

Photo Story OK²

The story describes the development of a selfbuild loudspeaker, the OK².
No known commercial loudspeaker has the new technology applied in the OK².

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Loudspeakers: Visaton, Monacor

Crossover parts: Intertechnik

A development of the

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1. The high frequency range

W1 Theory: Comparison of sound radiation of sound baffle and Waveguide

1.1 The Waveguide



Pic. 1.1 Waveguide WG-300
The form is that of a spherical horn



Ausführung:
Kunststoff Gehäuse
mit eingelassenen Gewinden
zur Befestigung des Hochtöners

Pic. 1.2 Edition

1.2 The Tweeter:

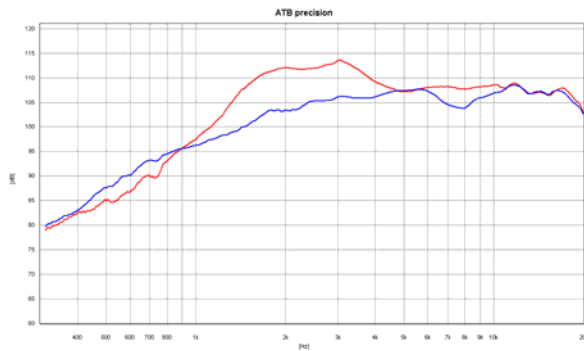


Pic. 1.3 Tweeter Visaton SC 10 N

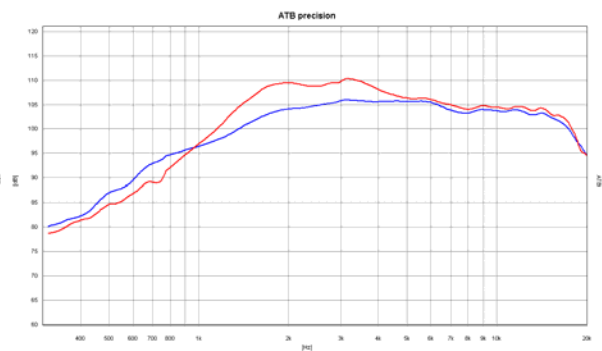
Technical Data:

25mm fabric Soft dome
Magnetic shield
Nominal power handling 100 / 50W
Peak power handling 150 / 80W
Impedance 8Ω
Frequency response 1000Hz – 20000Hz
Sound pressure level 90dB (1W/1m)
Resonance frequency 1700Hz
Magnetic Inductance 1.3T

1.3 The sound radiation behaviour of the Waveguide

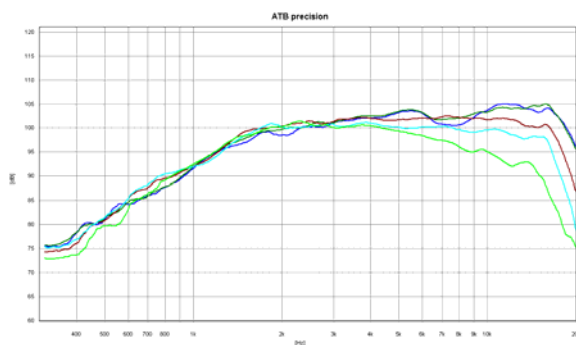


Pic. 1.4 Comparison of frequency response
The blue curve shows the frequency response of the tweeter and the red curve that of the Waveguide on axis. At lower frequencies the sound pressure level is amplified due to the sound radiation resistance of the Waveguide.

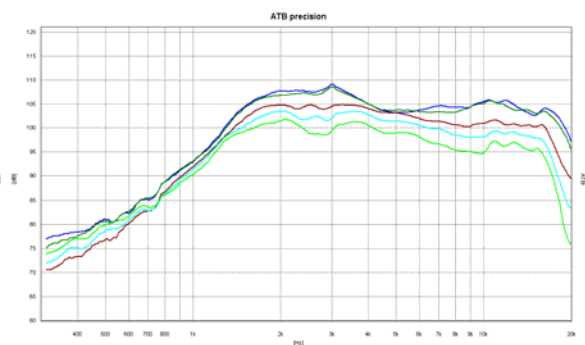


Pic. 1.5 Sound power level
The blue curve shows the power level of the tweeter and the red curve that of the Waveguide in relation to frequency.

To measure the power level radiated from the speaker the sound radiation field of the speaker is measured. Doing this, several measurements are averaged, where by the microphone positions describe a half sphere around the speaker. Above 5 kHz both soft dome and Waveguide show nearly identical power levels, as the membrane surfaces are the same. At lower frequencies the power level of the Waveguide, red curve, increases. Here, the power level is amplified due to the sound radiation resistance. This corresponds to an increase of membrane surface.

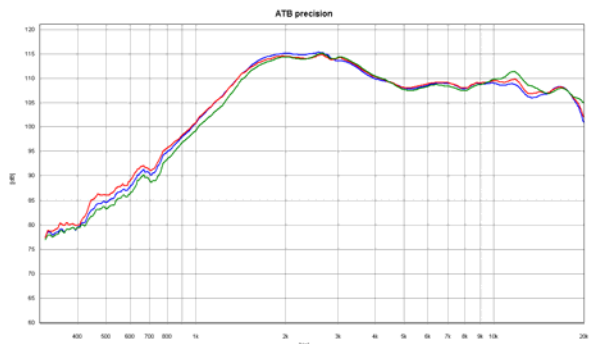


Pic.1.5 Tweeter sound radiation behaviour
Blue=0°, darkgreen=15°, red=30°, lightblue=45°, lightgreen= 60°.
At a greater angle the curve decreases at higher frequencies. This makes the sound impression hearing position dependant. At a greater angle there is a decrease of higher frequencies.

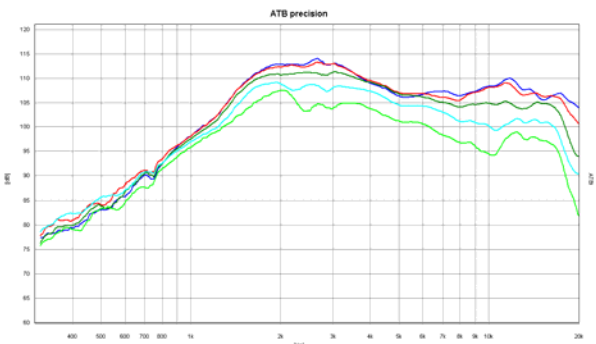


Pic.1.6 Waveguide sound radiation behaviour
Blue=0°, darkgreen=15°, red=30°, lightblue=45°, lightgreen= 60°.
At a greater angle the sound pressure level decreases, the characteristic of the curve stays the same. This shows that the sound impression is independent of the hearing position.

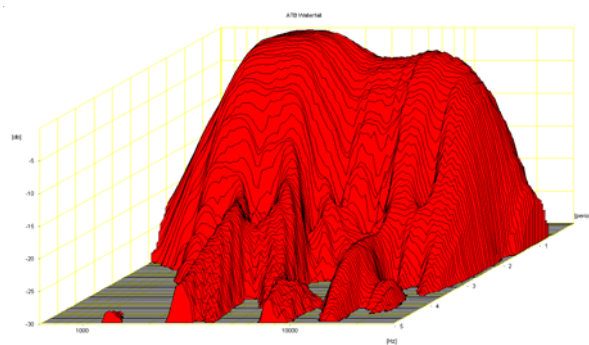
1.4 Waveguide adjustment



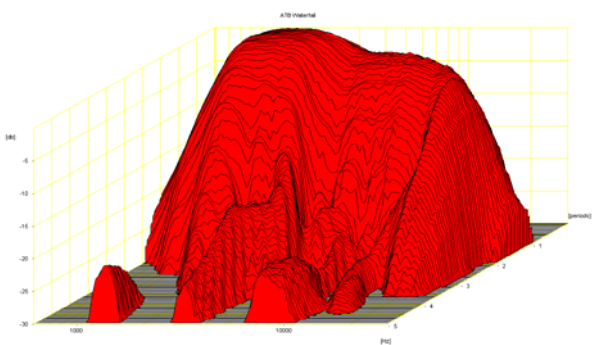
Pic. 1.7 The different lengths
The green curve shows the frequency response of the original Waveguide, the blue the 1mm too much shortened Waveguide. The red curve is best balanced.
The Waveguide is 5mm shortened.



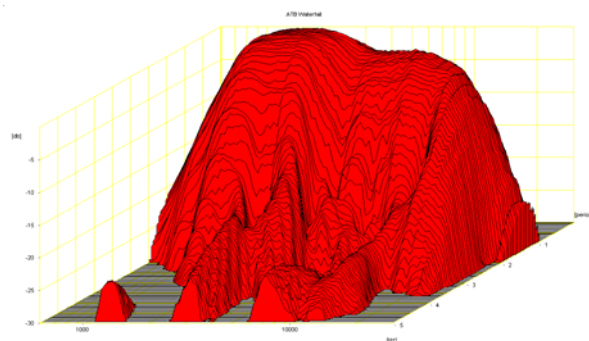
Pic. 1.8 Sound radiation behaviour of original
blue=0°, darkgreen=15°, red=30°, lightblue=45°, lightgreen= 60°.
The sound radiation behaviour of the original, too long, Waveguide is out of balance.



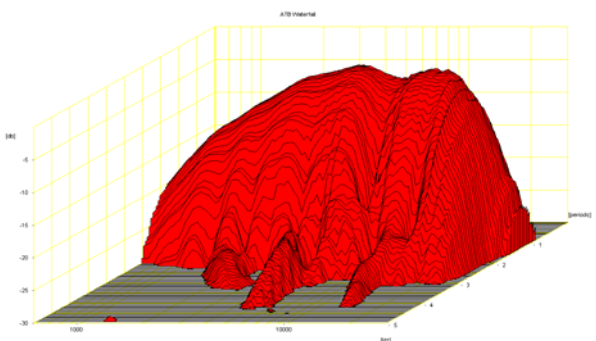
Pic. 1.9 Original time behaviour
The Waterfall measurement (Decayspectrum) shows the properties of the Waveguide best.
The original Waveguide has two resonances in the high frequency range.



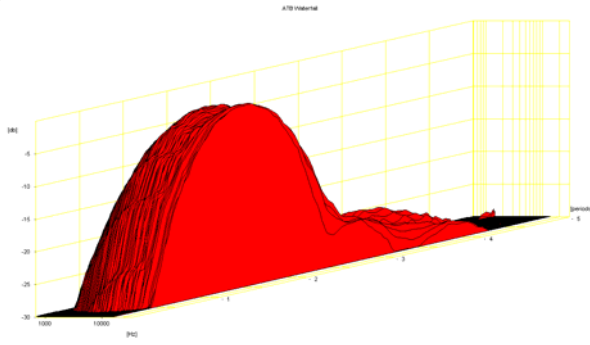
Pic. 1.10 Time behaviour too short
The resonances of the, 1mm too short Waveguide are more distinctive.



Pic. 1.1 Time behaviour with correct length
The 5mm shortened Waveguide shows the the best balanced time behaviour.



Pic. 1.12 Time behaviour of soft dome
The time behaviour of the soft dome shows two breakdowns.



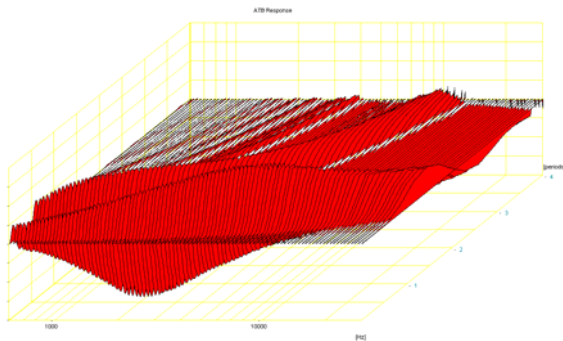
Pic. 1.13 The 1. Depletion of the soft dome. The breakdown is caused by reflexion of the sound baffle.



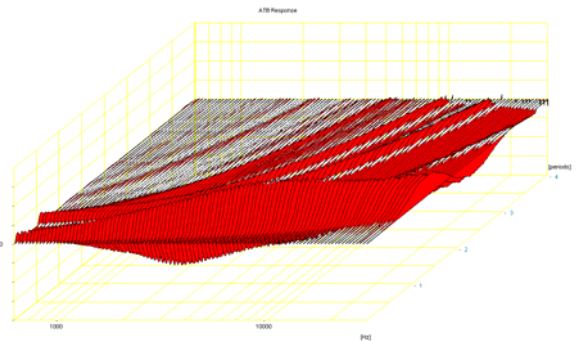
Pic. 1.14 The 2. Depletion of the soft dome. The breakdown at higher Frequencies is caused by the not so optimal construction of the soft dome horn throat.

1.5 Dynamic-Measurement

For the Dynamic-Measurement measurement the speaker is driven with a half sine wave. This tests the impulse behaviour, as the speaker is measured in the not swung-in state (or non steady state).



Pic. 1.15 Impulse behaviour of the Waveguide



Pic. 1.16 Impulse behaviour of the soft dome

Because of the higher sound radiation resistance of the Waveguide the resonance of the tweeter becomes more visible. This is shown in the left picture by the stronger swing-through and by the backward running mount. With use of a notch filter in the crossover this resonance is suppressed.

1.6 *Mounting Waveguide and Tweeter*



Pic 1.17 The Waveguide is shortened
The picture shows the original and the 5mm shortened Waveguide. This can be done using file.



Pic 1.18 The Waveguide and tweeter
The Waveguide is screwed to the tweeter.
To do this you have to make notches in the mounting plate of the tweeter.

Shortening and making notches is best done with special tools.

2. The mid-low frequency range

2.1 The mid-low frequency loudspeaker



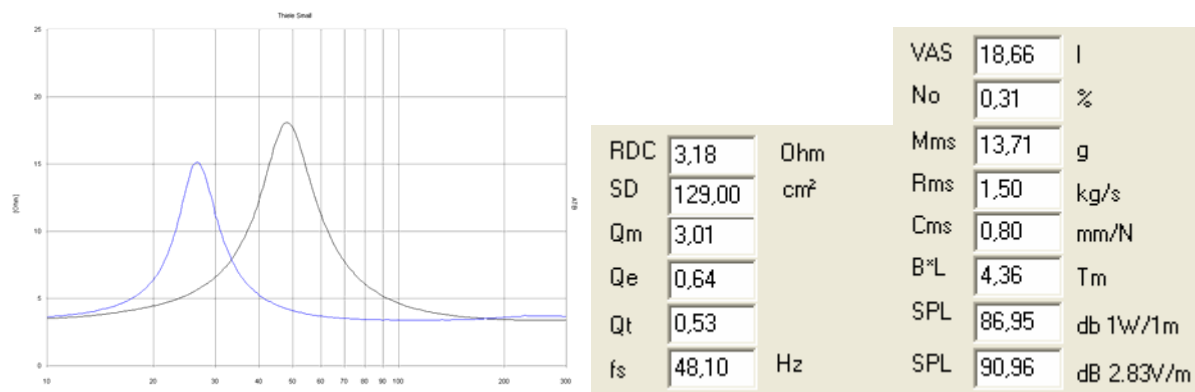
Technical Data:	
Size:	17cm (6.5")
Nominal power handling:	50W
Peak power handling:	80W
Impedance:	4Ω
Average sound pressure level:	87dB1W/1m
Sound pressure level:	87dB1W/1m
Maximum cone displacement:	20mm
Linear cone displacement:	±4,2mm

Voice coil diameter:	25mm
Weight:	0,95kg

Pic. 2.1 The W170S/4

The W170S was chosen because of its musical properties. The sound impression is very natural without the artificial sound that most modern speakers have. Due to the light coated membrane it's very fast and reproduces details well. The speaker has been used in a small box for shelves for 16 years. The speaker uses the Visaton Alto I cabinet The tweeter is an Audax soft dome.

2.2 The Thiele-Small Parameter



Pic. 2.2 The Thiele-Small Parameter of W170S/4

With a Q_t of 0.53 a speaker of the usual design criteria seems not to be advantageous. This high value is because of the low moving mass and the relative high resonance frequency. But both values allow the conclusion of a very good impulse reproduction. That's why it's worth the effort to find an alignment that doesn't demand the usual bassreflex tuning. A closed box needs a volume of 34l. That would be too large for a loudspeaker appropriate for the living room.

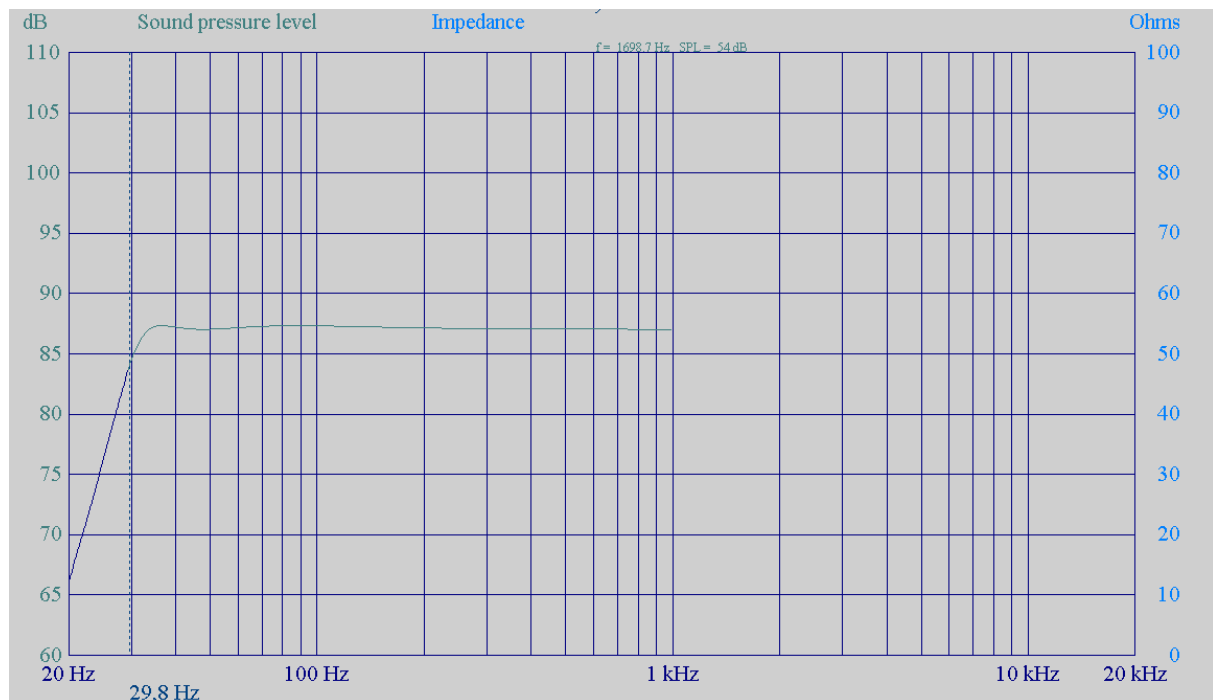
The following calculations demonstrate the difficulties of a bassreflex alignment.

2.3 The enclosure calculation

Driver name	W170S/4	Net box volume (Vb) l	59,001
Box type	Bass reflex	Port diameter (Dp) cm	5,731
Number of equal driver	1,0	Port length (Lv) cm	6,982
Resonance frequency (fs) Hz	45,0	Port resonance frequency (fp) Hz	34,168
Equivalent volume (Vas) l	18,66	-3 dB frequency (f3) Hz	29,712
Total Q (Qt)	0,563	Reference SPL dB	87,03
Mechanical Q (Qm)	4,01	Efficiency bandwidth produkt (EBP)	76,835
Electrical Q (Qe)	0,64	Alpha (fcb/fs) ² -1 (a)	0,316
DC resistance (Re) Ohms	3,3	Ratio fp/fs (h)	0,712
Serial resistance (Rs) Ohms	0,3		
MONACOR MBR		SUGGESTED BOX (inclusive Vb-)	
Effective cone area (Sd) cm ²	129,0	Internal width cm	31,319
Port area (Ap) cm ²	25,8	Internal height cm	48,936
Leakage-Q (Ql)	7,0	Internal depth cm	39,149
Leakage volume (Vb-) l	0,0	Box volume (VbG) in l	60,001

Pic. 2.3 Calculation of the bassreflex enclosure

According to calculation the optimal bassreflex volume is 60l. This is for a 17cm speaker that in a 2-way system should also reproduce the mid frequency range not suited. The speaker is missing the air pillow, needed for correct impulse reproduction of the mid frequencies.



