Jaap van Loon, May 2025

(passive) open baffle design

This pdf describes a possible method for the design of open baffle speakers.
The showcase aims for a passive linear phase open baffle speaker.
The simulator used is Boxsim, supplemented by some Vituix tools.

1. OB simulation basics

The argument for OB simulation in Boxsim goes as follows:

Define a box of say 80 x 40 cm but keep the depth of the box (almost) zero. Place the driver on a baffle and let it fire to the listener. Then, to simulate the back site of the driver cone, place a second identical driver at the same place on the baffle but let it fire backwards in opposite phase. Give both drivers an almost infinite box volume.
Now the real driver plus the virtual driver behave together as a single driver in an open baffle. You can do this for as many drivers as you want.

2. design goals

My design goals for the speakers are as follows:

- focus on constant directivity
- focus on correct impulse and step response
- modest sized open baffle

there is no priority for high output level and flat spl.

Correct impulse and step response asks for a linear phase system. This implies that filtering is practical limited to first order filters.

3. Driver selection

First order filters requires drivers with flat spl, also far under and above their actual working range. I could not make it work with three drivers, so I had to use four.

I choose the following drivers for this demonstration study:

- BIANCO-120B150-01 — 12″ woofer (SB Audience)
- AL170-8 — 6½″ midbass (Visaton)
- BG80-8 — 3,3″ full range (Visaton)
- D2905/930000 — 1″ tweeter (scan speak)

The drivers were selected for their relative flat spl graph, low FS and relative high Qt.

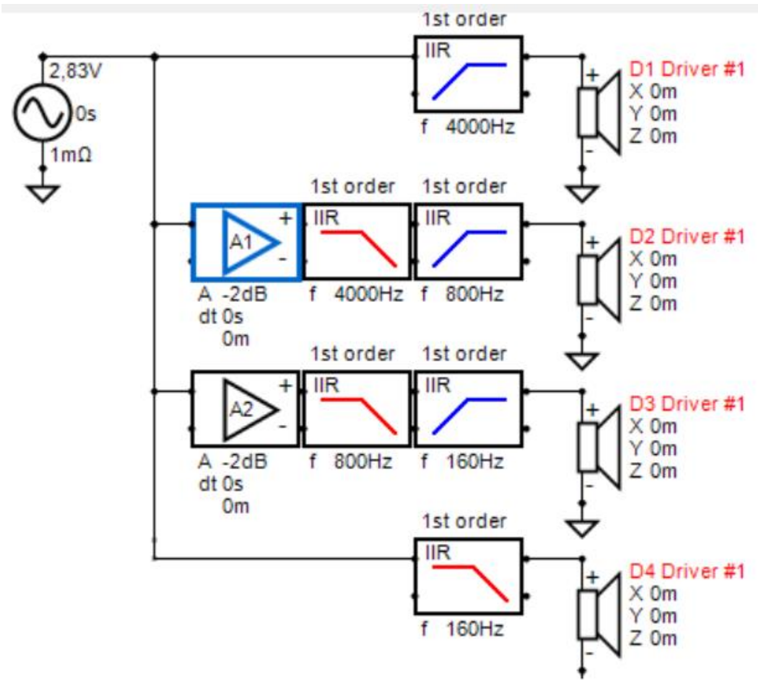
Looking at the spl graphs I choose the flowing preliminary cross-over frequencies:

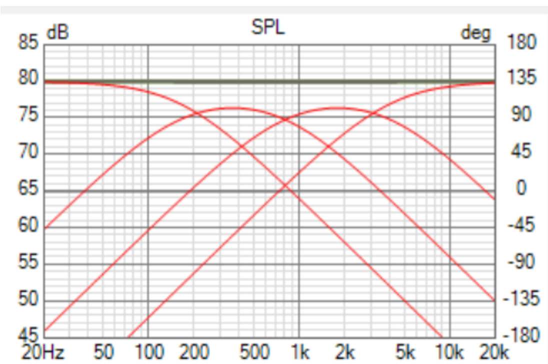
- 200 Hz
- 800 Hz
- 3200 Hz

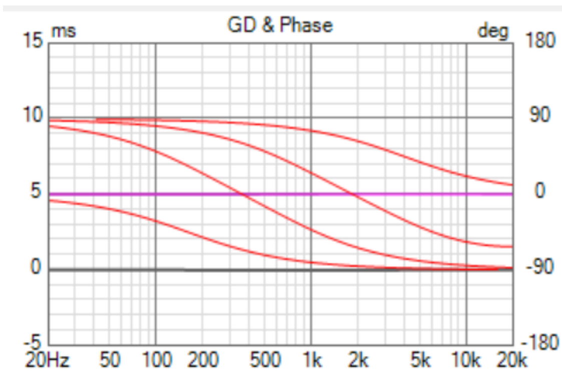
4. Basic cross-over design

For reasons of convenience the cross-over is first constructed for an active filter. Vituix is used here for visualization.

