The 2.5 clone papers

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This is a compilation of former 2.5 clone files found at http://members.chello.se/jpo/

Only a few changes have been made to the files, thus reflecting the project progression during the last 9 months of work on the Response 2.5 clone. New are some comments on the ProAc sound at page 41.

Thanks to those who started the project and gathered the basic information needed to get it all going. Thanks to Paulie, US, for the basic crossover design. And thanks to all who reported their project on the web (a large number of links can be found at http://members.chello.se/jpo/. Without the inspiration from these people, this would never have evolved to such a long story.
Thanks to Darryl Nixon, Australia, for all the discussions and constructive criticism. Without the help of Darryl and his “One Cloner’s Journey” found at http://www.diyaudio.com , we would not have had such a fruitful discussion on the merits and deficiencies of speakers in general and of the 2.5 clone in particular. There will be different views on the “right sound” of the clones, but only your ears can tell, what is best for you and your favorite music.

If you have any questions regarding the project, you are welcome to address troels.gravesen@danisco.com
Please refer to page numbers on specific questions.
Aarhus, 28th September, 2003.

2.5 clone measurements and construction, v5

Hello, 2.5 cloners!
Thanks to all for the huge number of mails coming in from Canada, US, Australia, Hungary, Norway, Sweden, UK, Finland, Russia, Greece, New Zealand, etc. as response to these pages. And I cannot thank 'JPO' enough for lending me the space on his website. Thanks to all who wrote, and commented on the work. Without these mails the project would have ended another place.
In this 5th (!) version of my file I have added the construction of bass reflex enclosures with final measurements and comments. Initially the drivers were mounted in transmission line cabinets available, similar in size to the 2.5s, making reliable measurements.
I have had a lot of mails describing the benefits of adding the LCR circuit to the original design in order to get a more even frequency response but also with some regrets over loosing some of this immediate appealing 'technicolor' sound of the originals.
Some people have been confused over the increasing numbers of crossover designs; they want solutions, not options. For good reasons, they want to stay faithful to the original design and that's fair enough. However, we cannot acquire the original drivers and we will never be able to make an exact copy of the originals. But reports from people comparing the clones and the originals tell us that the clone can be just as good or even better.
The crossover modifications are fairly simple and the choice is yours! The starting point is the crossover in fig. 1. This design can be added a LCR notch filter, fig. 14, and you can leave it here. The latest modification I have made were done to fine-tune frequency and phase response and has - in my opinion – improved midrange response but has minor impact on the overall perceived sound.

Fig. 1 is the basic crossover (version 1) design I have been testing.

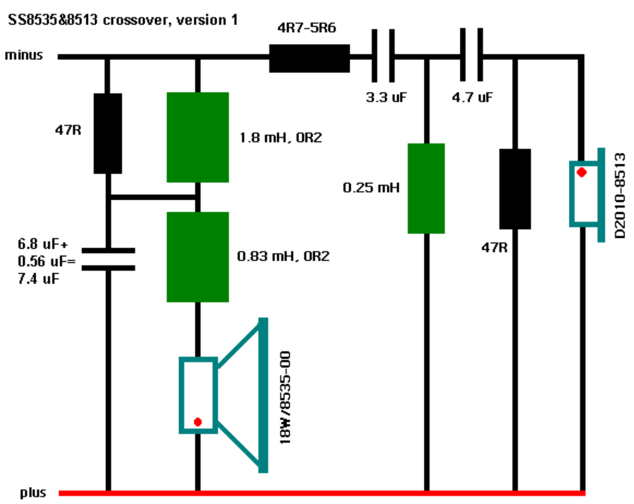

Fig 1. Basic crossover, 'version 1'.

And here are the MLS measurements from the Stereophile magazine, as a target for designing the crossover.

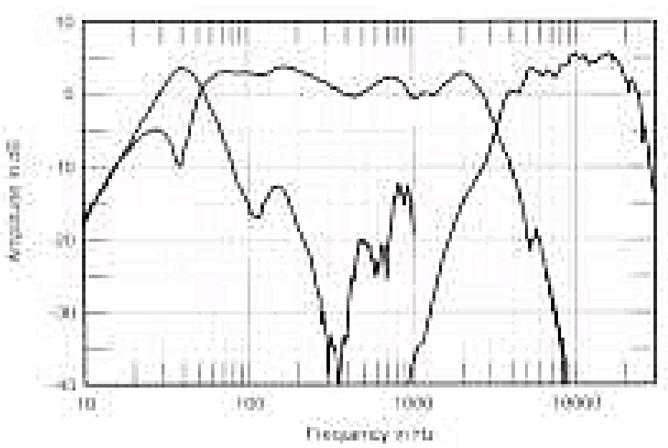

Fig 2: Stereophile measurements.
I was excited to see if the 2 kHz bump would appear as predicted from Al.M's writing at http://www.geocities.com/diyproac25/.
The bump came out beautifully as seen from the graphs on page 2!

Tweeter polarity

My first comment to the information available is on the discussion on tweeter polarity. It is suggested you try both options and choose what suits you the best.

With same polarity of woofer and tweeter there will be a major dip in frequency response, which at the same time can be used to fine-tune the crossover.

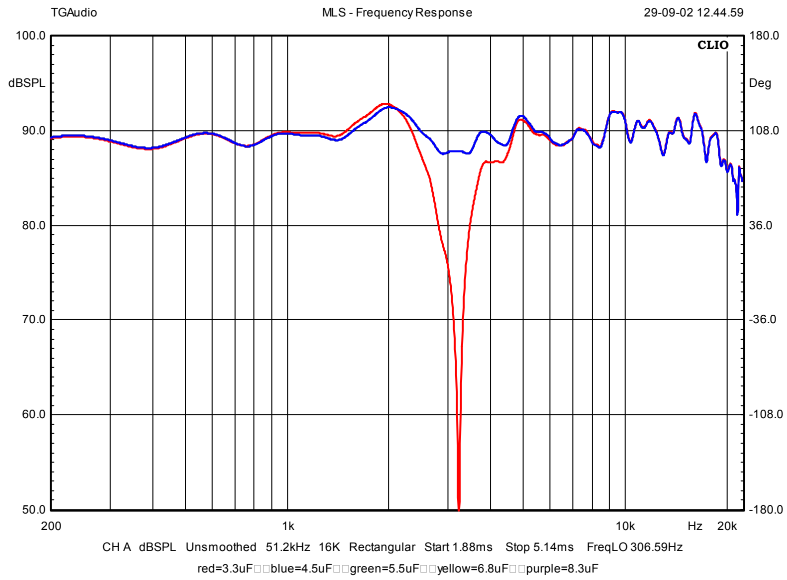

Fig 3: Polarity of tweeter.

The tweeter certainly has to be connected with <u>inverted</u> polarity.

Measurements on LP-section, inductor L2 values:

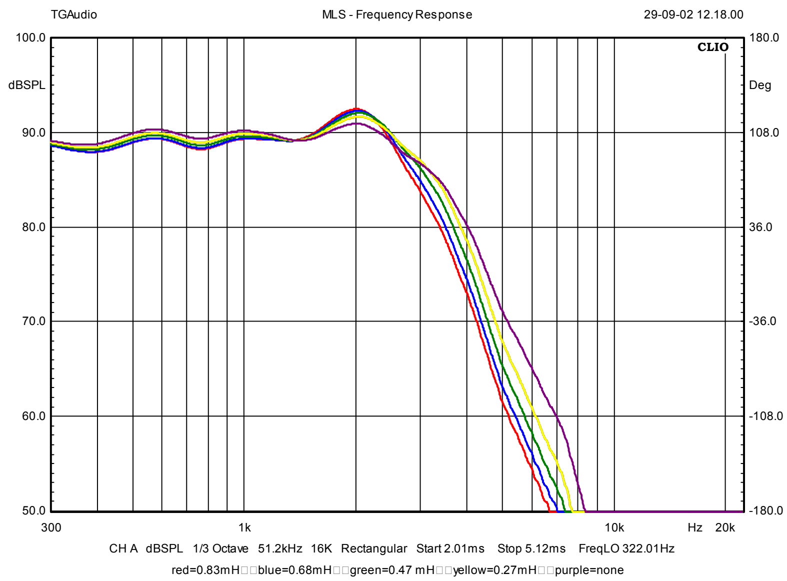

Fig 4. Initial measurements of 8535 with 0.83, 0.68, 0.47 and 0.27 mH inductor value of 2nd inductor in LP section. Not much chance of getting rid of the 2 kHz bump without a LCR circuit. I does strike me however that that lowest value gives a response closer to the Stereophile measurements. Making the textbook LP crossover the response is 40dB down at 7 kHz where the target seems to more like 40 dB down at 9 kHz.

For the time being I stayed with the 0.83 mH. The 300-1500 Hz response is rather smooth which pleases me a lot.

Significance of value of capacitor in LP section.

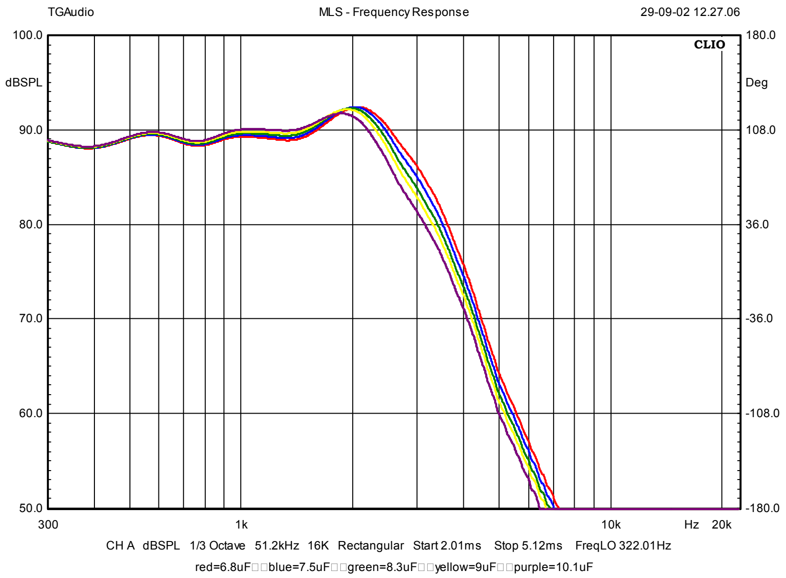

Fig. 5.

The value of this capacitor makes a fine instrument of changing crossover frequency.

Significance of C1 in LP section on full range response.