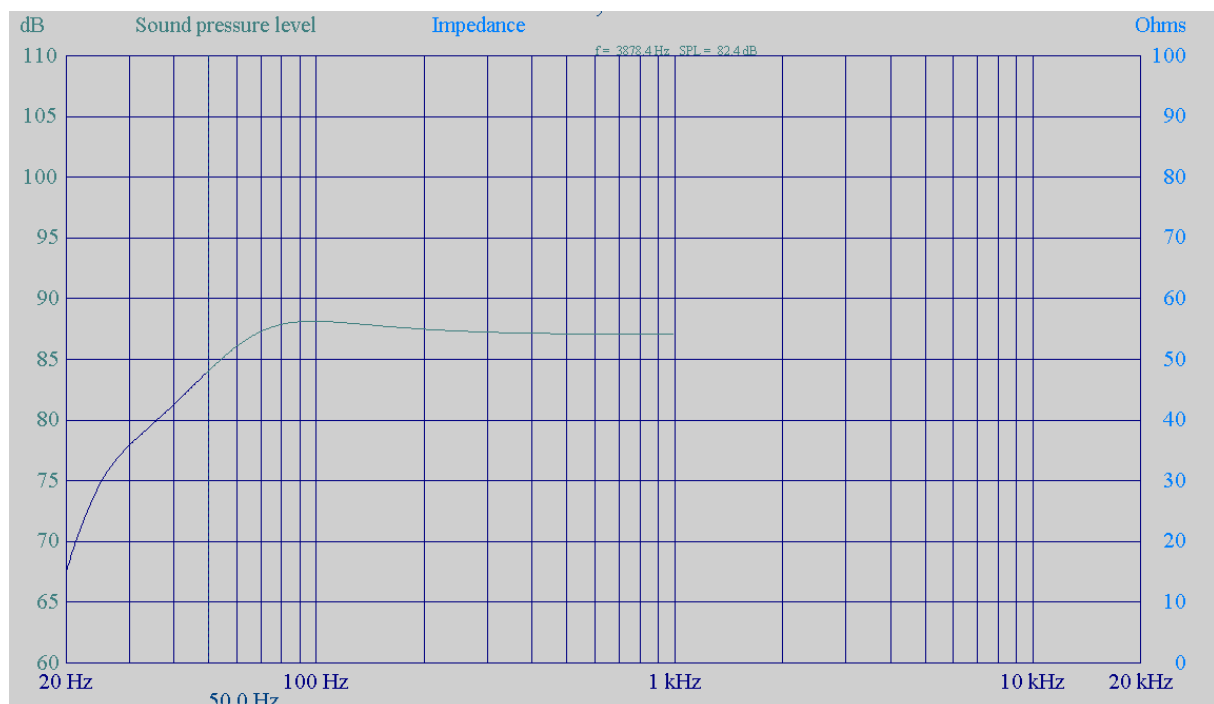
Pic. 2.4 The frequency response in a 60l enclosure

If the speaker is used in a 3-way system as bass, the lower roll off frequency is 30Hz. This is a very good value but all the same you would choose a larger speaker for a 60l enclosure that can produce a higher sound level pressure.

Driver name	W170S/4	Net box volume (Vb) l	18,0
Box type	Bass reflex	Port diameter (Dp) cm	4,787
Number of equal driver	1,0	Port length (Lv) cm	22,034
Resonance frequency (fs) Hz	48,0	Port resonance frequency (fp) Hz	34,168
Equivalent volume (Vas) l	18,66	-3 dB frequency (f3) Hz	49,957
Total Q (Qt)	0,343	Reference SPL dB	87,03
Mechanical Q (Qm)	3,01	Efficiency bandwidth produkt (EBP)	76,835
Electrical Q (Qe)	0,64	Alpha (fcb/fs) ² -1 (a)	1,037
DC resistance (Re) Ohms	3,2	Ratio fp/fs (h)	0,712
Serial resistance (Rs) Ohms	0,3		
MONACOR MBR		SUGGESTED BOX (inclusive Vb-)	
Effective cone area (Sd) cm ²	129,0	Internal width cm	21,347
Port area (Ap) cm ²	18,0	Internal height cm	33,355
Leakage-Q (Ql)	7,0	Internal depth cm	26,684
Leakage volume (Vb-) l	0,0	Box volume (VbG) in l	19,0

Pic. 2.5 Calculation for an 18l enclosure

For a 17cm loudspeaker an 18l enclosure appears to be a practical value. The length of the bassreflex vent is calculated. The 18l are adequate, as the example, the Alto I, has a volume of 13l. Due to the appropriate padding of the enclosure the Alto I doesn't exaggerate the low frequency range in a harmful way.

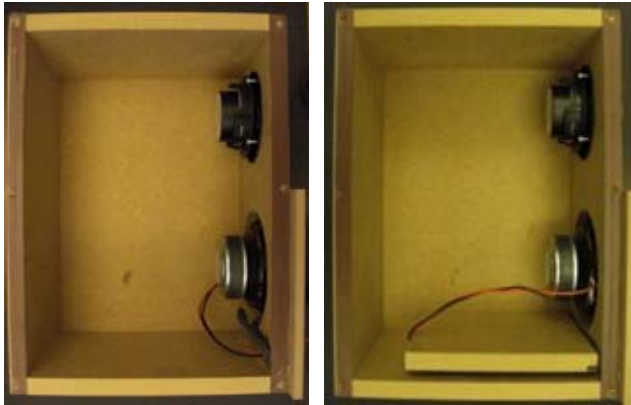


Pic. 2.6 The frequency response in 18l enclosure

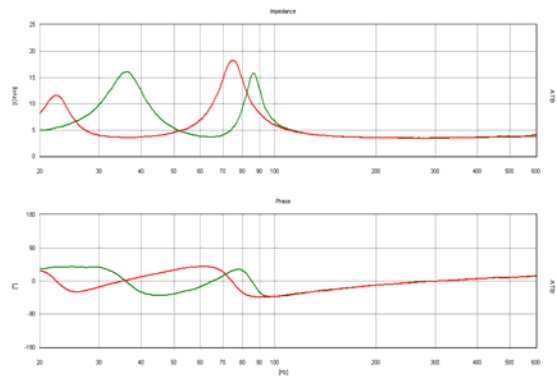
In an undamped 18l enclosure the frequency response shows an exceed of 1,2dB at 90Hz. This slight rise has to be suppressed by padding the enclosure.

As the calculation results are not satisfactory, an optimal enclosure construction is to be found for the woofer using measurement technical techniques.

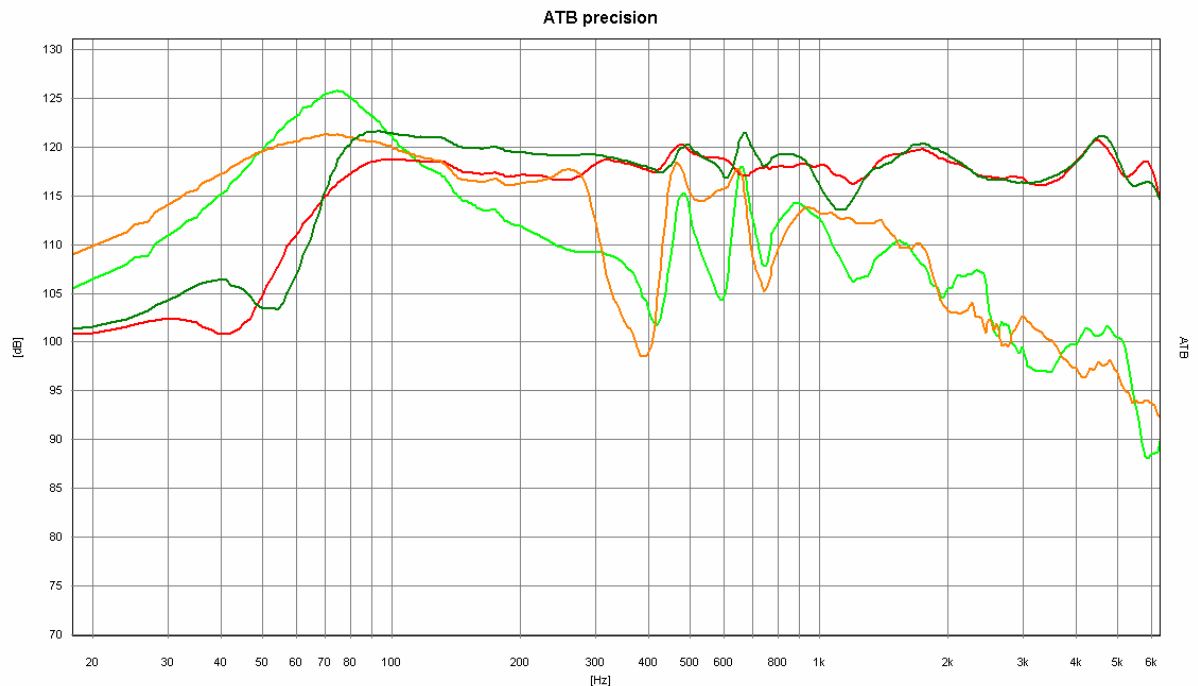
2.4 Measurement technical enclosure alignment



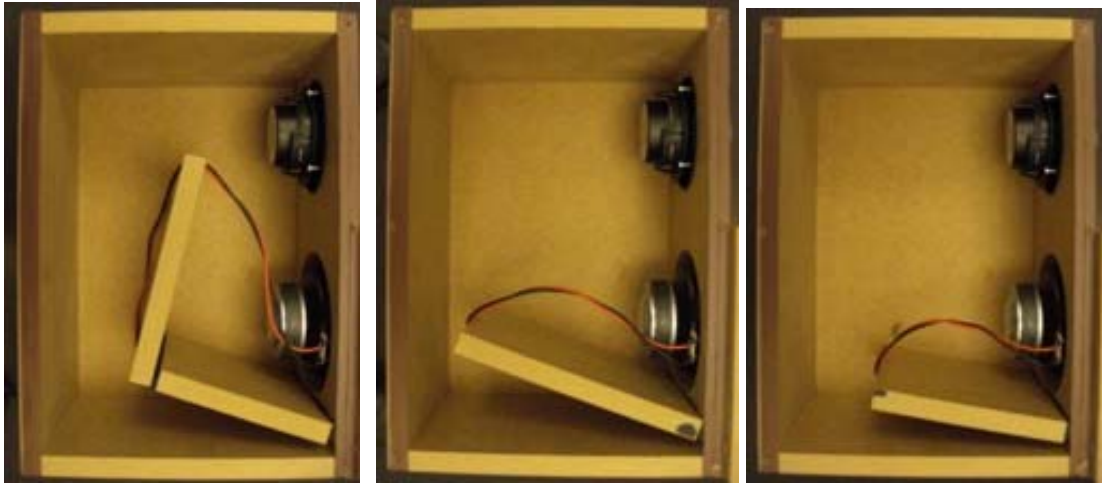
Pic. 2.7 Bassreflex enclosure
The pictures show the enclosures with bassreflex channels of 3cm and 22cm length. The box with the 22cm long channel corresponds to the calculated alignment.



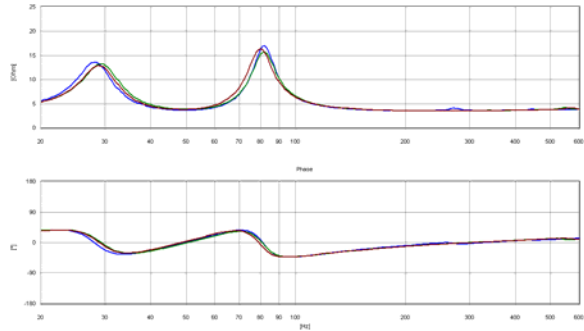
Pic. 2.8 Impedance measurement
The impedance curves show the alignments. The green curve shows the high alignment of 70Hz and the red the calculated alignment of 35Hz.



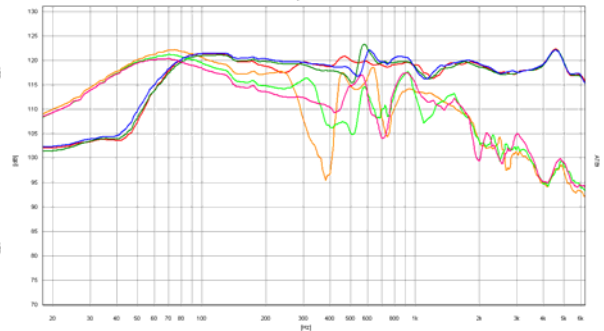
Pic. 2.9 The frequency response of bass und bassreflex opening near field measurement
The green curve is the to lower frequencies increasing frequency response of the woofer As also the lightgreen curve of the opening is strongly distinctive, there is an exaggeration of the low frequency range. The red curve shows the calculated alignment. This is in practice far too low. The low frequency response rolls off too early and cannot be compensated by the weak sound pressure level of the reflex opening, orange curve.



Pic. 2.10 Bassreflex channel editions
 As the calculated alignment is not suitable, other alignments are tested. The left one corresponds to the TQWT. With the two other ones a more balanced sound pressure at the port opening is achieved by slanting the board.



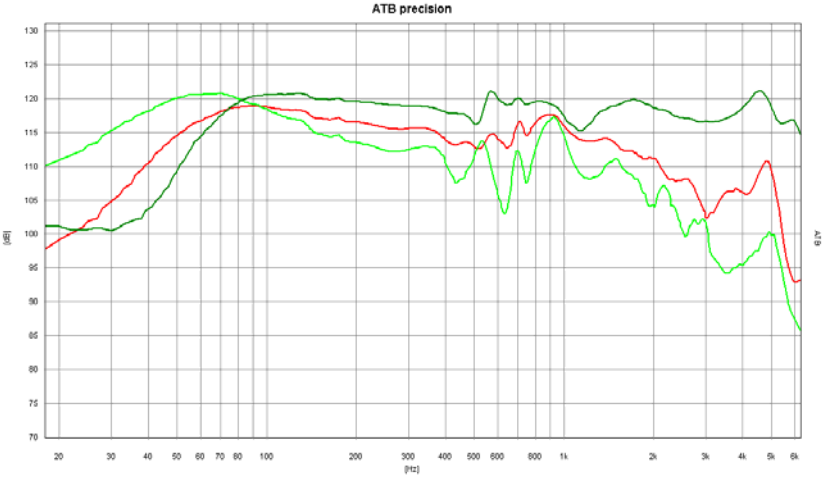
Pic. 2.11 Impedance measurements
 The impedance curves show only slight differences. All alignments are possible.



Pic. 2.12 Frequency responses
 The frequency responses of the TQWT red curve and TQWT opening orange curve are conspicuous. This alignment is inappropriate



Pic. 2.13 chosen enclosure
 The triangle cut out in the board suppresses air motion noise.

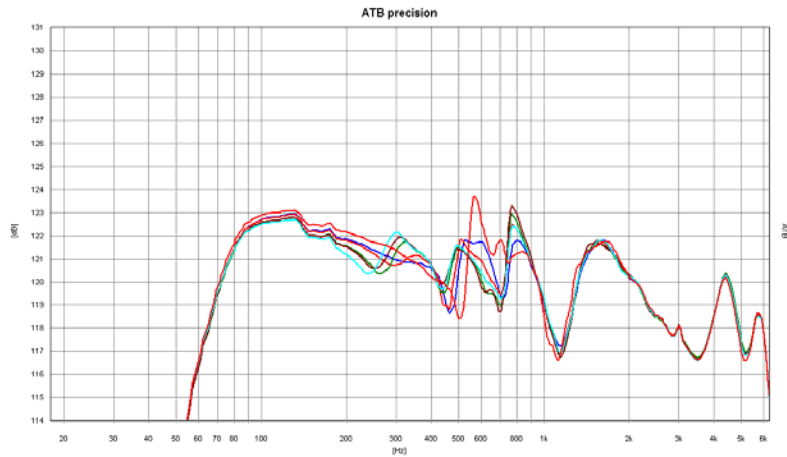


Pic. 2.14 Frequency response of chosen alignment
 The picture show the summary of woofer, green, and bass opening, lightgreen, to frequency response, red.

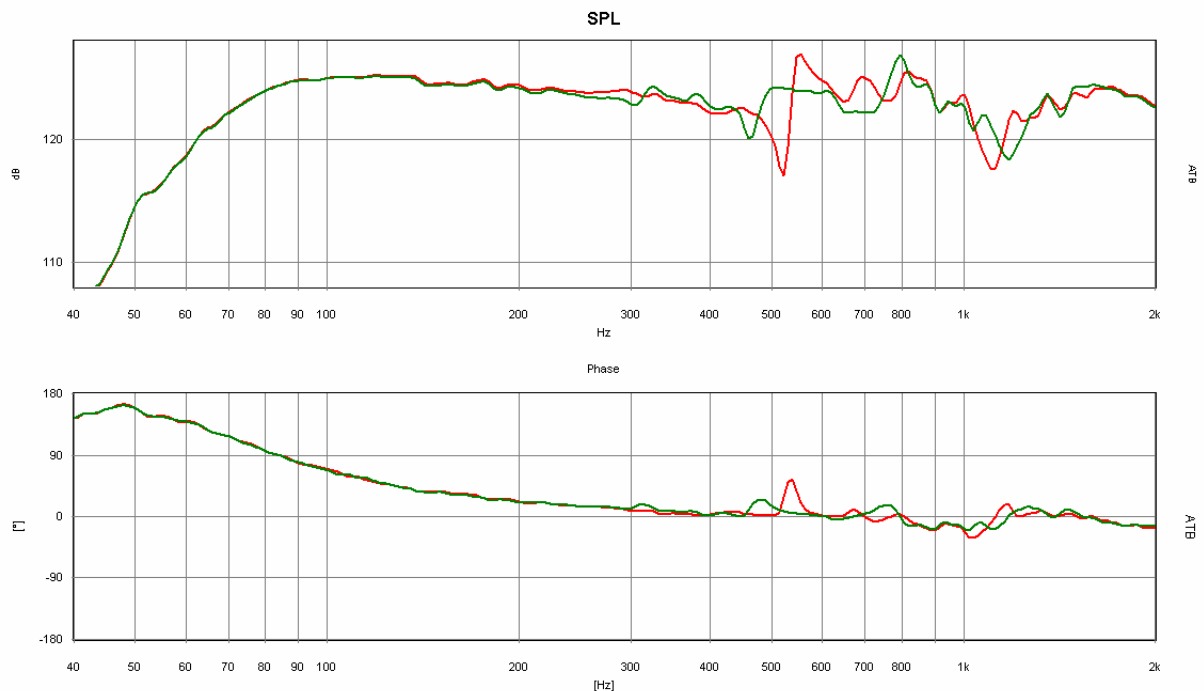
2.5 Suppression of standing waves



Pic. 2.15 Board
To suppress standing waves in the enclosure a board is used.



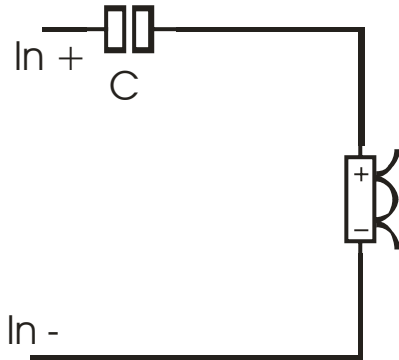
Pic. 2.16 Measurements to optimise board
The frequency response curve in Pic. 2.13 shows a strong wobble at 500Hz. This comes from a standing wave inside the enclosure, **red** curve in upper picture. The measurement shows boards of different lengths and position. Around the 250Hz range new resonances are built up if the position of the board is not correct.



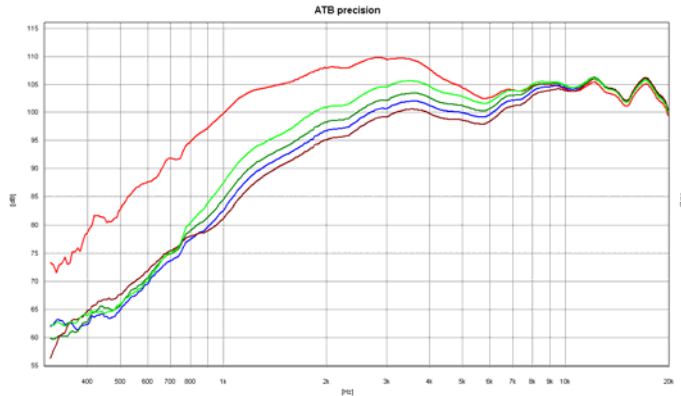
Pic. 2.17 Acoustical SPL und phase measurement
The picture shows the frequency and phase response of the loudspeaker. The **red** curve is the frequency response in near field without a board to suppress the standing wave. The wobble at 530Hz is clearly visible. To this wobble, as it's created by the standing wave, belongs also the jump in the phase. Due to the board, **green** curve, the resonance is suppressed. This results in a clearer sound reproduction.

