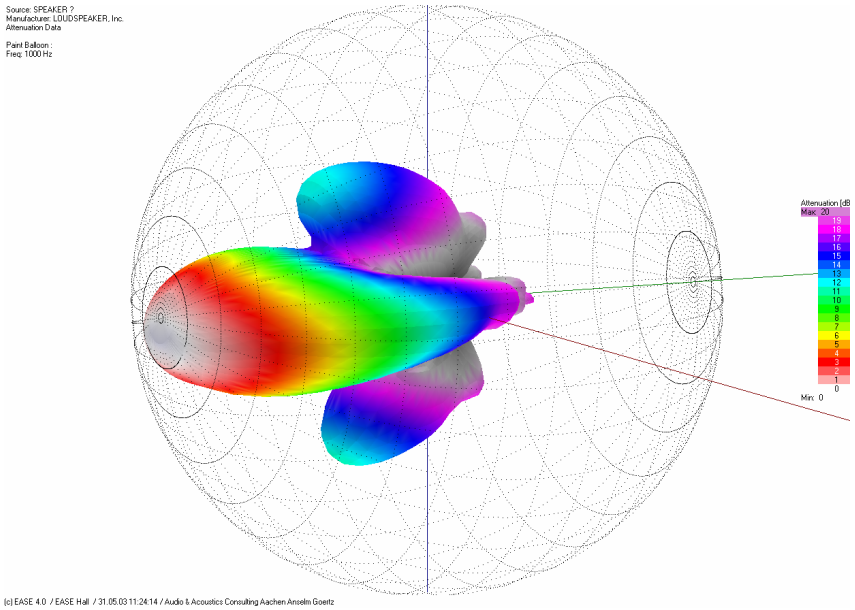






Balloon Data for Simulations

- The typical horizontal and vertical directivity measurements are not sufficient
- simulations need the complete behavior of the speaker in all directions
- Balloon measurements or interpolations from the hor. and ver. polar data are required (interpolation should be used only in exceptional cases)



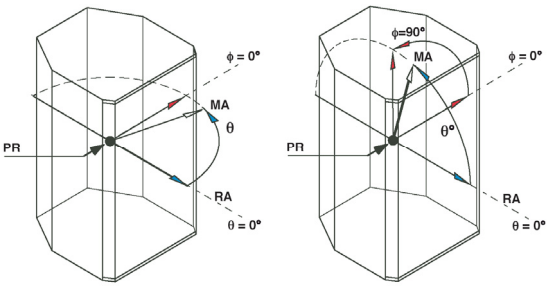
Current Balloon Data Formats

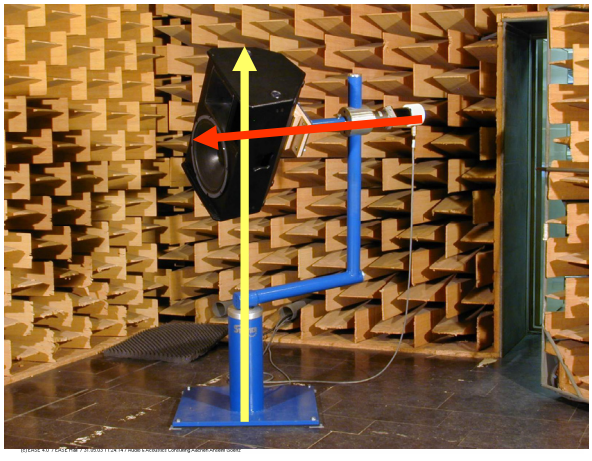
Winkelauflösung in °	Anzahl Messpunkte	Frequenzauflösung in Oct.	Messdauer in h *1	Nahfeld-Fernfeld-Betrachtung	Phasendaten	Formate
10	614	1/1	1	Fernfeld	Nein	EASE 2.1 CATT Bose Modeler CADP2
5	2522	1/1	1-3	Fernfeld	Nein	Ulysses 2.60
5	2522	1/3	1-3	Fernfeld	Nein	EASE 3.0 CLF
5	**2522**	**1/3**	**1-3**	**Fernfeld**	**Ja**	**EASE 4.0**
beliebig	-	beliebig	1-48	Nahfeld-Fernfeld	Ja	EASE bzw. CATT DLL
beliebig	**-**	**beliebig**	**1-48**	**Nahfeld-Fernfeld**	**Ja**	**Speaker LAB GLL**