The following configuration provides the desired cross-over frequencies:







We need the phase behavior later in Boxsim.

5. Set-up in Boxsim

Open Boxsim, and define a new project with 4 amplifiers and 7 drivers.
Set driver 1 to the following values:

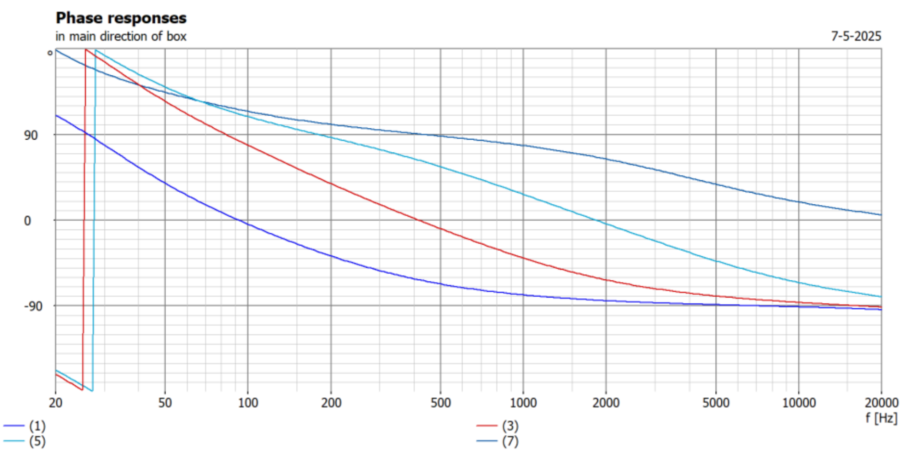
Resonance frequency fs [Hz]	30	Linear excursion per side [mm]	10
Electrical Q-faktor Qes	1	DC resistance Rdc [ohm]	8
Mechanical Q-factor Qms	2	Inductance of voice coil Le [mH]	1,E-8
equivalent volume Vas [liter]	100	substitution resistor Re2 [ohm]	0,001
Effective piston area [cm2]	530	substitution inductance Le2 [mH]	0,001
P max [W]	100	substitution resistor Re3 [ohm]	0,001
Nominal impedance [ohm]	8	substitution inductance Le3 [mH]	0,001

Make sure you have selected “infinite baffle”.
Check on “closed enclosure”, and set a very large box volume
Copy driver 1 to the other six. We now have 7 identical ideal drivers.
Go to “common outer housing” and define a box 40x40 cm, 1 cm deep and park the drivers 2, 4, and 6 on that box.
Put the drivers 1, 3, 5 and 7 each on a separate baffle (40x40x1 cm) and check all diffraction options off.

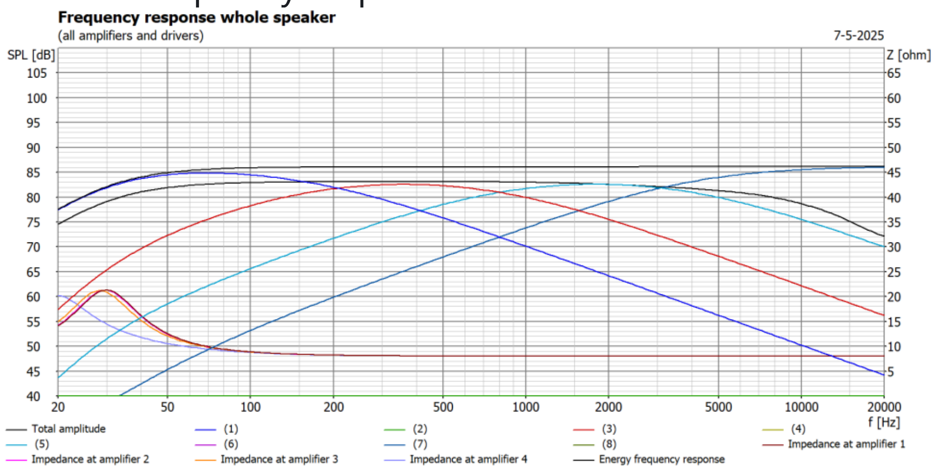
Connect drivers 1, 3, 5, 7 to resp. amps 1, 2, 3, 4
Park drivers 2, 4 and 6 in resp. cross-over box 1, 2, 3