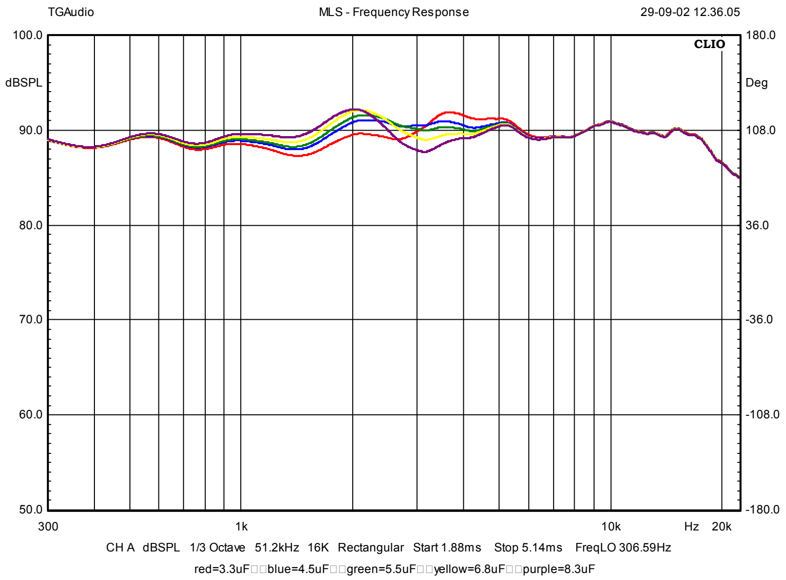

Fig 6. MLS 0.33 oct. smoothing.
8.3 uF seems to be a too high value, where 5.5 to 6.8 uF looks more appropriate but as seen from the curves this capacitor plays an important role in determining frequency response.

Series resistor in HP section

I would go for the 5R6 value, giving a quite flat frequency response. Going lower may give you an immediate appealing sound, but may add to listening fatigue in the long run. But this can be depending on room acoustics and listening distance.

47 ohms resistor in HP section.

In crossover diagrams available, the 47 ohms (R3) resistor is placed at different locations.

1. on tweeter terminals
2. before the 4.7 uF capacitor to ground

The graph above demonstrates the (minor) significance of this resistor placement. I've chosen to place the resistor on tweeter terminals.

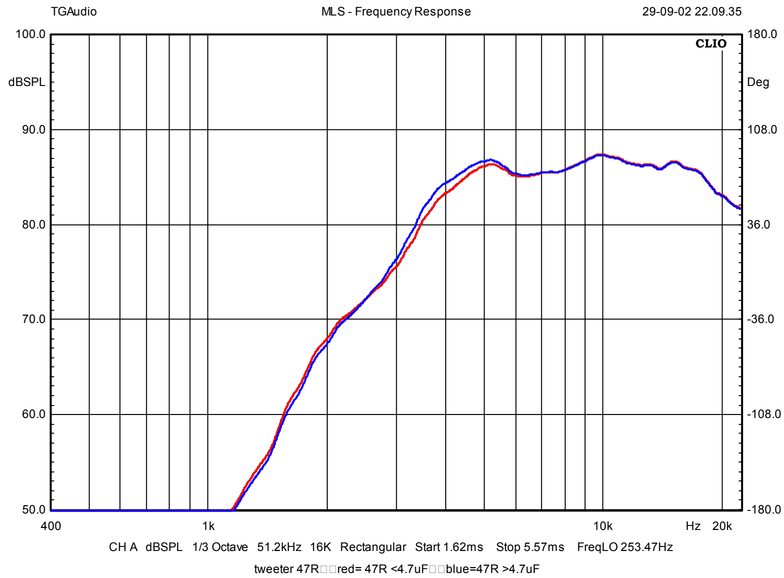

Fig 8. Tweeter, MLS, 0.33 oct smoothing.

Construction of notch filter for the 2 KHz bump:

A LCR notch filter was designed to smooth the frequency response between 1500 and 3000 Hz consisting of 1.5mH(0R35)+3.3 uF+10 ohm resistor.
Fig. 9 displays the impact on 8535 response, MLS with no smoothing.

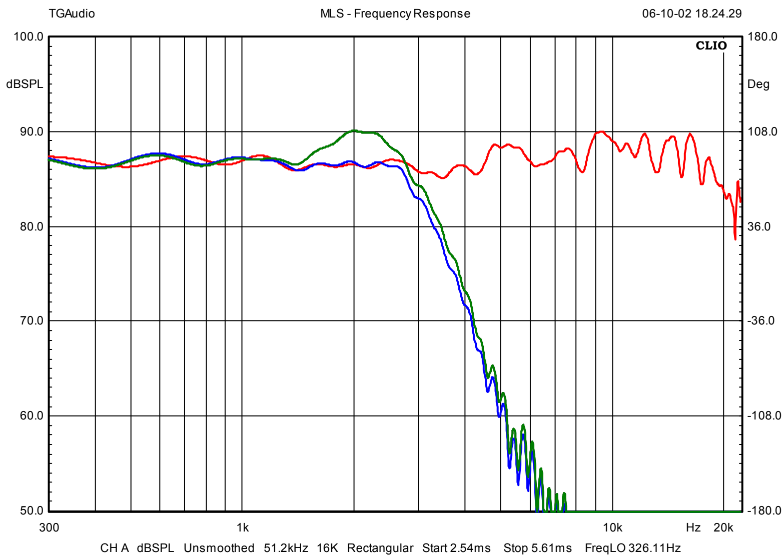

Fig.9. LP section +/- LCR and full range response with LCR.

Notice that crossover target is only slightly affected and can easily be adjusted with C1. Fig.5.

LCR impact on full range response

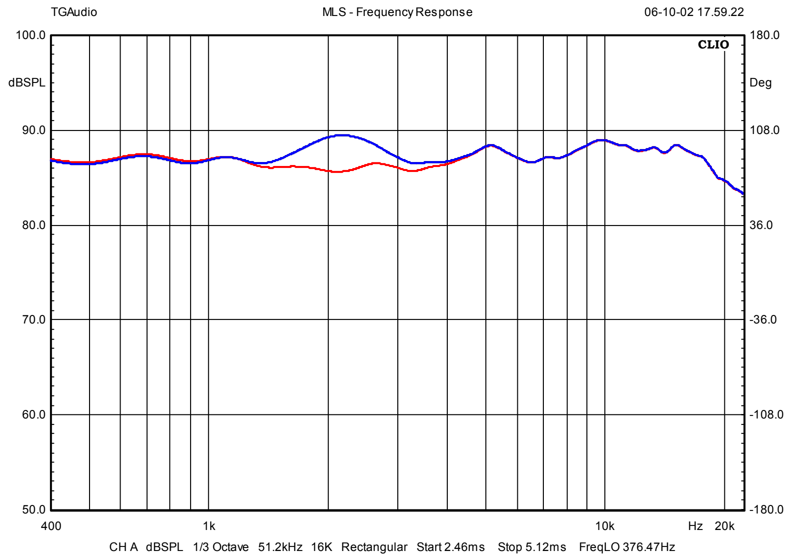

Fig.10. Full range response +/- LCR, 0.33 oct. smoothing.

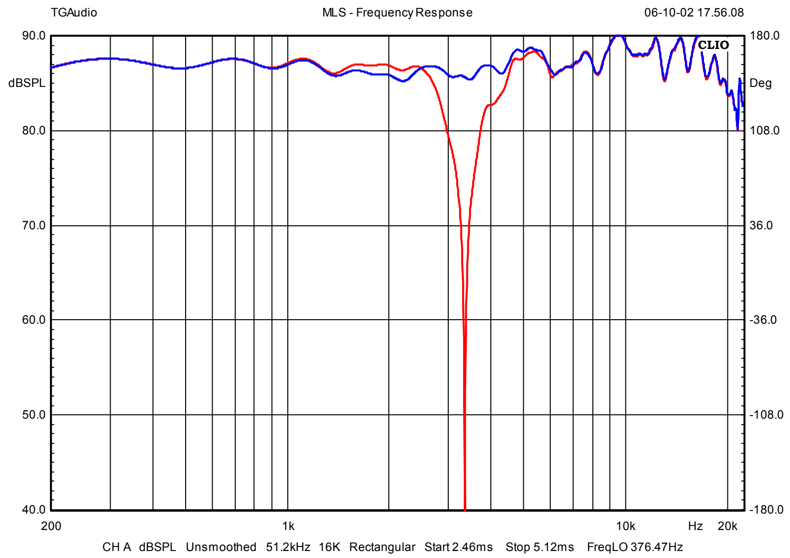

Fig. 11. Full range response + LCR, same and reverse polarity (no smoothing). 1 meter distance, tweeter height.

Significance of LCR on cumulative spectral decay.

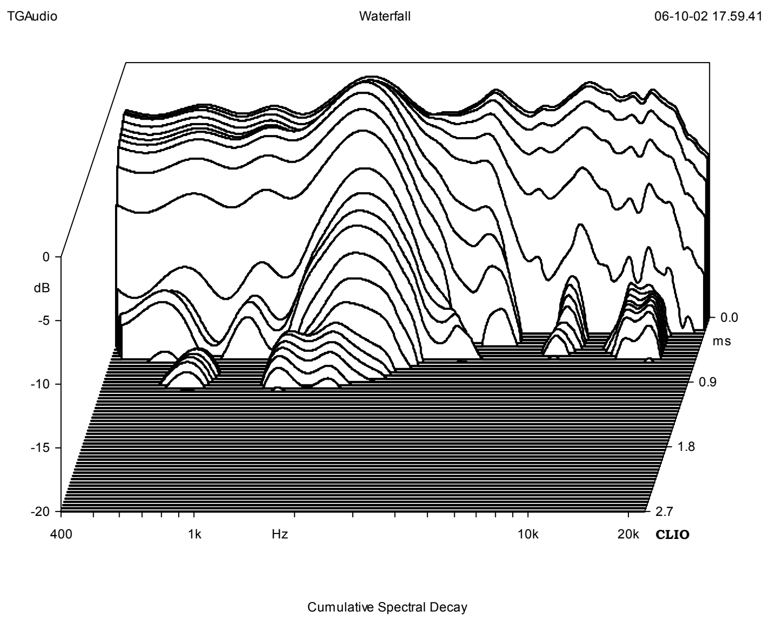

Fig.12. 20 dB range CSD, without notch filter.

