Optimo

The Optimo – When is a speaker a Transmission Line?

A high-end two-way transmission line floor standing loudspeaker. The cabinet design resulted from extensive measurements and listening tests with various internal partitions and cross-sections of the line.

The tweeter

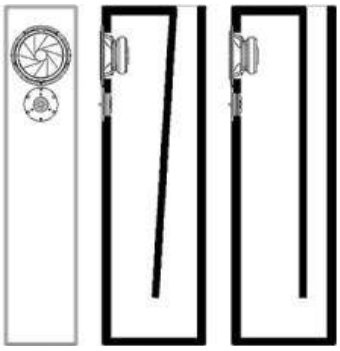
The Scanspeak R2904-7000 is a 1" ring radiator, featuring, SD-2 neodymium motor, non-resonant aluminium chamber, multiple chamber low compression design, machined aluminium faceplate and phase plug. It is a 4-ohm driver with a high sensitivity and an upper frequency limit above 40 kHz.

The mid-woofer

The Scanspeak 18W4531G00 features a non-resonant cone and dust cap structure, dynamic linear suspension, SD-1 patented magnet system, and "Grasshopper" chassis for maximized airflow, and anti-resonance mounting system. Also being a 4-ohm driver it should match the tweeter well.

Cabinet variations

The woofer parameters make this driver a very versatile unit. Original tests in a 32 litre bass-reflex enclosure were not very promising (good but I had the feeling that this woofer could do better) so I decided to give the transmission line a try – I wanted deep strong bass which wasn't possible with a closed box. But when is an enclosure a transmission line? If you look at a line folded once and therefore having one panel dividing the enclosure in a front half and back half, varying the position and angle of this centre panel will make the enclosure work more like a transmission line / terminated line / tapered line / bass-reflex / closed box. The main objective behind these cabinet variations was to find out which one sounded best for this combination of drivers.



The only difference is the angle of the partition. When is it a TL and when is it a BR enclosure and how different do they sound?

Also should a TL be tapered or have a constant cross-section and do they sound different? Imagine the "reflex" enclosure in the above image with the partition placed exactly half way front to back. I investigated a few existing TL designs with a constant cross-section to see if I could find some kind of "rule", five made by the German magazine Klang&Ton and four commercial designs made by Newtronics. I have compared the line cross-section Ld with the cone area of the driver and also the length L of the lines compared to the resonant frequency fs of the driver:

Klang&Ton:
1) Ld = Sd; L = 130cm - fs = 51Hz; 1 woofer at the beginning of the line.
2) Ld = 1,16x Sd; L = 210cm - fs = 45Hz; 2 woofers at a third and fifth of the line.
3) Ld = 0,9x Sd; L = 159cm - fs = 49Hz; 2 woofers at a third and fifth of the line.

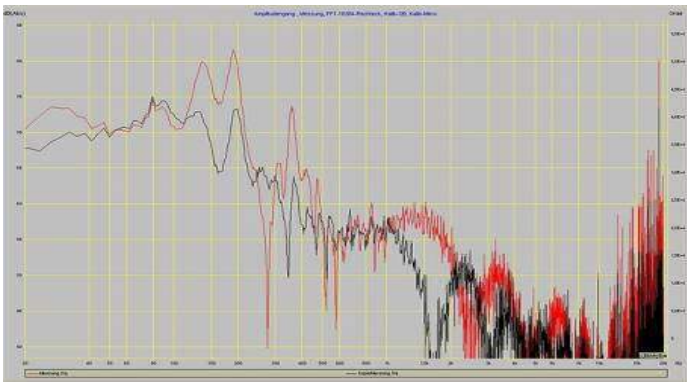
4) Ld = 0,9x Sd; L = 150cm - fs = 41Hz; 1 woofer at a third of the line.
5) Ld = 0,9x Sd; L = 182cm - fs = 43Hz; 1 woofer a third of the line.