*1 Messdauer je nach Symmetrie der Box ohne Interpolation

Balloon Measurements

- Definition with balloon data
  - Amplitude- and Phasendata
  - For each position a complex frequency response or impulse response is captured (min. Δf = 3 Hz)
- The speaker axis points by the polar axis to the microphone
- The measurement points are on the great circles through the pole
- Angel resolution
  - Standard : 5°
  - Arrays sources: *1
    - Single source up to 0,1 m: 10°
    - Single source up to 0,2 m: 5°
    - Single source up to 0,4 m: 2°
    - Single source up to 0,8 m: 1°

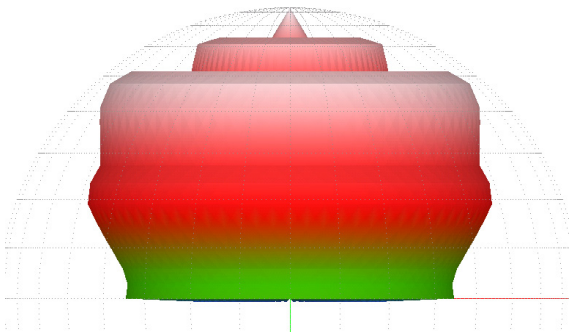


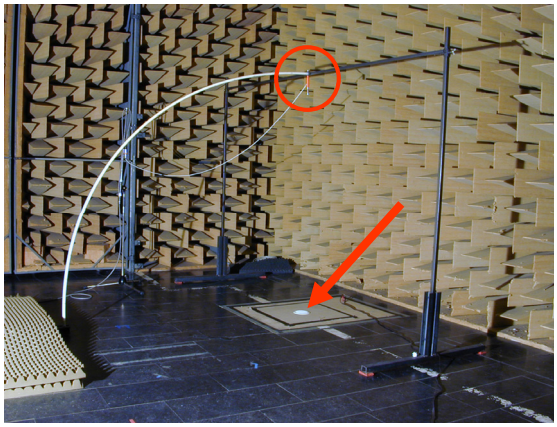


*1 **Methods and Limitations of Line Source Simulation Feistel et al. AES Convention Paper 2008 Oct.**

Balloon Measurements (part 2)

- Quantity of measurement points
  each with 64 kB data (Δf = 2,93 Hz at 48 kHz)
  - 10° : 703 45 MB
  - 5° : 2701 180 MB
  - 2° : 16471 1125 MB
  - 1° : 65314 4500 MB
- Use of Symmetry
  - Horizontal
  - Vertical
  - Horizontal and Vertical
  - circle
- Half space measurements for ceiling or on wall speakers
- Interpolation from hor. and ver. measurements only for speakers with a simple and plain directivity (broadband speakers, coax systems)
- Balloon data has to be measured in the far field!



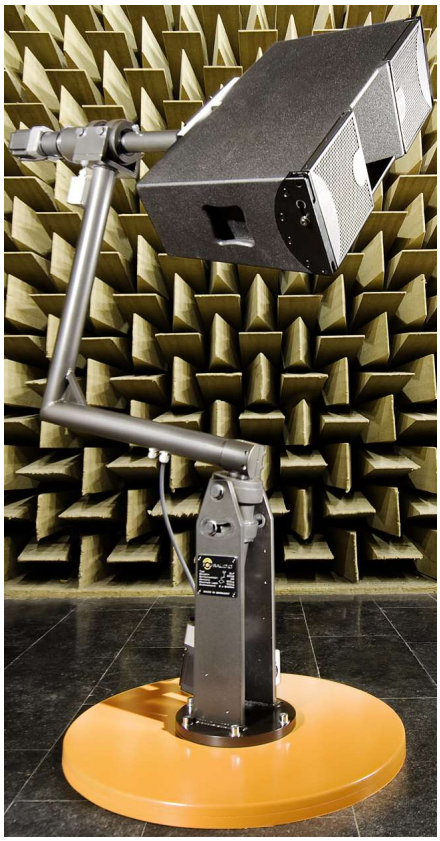


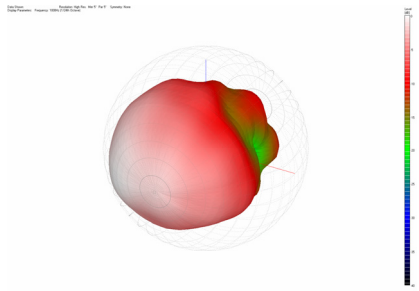
Data Sets for Simulation Tools

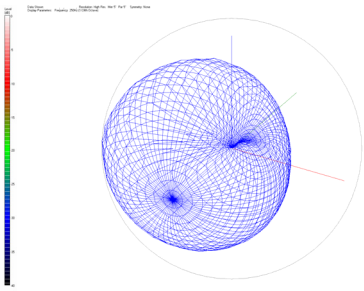
- To capture a complete speaker in one measurement is in the majority of cases not accurate
  - A far field - near field differentiation is not possible
  - Max. SPL is not accurately calculated
  - The speaker model is unflexible
- A more detailed model
  - All ways and the corresponding filters are measured separately in the first step.
  - Afterwards the data set is constructed from this data