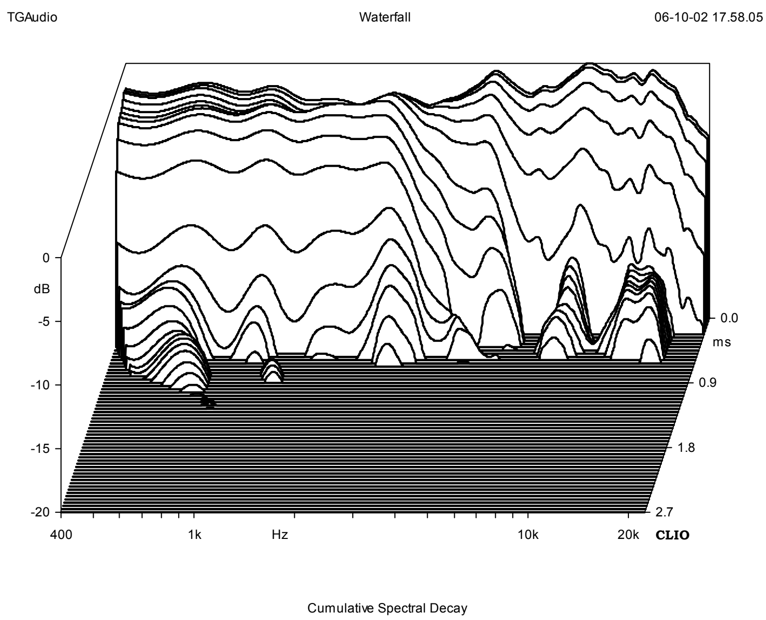

Fig.13. 20 dB range CSD, with notch filter.

The impact of the notch filter speaks for itself. With the LCR circuit in place an impressive ± 1 dB frequency response is achieved between 300 and 4000 Hz, and the lack of the 2 kHz bump is clearly audible, where especially female voices gets a natural balance and acoustic guitars which may sound almost too good with the bump, now are presented with a much more realistic timbre. Listening to pink noise on the 8535 +/- LCR filter strongly suggests we get rid of the bump. Read Lynn Olson (Ariel) on the use of pink noise! http://www.aloha-audio.com/Arieltxt2.html#top

And best of all, the 8535 does not loose its fresh and crisp presentation. The sound of the 8535 is hard to describe (isn't sound always?), but certainly this is a very lucky/clever combination of the right matrix of paper pulp and carbon fiber, the right cone size and weight (the cone is more flexible that the 8545), voice coil dimensions, magnet size, all giving a smooth roll off characteristic and simplifying crossover design.

Modified crossover, basic design + notch filter (version 2):

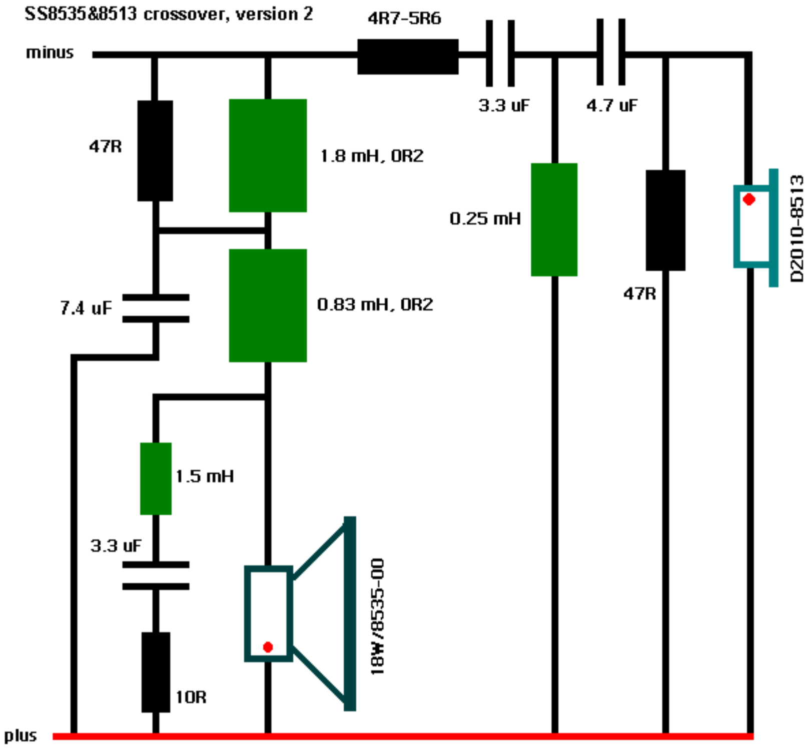

Fig 14. Version 2 crossover.

Fine tuning of crossover, version 3:
In order to improve frequency and phase response I have modified the crossover and it looks like this. Red indicates changes.

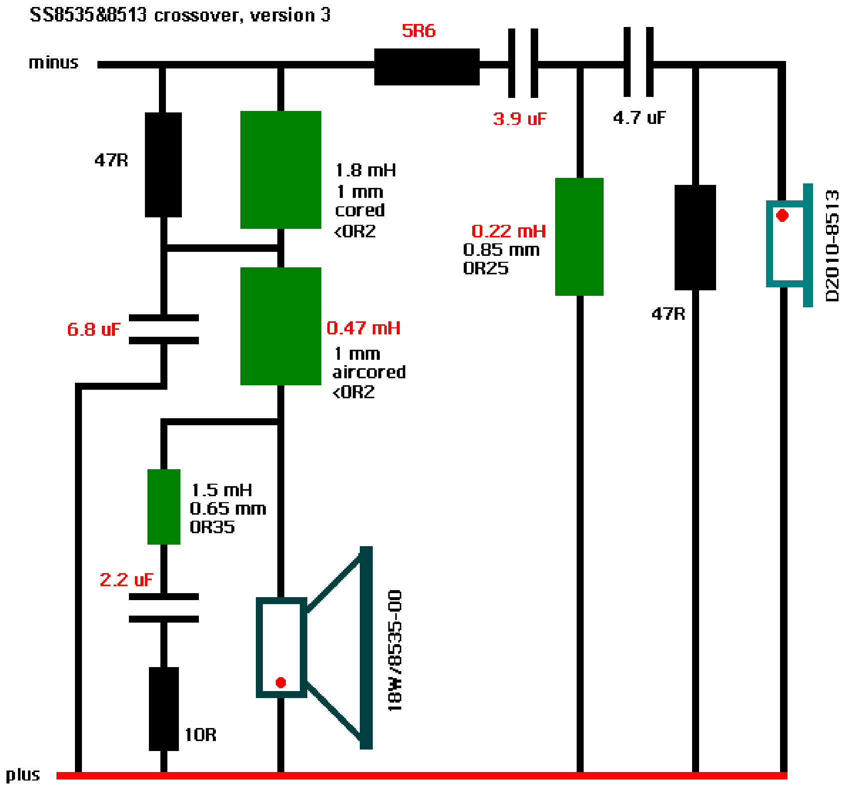

Fig 15. Version 3 crossover.
Some people have made complaints on the crossover presentation and here is a more graphic presentation for bi-wiring. The components in the LCR circuit can be put together in <u>any</u> order,
it <u>does not</u> matter! And be sure to have a decent distance between inductors - like 5 cm, in order to reduce interaction.

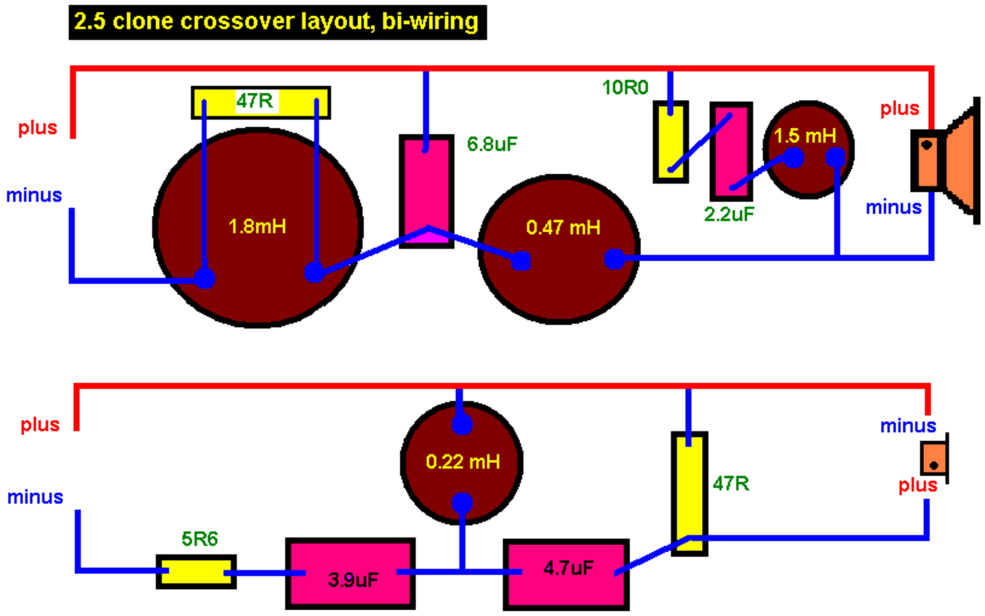

Fig.16.

System response with Fig. 14 (version 3) crossover:

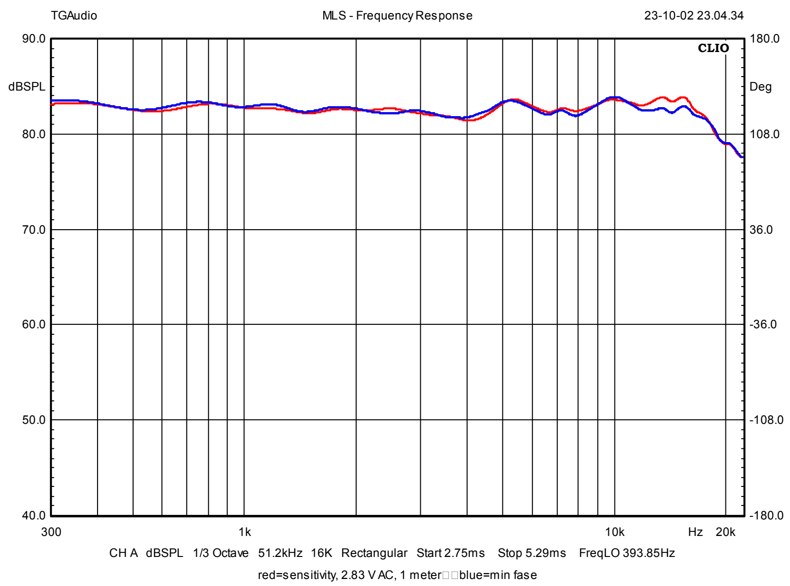

Fig.17. System response, version 3.
Red/blue=left and right speaker.