Newtronics:
1) Ld = 0,66x Sd; L = 100cm - fs = 61Hz; 2 woofers starting at the beginning of the line.
2) Ld = 0,57x Sd; L = 180cm - fs = 39Hz; 2 woofers starting at the beginning of the line.
3) Ld = 0,54 tot 0,39x Sd; L = 270cm - fs = 39Hz; 3 starting at the beginning of the line.
4) Ld = 0,57x Sd; L = 218cm - fs = 57Hz; 3 woofers starting at the beginning of the line.

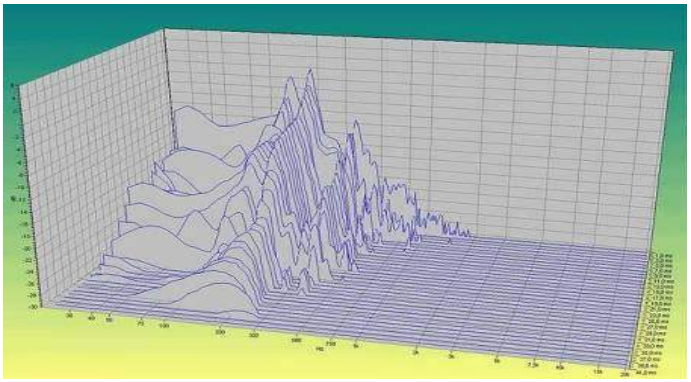
The Klang&Ton lines generally have a cross-section that is slightly smaller the cone area. The length of their lines doesn't meet any rules. The correction factor for the amount of damping material in the line varies between 0,71 and 0,9 times the length that would have been needed if there was no damping material in the line. The Newtronics lines have a cross-section that is far too small seeing that their lines contain multiple woofers. The correction factor for the amount of damping material in the line varies between 0,69 and 1,46!!! times the length that would have been needed if there were no damping material in the line, so some of their lines are too long. My first cabinet comparison was between the bass-reflex and a standard tapered-line:

The net volume of 40 litres, port opening of 105cm2 and amount and place of the damping material of both enclosures are the same, the only difference being that the partition is vertical for the reflex version and placed at an angle for the TL version. Depending on the cabinet stuffing the TL should be tuned to a quarter wavelength of about 35-38Hz, slightly above 33Hz fs of the woofer. For the complete test I have deliberately only listened to the different cabinets before I did any measurements. You would expect not much difference is sound between the two enclosures but actually they are quite different! The BR produces a "fuller" sounding bass, the TL produces a less "closed-in" sounding bass, and its bass seems to rollout easier. But the most astonishing difference is in the midrange! The midrange of the TL is a lot more open and dynamic; the BR in comparison has a sort of "loudness" effect. At this point I was sure I wasn't going to put the 18W4531G-00 in a reflex enclosure because I preferred the TL's midrange.

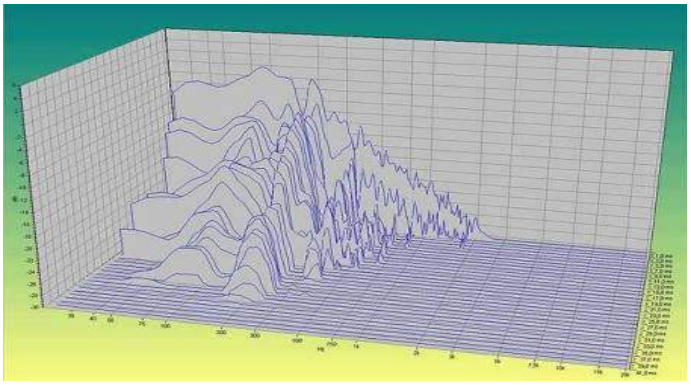
The measurements of the BR (red) compared to the TL (black). The measurements were taken with the microphone directly above the opening in the top of the cabinet. The vertical scale is 5dB. The BR shows 3-4dB more output between 20-40Hz but peaks severely in the 100-500Hz range; the TL is smoother. I could get the BR smoother by adding more damping material in the cabinet, but the whole idea was to compare the relative differences between each cabinet. In this specific case I presume that the "peaky" character is caused by the port being very large which let the port resonances start at a lower frequency than normal.