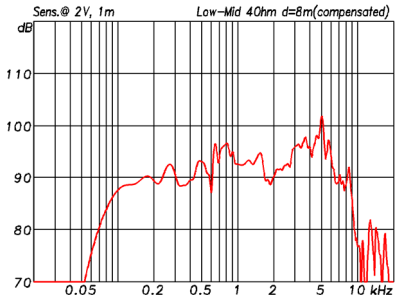
➢ **GLL Data (Generic Loudspeaker Library)**

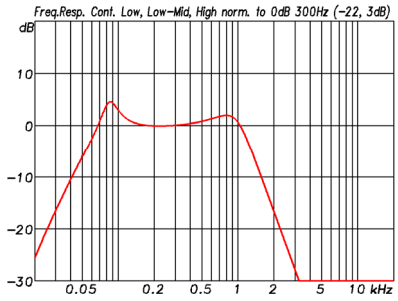
Example of a 3-Way line array speaker module

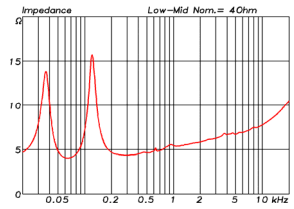






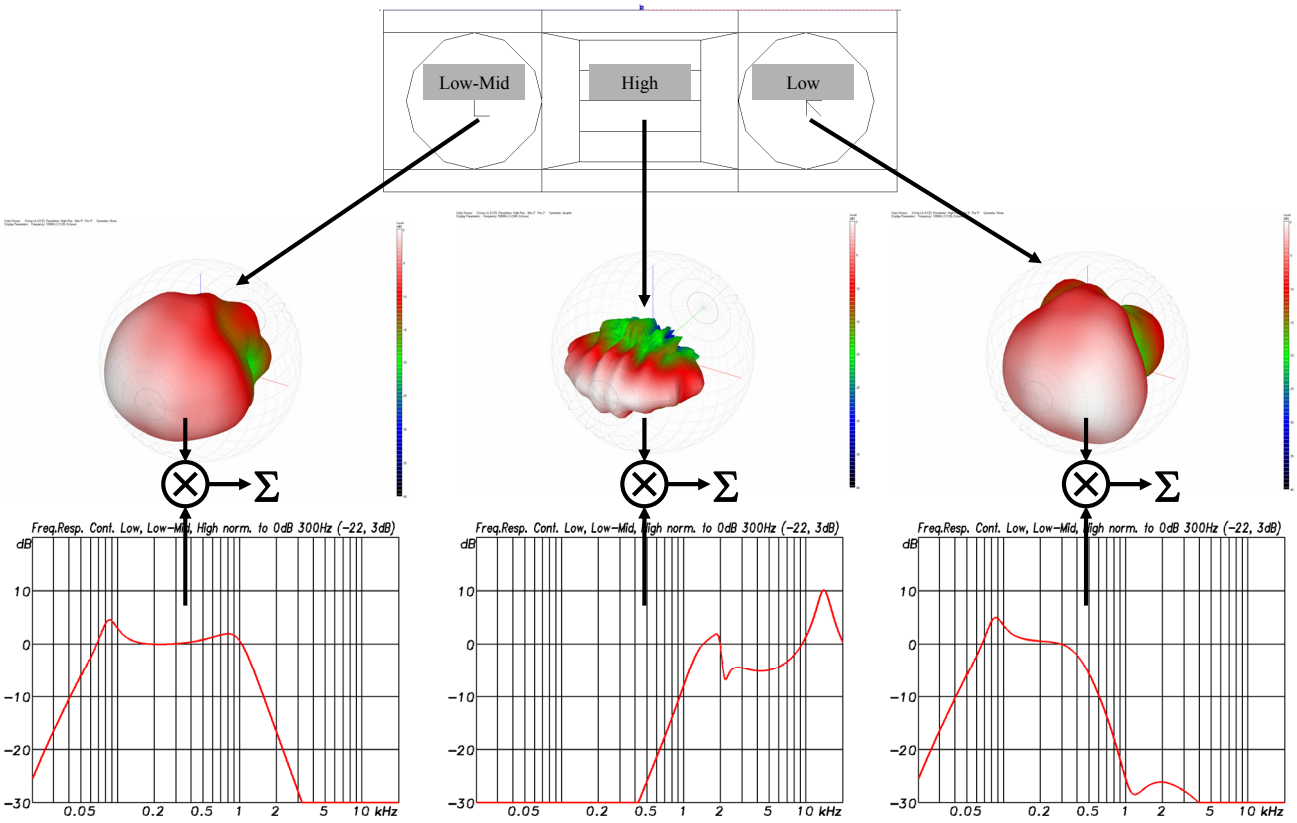






- Amplitude- and Phase Balloon
- Frequency response on axis with a sensitivity for 2.83V/1m
- Controller response in ampl. and phase
- Electrical impedance

Composition of a GLL



Near field - Far field

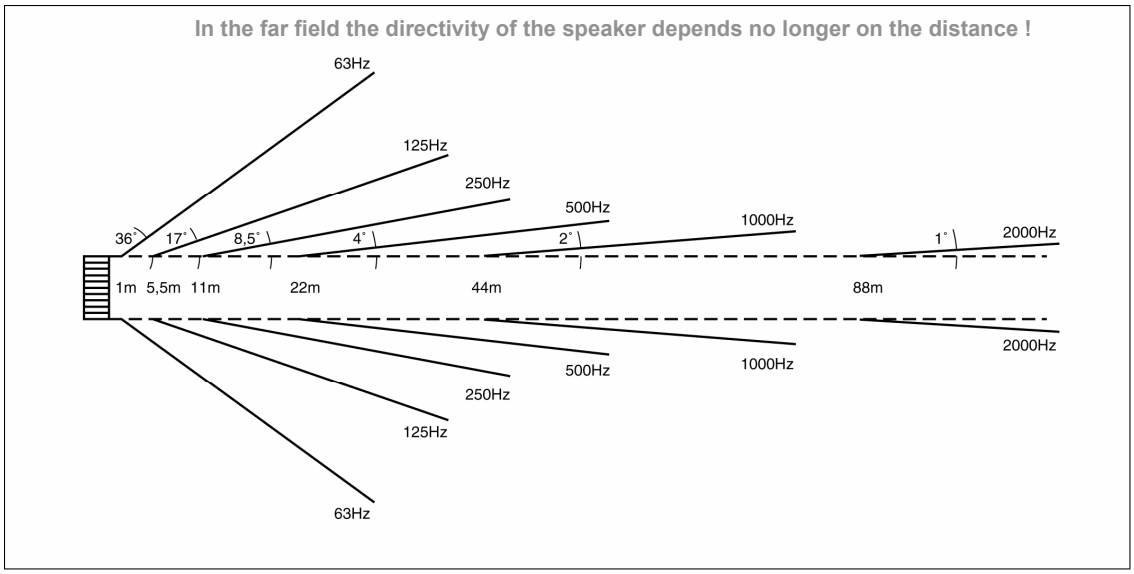
- Problem
  - Typical balloon data is valid only in the far field
  - For line sources, line arrays and other spacious speaker arrangements with an extensive near field the simulation needs a correct near field – far field consideration !
  - The directivity of this speakers changes in the typical distance of use.
    - Bear in mind:
      The near field of a 3,72 m line source
      extends at 2,5 kHz to 100 m !
      The listener is in the Near Field !

$$r_{Farfield} = \frac{l^2 \cdot f}{340\ {}^{m}/_{s}}$$

Near field - Far field

$$r_{Farfield} = \frac{l^2 \cdot f}{340\ {}^{m}/_{s}}$$

Frequency f in Hz
and Lenght l in m



Example for a line source with a length of approximate 4m

Near field - Far field

- Solution
  - Measurements of the individual sources from a line source with a high angle resolution and including phase data !
  - From this data the software calculates the behavior of the total speaker arrangement with a correct near field – far field consideration.
- Requirements
  - Its possible to deconstruct a complex source in his components.
  - Bear in mind : The correct calculation for the complete system starts first with the far field of the biggest individual source.
    At 10 kHz it means:
    - individual source 0,2 m r_{FF} = 1,17 m
    - individual source 0,4 m r_{FF} = 4,70 m
    - individual source 0,8 m r_{FF} = 18,82 m
  - Some line sources can not be divided into smaller sources.
    In this case a BEM based balloon calculation of the sources is an alternative solution.