System impedance

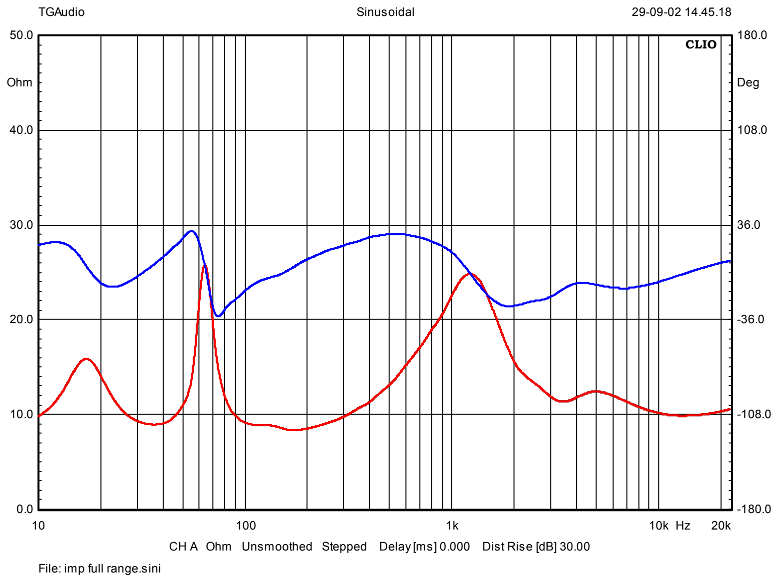

Fig. 18. Impedance of full range (without notch filter) system.
Not that much different from the Stereophile measurement, although it's difficult to read the scale on the Stereophile scanning.
The high damping of the lower impedance peak in the bass is caused by the stuffing of the transmission line and should be disregarded in this context.

ScanSpeak 18W/8535-00
Finally, here are the TS parameters of my 8535s: The data for the two units are remarkably alike, but the Qt is significantly higher that the promised 0.4!
ScanSpeak data: Vas=69 litres, Qt= 0.38 and Fs= 26 Hz.
My measurements: Vas = 44 litres, Qts= 0.52 and Fs= 34 Hz.
ScanSpeak is using constant current method at high level, 36 mA, which may account for lack of correlation.
My speaker calculation software says ~ 42 liters from the SS-data, my measurements suggests ~ 67 liters. Another software tells me this unit is best suited for a closed box!

MANUFACTURER	**ScanSpeak**	**ScanSpeak**
MODEL	**18W8535-I**	**18W8535-II**
DATE	20-09-2002	20-09-2002
Fs	**33.9**	**34.8**
Qms	**2.92**	**2.93**
Qes	**0.63**	**0.63**
Qts	**0.52**	**0.52**
VAS	**43.9**	**43.1**
Mms	**14.4**	**13.9**
BL	**5.34**	**5.36**
dBSPL	**86.3**	**86.6**
SD	**0.0143**	**0.0143**
Re	**5.88**	**5.94**

Fig.19. TS data.

These data were generated with my CLIO measurement system set at 0dB level. Adding another 0.4 ohm resistance (from inductors) in series with the woofer makes things even worse. The magnet on the 8535 seems to be too small for a 33-liter cabinet. Object for some tweaking!

TS parameters at different measuring level:

measuring level	+10dB	0dB	-10dB	-20dB
MANUFACTURER	**scanspeak**	**scanspeak**	**scanspeak**	**scanspeak**
MODEL	**18W8535**	**18W8535**	**18W8535**	**18W8535**
DATE	**30-01-2003**	**30-01-2003**	**30-01-2003**	**30-01-2003**
Fs	**32.37**	**35.16**	**36.65**	**37.35**
Re	5.86	5.86	5.86	5.86
Rms	1.15	1.00	1.01	0.92
Qms	2.64	2.96	3.47	3.72
Qes	0.54	0.60	0.66	0.68
Qts	**0.45**	**0.50**	**0.55**	**0.58**
Cms	1.62	1.53	1.24	1.24
Mms	14.96	13.41	15.24	14.68
BL	5.74	5.36	5.60	5.44
VAS	**46.25**	**43.71**	**35.40**	**35.40**

Fig.21

Series filters

At http://audioclone.free.fr/ two series filters have been proposed and I have tried to wire up the circuits, and here are my measurements:

Version 1:

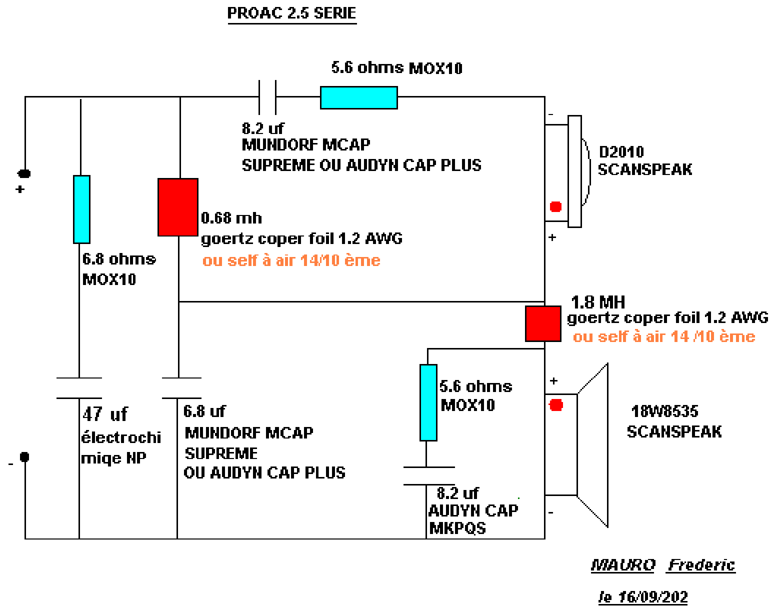

Fig. 22. Series filter #1.

First of all a RC circuit has been placed at the crossover terminals which is a strange feature as it generally lowers the sensitivity of the whole system. I'll show later the impact of this on frequency response.

Frequency response, series filter #1, no RC circuit:

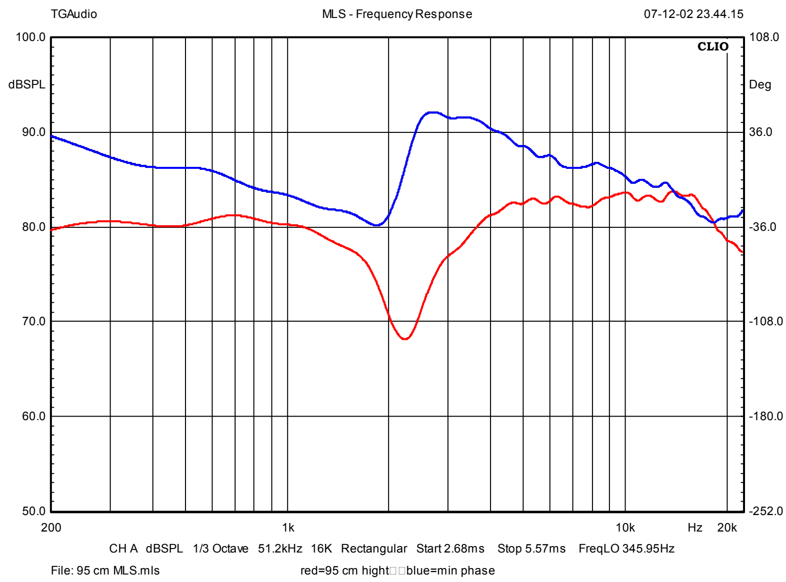

Fig.23. Series filter #1, 1 meter distance, tweeter height. Red=freq.resp. blue=min.phase.
When I first looked at this I thought I'd done a serious mistake and checked the setup several times. Couldn't fine anything wrong. Minimum phase indicates serious problems and I tried same polarity of woofer and tweeter:

Frequency response, series filter #1, no RC circuit, same polarity:

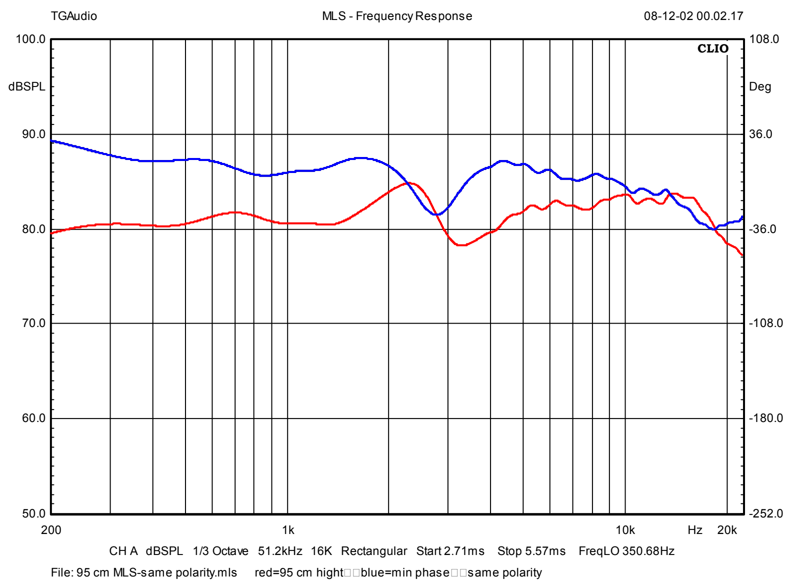

Fig.24. Series filter #1, same pol. Red = freq.resp., blue=min.phase

Well, at least the major dip in frequency response at 2 kHz was gone, but the 2 kHz bump came to life again and min. phase still isn't to pretty.
I suppose the series filter was constructed with the intention of keeping inverted polarity of the drivers, so I went back to this and tried different measuring heights.
Next is the response measured at 1 meter distance, microphone between tweeter and woofer:

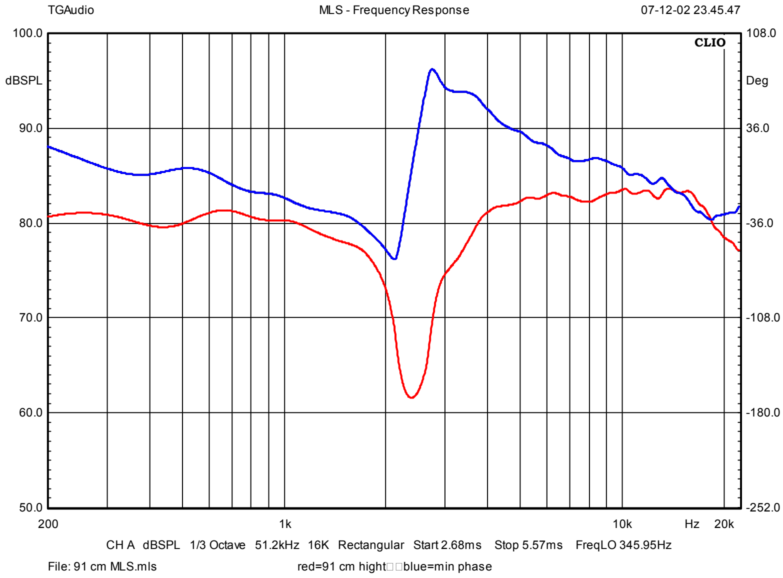

Fig.25, series filter #1, 1 meter distance, mic. between tweeter and woofer. Red=freq.resp., blue=min.phase. This turned out even worse, almost an 180° phase shift at 2.5 kHz.
I went back to measuring at tweeter height!