3. The crossover

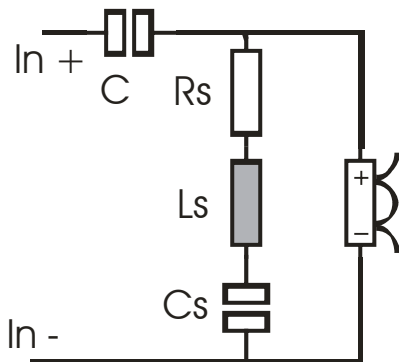
3.1 Highpass



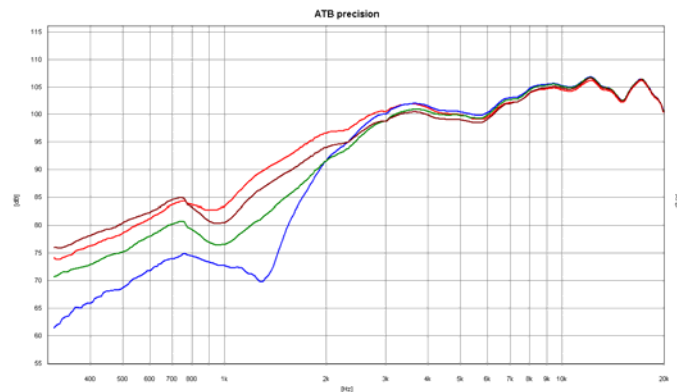
Pic. 3.1 Highpass
The highpass 1st order consists of series circuit tweeter and capacitor.



Pic. 3.2 Frequency responses highpass 6dB/Octave
The red curve shows the frequency response of the tweeter without crossover.
For the other curves C has following values: brown=2.2uf, blue=2.7uf, green=3.3uf, lightgreen=4.7uf

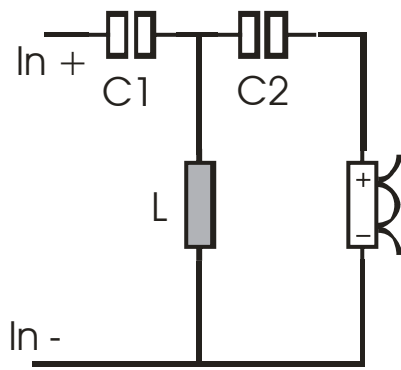


Pic. 3.3 Highpass
The notch filter consists of series circuit of R_s , L_s and C_s .



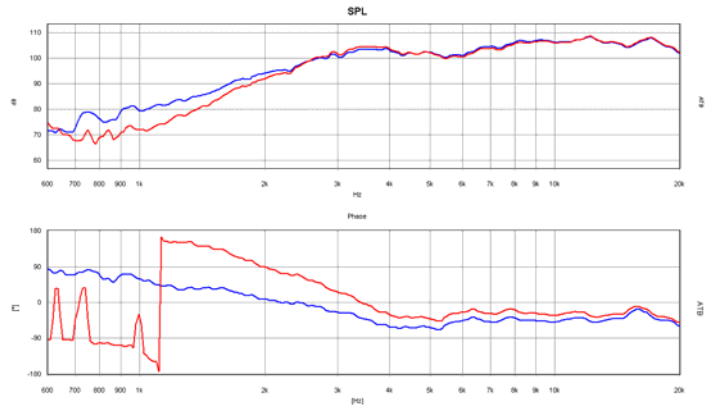
Pic. 3.4 Frequency response with notch filter
the picture shows the frequency response for different Q-factors. The blue curve shows the smallest Q-factor $R_s=0$. For green $R_s=4.7$, brown $R_s=18$ and red $R_s=\infty$, notch filter not connected.

The measurements show the different combinations. In the end the values used for the woofer are found in combination with the crossover.



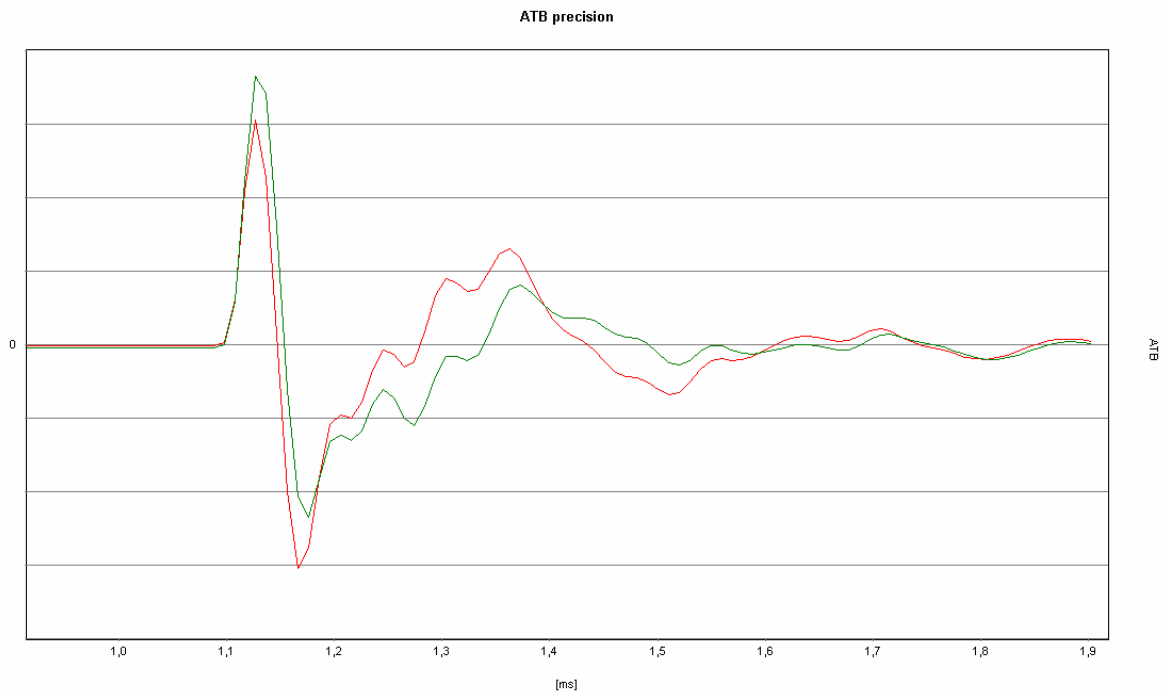
Pic. 3.5 Highpass

The picture shows a highpass 3rd order which is standard for comparable tweeters.



Pic. 3.6 SPL and acoustical phase response

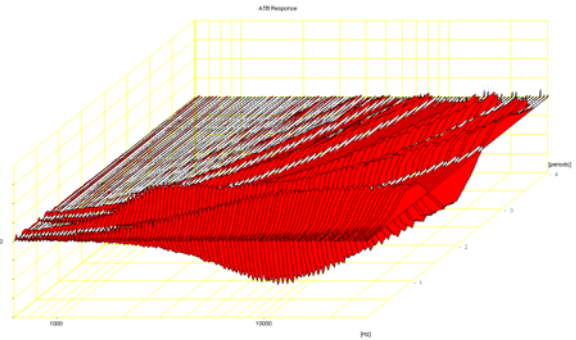
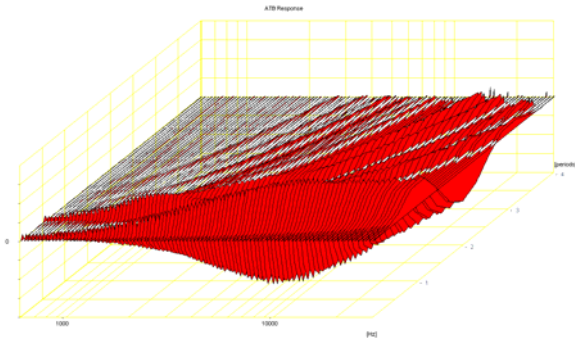
The picture shows the Waveguide with the 6dB/Oct. crossover, blue and 18dB/Oct. Crossover red. For the 18dB/Oct crossover the phase shift of 270° makes a loudspeaker that is correctly timed impossible.



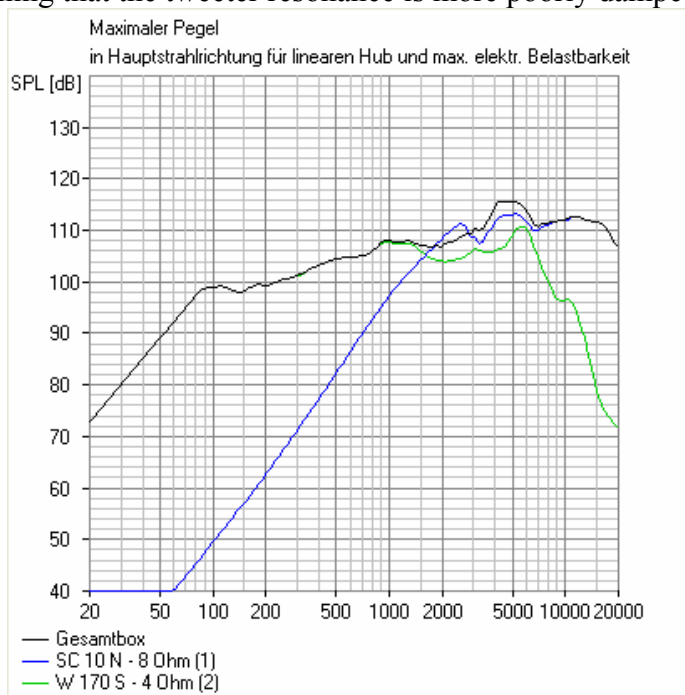
Pic. 3.7 Step response

The step response shows the loudspeaker behaviour during time.

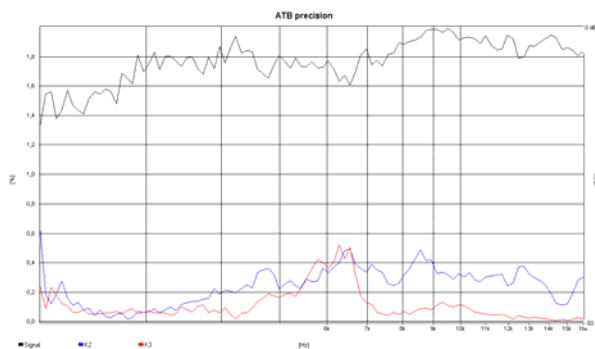
The green curve shows the Waveguide tweeter with 6dB crossover and notch filter. The red curve the tweeter with the 18dB crossover. The green curve has higher amplitude at the start indicating that the tweeter swings-in better, is faster. At swing-over the green curve shows lower amplitude. Also the swing-out amplitude is decisively smaller. This indicates that the speaker is damped better. The step response of a speaker with 18dB crossover, red curve, is not suitable for a true impulse loudspeaker.



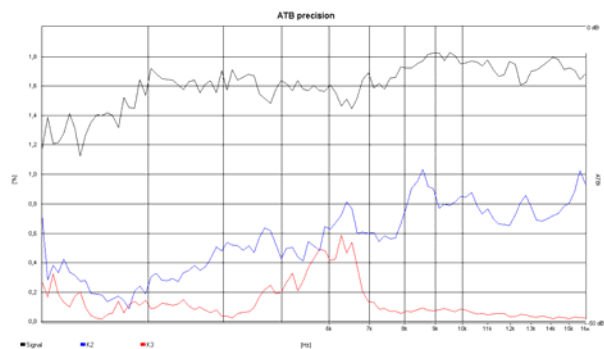
Pic. 3.8 Dynamic-Measurement 6dB/Octave Pic. 3.9 Dynamic-Measurement 18dB/Octave
 The Dynamic-Measurement shows the step response with frequency axis. This makes it easier to interpret the step response. The strong swing-out that appears in the step response becomes interpretable due to the 3D display. Clear to see is the higher amount at 2kHz in picture 3.9. meaning that the tweeter resonance is more poorly damped.



Pic. 3.10 The maximal amplitude
 Developing crossovers the maximal power handling of the speaker driven from the crossover has to be calculated. The calculation for the 6dB crossover shows that the crossover has optimal power behaviour.

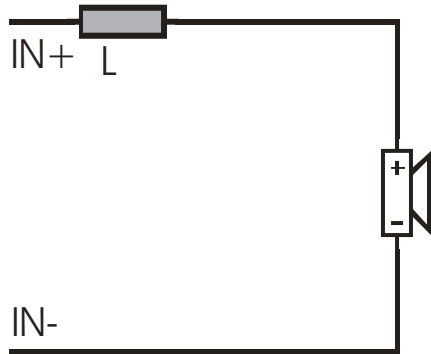


Pic. 3.11 Distortion factor at 90dB/1m
 At normal hearing level there are no distortions to be heard.

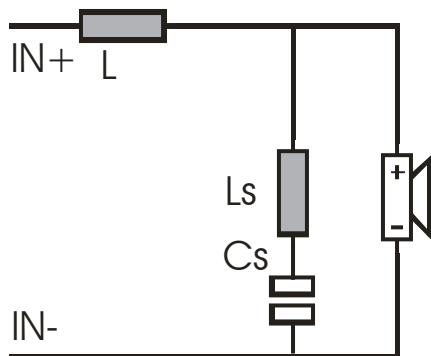


Pic. 3.12 Distortion factor at 96dB/1m
 At very high hearing level the distortions are under 1%, a very good value.

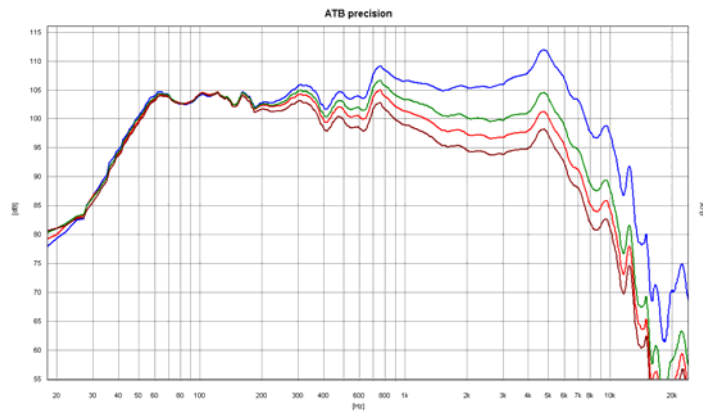
3.2 Lowpass



Pic. 3.13 Lowpass
The circuit diagram shows the inductances lowpass 1st order 6dB/Oct.

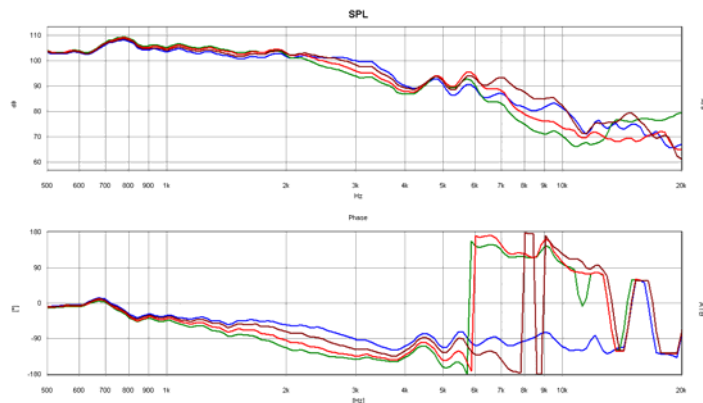


Pic. 3.15 Lowpass
The circuit diagram shows the notch filter parallel to the woofer to suppress membrane resonances.

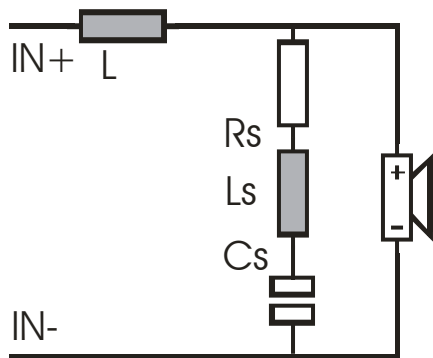


Pic. 3.14 Frequency responses for L
The frequency responses in dependency of the

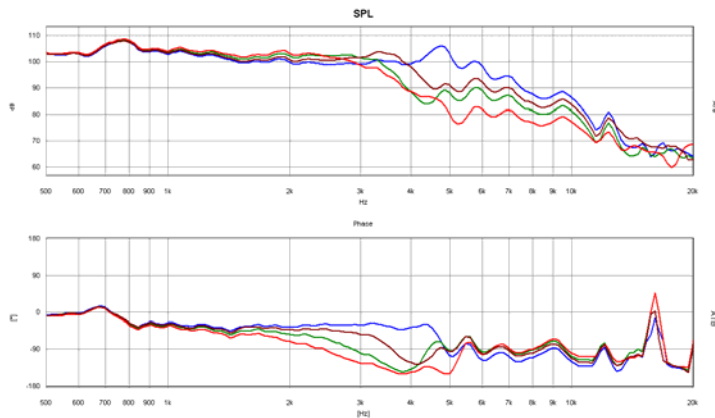
No L is blue, L=0.47mH green, L=0.82mH red, L=1.2mH brown. Important is an even run below 1kHz. L=0.82mH is chosen.



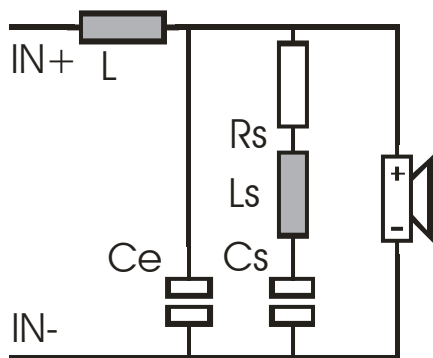
Pic. 3.16 Frequency responses of notch filter without R
Developing the crossover, when measuring the frequency response the phase also has to be measured. This is more important for the combination than any small non linearities of the frequency response. For the same frequency a notch filter circuit has different Q-factors depending on the chosen values for Ls and Cs. From the green to the blue curve the Q-factor increases.



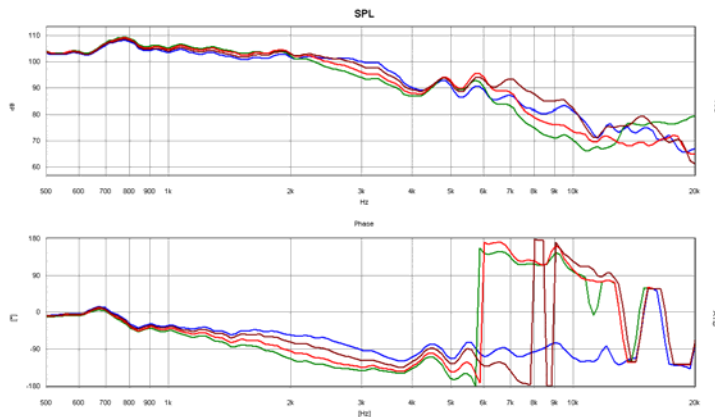
Pic. 3.17 Lowpass
The Q-factor of the notch filter circuit is also dependant on R_s .



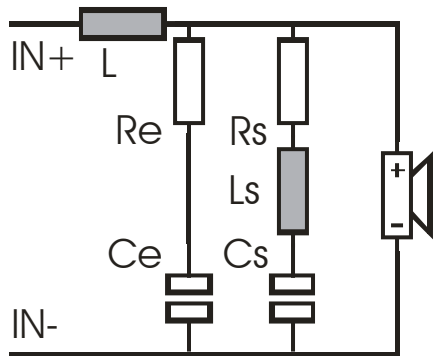
Pic. 3.18 Frequency responses in dependency of R_s
The curves show how the resistance R_s influences the frequency response. For this measurement $L_s=0.22\text{mH}$ and $C_s=5.5\text{mH}$. No notch filter is blue, $R_s=0$ red, $R_s=1\text{ohm}$ green, $R_s=4.7$ brown. Because of the lesser of phase shift $R_s=1\text{ohm}$ is chosen.



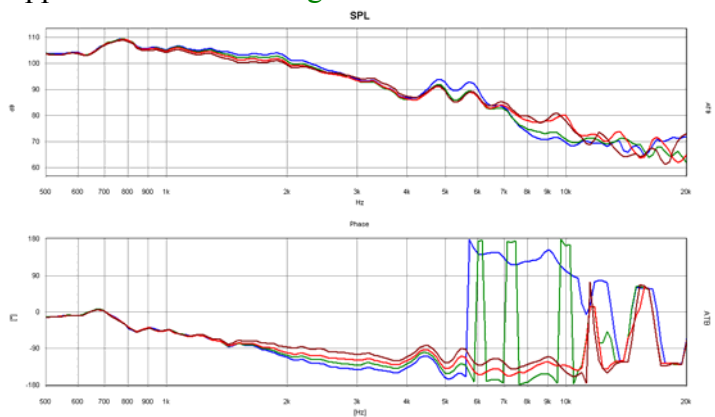
Pic. 3.19 Lowpass
With C_e the crossover becomes a 12dB/Oct crossover. But this is just to test C_e .



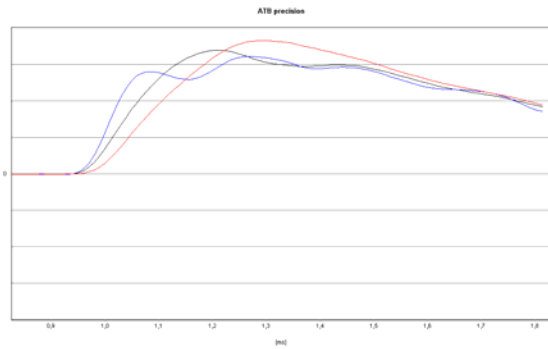
Pic. 3.20 Frequency response dependant on C_e
The capacitor C_e is supposed to achieve a higher suppression of the higher frequencies. But this only applies when $C_e=15\text{uf}$ green and $C_e=10\text{uf}$ red.