Load the filters in the four active amplifiers of Boxsim.
The simulator should now report a successful calculation.

Look at the phase response. Now adjust de (negative) delay’s of the amplifiers in such a way that the phases of drivers 1,3,5 and 7 looks like the Vituix phase picture.
The phase response should now be like this:



and the frequency response like this:

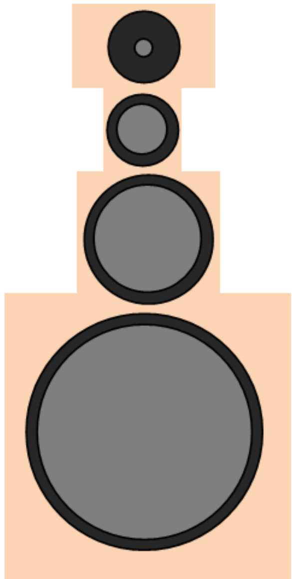


When building the real thing, we have to replace the delays by physical offset for the drivers

6. Position of the drivers on the baffle

I want the baffle to be 40 cm wide an 80 cm high.
I played a bit with the diffraction tool in Vituix and found that:

- The baffle width for the woofer should be as large as possible for deep bass response
- The width for midbass and the full range should be as small as possible for minimum diffraction
- The width of the tweeter baffle can be wider in order to push the diffraction dips and peaks out of the frequency range of the tweeter
- The height position of the drivers is also important. For the woofer there is not much choice. For the midbass, I found a height of 46 cm as an optimum. The tweeter showed the best response when placed as high as possible on a somewhat wider baffle. Doing so, for the full range was just sufficient space between midbass and tweeter.



80 x 40

< I ended up with this baffle

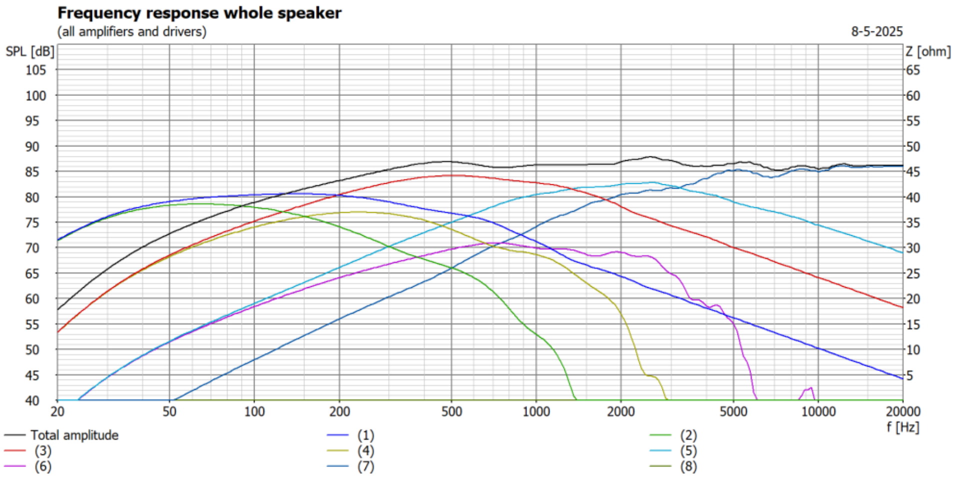
(note: I did the simulation for the woofer with a 100 cm wide baffle, so taking the back-folded side-wings into account)

7. Insert diffraction

Make all the baffles 1 cm thick.
Place the drivers on the baffle as in the baffle drawing above. Place drivers 3 and 7 on a common outer housing, 80 cm high and 20 cm wide. Place driver 4 at the same position as driver 3 but let it fire backwards. We don’t have a back firing tweeter. Place driver 1 in the middle of another baffle, 40 cm high and 100 cm wide. Place driver 2 at the same position as driver 1 but let it fire backwards. Switch the diffraction options on.