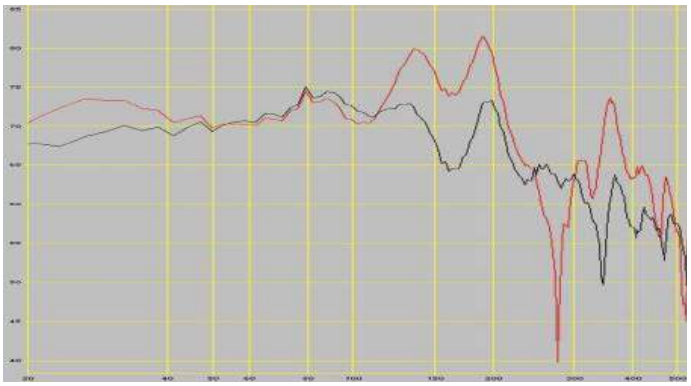
Frequency-curve BR and TL; 20-20.000Hz



waterfall-spectrum BR - 41ms/-30dB

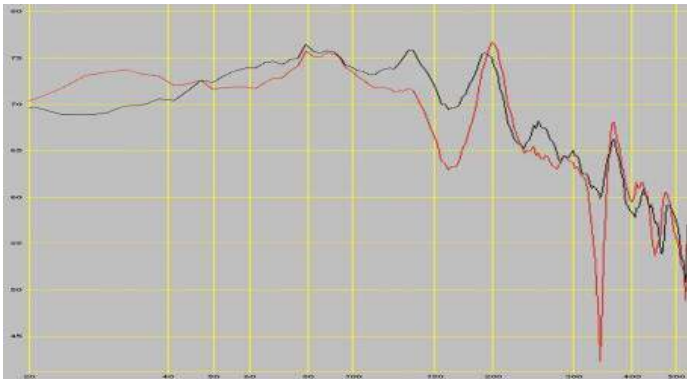


waterfall-spectrum TL - 41ms/-30dB



The next step was to compare TL of constant cross-section with a strongly tapered line.

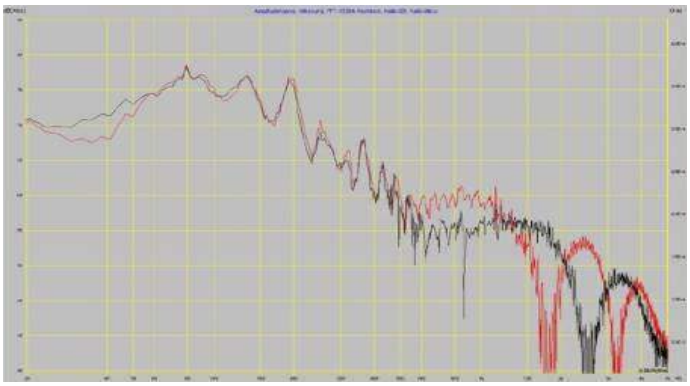
The strongly tapered line produces a slightly tighter bass, both seem to go as deep but the TL with a constant area has more "volume" at the cost of some detailing. The constant area TL has more open and forward sounding midrange, especially noticeable with acoustic guitar, percussion and wind instruments.



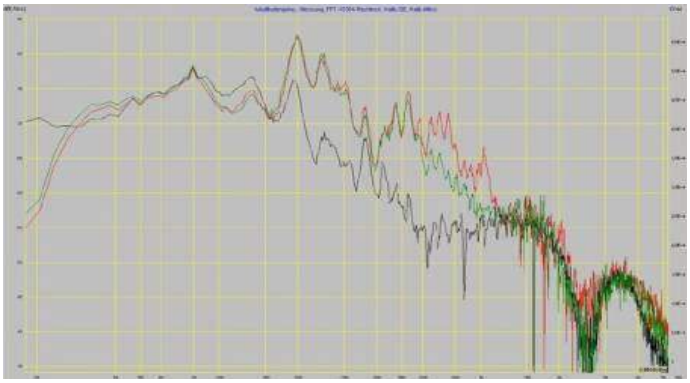
TL constant cross-section = red; strongly tapered TL = black

The strongly tapered line shows great similarity with the slightly tapered line. The TL with constant area looks a lot like the BR version (peaky due to the parallel walls). The main difference with the BR is that the peaks of the constant cross-section TL aren't as severe – the BR peaks were nearly 10dB greater. Conclusion: I prefer the sound of the constant cross-section TL, the tapered line measures better……..interesting. Next was to compare a TL with constant cross-section and the woofer at one third of the line with a TQWT enclosure (or is it a horn with a small mouth?).