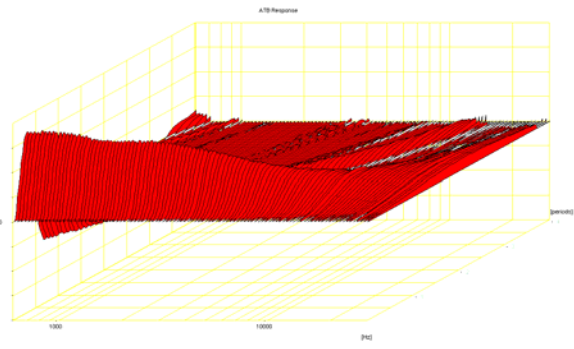
Pic. 3.21 Lowpass
Through R_e the crossover becomes a 6dB/Oct crossover with equalizer



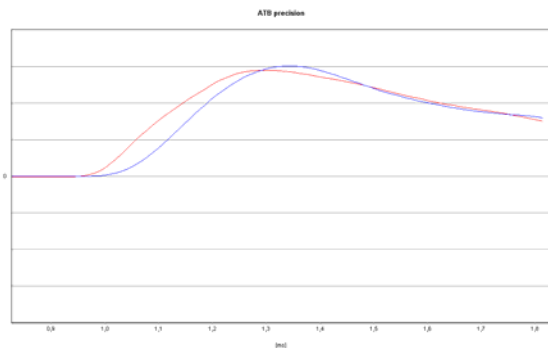
Pic. 3.22 Frequency responses dependant on R_e
 $R_e=0$ blue, $R_e=1\text{ohm}$ green, $R_e=2.2$ red, $R_e=4.7$ brown. Chosen $R_e=2.2\text{ohm}$.



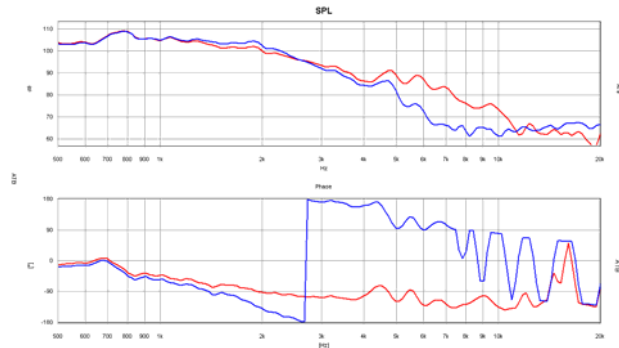
Pic. 3.23 Step response
The red curve shows the step response of the developed lowpass. Blue shows the woofer without notch filter and equalizer. Black is without the equalizer.



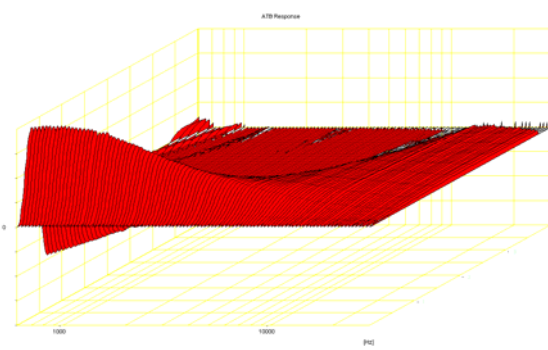
Pic. 3.24 Dynamic-Measurement
The measurement shows the woofer without notch filter and equalizer. The backward running mount of the membrane resonance is clearly visible.



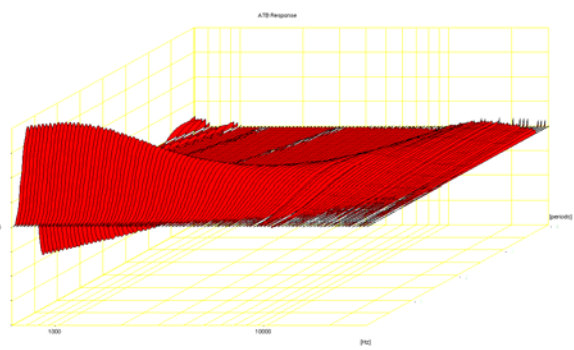
Pic. 3.25 Step response
Comparison between the developed crossover, red and the 18dB/Oct crossover blue, shows the shorter delay of the developed crossover.



Pic. 3.26 SPL und phase
The 18dB/Oct crossover has a sharper cut-off. Because of the strong phase shift of, 270°, the crossover is not suited for a correctly timed loudspeaker.



Pic. 3.27 Dynamic-Measurement
The measurement shows the good time behaviour of the developed lowpass. Also there is nothing to be seen of the membrane resonances of the speaker.

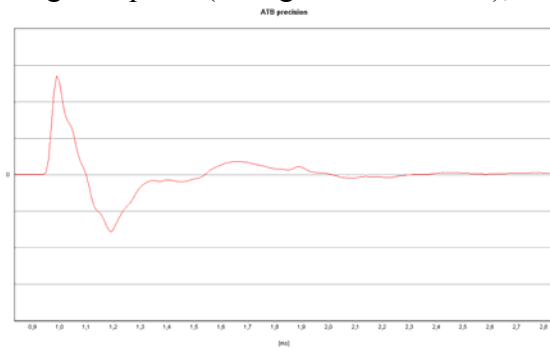


Pic. 3.28 Dynamic-Measurement
The measurement of the 18dB/Oct crossover shows a delay of the higher frequencies. This makes a correctly timed sound reproduction of the loudspeaker in combination with the tweeter impossible.

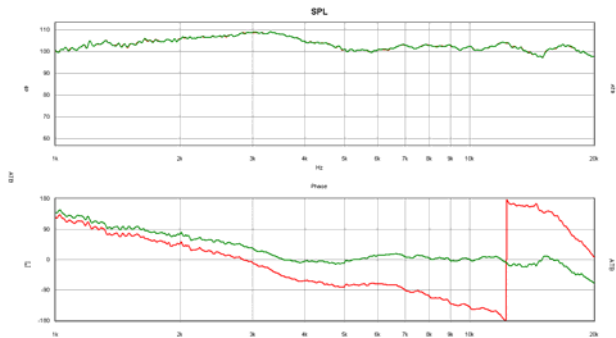
3.3 The acoustical center

Without crossover

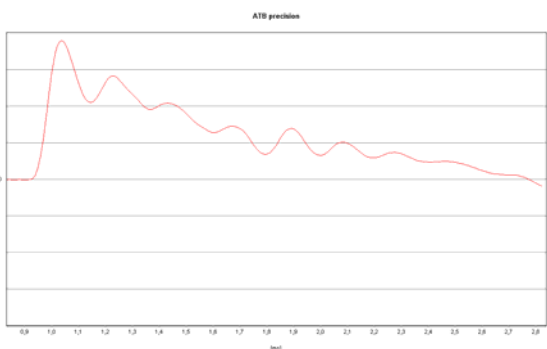
To build a loudspeaker box that is correctly timed, the phase positions of the speakers connected to the crossover have to be above one another. Here the acoustical center or sound emergence place (SEP germanic = SEO), is decisive.



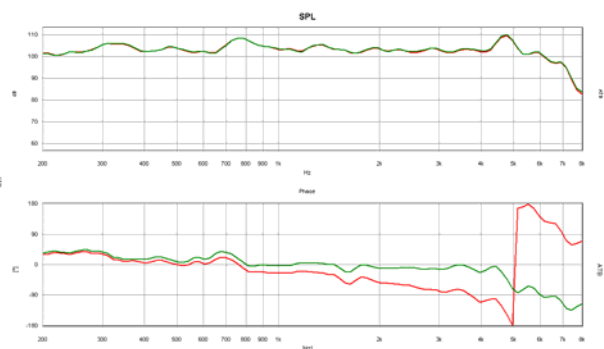
Pic. 3.29 Step response of the SC10N
The picture shows the step response for measurement of the distance between speaker and microphone. The measurement corresponds to the measurement of the Impulse response to determine distance. 32.5cm.



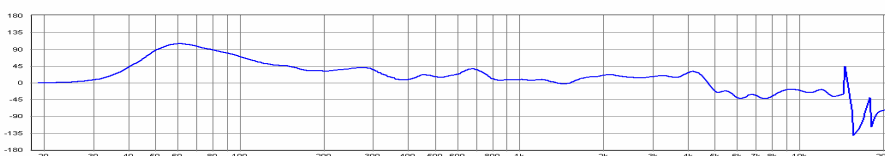
Pic. 3.30 Acoustical phase
Phase measurement corresponding with step response measured distance, 30.7cm, red curve. The green curve shows the distance to the Sound Emergence Place.



Pic. 3.31 Step response of W170S
The picture shows the step response for measurement of the distance between microphone and loudspeaker.



Pic. 3.32 Acoustical phase.
The red curve shows phase corresponding to distance of 39cm measured with the step response. The green curve corresponds to the Sound Emergence Place 41.5cm.



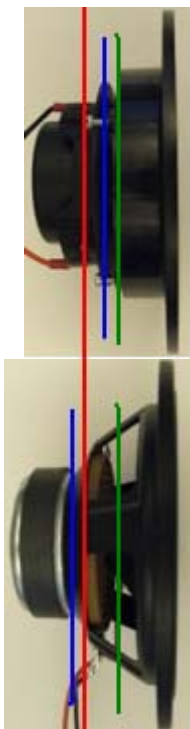
Pic. 3.33 Acoustical phase of W170S
The picture shows the acoustical phase of the W170S measured with the ATB PC Pro. The measurement program calculates the phase through correlation of the measured signal and measurement signal. Here the measurement result is independent of the measurement distance.
This means that all users receive the same results, making phase measurements comparable. The measurement corresponds to the revised distance phase measurement in picture 3.32, green curve.



Pic. 3.34 Measurement setup

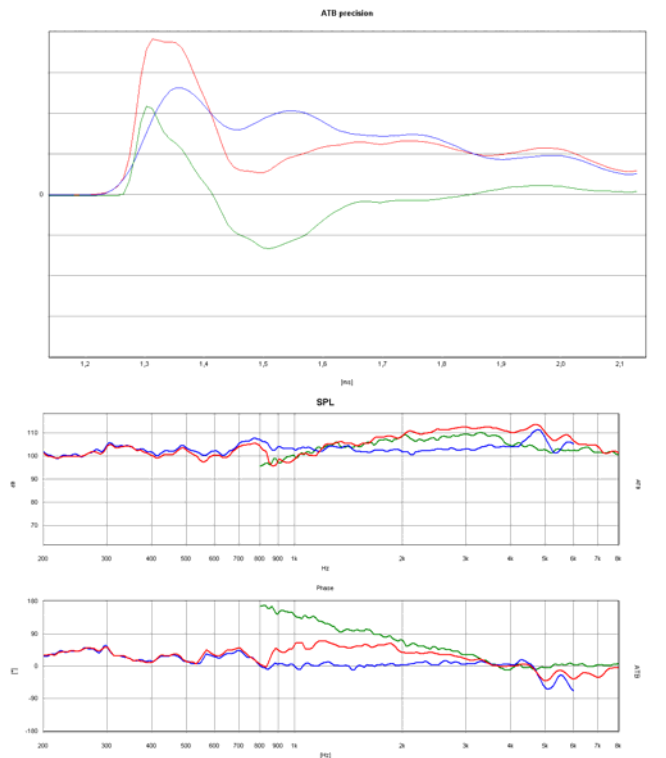
The picture shows the setup for the acoustical measurement of two loudspeakers. The microphone is positioned between tweeter and mid-low speaker. Experience has shown that in this position hearing experience and measurement results correlate. The position in front of the tweeter results in a nicer curve, but doesn't show the sound radiated to the room.

Without crossover



Pic. 3.35 Alignment

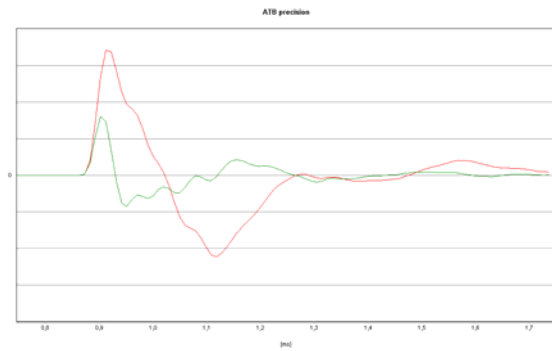
The lines show the decisive depths:
 blue=voice coil,
 green=distance according to impulse,
 red=Sound emergence place (SEP)



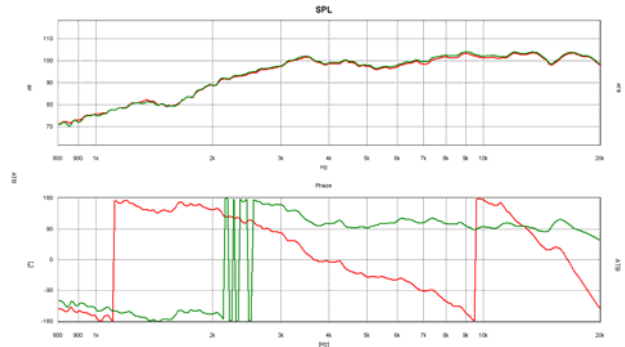
Pic. 3.36 Step response, SPL und Phase

Curve colours: green=tweeter, blue=mid-low speaker, red=addition.
 The step response shows that when the phase is correct the distances are not the same.

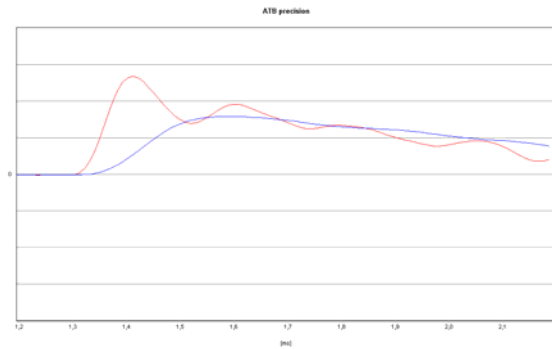
With crossover



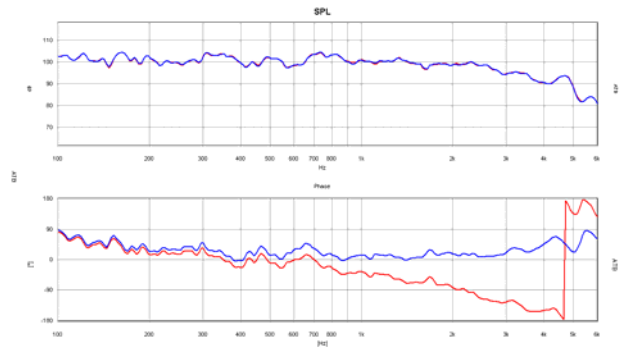
Pic. 3.37 Step response tweeter
The step responses show the same distance with or without crossover.



Pic.3.38 SPL und phase
The difference distances according to step response and with correction in correlation with the phase is 2.8cm.



Pic. 3.39 Step response mid-low speaker
For the woofer a slight time difference due to the crossover is to be seen.

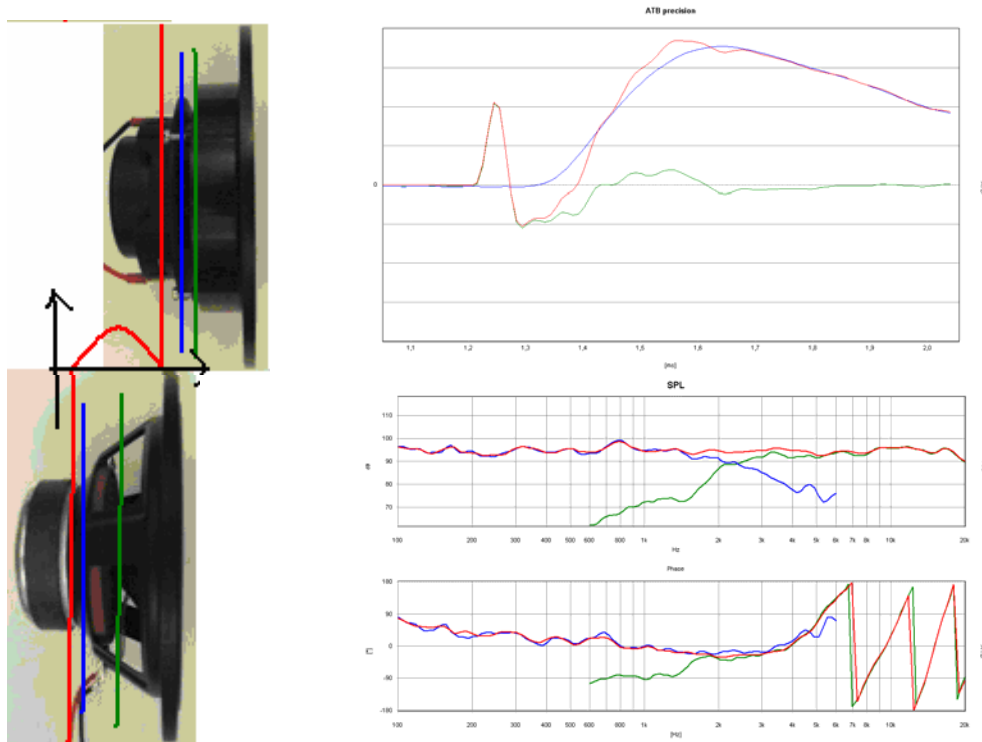


Pic. 3.40 SPL und phase
The difference of distance between step response and corrected phase is 4.5cm.

The speaker combination

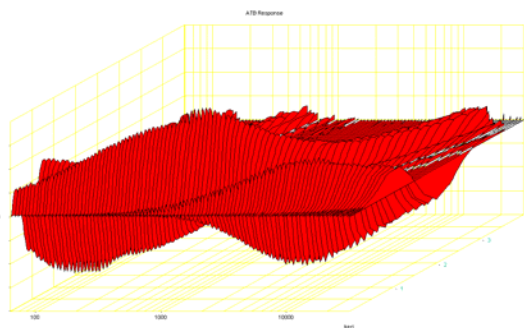
Both speakers are connected with the same poling. So that phases fit to each other, the tweeter is moved forward. The distance is a half wave length of the crossover frequency. This is calculated as follows:

$$340\text{m/sec} \times \text{sec} / (2500 \times 2) = 0,068\text{m} = 6,8\text{cm}$$

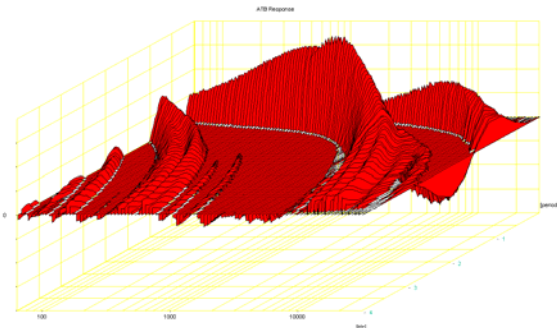


Pic. 3.41 Alignment
For this alignment the tweeter is far in front. Nearly all bassreflex speakers with soft domes are built like this.

Pic. 3.42 SPL und phase
The step response shows that signal from the tweeter is far in front of that of the mid-low speaker. As such both signals layover each other without obstruction. The phase is strongly forward running. The speaker is not correctly timed.



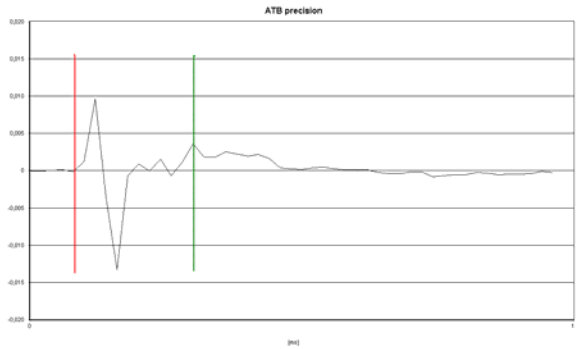
Pic. 3.43 Dynamic-Measurement
The picture shows the point in time a certain signal with a certain frequency emerges. At the front the high frequency signal and at the back of that, that of the mid-low speaker. Both signals are separated in time.



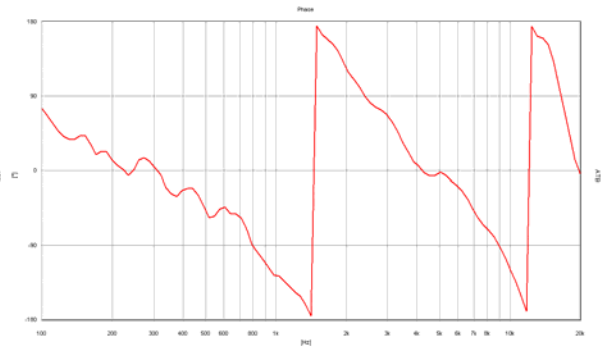
Pic. 3.44 Dynamic-Measurement
The backward view shows the swing-out behaviour. Here the chopped up signals are nicely shown. With this speaker alignment the high frequency range has own life.