Series filter #2, no RC circuit

In this setup a 1 mH coil is introduced across the tweeter and there are minor modifications to the other components.

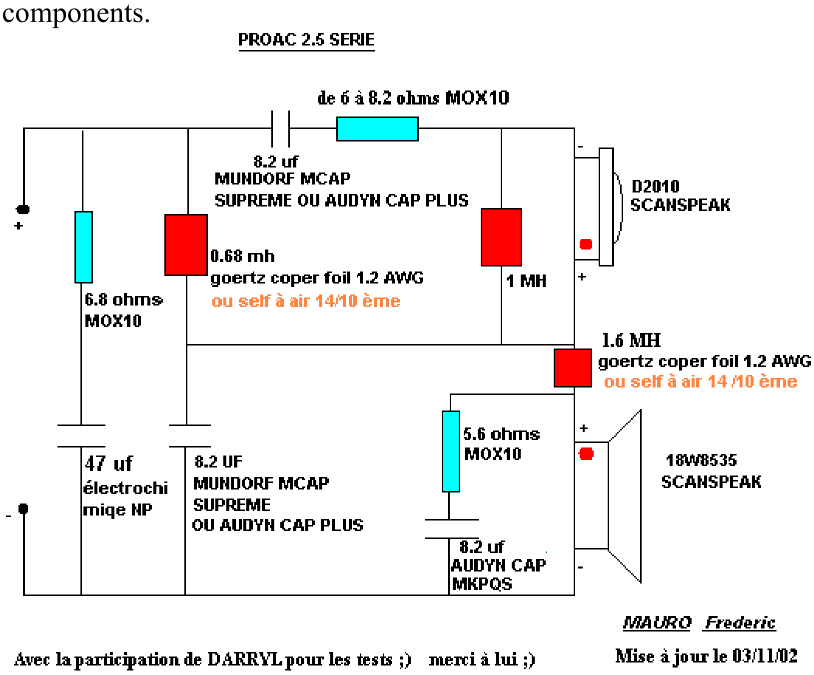

Fig. 26. Series filter #2.

Frequency response of series filter #2, no RC circuit:

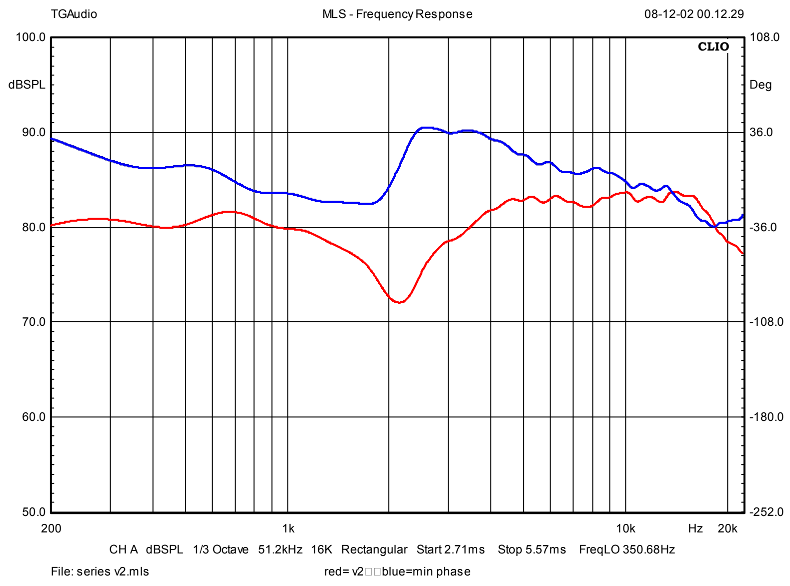

Fig.27. Series filter #2, no RC. Red= freq.resp., blue=min.phase.

The serious dip in response at 2.3 kHz has been reduced slightly, but this is far from being an acceptable frequency response. And still there are serious phase problems.

Impact of RC circuit on system response, series filter v.2:

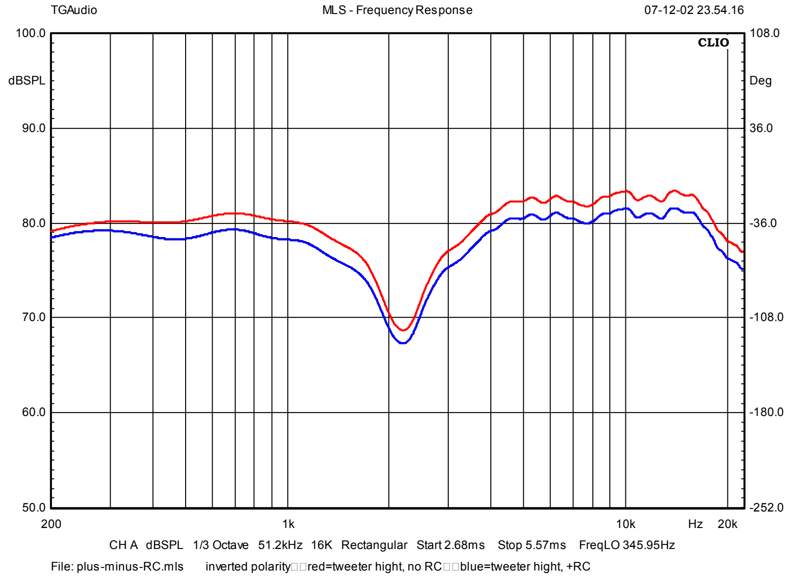

Fig 28, System response, series filter #2, with/without RC circuit. Blue = with RC.
The system response is generally lowered by 2 dB.
The system response of the 2.5 clone is around 83 dB/2.83 V/1meter, which is pretty low. No reason to burn more energy in the RC circuit.

<u>Impedance of system with series filter #2, +/- RC circuit:</u>

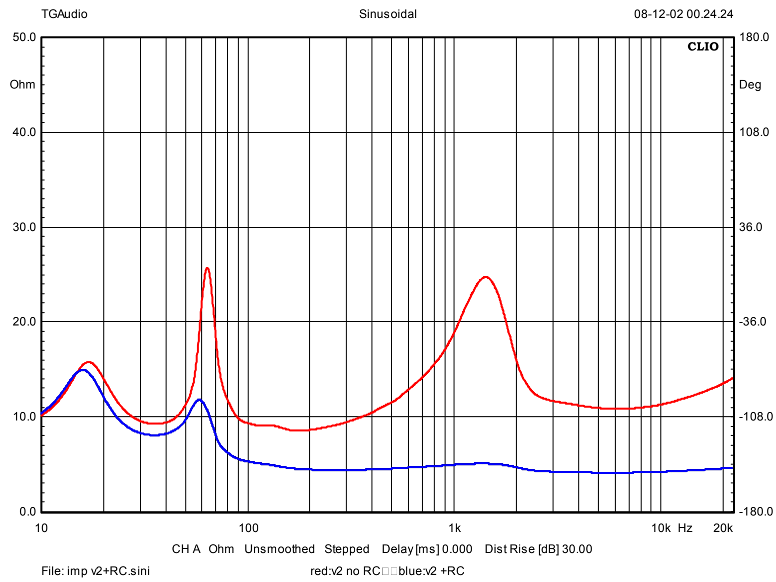

Fig. 29. Series filter, impedance, +/- RC circuit.
Indeed the impedance is flattened to around 4 ohm above 100 Hz.
My only comment to the RC circuit is that this must be a mistake.

Well, those who might have been annoyed with the 2 kHz bump in the original design certainly eliminate this problem with the series filter, but this seems to introduce new and more serious problems. Frequency and phase responses are unacceptable and serious tweaking is necessary to get it right.
The problem with series filters is that it's difficult to measure the response of the individual drivers. John Kreskovskij has a method, but I haven't tried it yet.
http://www.geocities.com/kreskovs/Series-1.html
I have only briefly done listening tests with the series filter but I find the dip at 2 kHz clearly audible and the tweeter far to loud for my taste.

Replacing the drivers with 8 ohm resistors is not strictly correct but can give us an idea of what is going on.

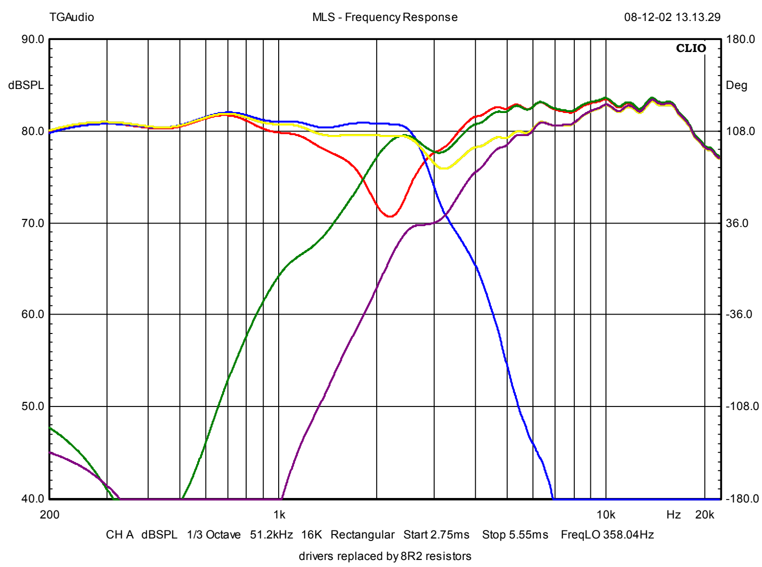

Fig. 30.
Red= frequency response of system with series filter.
Blue= 8535 woofer with series filter.
Green= 8513 tweeter with series filter.
Purple= with resistor and capacitor for tweeter inverted, which gives a better response because now the capacitor 'sees' a much more reasonable impedance.
Yellow = system response with this modification.

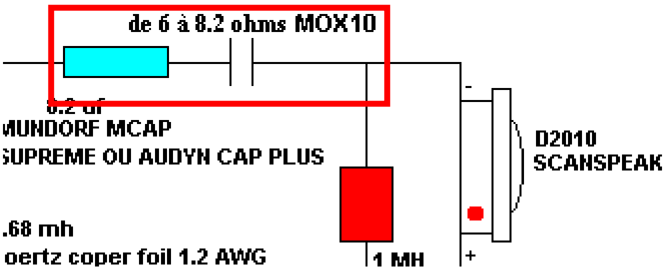

Fig 31. Part of series filter with inverted C and R for tweeter.