Construction of a Line-Array System

Line array system 4x 50cm

$$r_{Farfield} = \frac{l^2 \cdot f}{340\ m/s}$$

$$l_{max} = \sqrt{\frac{r_{FF} \cdot 340\ m/s}{f}}$$

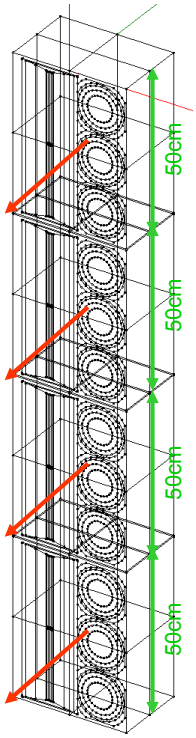
with r_{FF} = 1 m

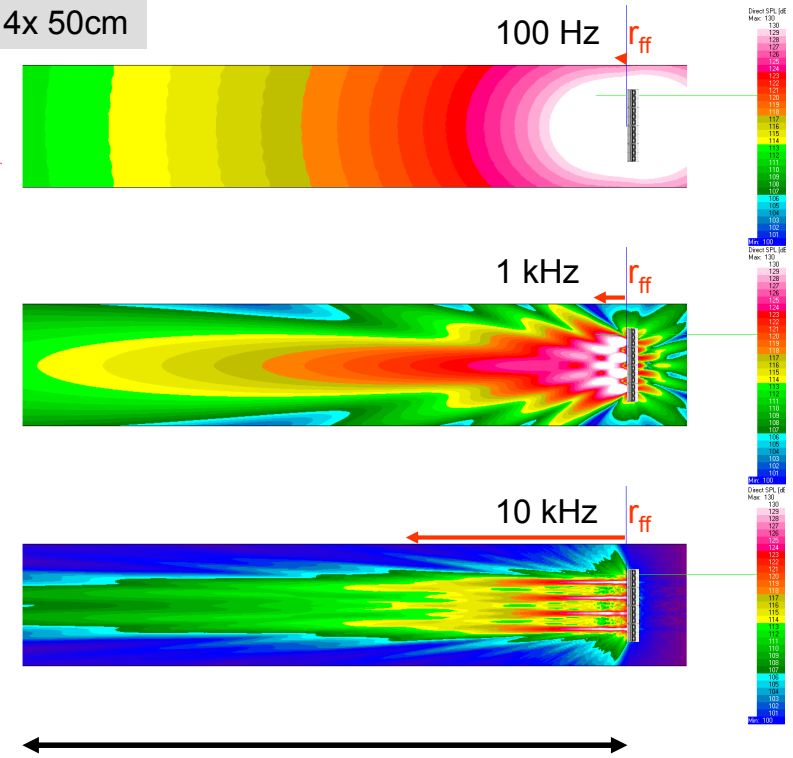
and

f = 10 kHz

follows

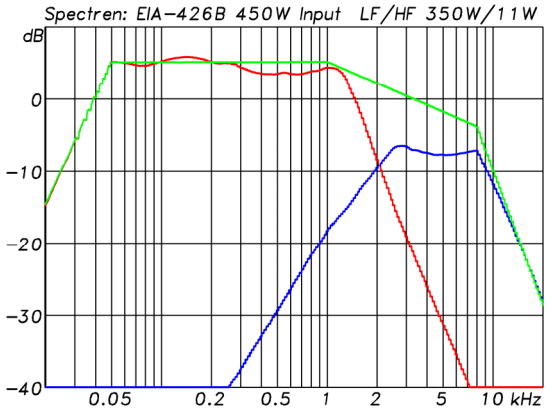
l_{max} ≤ 0,184 m

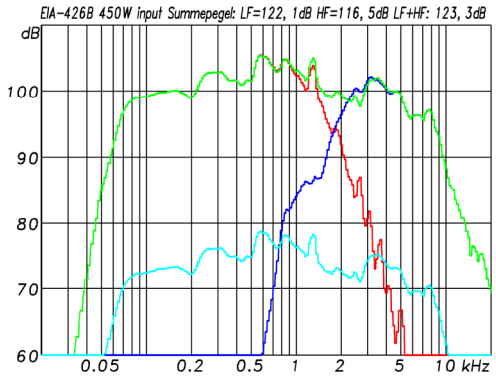




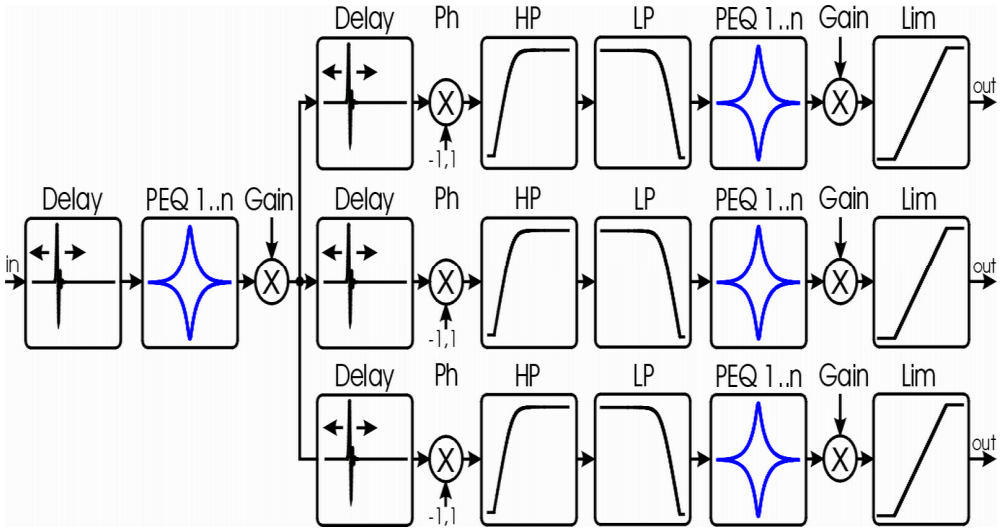
Simulated Max. SPL

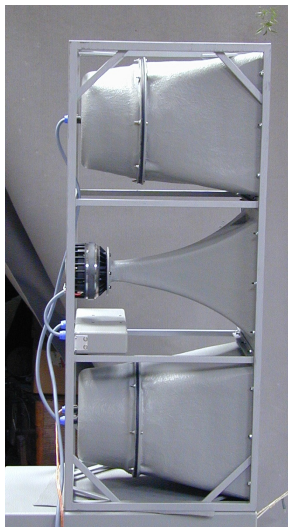
- Input values:
  - Signal spectrum
  - Filter functions for LF, MF, HF, …
  - Max. power of LF, MF, HF, …
- Calculations
  - **Which way first reaches his limit?**
  - **Background of limits for max. power?**
  - Typical test methods for max. power are only thermal or mechanical destructive tests
- Not considered are:
  - Distortions (THD and IMD)
  - Power compression
  - Reduction of the crest factor