Phase measurement with MLS Measurement systems

This simple loudspeaker combination is a good example for phase measurements using an MLS measurement system. The distance is laid down with use of the step response measurement.

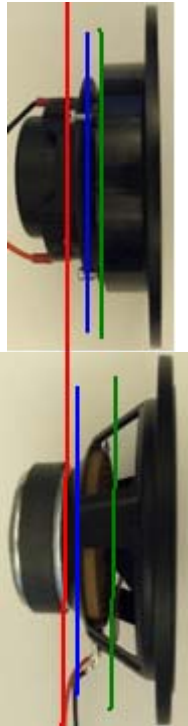


Pic. 3.45 Impulse response
The window for the measurement evaluation has to begin at the red line. For the correct evaluation of the phase the window has to begin at the green line. That though is not possible.

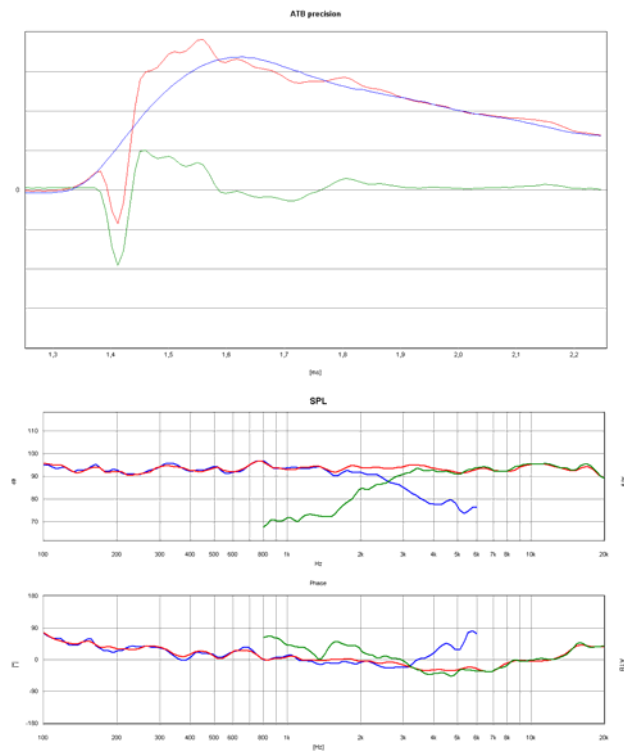


Pic. 3.46 Acoustical phase
The acoustical phase of the speaker. As the correct distance for evaluation can't be setup the measurement has no relevance.

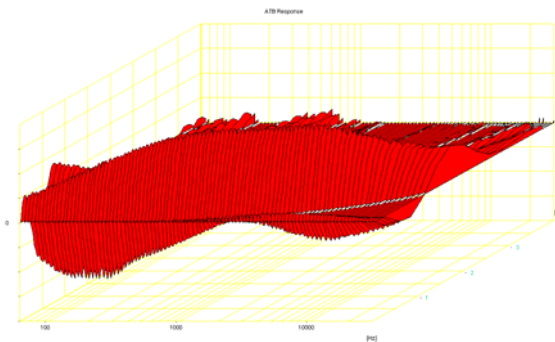
3.4 The correctly timed Loudspeaker



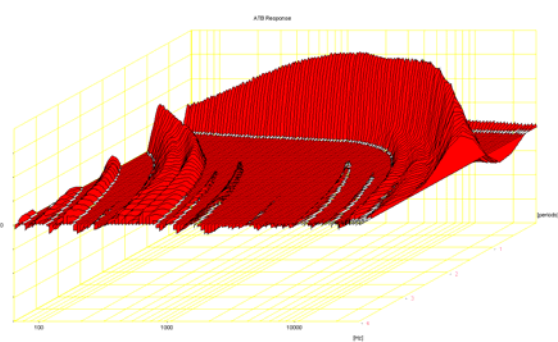
Pic. 3.47 Alignment
The lines show the describe depths
blue=voice coil,
Green=distance of corresponding impulse
red=sound emergence place (SEP).



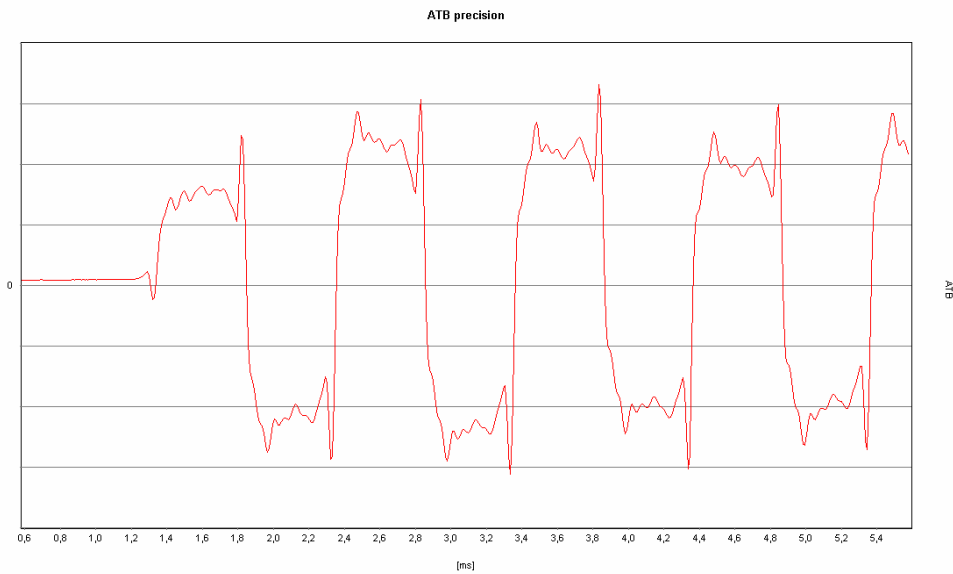
Pic. 3.48 SPL und phase
Curve colours: green=tweeter, blue=
mid-low speaker, red=addition.
The step response shows the good layover of
the single signals. The tweeter is anti poled. The
phases are close together in the crossover area.



Pic. 3.49 Dynamic-Measurement
For the correctly timed loudspeaker a in
general even mount for all frequencies is
shown. The tones are created and heard
simultaneously.



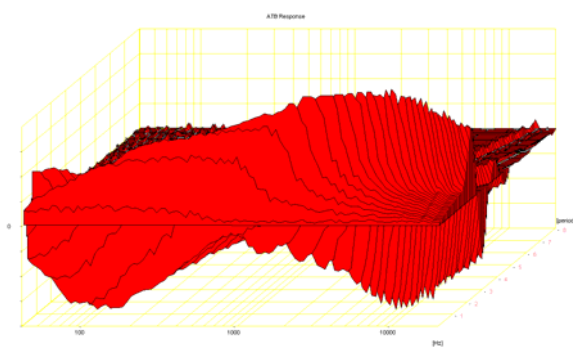
Pic. 3.50 Dynamic-Measurement
Also the backward view of the measurement
shows exact reproduction. The backward
running mount in the low frequencies is
sound coming from the bassreflex opening.



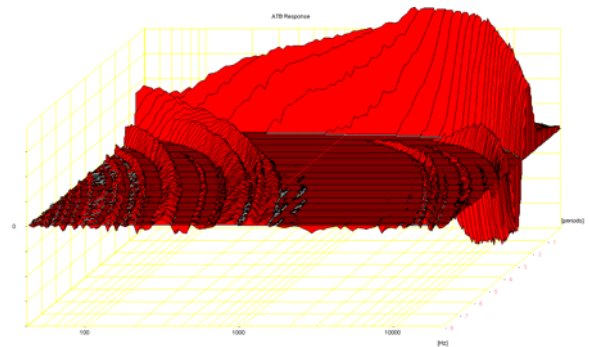
Pic. 3.51 Square wave behaviour at the frequency 1kHz
 As you would expect for correctly timed loudspeaker, the developed speaker has a good square wave behaviour.



Pic. 3.52 Analog on "Richtig" (= right)
 The Loudspeaker Analog on "Richtig" is the loudspeaker with the as absolute contemplated time behaviour. In contrary to the described loudspeaker the Dynamic-Measurement 3D measurement, viewed from in front, has just an even mount across the whole frequency range. For the Richtig the speakers are poled the same. The light advantages of the Richtig concerning the room imaging detail capabilities might just have something to do with the 5 times more expensive mid-low speaker. That speaker can be found also the most expensive high-end studio monitors.



Pic. 3.53 Dynamic-Measurement



Pic. 3.54 Dynamic-Measurement

4. The Loudspeaker V-Monitor



Technology: 2-way correctly timed ported.
Speakers: 25mm fabric soft dome with Waveguide
17cm (6.5inch) mid-low woofer with coated
paper membrane.

Power handling: 50W sinus, 100W music

Impedance: 4ohm

Frequency response: 50Hz – 20kHz

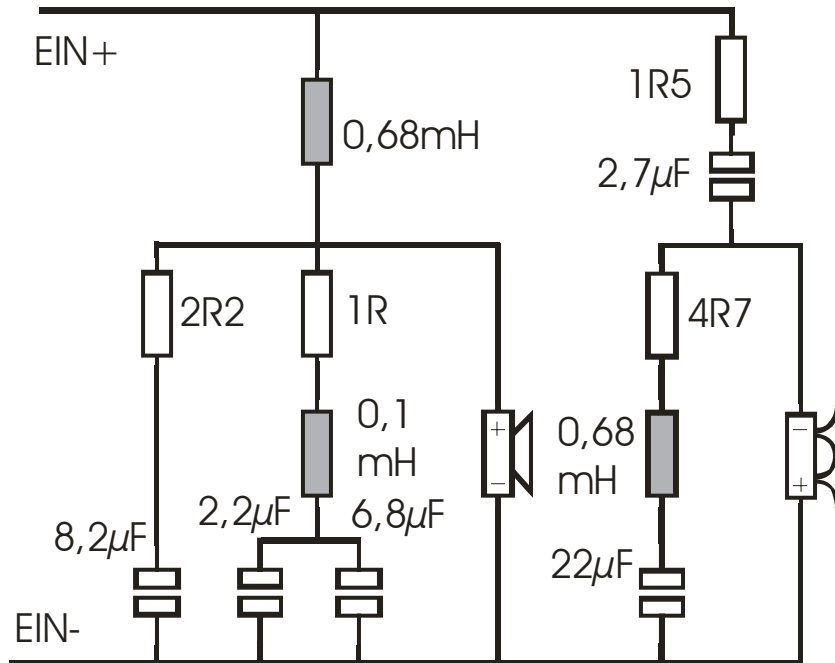
Sensitivity: 87dB 1W/1m

Dimensions: H=41cm, W=23cm, D=32cm.

Pic. 4.1 V-Monitor

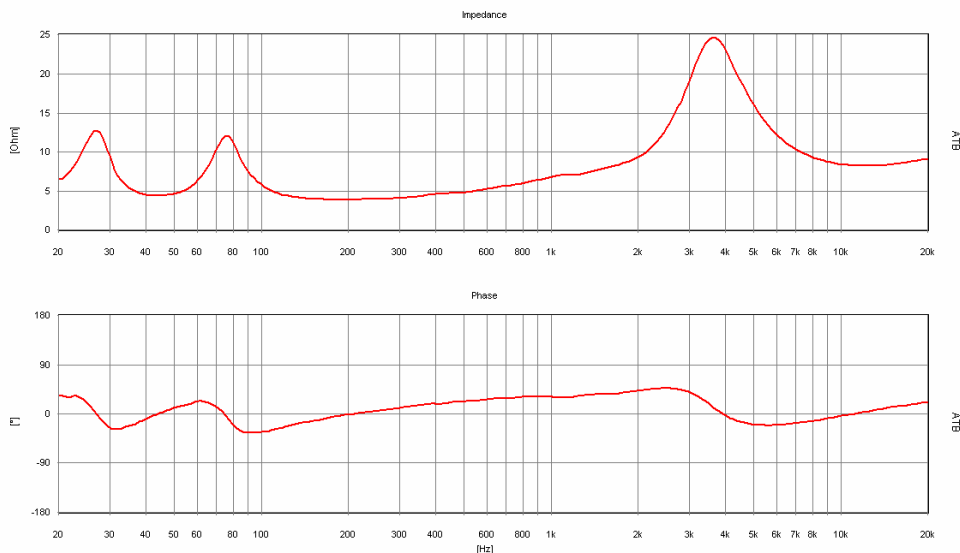
4.1 The crossover circuit diagram

Visaton W170S/4, SC10N,
Monacor WG-300,



Pic. 4.2 The crossover circuit diagram of the V-Monitor

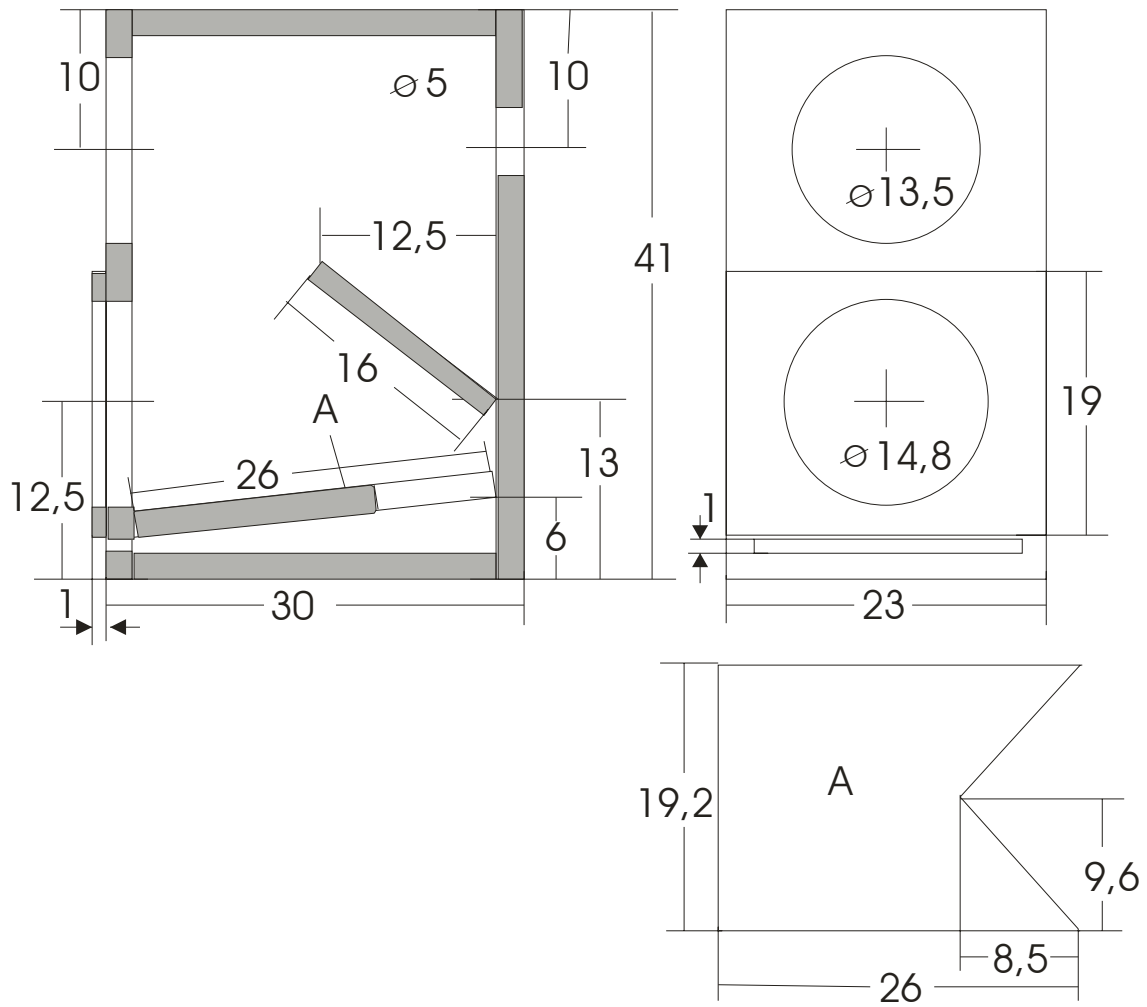
The crossover was developed by constant change between hearing and measuring. The test listeners are customers of the Analog.on Studios. Our customers have such high expectancies on the sound reproduction impression, that they are not satisfied with products offered in HiFi shops. The really good loudspeakers are too expensive for them to be able to buy. For over 3 months the crossover was filed on.



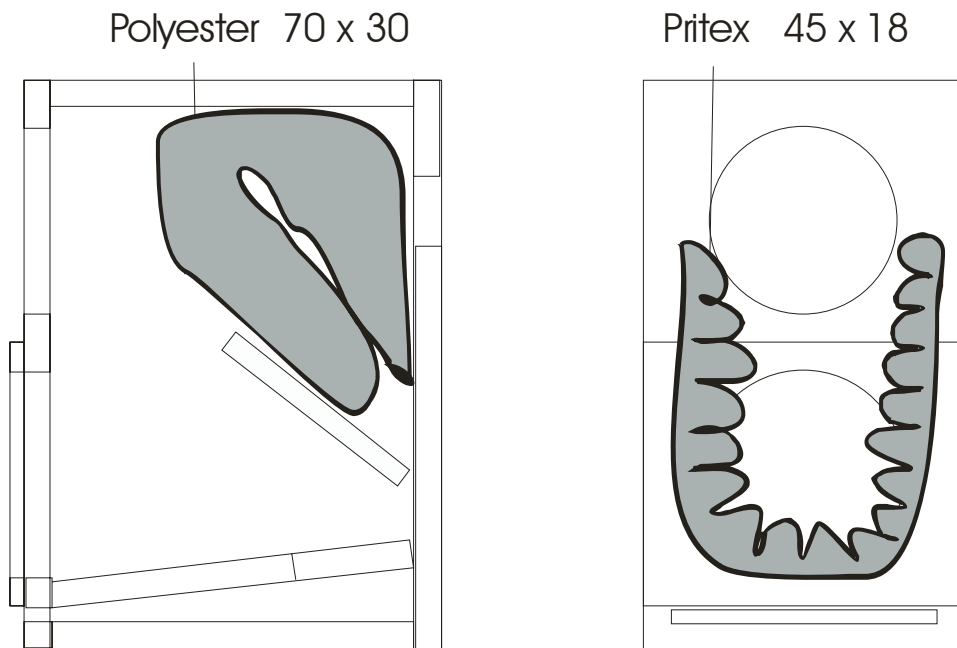
Pic. 4.3 Impedance and phase

Because of the easy drive ability characteristic of the impedance and phase of the loudspeaker, it's also well suited for more simple kinds of amplifiers.