Place driver 5 on another baffle, 80 cm high and 10 cm wide. Place driver 6 at the same position as driver 5 but let it fire backwards. Switch the diffraction options on. Connect now the drivers 2, 4 and 6 to resp. the amplifiers 1, 2 and 3. Connect these drivers in opposite phase.

The frequency response should now be like this:



Now you can play a bit with the placement of the drivers to see the effects on diffraction.

8. Insert real driver data

BIANCO as driver 1

AL170 as driver 3

B80 as driver 5

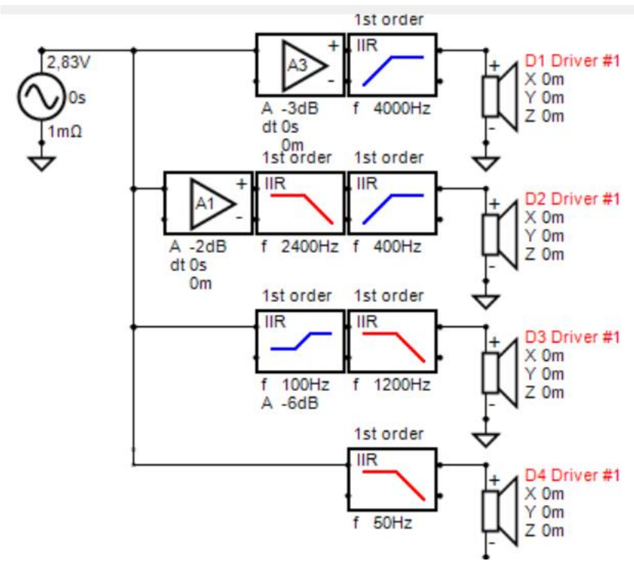
D2905 as driver 7

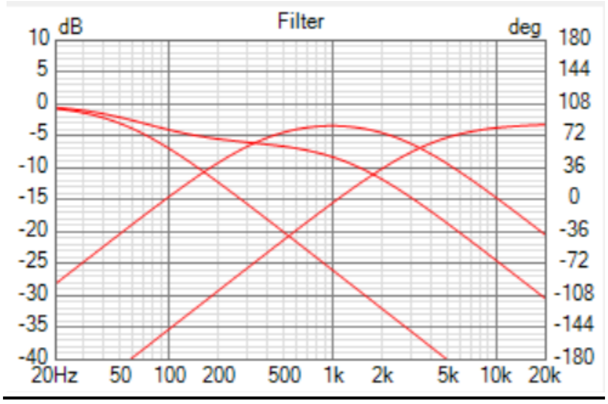
For the Visaton drivers, these data can simple be loaded from the Visaton data base.

For the woofer and tweeter, first the T/S data has to be filed in in Boxsim.
(note: for the tweeter, Vas has to be adjusted such that the output level is equal to the specified spl on the data sheet).
For the spl and zma data, I took the manufacturers data sheets, With the “spl-trace” tool in Vituix I derived the .spl and .zma data and exported it to Boxsim.
For all drivers the frequency, phase, impedance and electrical phase options has to be checked on.
Copy driver 1 to 2, 3 to 4 and 5 to 6 (excl. baffle data) in order to define the back firing drivers.

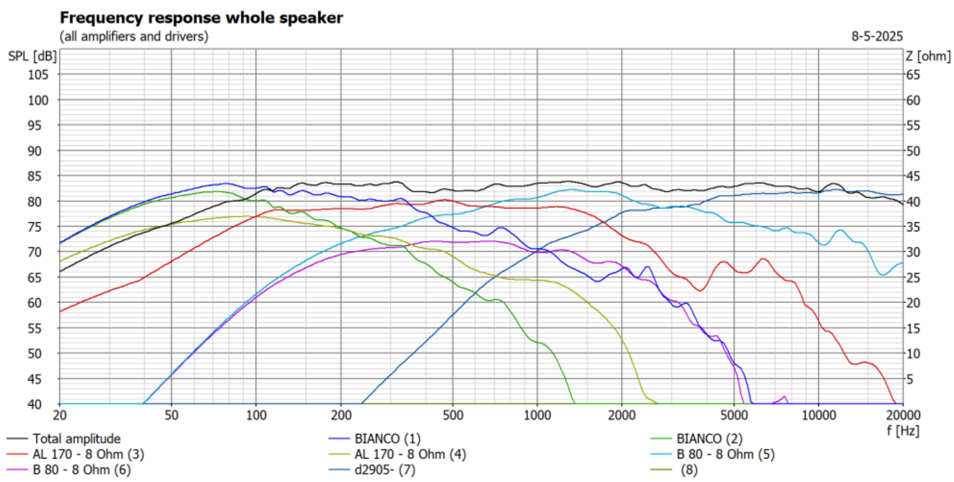
Now the cross-over’s must be modified (in the Boxsim’s active filters) to get the best response out of the system.
This is a bit trial and error. I decided to leave out the high-pass filtering for the midbass.
If necessary, readjust the delays till the phase behavior of the four drivers is OK.