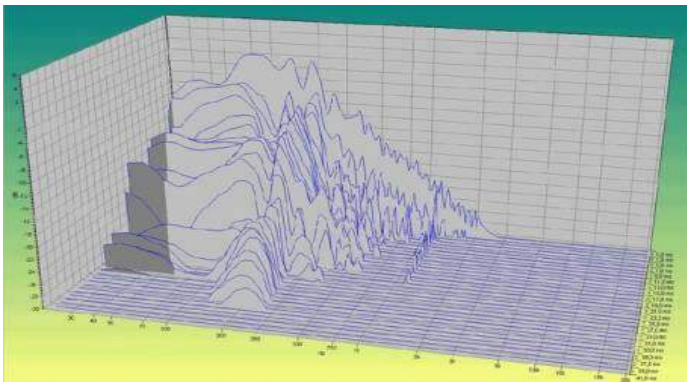
The TQWT showed (in comparison to the constant cross-section TL) similar properties as between the tapered line and the constant line. More and direct midrange at the cost of some depth in the lower octaves. Basically more midrange energy exits the line so that relatively speaking there is less bass. The character of the TQWT suggested filter less woofers, single cap tweeters, SET-amps, etc. Maybe a cliché but cliché exist because of a reason. The TL with constant cross-section and the woofer at one third wasn't a success in my case. The speaker sounded closed-in and deep bass was missing. I played around with the damping material a bit but the character stayed. In the end I closed off the port (to create a closed box) and funnily enough there was hardly any difference. There was a fraction less bass but the closed-in and compressed character was the same. And now the measurements: TL with constant cross-section and the woofer at the beginning of the line = black / TQWT = red. Interesting is the similarities between 60-500Hz and that the harmonics at higher frequencies are opposite. You can see that the TL has more output below 60Hz.



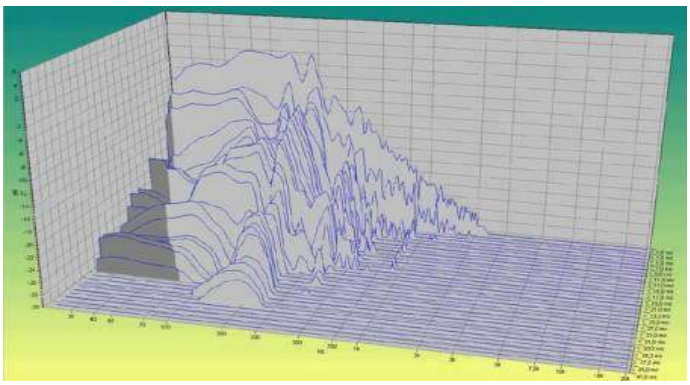
And then the TL with constant cross-section and the woofer at the beginning (black) of the line compared to the woofer at one third of the line (green). The red curve is the same as the green curve except the piece of Pritex foam at the bottom was removed.