4.2 The construction plan



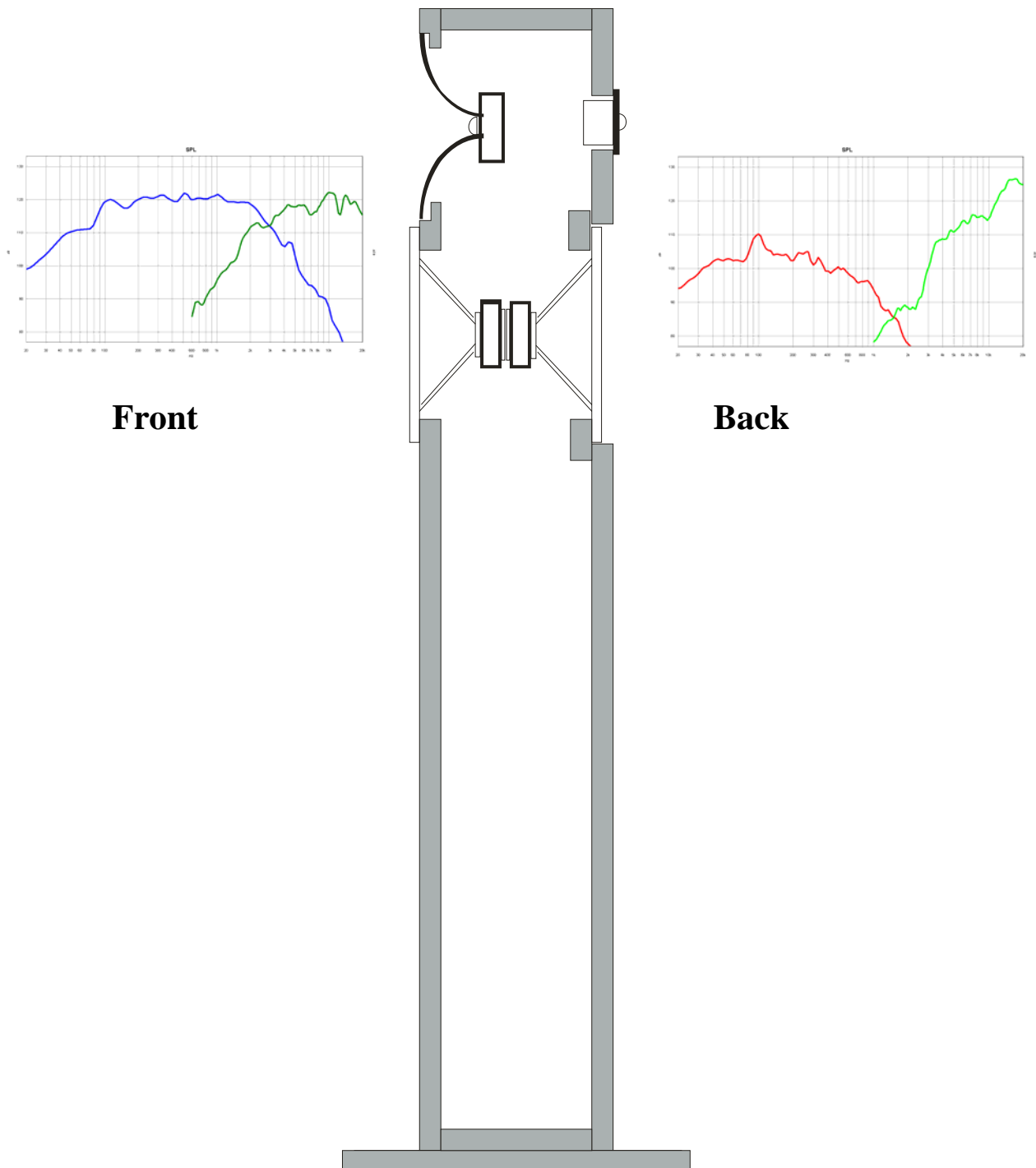
Pic. 4.4 Construction plan of the cabinet



Pic. 4.5 Dampening plan

5. The unique technology

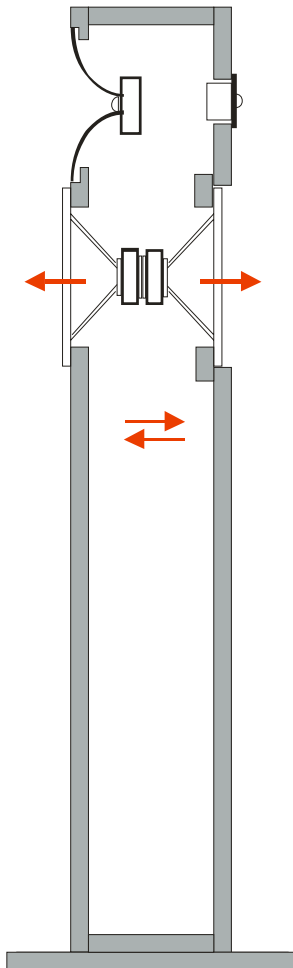
5.1 Sound radiation behaviour



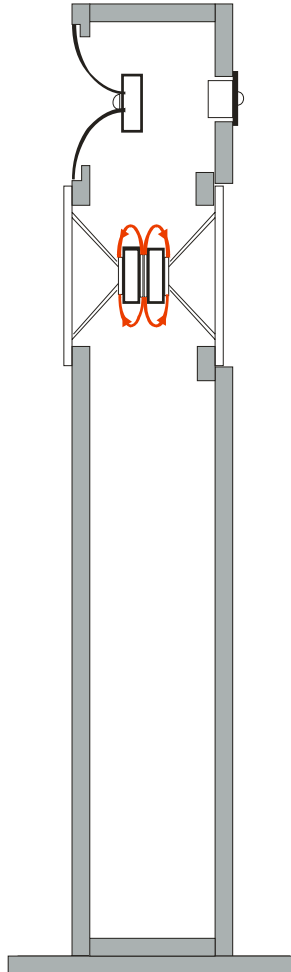
Pic. 5.1 The loudspeaker OK² and its sound radiation character

The pre-runner Analog.on OK has been sold hundred fold since 12 years. There are no unsatisfied customers, as the natural sound reproduction impression is felt as being very close to the original source. Also discussions about amplifiers, cables and spikes are seldom amongst OK customers. Even after 12 years the OK customers still swear on their loudspeakers. The OK² is a new development that takes over the concept and design of the OK loudspeaker.

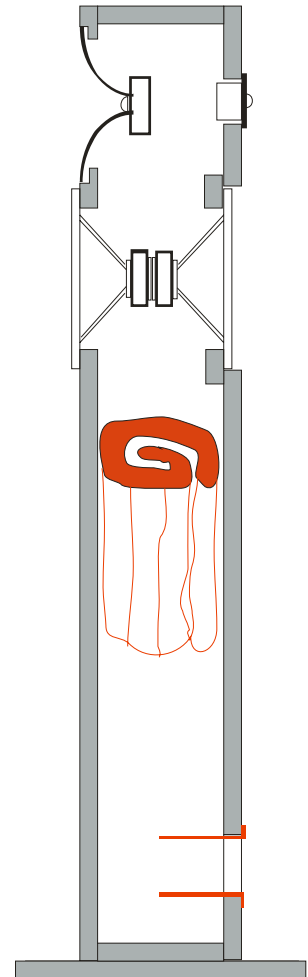
5.2 The speaker position alignment



Pic. 5.2 Forces
The opposite woofers put opposite forces on the cabinet. The forces deplete each other and the casing stands still.

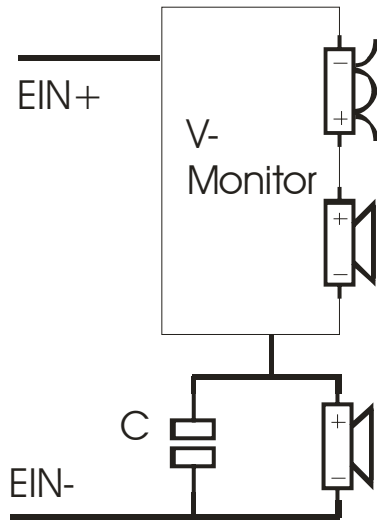


Pic. 5.3 Magnets
The magnets are close together and amplify each other. Also resulting in a smaller magnetic radiation feind.

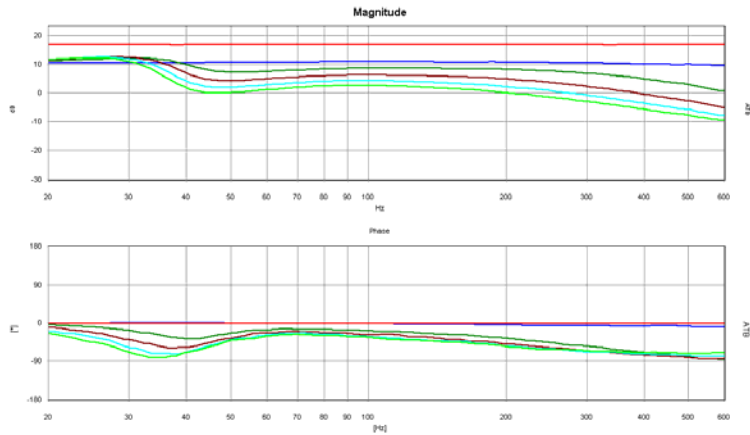


Pic. 5.4 Variovent
In the middle of the box there's an air-motion resistor, Variovent. This doubles the effective enclosure volume.

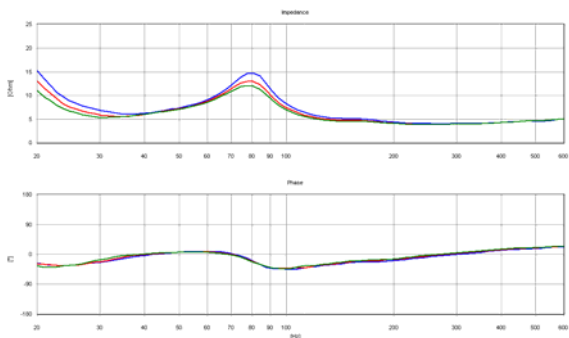
5.3 The built in subwoofer



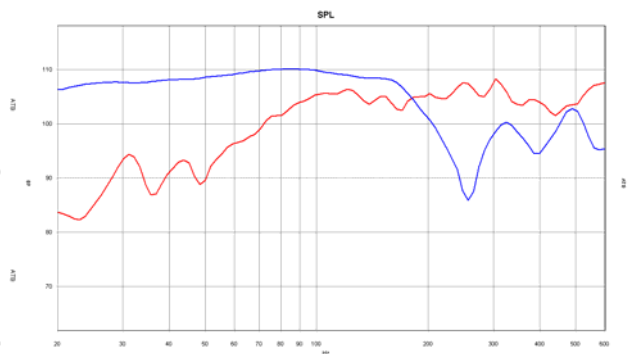
Pic. 5.5 Serial crossover
The rear bass is cut off from the mid-high tone range using a series crossover. This crossover has the least turn of phase.



Pic. 5.6 Voltage across the subwoofer
The red curve shows the output voltage of the amplifier. The other curves show the voltage across the subwoofer. Without a crossover the voltage is halved. Both speakers receive the same signal, blue curve. The other curves show different values for the capacitor C.



Pic. 5.7 Impedance with phase
The impedance curves show different values for C. An alignment can be setup with C.



Pic. 5.8 SPL in near field
The addition curve in near field between the woofers has the characteristic of speaker that's low frequency range doesn't get annoying even in difficult hearing rooms. The blue curve shows the sound pressure level of the port which evenly amplifies the low frequency range.

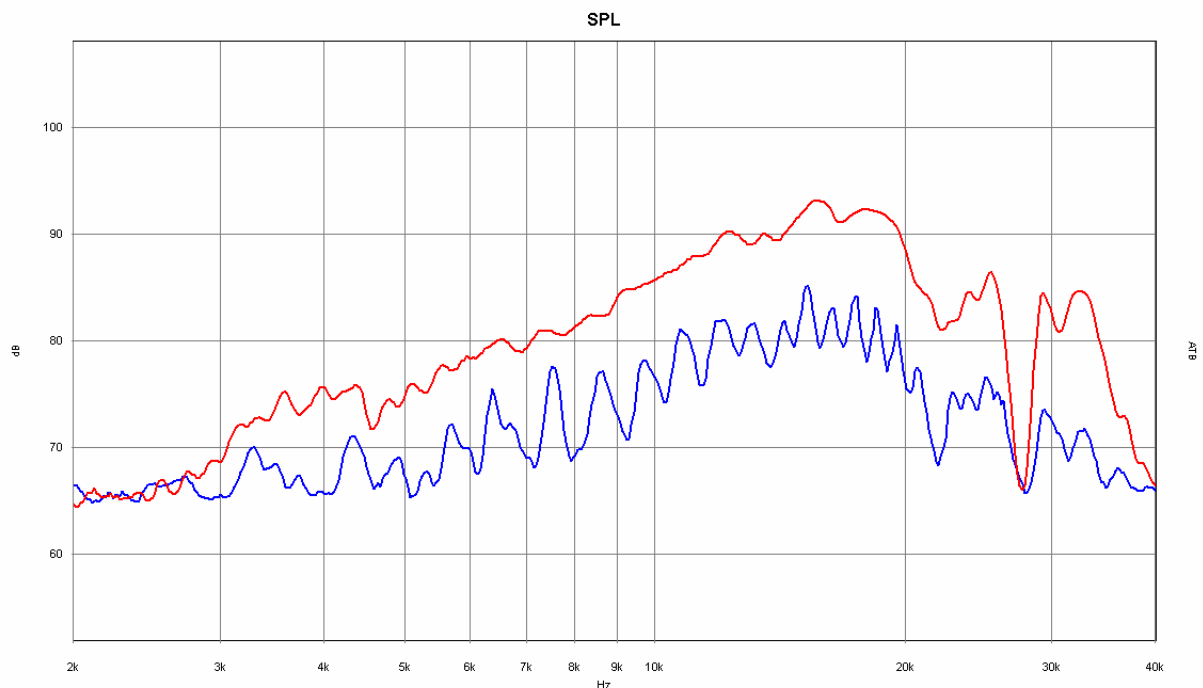
5.4 The rear tweeter



Technical data:

10mm Polycarbonate-dome	
Magnetically shielded	
Nominal power handling	60W
Maximal power handling	100W
Impedance	8Ω
Frequency response	1500Hz –22000Hz
Sensitivity	90dB (1W/1m)
Resonance frequency	2500Hz
Magnetic induction	0,7T

Pic. 5.9 The super high frequency tweeter SC5



Pic. 5.10 SPL of SC5 with crossover

The **red** curve shows the frequency response of the SC5. With its high roll-off frequency of 35kHz it belongs to the super high frequency tweeters for DVD Audio. The **blue** curve shows the reflexion from a plastered brick wall. The rear tweeter increases the high frequency energy transmitted to the listening room. Although not heard directly, it separates the sound radiation impression from the speakers. Instruments are imaged free in space and have a precise stage placement.

The tweeter is connected over a 6dB/Oct crossover. Due to the small turn of phase interferences with the front tweeter are reduced.



Pic. 5.11 Measurement microphone MC1

For the SPL Measurement up to 40kHz the microphone MC1 that comes with ATB PC measurement system is well suited.

6. The loudspeaker Analog.on OK²



Technical data: 2¹/₂-Way correctly timed ported
Speakers: 25mm fabric soft dome with Waveguide
10mm polycarbonate super high tweeter
17cm (6.5inch) mid-low woofer with
coated paper membrane.

Power handling: 100W sinus, 200W music

Impedance: 6ohm

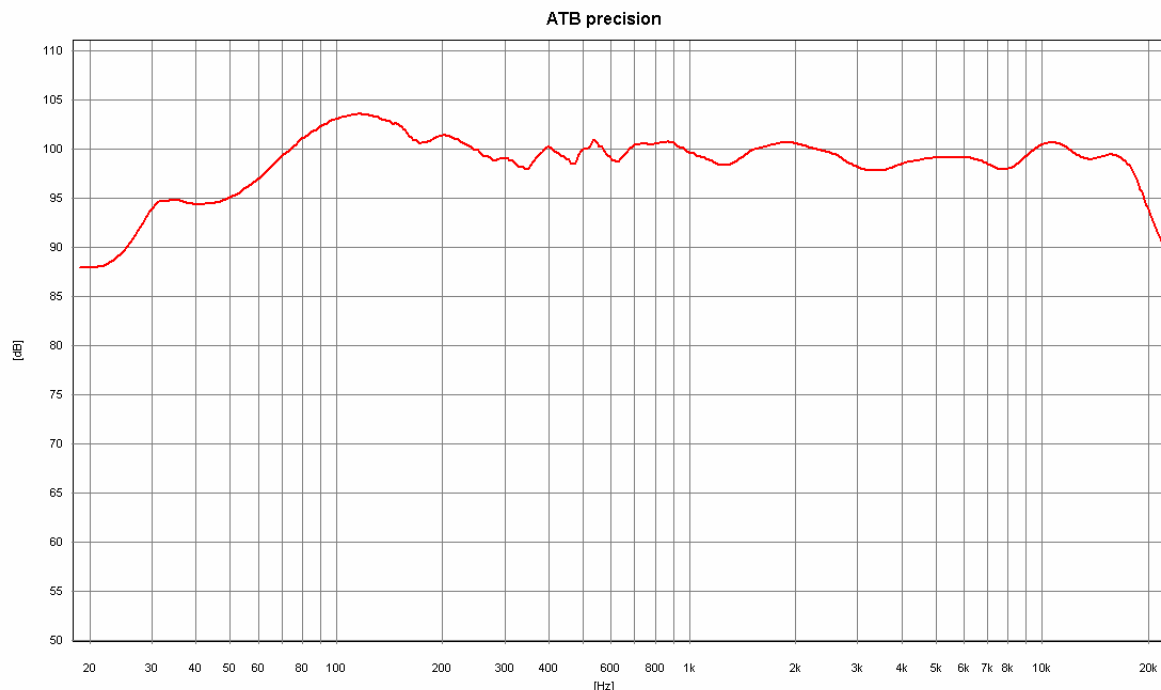
Sensitivity: 87dB 1W/1m

Dimensions: H=102cm, W=20.5cm, D=17cm

Base plate: W=30.5cm, D=27cm

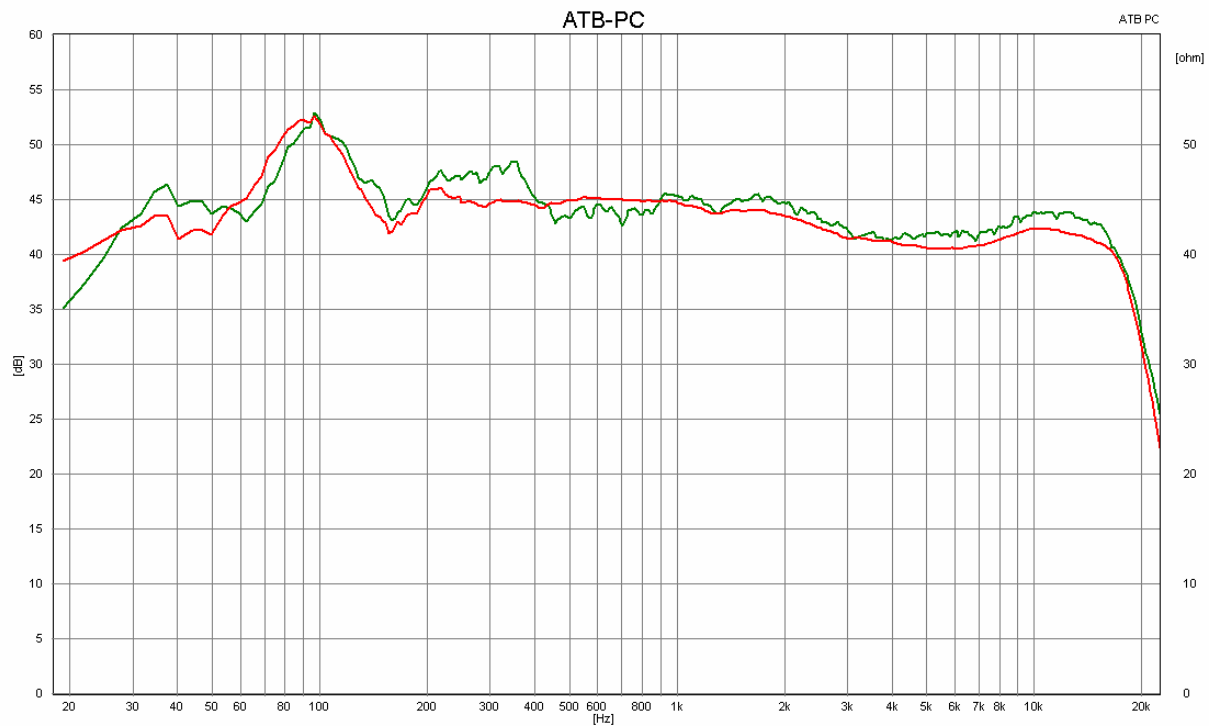
Pic. 6.1 The loudspeaker OK² front and back view