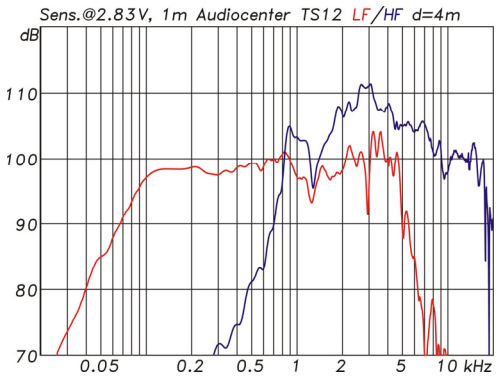
Block diagram speaker controller

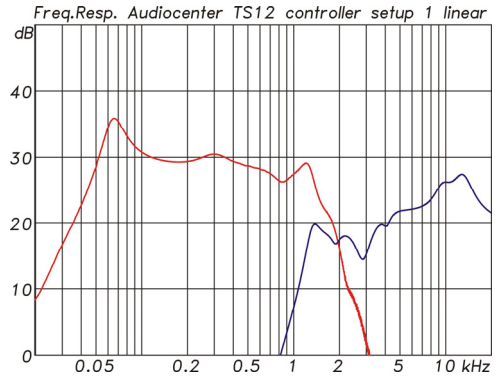


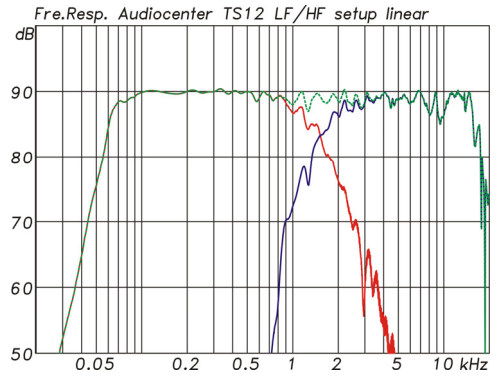


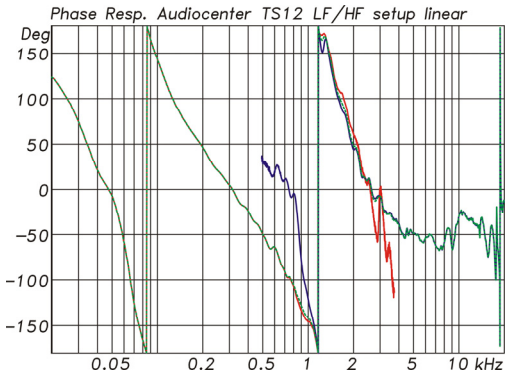
- Speakers in separate measurements without filters: LF, MF, HF
- Filter, X-Over, Delay, Level

Audiocenter TS12 Filter Setup

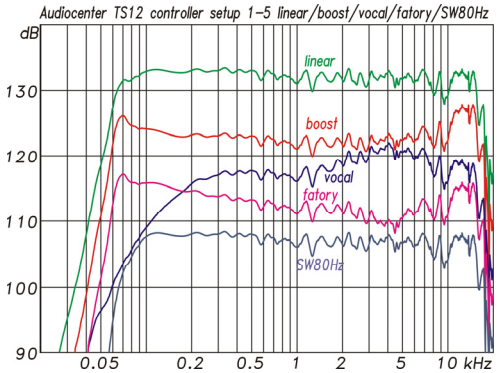


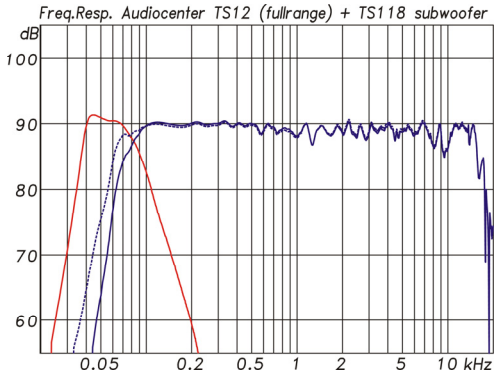






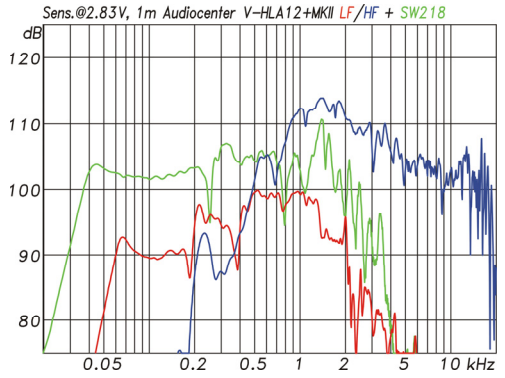
Controller Setups and Subwoofer Combination

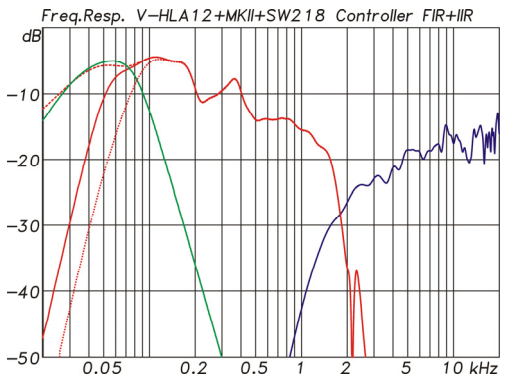




- Setup with different frequency responses:
  - Linear
  - Boost (Low and High +5 dB)
  - Vocal (low cut and presence boost)
  - Factory (Shop demo preset)
  - Subwoofer (low cut @ 80Hz)
- Combination with TS118 Subwoofer at 80Hz x-over