The cross-over I ended up with is shown in the following Vituix diagram:





The frequency response now looks like this in Boxsim:

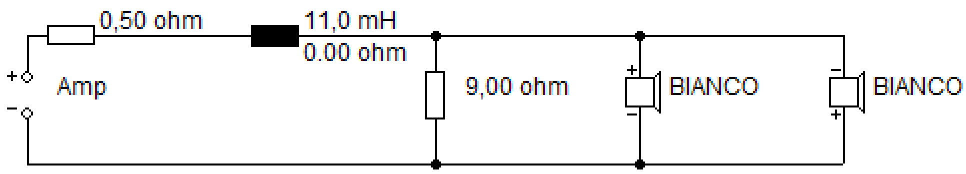


9. Passive filtering

First, I placed a shunt resistor on each driver to reduce the impedance peaks at resonance.

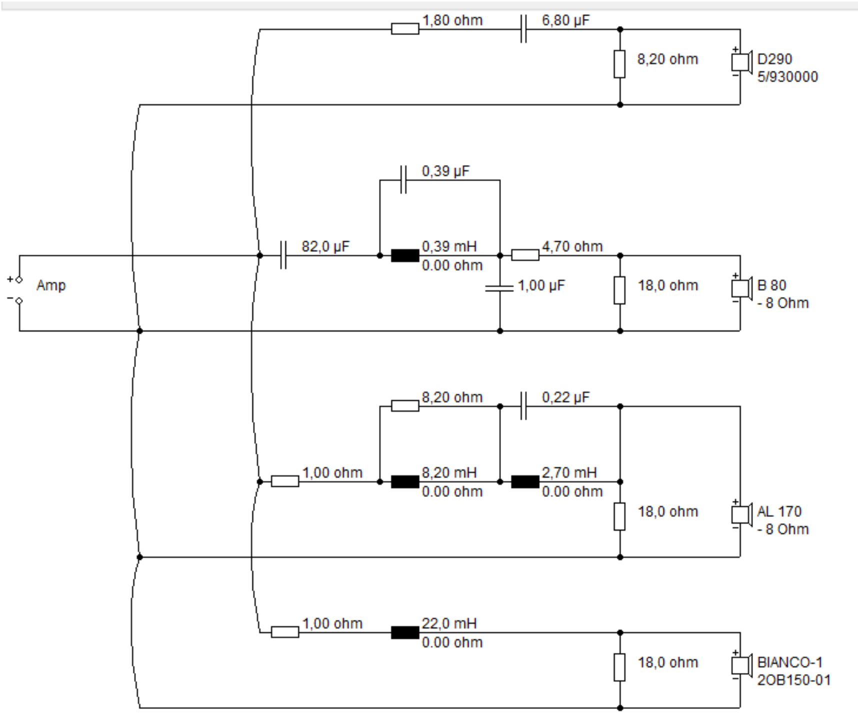
Next I replaced, step by step, each active filter function by the necessary passive component(s) in such a way that the frequency response changes as little as possible.