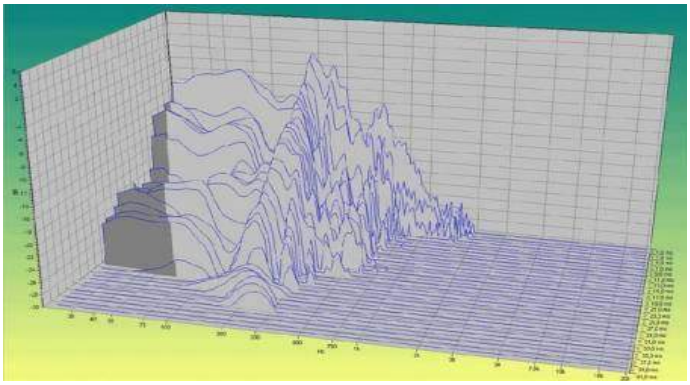
I hadn't expected such great differences! With the woofer at 1/3 of the line the bass seems to end at 30Hz and the midrange is much stronger (up to +15dB). The differences are of course partly to do with the different position of the woofer in the line but all the different sub-compartments now created by the different folding of the line also alter the output significantly.



TQWT (woofer at the beginning of the line)



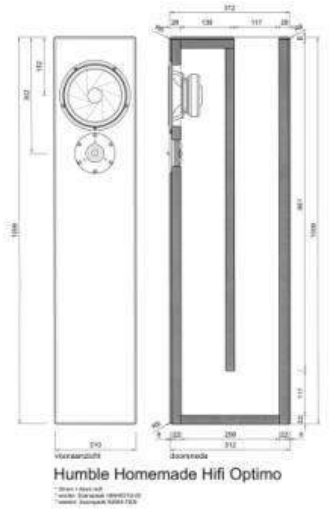
TL with constant cross-section (woofer at the beginning)



TL with constant cross-section (woofer at 3rd of the line)

Cabinet conclusion

From these six different cabinets I have chosen the TL with a constant cross-section. It proved a nice balance between deep bass, open midrange and dynamics. After these experiments I also feel that a TL with a constant cross-section will work best for a 2-way design due to the more open and direct midrange and that a 3-way TL with a separate midrange driver would work better in a tapered line due to the subjectively deeper and tighter bass. As with most things it's also a matter of taste, I prefer a more direct sounding midrange at the cost of some depth in the bass department. The cabinets were then lined on the inside with Hawaphon damping sheets to add mass and dampen panel born resonances. The outside of the 22mm thick mdf enclosures was then covered with an extra 6mm layer of mdf totalling the wall thickness to 28mm with varying density. The line length is about 190cm and the line area is a constant 172cm2 (taking the Hawaphon into account). Damping material is BAF completely filling the first half of the line with only a small piece in the second half (see the photo). The bass can be tuned from full and deep (no damping material at all in the second half) to tight and punchy when the second half is also completely filled with BAF.



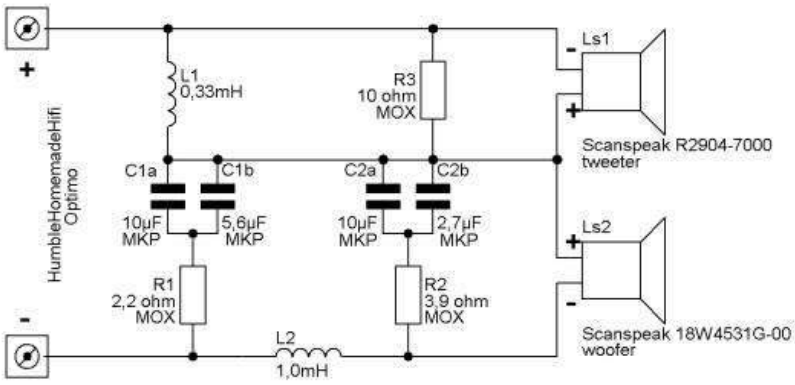

A higher resolution drawing is available on request

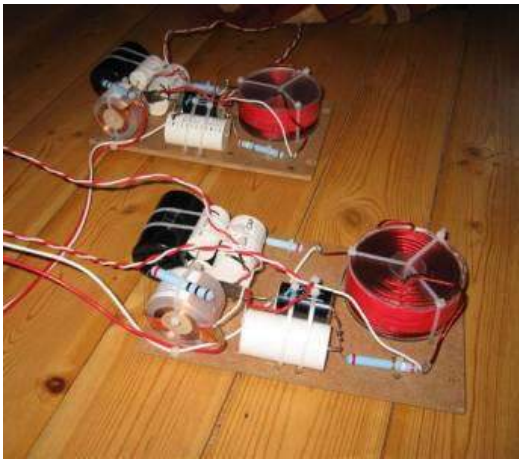


Note that the BAF has been left out behind the woofer for the photo.