6.1 The frequency response



Pic. 6.2 SPL of the OK² measured under laboratory conditions

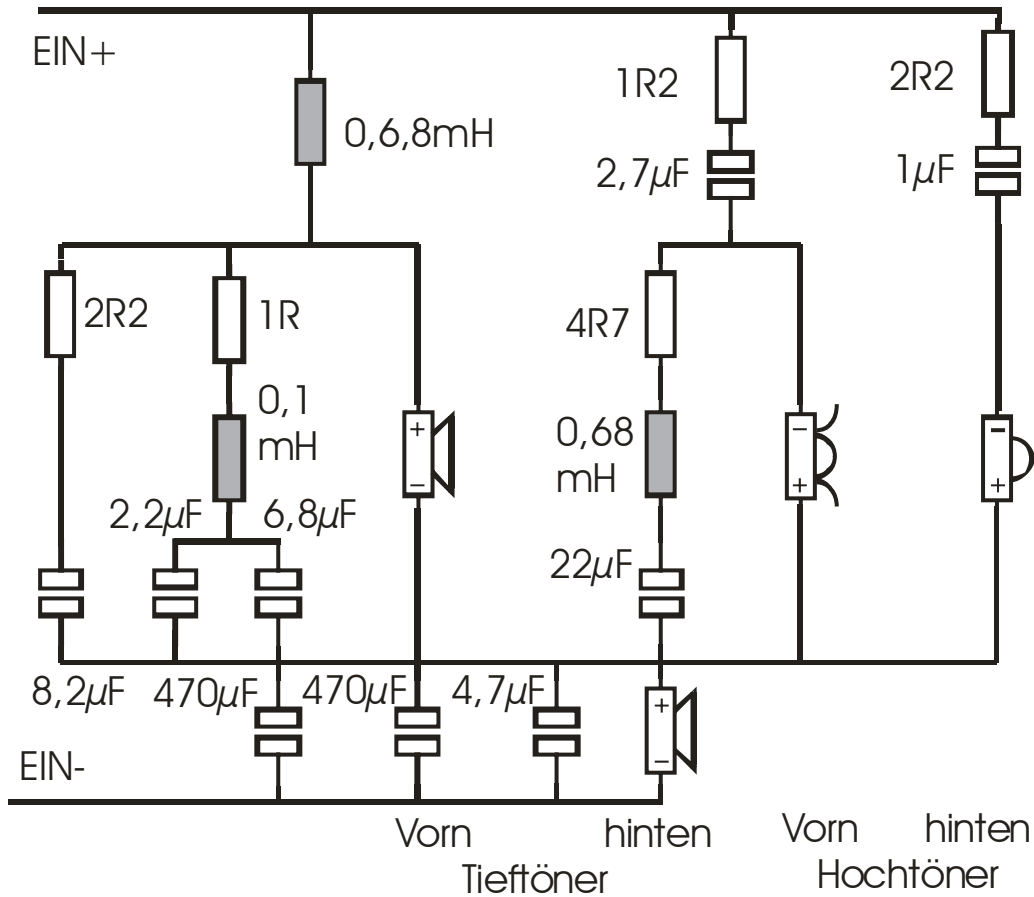
6.2 Der frequency response in room



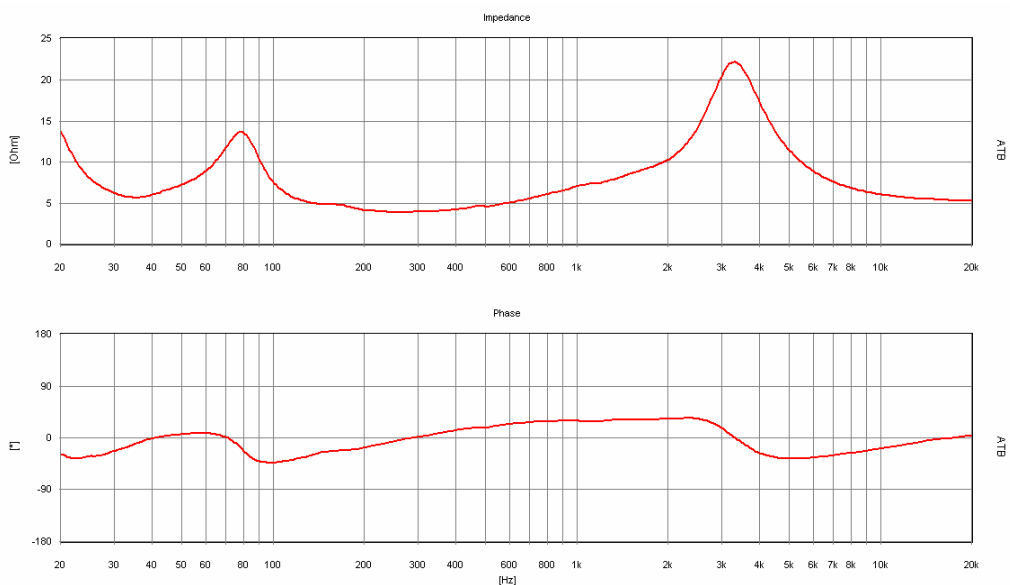
Pic. 6.3 SPL of the OK² measured in room with the ATB PC Measurement system
The loudspeaker position in our listening room is approximately 22cm from the back wall and 95cm from the side wall. The red curve shows the averaged frequency response measured at the hearing point to demonstrate the room characteristic. If at all, an equalizer should be set according to this measurement result. The OK² transmits the whole audible frequency range very evenly.

6.3 The crossover circuit diagram

Visaton 2 x W170S/4, SC10N,
Monacor WG-300, 10mm Hochtonkalotte



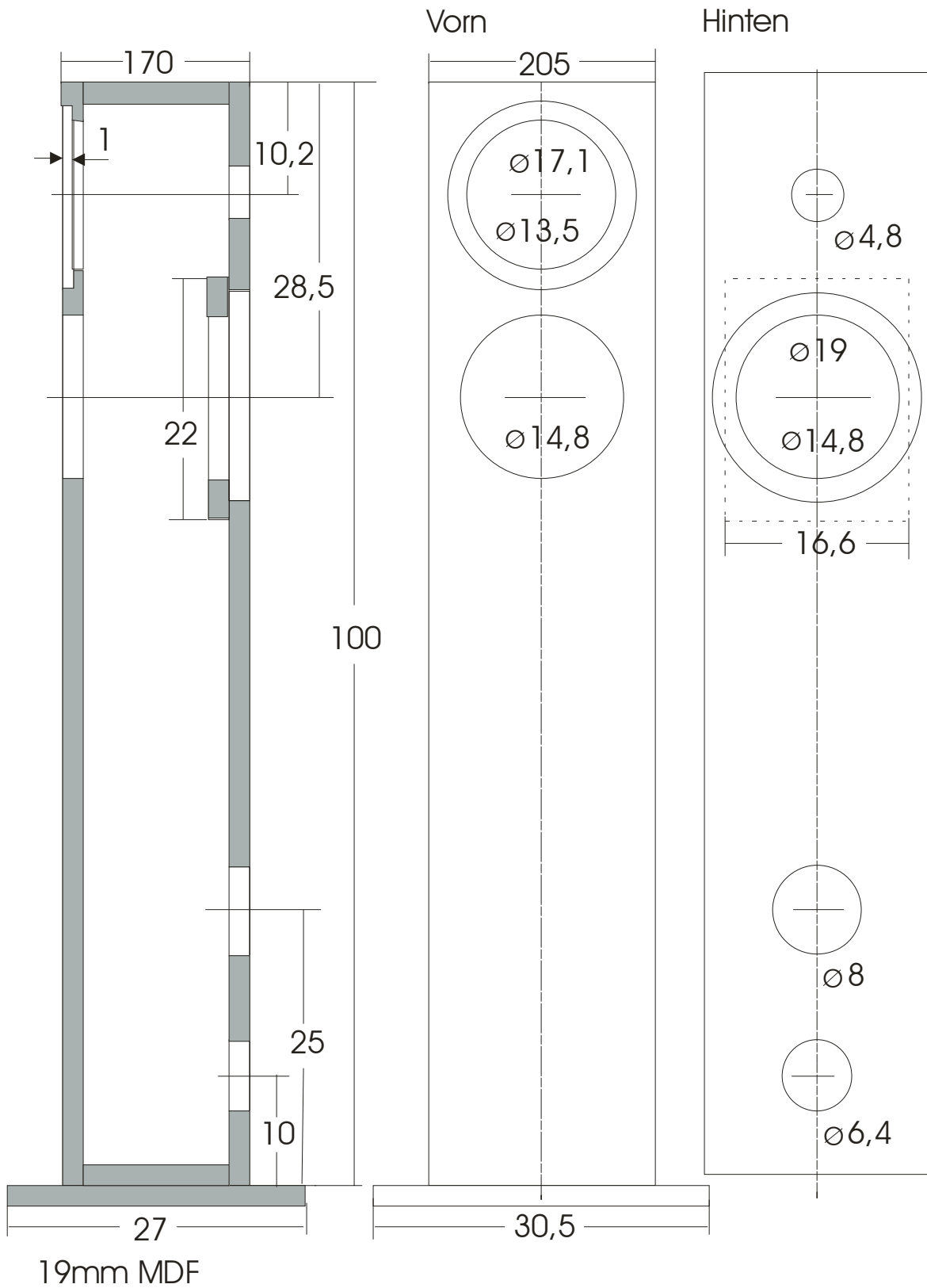
Pic. 6.4 The crossover of the OK²



Pic. 6.5 Impedance with phase of the OK²

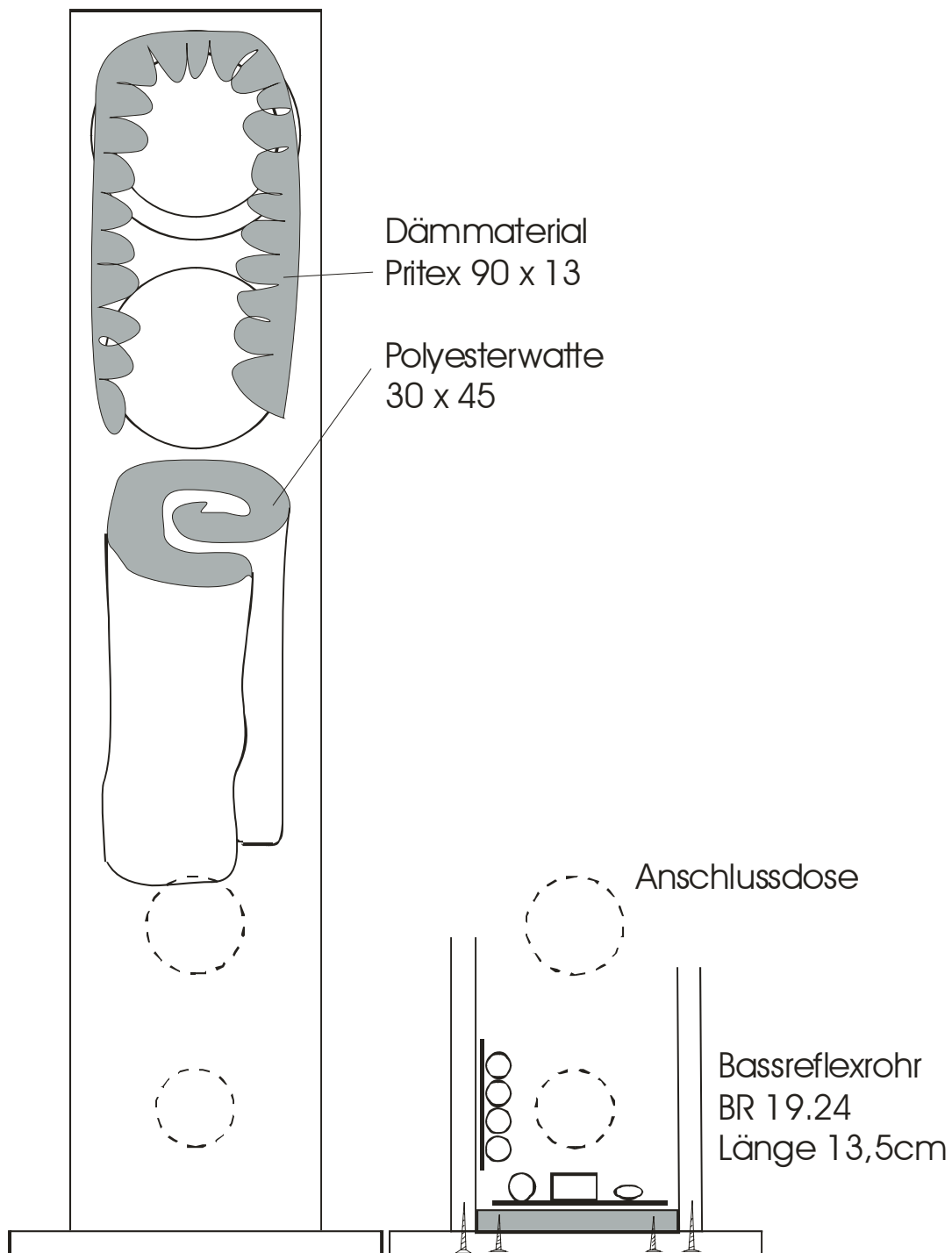
The Impedance shows a 6Ω loudspeaker, so that no sound quality reduction is to be expected even in combination with a surround receiver.

6.4 The construction plan



Pic. 6.6 Construction plan of the OK²

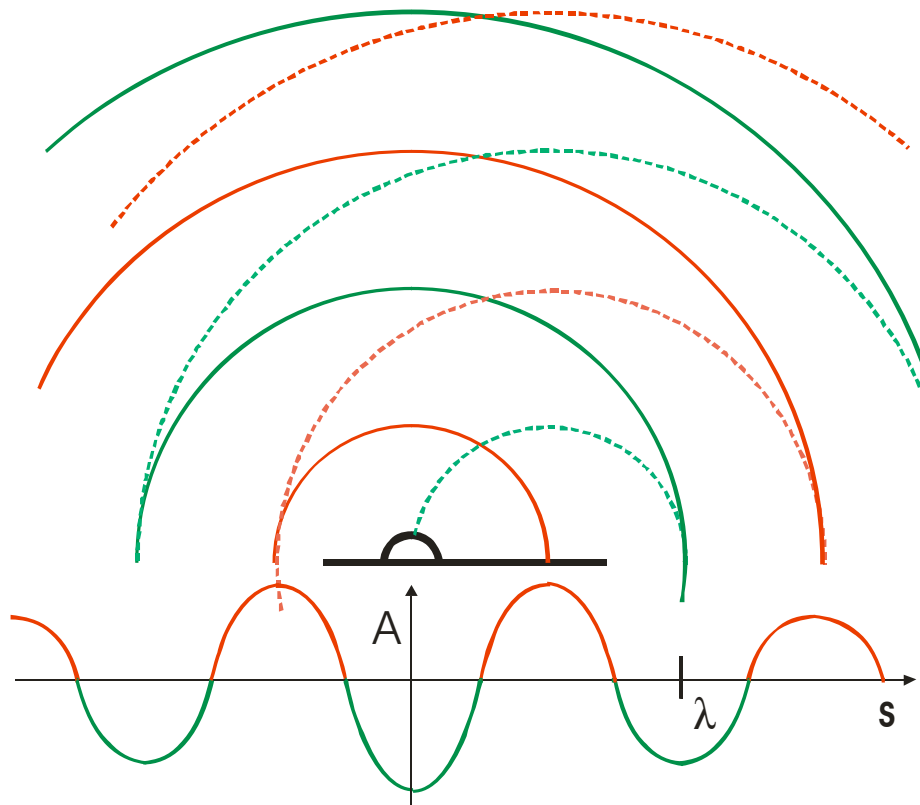
The damping plan



Pic. 6.7 Damping plan of the OK²

W1 Comparison of the sound radiation of sound baffle and Waveguide

W1.1 The phantom or secondary sound source



Pic. 1.1 Sound field

The picture shows the sound field of an omnidirectional radiating soft dome loudspeaker on a sound baffle. The circular lines show the sound field as a snapshot of the stable state. The red lines show an over pressure or positive amplitude and the green line an under pressure or negative amplitude. The full lines show the primary and the dotted lines the secondary sound sources. In the lower area the oscillogram of the sine signal is shown, on the Y-axis the amplitude and on the X-axis the time. Over the speed of sound, $c=340\text{m/sec}$, the length of a sine wave in the air, the wave length is λ calculated. Which is dependant on the frequency f . Correspondingly the wave length is:

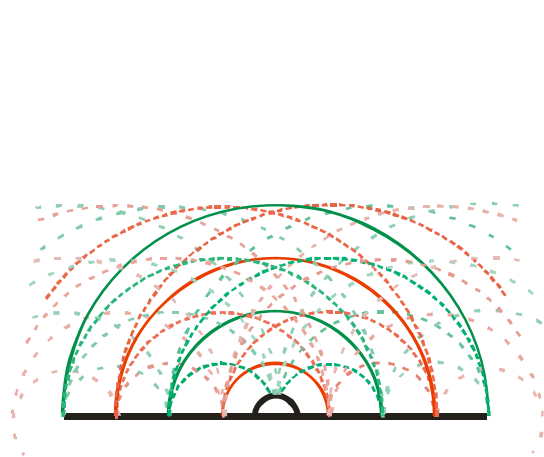
$$\lambda = c * f = (340\text{m/sec}) / (f / \text{sec}) = 340\text{m} / f$$

The wave length λ is the decisive factor when looking into sound spreading in enclosures, rooms and on sound baffles.

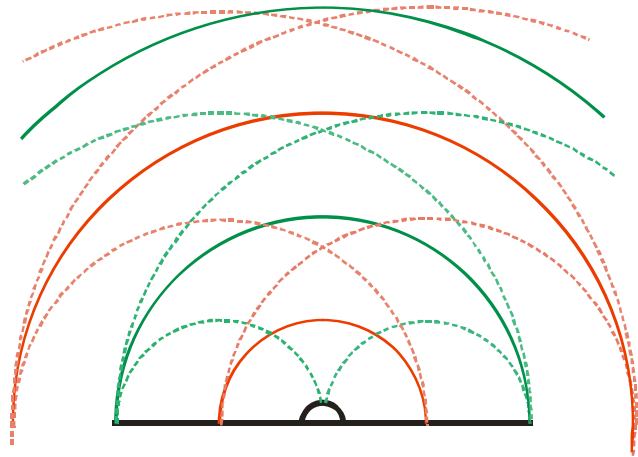
To explain phantom or secondary sound sources the sound baffle is constructed as such that the secondary sound source only appears on the right-hand side. Here the primary sound wave hits the sound baffle and is reflected. With that a new, the secondary sound wave, is created. It has lower amplitude so that by overlay of both signals a part of the primary sound wave is still there. On the left-hand side no secondary wave is created.

W1.2 The Baffle Step

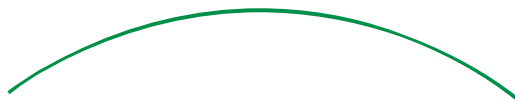
The following pictures show the sound behaviour for different frequencies on a sound baffle.



Pic. 2.1 $\lambda < D$



Pic. 2.2 $\lambda = \frac{1}{2} D$



Pic. 2.3 $\lambda = D$



Pic. 2.4 $\lambda > D$

For Pic. 2.1 is the wave length $\lambda < D$, $D =$ sound baffle dimension.

The overlay of the primary signal with the secondary signal looked at from the loudspeaker axis result in an even overlay. The sound pressure level is reduced, but even over a broad frequency range. This alignment results in the most even frequency response when measuring with a norm sound baffle.

For Pic. 2.2 λ is $= \frac{1}{2} D$.

Here the primary sound wave overlays with 2 secondary sound sources. The greatest influence of the sound baffle is to be seen and there is when measuring the sound pressure level on axis a large breakdown in the frequency response.

For Pic. 2.3 λ is $= D$.

For this frequency range no secondary sound source appears. Measured on axis the run of the sound pressure level is higher.

For Pic. 2.4 λ is $> D$.

At this low frequency the sound radiation goes from the half sphere room, 2π , into the full sphere room, 4π . The Baffle Step appears and the sound pressure level falls with 6dB for lower frequencies.

W1.3 Proof of the secondary sound sources

The pictures in capital 2 show the theory. Here the theory is proven with measurement technology. For Pic. 2.2 with λ is $=\frac{1}{2}D$ the greatest depletion of primary and secondary sound source is to be expected. The run of sound pressure level for this λ at the frequency f , $f = 1/\lambda$ shows the largest breakdown.

So that the proof isn't just a result of a measurement mistake, the measurement is performed on 3 different sound baffles. Measurement is performed on round sound baffles, as they have the same geometry at all sides.

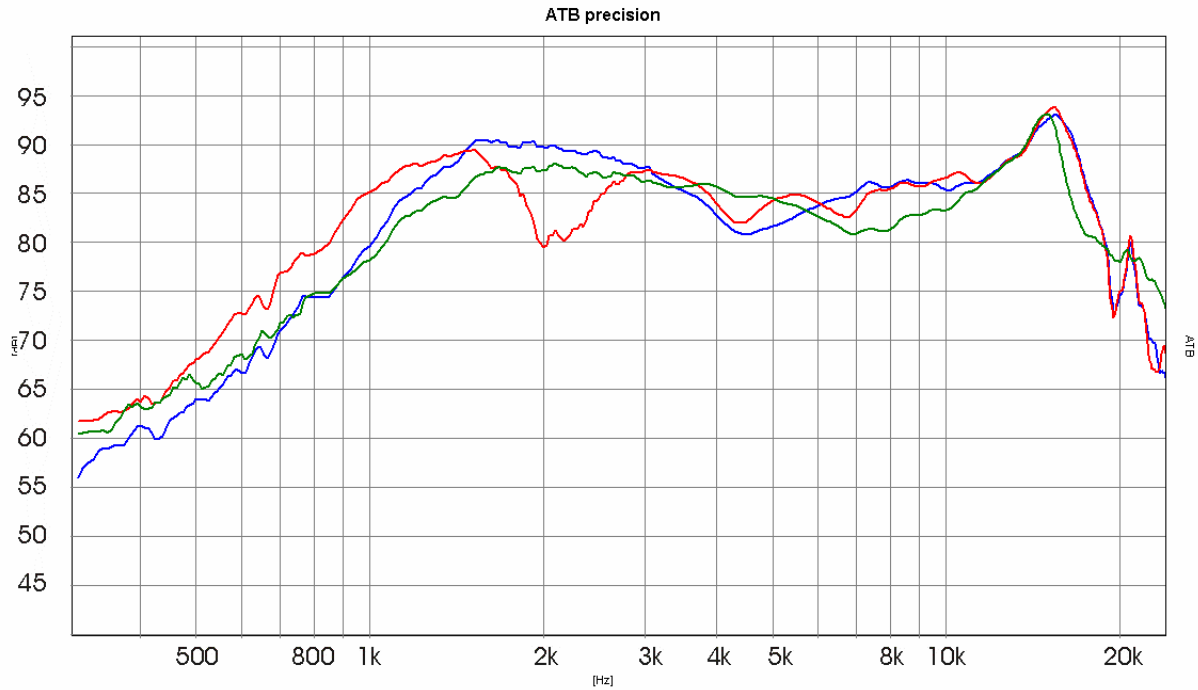


Pic. 3.1 Sound baffle with $D = 8$ Pic. 3.2 Sound baffle with $D = 13$ Pic. 3.3 Sound baffle with $D = 27$



Pic. 3.4 Measurement setup

Pic. 3.4 Shows the measurement setup. The speaker is fixed on a rod so that no influencing surfaces are in the vicinity.