With the suggested design the tweeter reaches down to 1500 Hz giving serious phase problems in the crossover region.
Inverting the resistor and capacitor helps a lot, but there are months of work to get it right!

Conclusion on series filters:
The series filter has a less than acceptable frequency response, serious phase problems and cannot be recommended.
And don't place a RC circuit on top of the whole crossover, this way you will just burn energy and reduce system efficiency, which is so much needed.

Construction of bass reflex cabinets:

A lot of cabinet construction papers have been published and I won’t go into much detail about this.
I have maintained the internal volume but outer dimensions have been changed to 20 x 26.5 x 100 cm and the bottom plate have been lifted to give room for the crossover to be placed externally. This way it’s easy to make changes, and the components are not affected by vibration from the driver. The tweeter has it’s own sealed back chamber in order to reduce vibrations from the woofer. Cross bracing has been added to reduce cabinet resonance. Cabinets are constructed from 20 mm pre-veneered MDF and front panels are 25 mm (15 mm solid mahogany + 10 mm MDF). Internal bracing is 10 mm MDF.

Fig 32. Cabinets partly assembled.
All walls are damped with 10 mm heavy polyester foam (glued to the panels) and a mixture of polyester and lambs wool available from Monacor is used for further damping.
Right behind the 8535 several layers of the lambs wool is placed in order to reduce standing waves hitting back on the membrane.
Deflex damping material is to my knowledge not available in Denmark (?).

Some more pictures:

Fig.33, 2.5-crossover.
Cored 1.8 mH coil and air-cored 0.47 mH, both <0R2.
Polypropylene capacitors and film resistors. (Still waiting for the 47 ohm film resistors).

I don’t think this construction justifies the ultimate crossover components unless you think this is THE speaker of your life. There are a lot of other variables that have greater influence on the sound.


Fig. 34, front plate.


Fig.35, back side of front plate.


Fig.36, damping material.

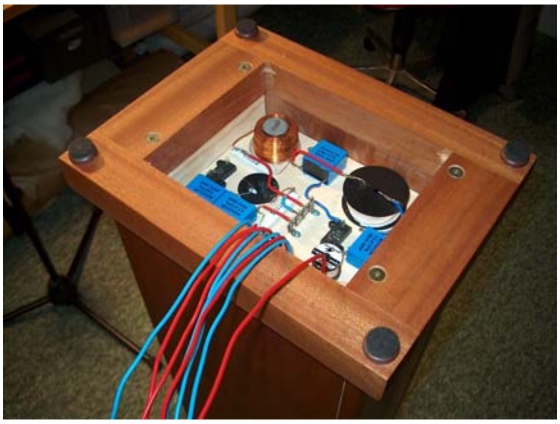
Fig.37, CO at base plate.

At last, the final cabinets with drivers, first play in my workshop; why is it that I after just a couple of months forget how many hours it takes to build a pair of cabinets!?

Fig 38. First time setup in my workshop.

Crossovers, the never ending story…
- and short presentation of features:

1. The 'original' design, version 1 (fig.1)
You are likely to have a major bump at 2 kHz, which sounds very well on certain recordings but makes voices and violins intolerable. Darryl from Australia calls this the 'technicolor sound' and that is just what it is.

2. Original design + LCR, version 2 (fig 14)
You get rid of the 2 kHz bump and can enjoy a wider spectrum of recordings. Enhanced three-dimensionality and lots of space.

3. Modified crossover + modified LCR, version 3 (fig15)
An even flatter frequency and improved phase response in the critical upper midrange. The choice is yours.
Having finished my bass reflex enclosures I have wired up the three crossover (CO) versions again and was excited to see whether I could reproduce my measuring results 2-3 months ago! And it didn't turn out too bad. All measurements performed at 1 meter distance, tweeter height.
The Stereophile review suggests we have a crossover point of 3200-3300 Hz, where the version 1 gives 3000-3100 Hz, slightly below the original. The version 3 displays a crossover point of 3350 Hz. However, no need to be exited about +/- 100 Hz. The aim of the v3 crossover was to create a less steep roll-off as seen on the Stereophile measurements. The 8535 driver is down 40-45dB at 8.5 kHz where we - with the v1 crossover - reach this level already at 7 kHz. It has been suggested that the OEM-8535 has less carbon fiber and a more flexible membrane than the 'DIY' units. This could mean enhanced high frequency response and a smoother roll-of performance. The problem with having a notch filter at 2 kHz is that it is so close to the crossover point, that it's impact is stretched over the crossover region. I have tried a notch-filter acting exactly in the 1500-2500 Hz region, but this didn't perform well.
Fig. 39 and fig. 40 displays the 8535 performance with the v2 and v3 filter +/- notch filter.
Fig. 41 and fig. 42 displays the overall performance of drivers with same and inverted polarity and tells us that we have a very good phase correlation between drivers in both cases. The v3 has a more symmetrical >20 dB null at crossover point with same polarity. The 8535 with the v2 CO has a very abrupt, linear and steep roll-off behavior.

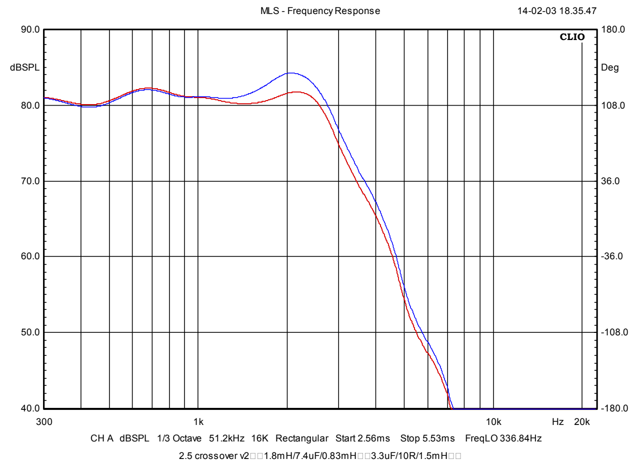

Fig. 39. 2.5 crossover, v2, red: + LCR, blue: no LCR

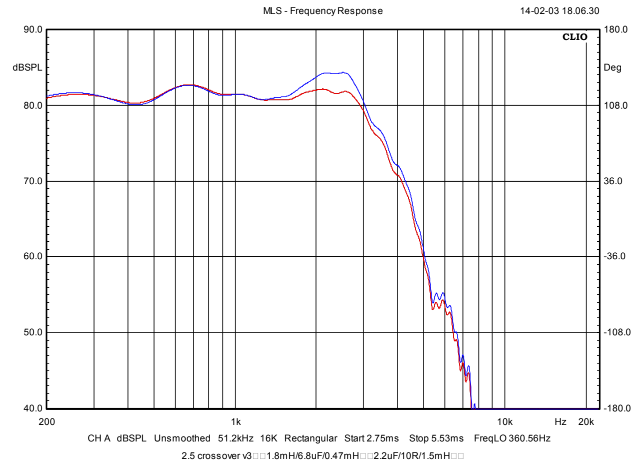

Fig. 40. 2.5 crossover, v3, red: + LCR, blue: no LCR

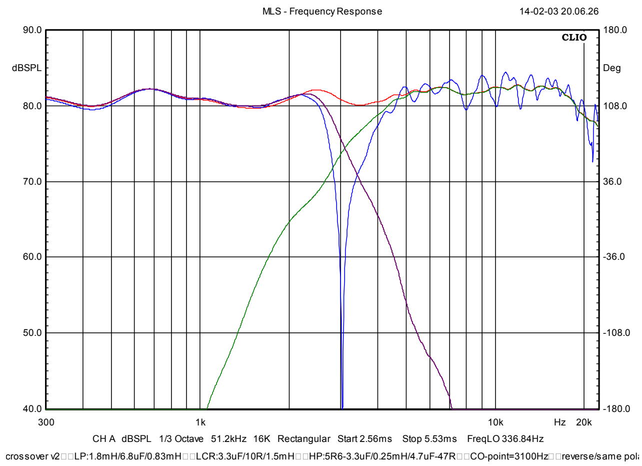

Fig. 41. 2.5 crossover, v2, all drivers, polarity
Crossover point = 3100 Hz
0.33 oct. Smoothing. Same polarity, no smoothing

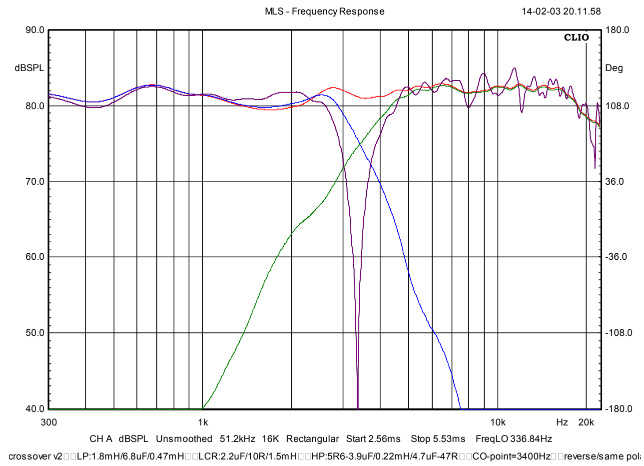

Fig.42. 2.5 crossover, v3, all drivers, polarity
Crossover point = 3350 Hz
0.33 oct. Smoothing. Same polarity, no smoothing

Frequency response of 2.5 with CO v2 and v3

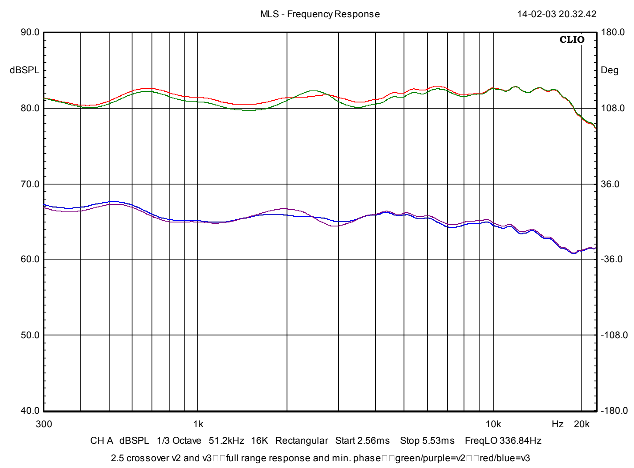

Fig. 43.Green/purple(min.ph) = v2, Red/blue(min.ph) = v3

Frequency response of CO v3 at 1 and 2 meters

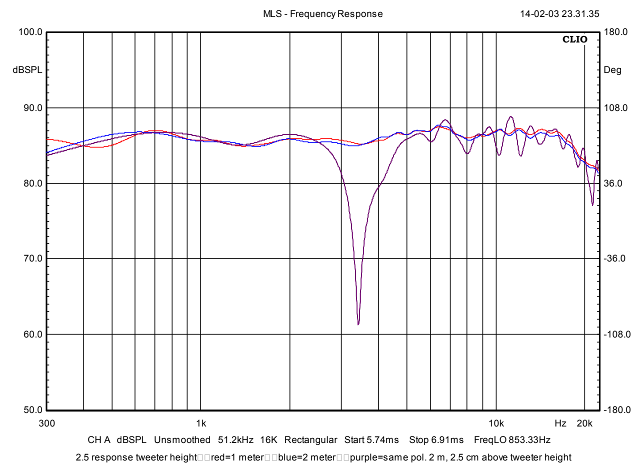

Fig. 44. Red=1m, blue=2m, purple=same pol.