The crossover network

It uses a second-order series-filter on the woofer and a first order on the tweeter. The crossover point is at about 2500Hz. The tweeter is connected out of phase.A single pair of WBT gold plated binding posts on the rear, internal wiring is silver coated OFC copper with Teflon insulation.





Crossover components (budget version):

L1 = 0,33 mH air-core inductor 2,0 mm wire, R = 0,09 ohms

L2 = 1,00 mH air-core inductor 2,0 mm wire, R = 0,17 ohms

C1a = 10uF MKP polypropylene foil capacitor – with 0,01uF MKP1837 bypass cap

C1b = 5,6uF Intertechnik Audyn Cap KPSN or Mundorf M-Cap Zn tin foil capacitor – 2,2uF + 3,3uF is close enough

C2a = 10uF MKP polypropylene foil capacitor

C2b = 2,7uF Intertechnik Audyn Cap KPSN or Mundorf M-Cap Zn tin foil capacitor

R1 = 2,2 ohms, 10 watts metal film resistor

R2 = 3,9 ohms, 10 watts metal film resistor

R3 = 10 ohms, 10 watts metal film resistor

Crossover components (high-end version):

L1 = 0,33 mH Intertechnik CFI foil inductor, R = 0,13 ohms or Mundorf CFC10, R = 0,08 ohms

L2 = 1,00 mH Intertechnik Tritec inductor 3,5 mm wire, R = 0,14 ohms or Mundorf CFC10, R = 0,15 ohms

C1a = 10uF Intertechnik Audyn Cap Plus or Mundorf M-Cap Supreme polypropylene foil capacitor – with 0,01uF MKP1837 bypass cap

C1b = 5,6uF Intertechnik Audyn Cap KPSN or Mundorf M-Cap Zn tin foil capacitor – 2,2uF + 3,3uF is close enough

C2a = 10uF Intertechnik Audyn Cap Plus or Mundorf M-Cap Supreme polypropylene foil capacitor – with 0,01uF MKP1837 bypass cap

C2b = 2,7uF Intertechnik Audyn Cap KPSN or Mundorf M-Cap Zn tin foil capacitor

R1 = 2,2 ohms, 10 watts metal film resistor

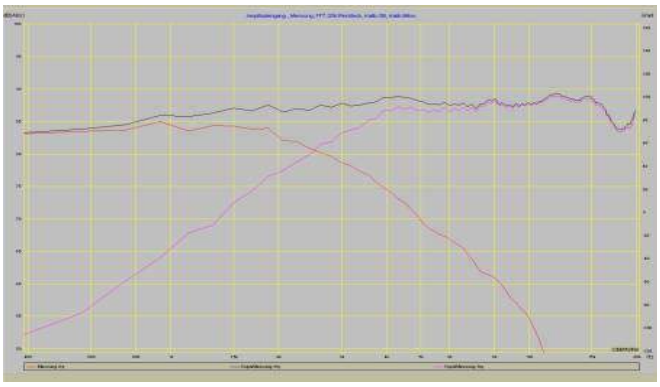
R2 = 3,9 ohms, 10 watts metal film resistor

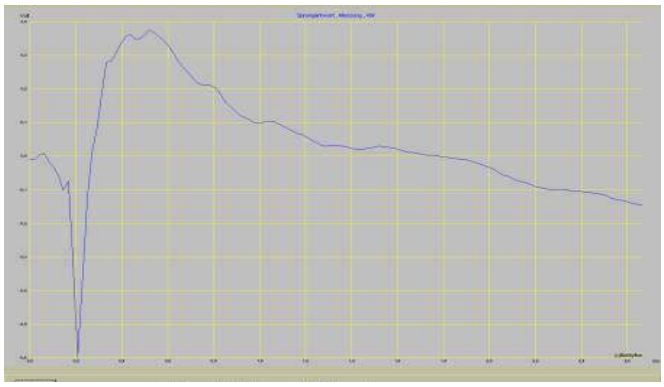
R3 = 10 ohms, 10 watts metal film resistor