As an example, see circuit for the Bianco:

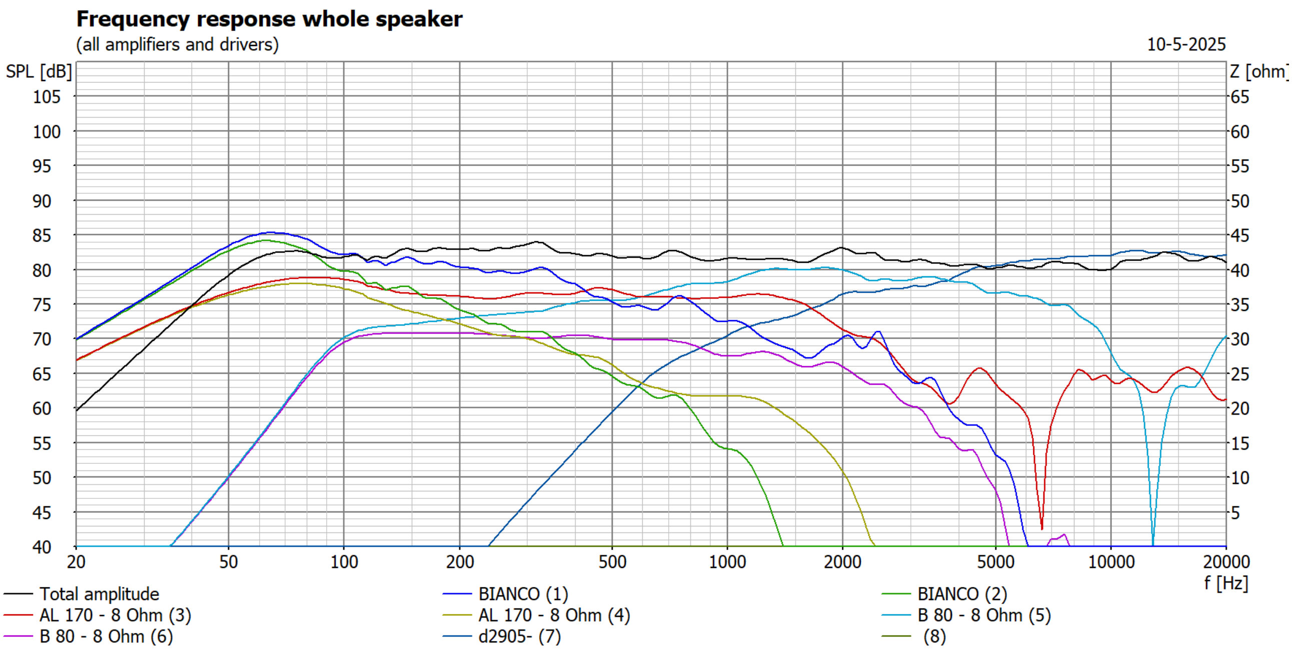


Of course, in the real thing we only have to drive one driver. Therefore the circuit has to be changed: all resistors and inductors double in value, all capacitors should get half the value.

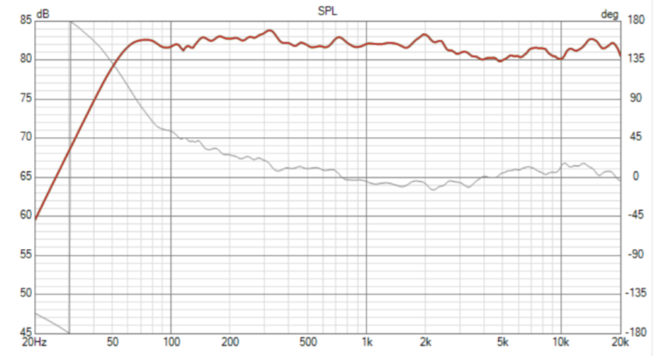
At the end we get then the following cross-over schematic diagram:

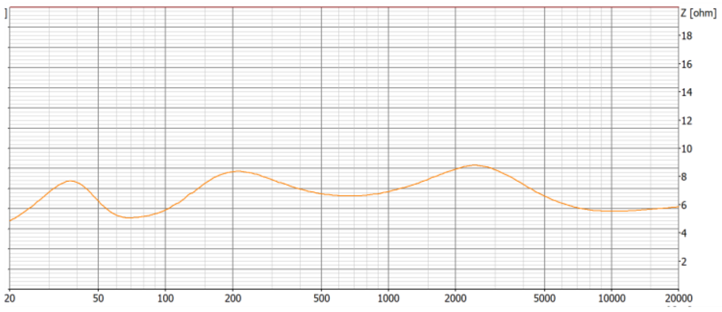


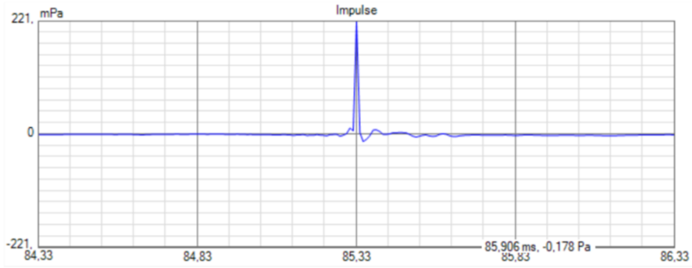
10. Simulation results

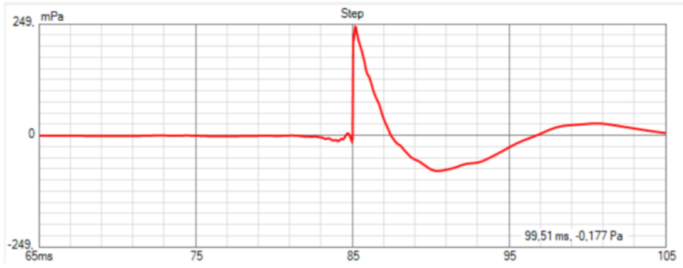


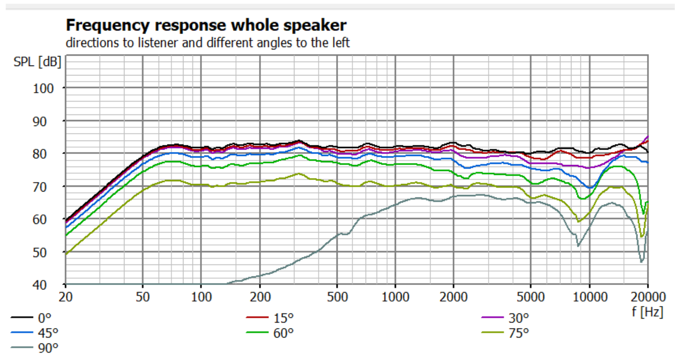
11.

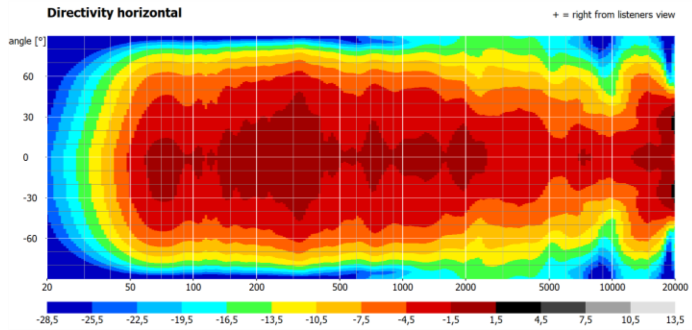








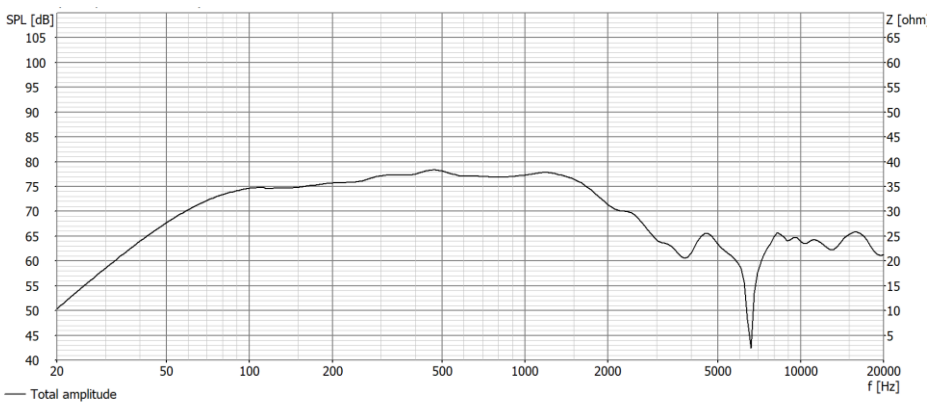




12. Building the real thing

I never built or tested an open baffle speaker, and it was my intention to say nothing about it.

However, there is one interesting point I want to mention:
If the speaker is built as simulated then you have the possibility to measure each driver separately and compare the response with the simulated response of that driver.
For illustration purposes herewith the spl of the AL170 as simulated (on-axis sum of (diffracted) forwards and backwards radiated sound)).



AL170 response (on-axis)