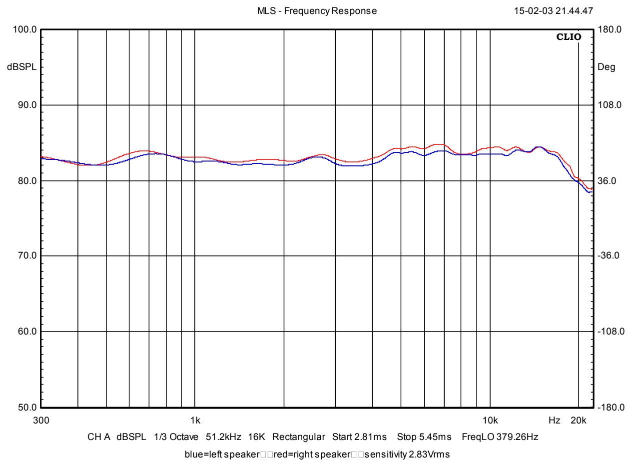

Fig.45. Freq. Response left and right speaker. Sensitivity at 1 meter, 2.83 Vrms, ~ 83 dB.

For comparison here are fresh Rogers LS3/5a (11 ohm version) frequency response curves, with and without front grille. A legendary loudspeaker with phase problems in the crossover region that today would make any home constructor ashamed of himself. <u>I keep these shoeboxes to remind myself of not overemphasizing any single parameter in loudspeaker construction because they sound so good.</u>

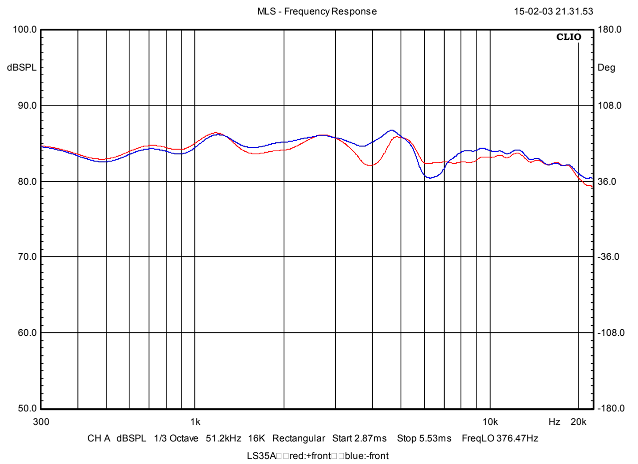

Fig.46. Rogers LS3/5a, 11 ohm version, 1989.

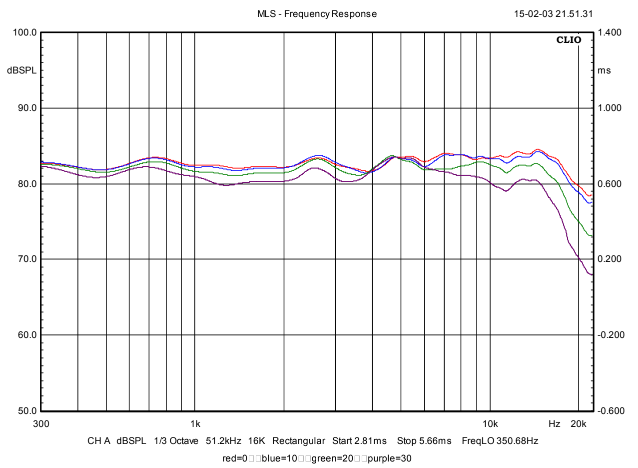

Fig. 47. CO v3 horizontal response, 0(red),10(blue),20(green)30^o(purple)

Well, whether you choose v2 or v3 crossover you will get a great speaker in any case.
Be sure to use the right component values in either case. The most important components are the capacitor in the LP section, 7.4 uF for v2 and 6.8 uF for V3, the coil in the HP section, 0.25 mH for v2 and 0.22 mH for v3 and finally the capacitor in the LCR circuit, 3.3 uF for v2 and 2.2 uF for v3.

I am very happy for the evaluation given by Darryl in Australia and with his permission, here are his comments:

I finally got around to experimenting with resistor value increases in the notch filter, which you suggested might restore some of the "life" or "technicolour" sound to your latest (final?) crossover version.

Increasing the resistor to 12 ohms does do this to some small extent I guess, but any greater value begins to re-introduce the upper midrange glare quite audibly (to my ears, anyway). All things considered, I still prefer the sound with the 10 ohm value, i.e. an optimally flat response in the 2 KHz area.

I did find that reducing the resistor on the tweeter from 5.6 ohms back down to 5 ohms produced quite an improvement - I should have tried this before - and restored much of that distinctive Proac sound, more so than I would have expected. (With the standard (Jacq) crossover + notch filter, I preferred the 5.6 ohms you recommend.) Increasing the tweeter output in your latest crossover makes it a lot harder to choose between the two versions. Even with increased tweeter level, sibilance is still better controlled and the midrange sounds more realistic than it does with the Jacq version + notch filter. I think I'll stay with your latest version for the time being, albeit with slightly increased treble. That change has swung things the other way for me. It seems a good compromise in my system, and 90 per cent of the time it sounds wonderful.

Incidentally, the listening tests I've been carrying out have been with a Dynaco PAS3X/Stereo 70 valve preamp and amp. I also have a Sugden C51/P51 solid state combo, but it's off for repair at the moment.

I was curious to see what would happen with a mid-fi solid state amp, so borrowed a friend's NAD 1155 preamp and Rotel RB-981 power amp. There is no doubt in my mind that the Proac is best suited to valve amplification. With this solid state set-up, there was a definite "hardness" in the midrange which was easily provoked by the wrong recording. Sibilance also became more of a problem. The sound was also quite "dry" and occasionally harsh, though bass depth and definition was astoundingly good. (A Superphon Revelation Basic Preamp did improve things at the top end.) Nevertheless, the speaker seemed a lot more tolerant of this set-up with your latest crossover than with the Jacq + notch filter. My own Sugden (although no longer young) works far better, having more valve-like warmth and a much superior presentation all round, though not as good as the Dynaco.

To my mind, the Proac Response 2.5 is a seriously good but extremely fussy speaker, easily provoked into sounding less than wonderful. The bass-mid is very transparent to the source, and can easily stray into hardness with inadequate SS amplification, disc-reproduction equipment or poor recordings. (I do wonder whether that hardness is in part due to cone break-up, albeit at a low level thanks to your notch filter.)
Another problem is the tweeter, which can easily stray into excessive sibilance with the wrong recording, though your latest crossover mods go a long way towards eliminating this. Yet another problem is a lack of energy in the lower midrange/upper bass, which seems to be room-boundary related. Careful positioning and a warm-sounding amp can minimise this, but it seems impossible to cure completely.
I guess I'm being over-critical, given the Proac's price-point. – and all "high-end" equipment is fussy. Nevertheless, this is the best speaker I have ever owned and pretty easy to live with - and it now works very well in my system. I just wonder how many people out there are disappointed due to matching problems in their systems!

Final evaluation
This is probably the most tough part of it all having to express sonic qualities in a foreign language.
But I'll give it a shot….

This is probably my 5th floorstander of this design being bass reflex or transmissionline constructions, all two-way designs of approx. 20x25x100 cm in size with SS8545+9500, Vifa PL18+XT25, Vifa M18WO+D27, etc.

My setup consists of a ROTEL CD modified with goodies from LCAudio, a CT101 audio buffer from **D**anish**A**udio**C**onnec**T** (www.dact.com) and a LCAudio, non-feedback 120 W power amplifier, Millenium edition (www.lcaudio.dk).

Listening sessions, version 3 crossover.

First disc was Charlie Haden & Pat Metheny: Missiouri Sky.
It's been a couple of months since I had my initial transmission lines running and the final setup with the reflex boxes by far exceeded my expectations. The bass is significantly better in the reflex boxes and I had to remove things from my living room that do not use to rattle with my 'reference' system! I can't believe they go this deep! A tiny 6½" woofer! The midrange is clear, crisp and transparent and listening to acoustic music it's very, very good. On track two the guitar is very closely miked with a lot of low-end information and the bass attack is most impressive.

The tonal balance seems to favor the highs and listening to female jazz-singers, strings and big-band music was not so impressive! 'S'-sounds and 'T'-sounds are much to pronounced and the tonal balance of violins are simply not correct compared to my 'reference' where voices can be played at loud volume without distress. The phenomenon is called sibilance!

Tried to unplug the tweeter and played the 8535 at loud levels and everything sounds fine except that you miss the tweeter. The problem doesn't seem to come from here.

Another comment from Darryl:
Do you also find a lack of energy in the lower midrange/upper bass? My own clones sound beautifully warm provided there are deep lows in the recording, but if not, they can sound quite "dry".

Yes and no. I can't say that I have experienced any lack of energy or level in upper bass register and I believe actual room acoustics plays an important role here. On the other hand I like a speaker that has a very dry sound. I've done a lot to reduce vibrations in my cabinets and this probably helps a lot in providing a dry sound. I don't feel any vibrations on sides, front and back of the cabinet, but strangely enough on the top plate and I'll have to ad additional material to eliminate this.