Listening impressions and remarks

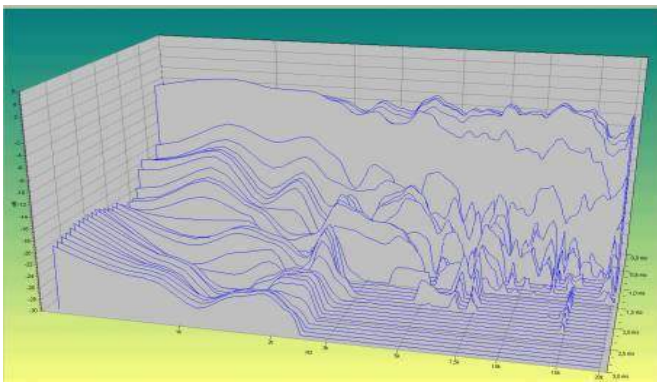
A lot has already been mentioned in the previous part but to some thing up it is a very coherent speaker. Bass is powerful and easy sounding; the midrange is open and direct and the treble is smooth and very detailed without getting too bright. It's not a background music speaker, it grabs your attention. Due to the revealing nature of this speaker it is very sensitive to the type of components used in the crossover but also to the other equipment and cables used in the rest of the system – it brings out their characters too. Dynamics are also very good considering the relatively small woofer. As far as two-ways go this is one of the best!

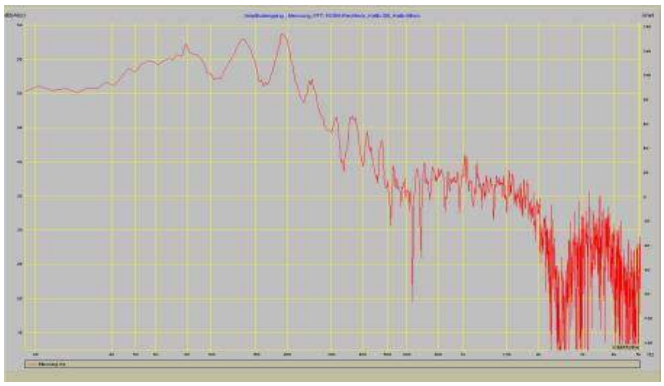
Final measurements



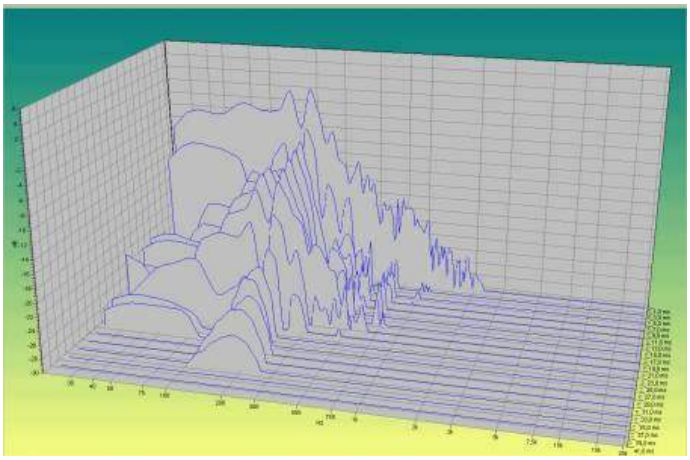


output level individual drivers and summed response; 5dB / 400Hz-20kHz; step-response 3ms time window





waterfall-spectrum finished speaker 3ms/-30dB; nearfield output from port, scale 5dB / 20-2000Hz



waterfall-spectrum port 41ms/-30dB; 20Hz-20kHz.

NOTE: This design is strictly for the home DIY enthusiast and not to be used professionally without my permission!

Tony Gee, The Netherlands

May 2004, updated June 2004