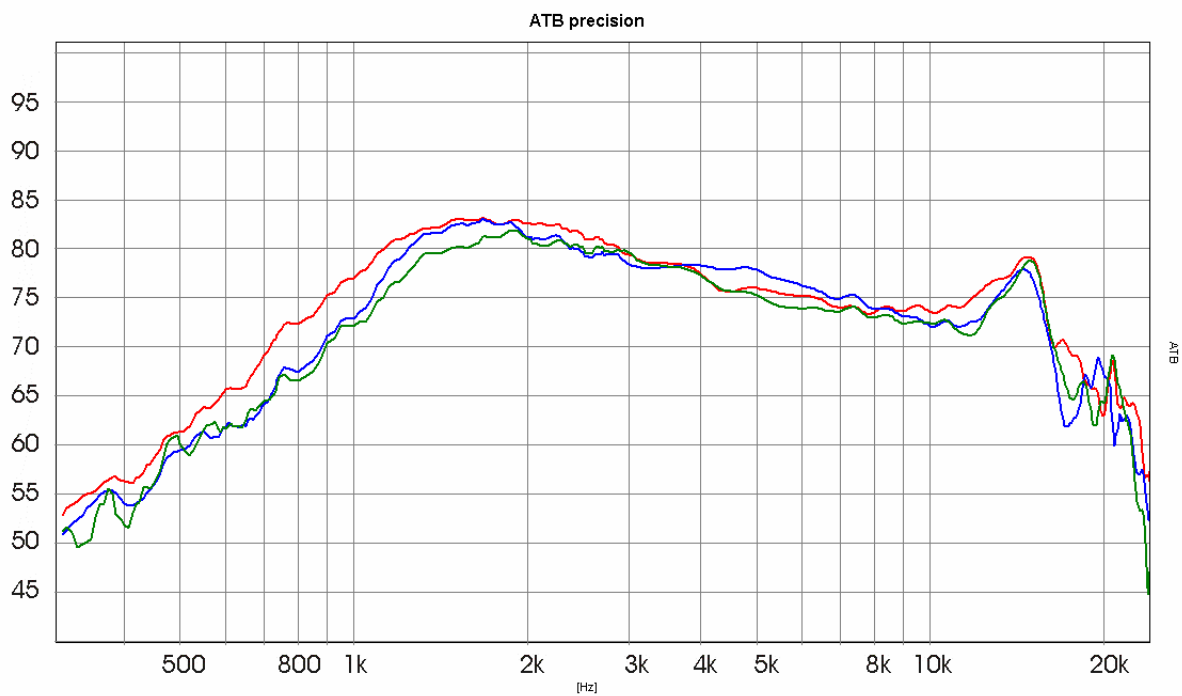


Pic. 3.4 Frequency responses of the sound baffles measured on axis
 green D = 8cm, blue D = 13cm, red D = 27cm

The Pic. 3.4 shows the breakdowns in frequency response at $f = c / (D/2 + \Delta E)$, $\Delta E =$ difference of distance between primary and secondary sound source. The calculation results in following frequencies:

D = 8cm $f = 8416$ Hz, D = 13cm $f = 4533$ Hz und D = 27cm $f = 2428$ Hz.

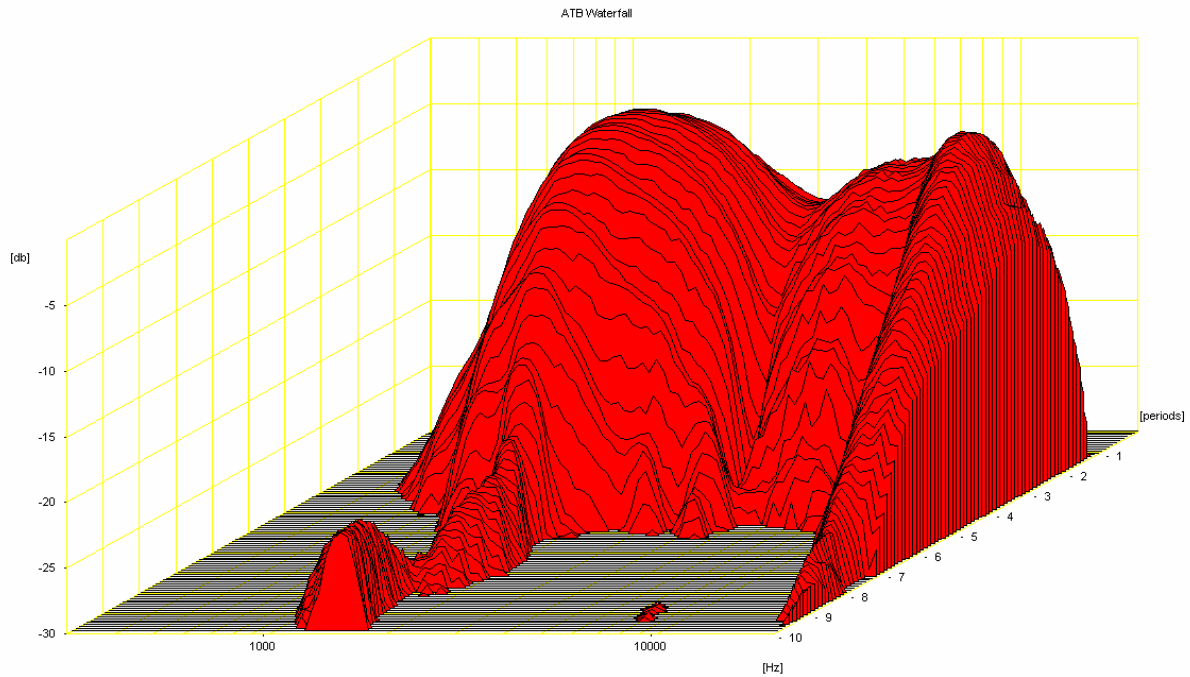
The calculation and measurement correlate. And also the exaggeration in sound level pressure on the large sound board is visible, about 6dB at 1kHz.



Pic. 3.5 Frequency response of the sound baffles measured at 45°.
 green D = 8cm, blue D = 13cm, red D = 27cm

The Pic. Shows that the directivity also is a function of the sound baffle.

In accordance with the theory a breakdown in frequency response is caused by the overlay of the primary and secondary sound sources. As the secondary sound source is reflected from the sound baffle, it's time delayed in relation to the primary sound source. The time delay is shown in the measurement of the waterfall diagram.

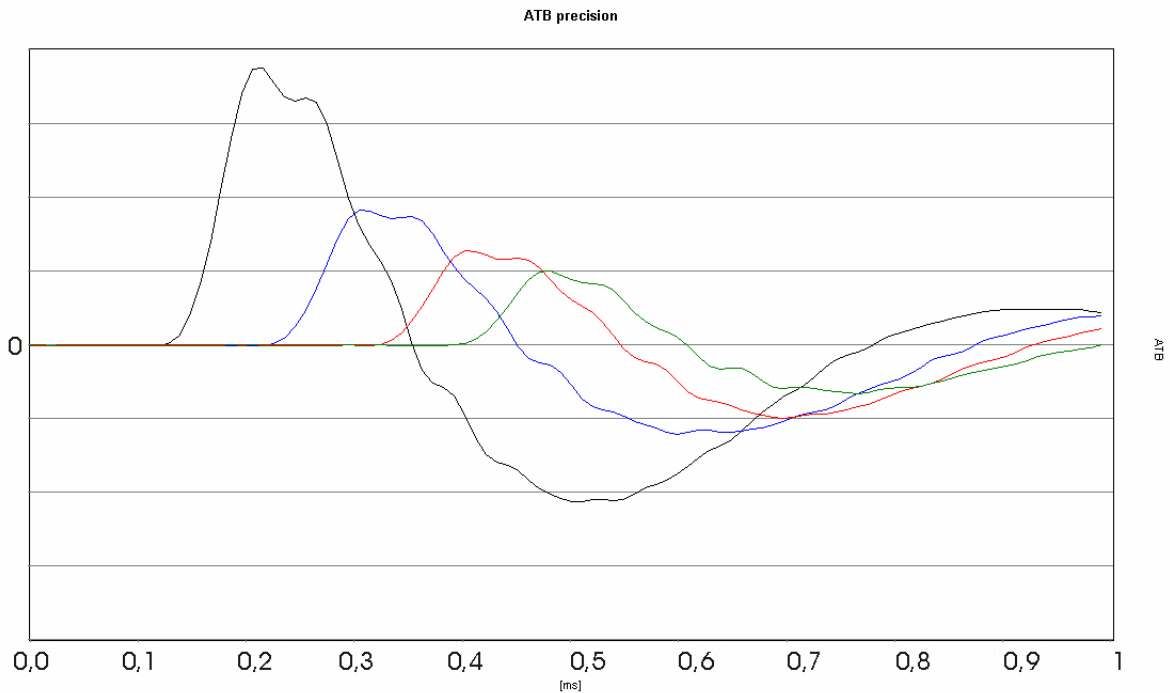


Pic. 3.6 Waterfall diagram

In Pic. 3.6 The breakdown in the mount at 5kHz is nicely seen. The front part of the mount shows the frequency response without the secondary sound source. First in the rear part the secondary sound source creates the breakdown.

W1.4 The time behaviour of the sound wave on the sound baffle

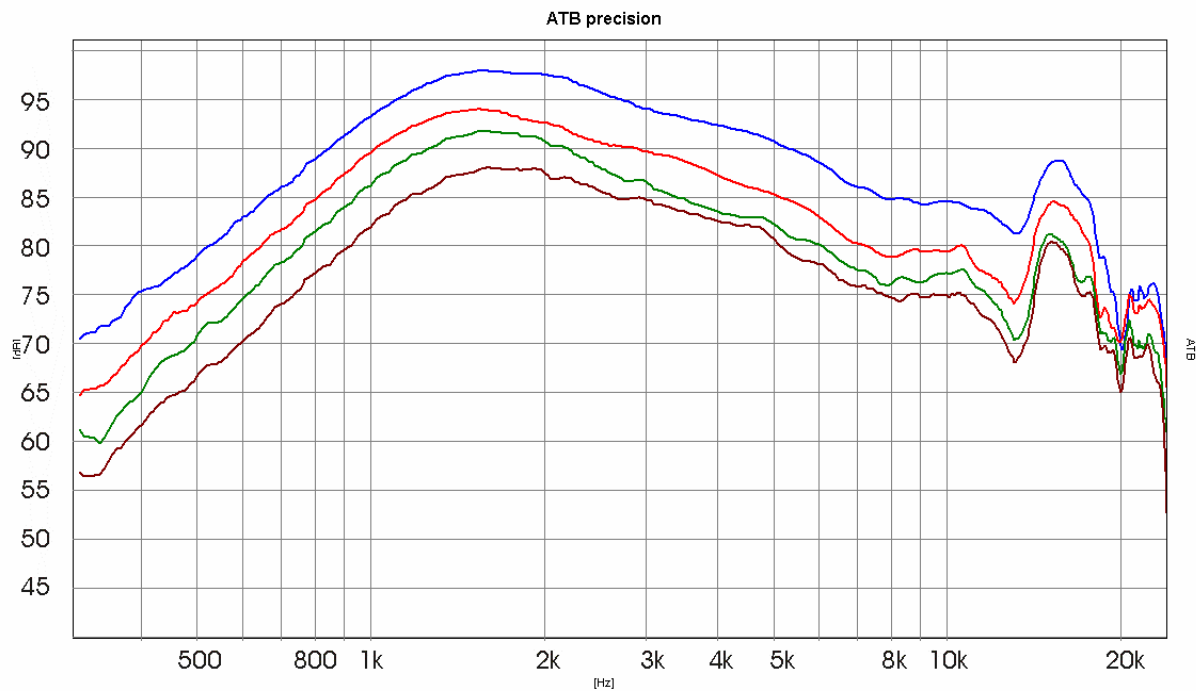
The sound waves hitting the sound baffle can be measured by the boundary area microphone method. To show the time behaviour the step response is measured.



Pic. 4.1 Step response measurement on the sound baffle

Distance from center: black = 4.5cm, blue = 7.5cm, red = 10.5cm, green = 13.5cm

In picture 4.1 there are 4 step response measurements shown. These were performed at the distances 4.5cm, 7.5cm, 10.5cm and 13.5cm from the center of the loudspeaker. The delay is clearly seen through the greater length of the running time of the sound. The amplitude decreases by increasing length, whereas the shape of the step response stays identical. In accordance with the theory of the edge reflexions, it is to be expected that these are to be seen in the impulse response. But as there is nothing to be seen, the edge reflexion can not have the supposed influence.



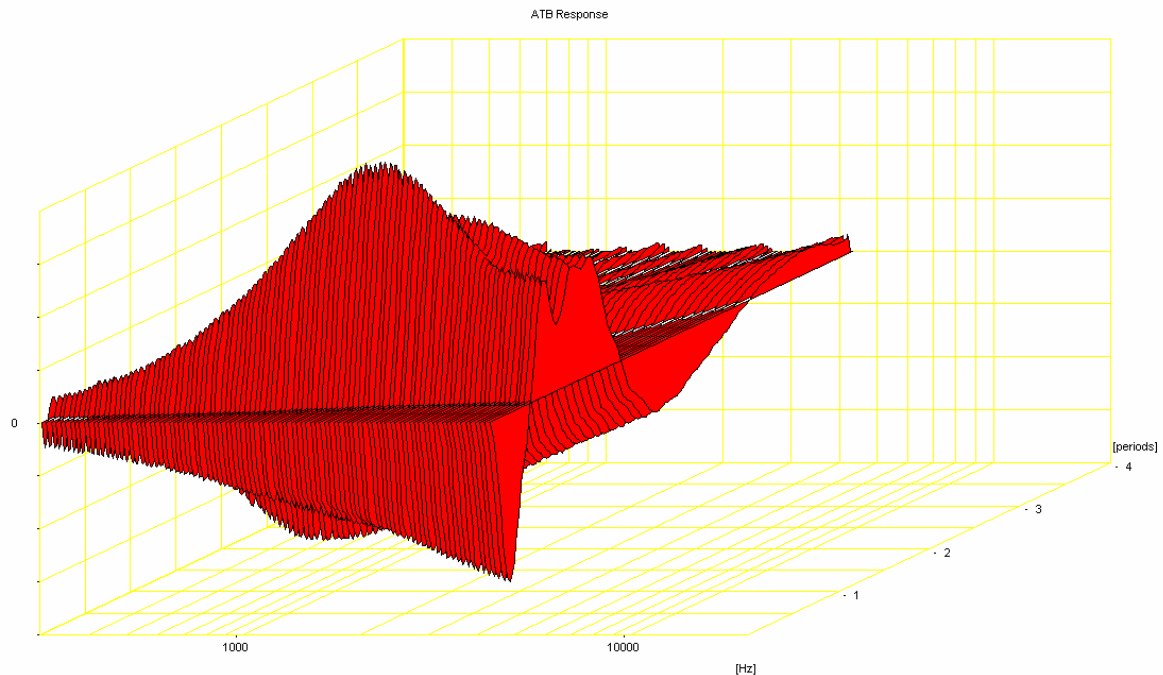
Pic. 4.2 Frequency responses in different distances measured on the sound baffle
 Distance from center: blue = 4.5cm, red = 7.5cm, green = 10.5cm, brown = 13.5cm

The Pic. 4.2 shows the frequency responses of the boundary area measurements at different distances. Due to the greater distances the amplitude gets smaller. The run of the curve stays to the most extent the same. And also at the edge there is nothing noticeable to be seen. This shows the edge reflexion is model that allows a near calculation of sound baffle influences. But the edge reflexion doesn't correspond to the physical properties of sound baffles.

Also the bending of the sound wave on the edge of the cabinet does not have the supposed influence. The rounding or slanting of the cabinet edges shows its influence on the sound with a change of the effective sound baffle size for the sound wave.

W1.5 The delayed reflexion of the sound baffle

A large sound baffle shows the most even frequency response. But this doesn't say anything about the correct sound radiation and as such about the sound reproduction impression. The delayed reflexions can be shown with Dynamic-Measurement program.



Pic. 5.1 Dynamic-Measurement measurement with the sound baffle $D = 8$

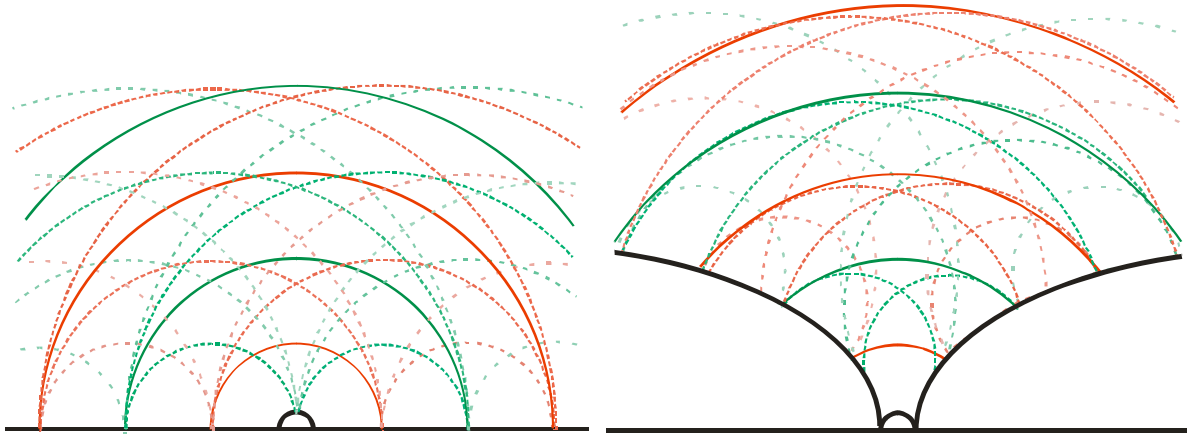
The Pic. 5.1 shows the inverted impulse behaviour of the loudspeaker on the sound baffle with $D = 8$. In the front the first inverted impulse is seen, after that the over swing mount. Towards higher frequencies a breakdown appears in the mount. This is caused by delayed reflexion of the sound baffle.

To judge the sound impression of an omni directional radiating loudspeaker on a large sound baffle a hearing test has to be performed. Here it shows that a large sound baffle does not have a good reproduction of the stage image. The sound appears to come out of a box. That's why modern loudspeakers are not only built narrow because of design reasons. The explanation why speakers with large sound baffles do not have good room impression qualities is, that the reflexions are delayed as such that the listener hears them as an additional sound sources. This stops the loudspeaker not being noticed as sound source by stereo reproduction.

The delayed reflexions can be avoided by sound absorbing materials on the sound baffle surface. Another solution is the use of sound directive speakers. Cone tweeters have proven well here. The best solution is the use of Waveguide tweeters. Through the special sound directive properties of the Waveguide sound baffle reflexions are avoided to the greatest extent.

W1.6 Comparison of sound baffle and Waveguide

The sound spread of sound baffle and Waveguide are compared following.



Pic. 6.1 Sound field of the sound baffle

Pic. 6.2 Sound field of the Waveguide

the **red** lines show the positive and the **green** lines the negative amplitude. The full lines are the primary and the dotted lines the secondary sound source.

The picture 6.1 shows the sound field of the sound baffle with the interferences of primary and secondary sound.

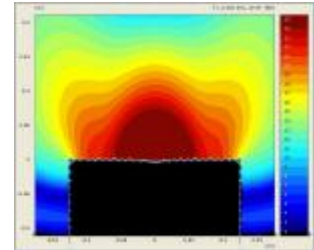
The picture 6.2 the sound field of the Waveguide, shows that with corresponding function the primary and secondary sound waves build a wave front. Through this the higher sound pressure for the shown frequencies is created. This is also seen across a broad frequency range.

In capital 1 the differences between sound baffle and Waveguide are also shown per measurement.

The comparison above is also shown by the computer simulation from the company Selmoni speakers from Switzerland

Simulation

The simulation shows that a tweeter without waveguide on an baffle has a very irregular sound distribution. There are three beams for the sound. The main beam has the direction to the audience. The two other beams will be reflected from the room walls and destroy a natural sound reproduction



The tweeter with waveguide has only one beam. The sound comes directly to the audience and will be very exact.