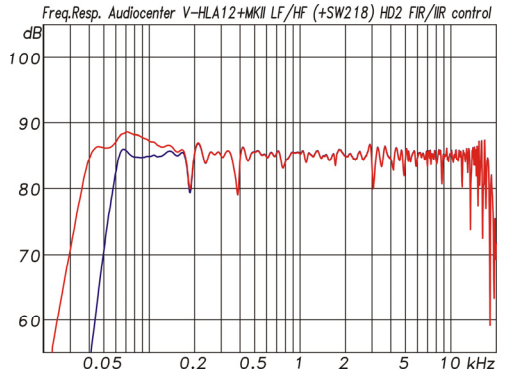
V-HLA12+ MKII + SW218 Setup

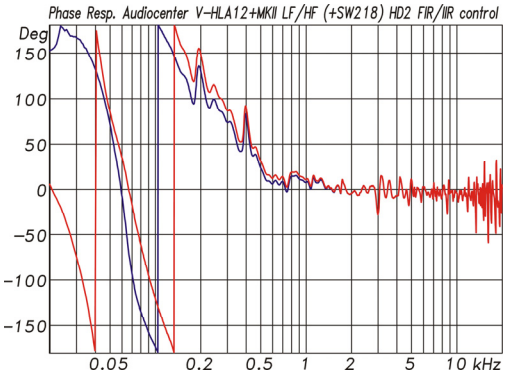




- Combination of FIR- and IIR-Filters for the LF and HF of V-HLA12+ MKII
- FIR latency only 10 ms
- Additional IIR filters for the lower frequencies (LF low cut)
- Setups for V-HLA12+ MKII
  - 2-way full range
  - 3-way with SW 218 subwoofer
  - Relation 4:1 tops : subs

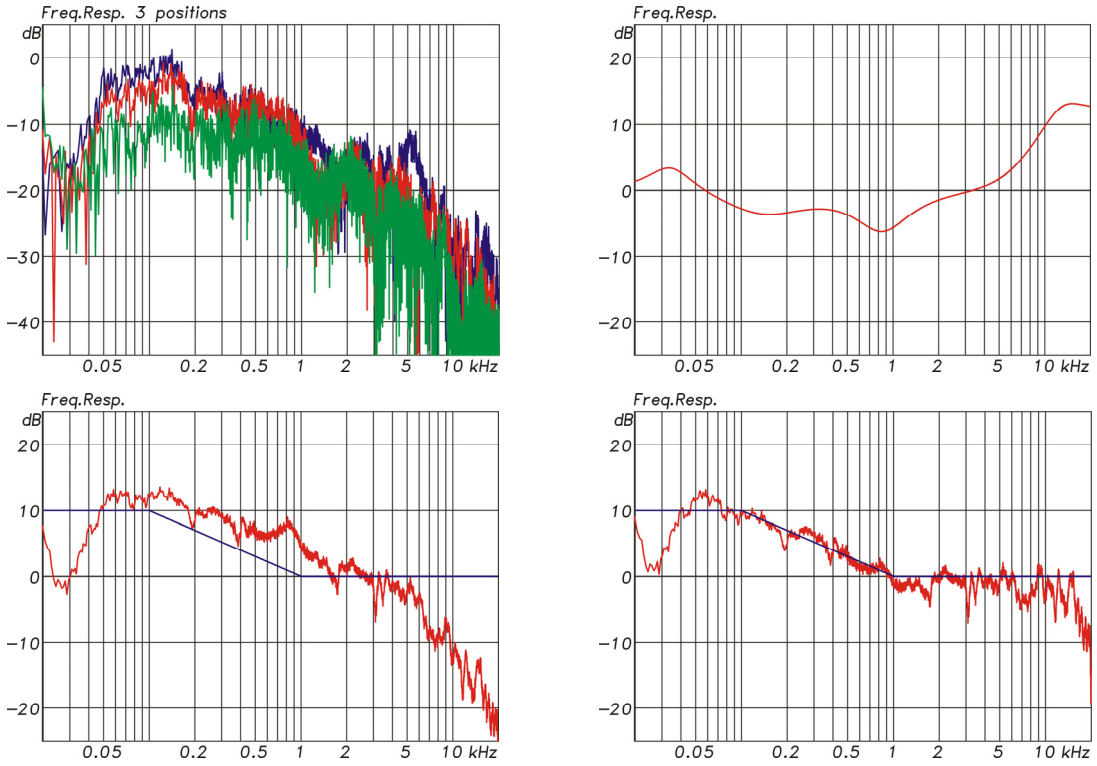
Results V-HLA12+ MKII





- Flat response for a basic combination of 4 tops and 1 subwoofer
- Linear phase equalization from 500 Hz to 20 kHz

Final Setup of the PA system



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