Let's take another look at the frequency response:

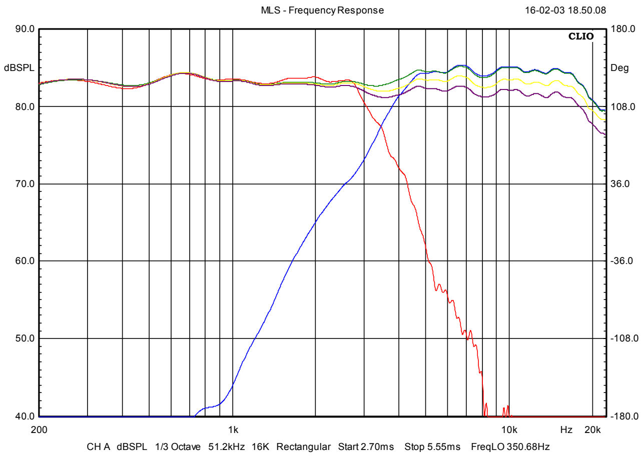

Fig.48. Value of tweeter series resistor
Green=5R6
Yellow=8R2 (sorry for the yellow, hope it's visible)
Purple=10R

Usually I try to target the BBC-dip curve, giving a ~2 dB dip in the upper midrange/lower highs usually giving a slightly more distant perspective, but an overall more balanced sound. The response of the clones do not exactly meet this criteria. We have a rather flat midrange response and it better be good with this level.

Fig. 48 graphs are showing the response at 2.83Vrms (measured at speaker terminals) and from 0.3-3.5 kHz we have a very flat response of +/- 1 dB. Quite impressive. But from 4-17 kHz we are least 2 dB higher and from another construction I learned that this could make a world of difference. I have worked a lot with the 8512 tweeter supplementing an ETON 4-300 midrange and this – when properly balanced – works very well. The 4-300 is a very revealing midrange driver and matching this driver with a slightly too highly pitched tweeter makes it intolerable to listen to.

Maybe the 8512 and –13 isn't that well suited to work with the much larger 8535 woofer/midrange cone. I would like to try the HIQUPHON OW1-tweeter without magnetic oil (and probably more heavily coated) and produced to very close tolerances with reported low distortion and coloration and an impressive CSD.

Changing the tweeter series resistor to 8R2 or 10R seems to correct things and I stayed with 8R2 because with 10R I would have to go through another fine-tuning of the HP section because it changes the crossover point to 3.7 kHz and creates a 1.5 dB dip at ~3.5 kHz.

It helped a great deal on the above mentioned problems although there are still recordings were they fall short compared to my 'reference'.

It's a gut feeling, that the 8513 may not be the one to pick if you want a more true presentation of the upper register of most instruments and voices. It has some intrinsic values in terms of speed and 'sparkling' sound, and possibly we can turn this speaker into something that will split constructors into two groups. One group that wants to stay true to the original design with its limitations in terms of not being able to obtain the 'real' OEM-drivers and another group that will take the best of the 8535's deep bass capabilities and midrange clarity and combine it with a tweeter that supplements these virtues with more fidelity.

Best regards
Troels Gravesen
troels.gravesen@danisco.com

PS, 30.03.2003

Have tried the OWI tweeters and except for size and sensitivity they can immediately replace the 8513, but the response turns out even flatter than with the 8513s and the sound wasn't so good. After some tweaking, I decided this would require a new crossover and tempting as it was, this is not the time.

The OWIs measures the best I have ever experienced. Ruler flat from 1 kHz to 20 kHz! Can't wait to incorporate these in some future design.

The 2.5 clone without notch filter

Sometimes it takes a journey to get back to your starting point and see what is the real problem in front of you.
This being the case with the 2.5 clone and the 2 kHz bump created by the 8535 driver itself and the crossover topology. One person at diyaudio.com working with active crossovers for the clone even predicted that there should be a bump at 2 kHz derived from the crossover.
In my latest paper at http://members.chello.se/jpo/ (***New 2.5 clone tweeter, crossover and speaker setup***) I have constructed a new crossover for implementing the ScanSpeak D2905-9500 tweeter.
By starting all over again with the crossover it was obvious to experiment with the Q of the parallel capacitor in the LP-section. In order to get the target point of crossover and the target roll-off characteristic a RC circuit was added. It appeared that no notch filter was needed.
When this was done it was obvious to try to apply this approach to the 8535+8513 drivers for those who want to maintain the 8513 tweeter.

Initial measurements of 8535 driver:

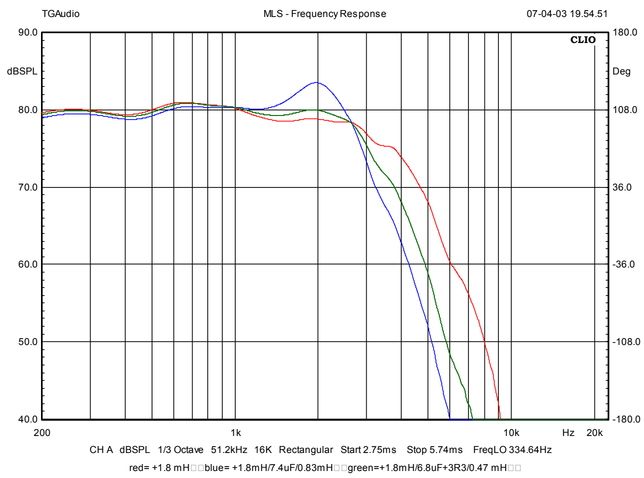

Fig.1. 8535 driver SPL response, 0.33 oct. smoothing.

Blue = 8535 driver with v1 crossover: 1.8 mH//47R + 7.4 uF + 0.83 mH
Red = 8535 driver + 1.8 mH
Green = 8535 driver with new crossover: 1.8mH + (6.8uF+3R3) + 0.47 mH

As seen from the graphs it is possible to eliminate the notch filter by adding a resistor to the capacitor. That simple!
And the point of crossover can still be adjusted by the capacitor value (data not shown).

I have tried to maintain all component values in the new design to minimise the cost of the change. This modification refers to the 'version 3' crossover found in ***'2.5 clone measurements and construction, v5'*** at http://members.chello.se/jpo/.
And it implies the use of DAMAR coating as described in 8535+9500 paper. However, I'm confident that this modification will also work fine without the DAMAR coating.

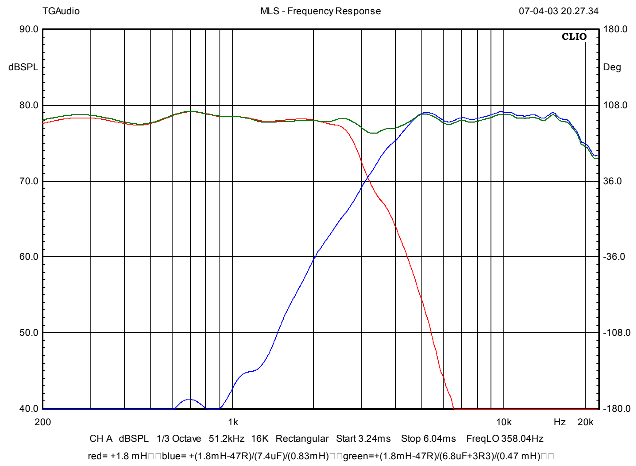

Fig.2. Driver response, 0.33 oct. smoothing.
As seen from the graphs the result is a smooth midrange response, and the level can be adjusted to personal taste by changing the value of the resistor in the in LP section, fig. 3.

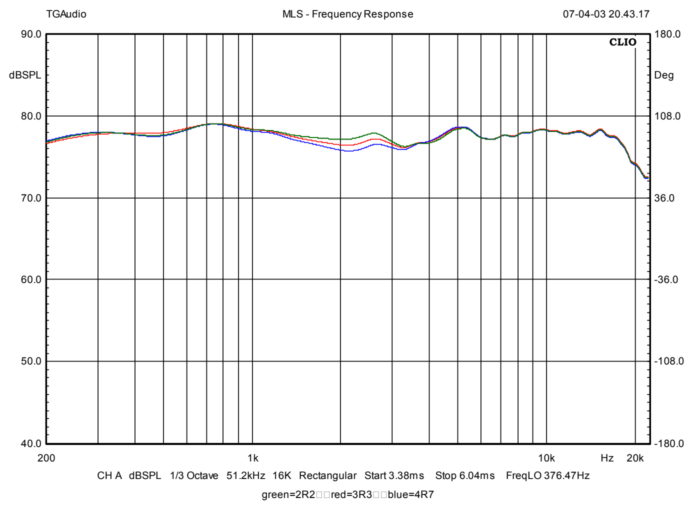

Fig.3. Value of R in LP section.
Green = 3R3, red = 4R7, blue = 5R6. I recommend 3R3.

Crossover changes:

- The 47R resistor parallel to the 1.8 mH inductor removed.
- The 6.8 uF capacitor is added a 3.3 ohm resistor.
- LCR notch filter is removed.
- No changes to the HP-section.

2.5 clone crossover, version 6.

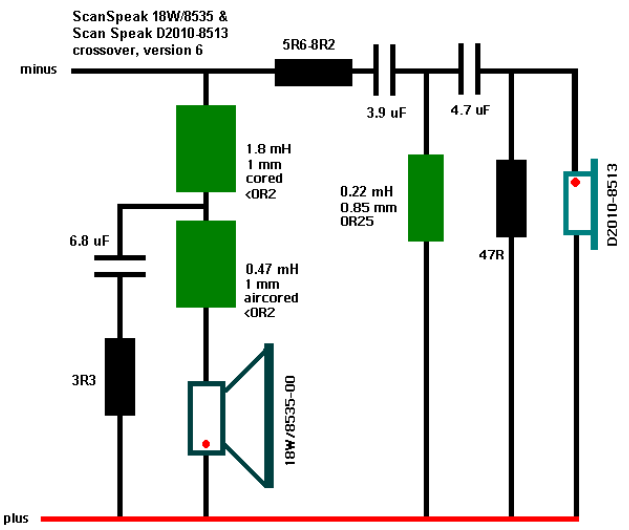

Fig. 4. crossover, v6.

(I'm sorry for having to call this version #6, but there have been a number of designs in between, and I have to keep track of all changes).

Here's a graphic presentation for bi-wiring:

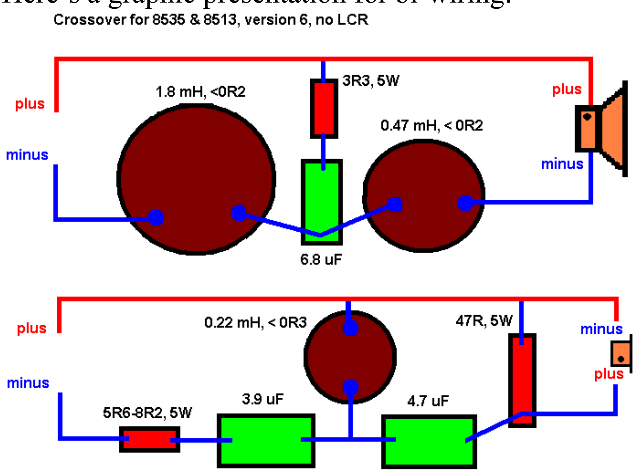

Fig.5, crossover, v6

Tweeter level

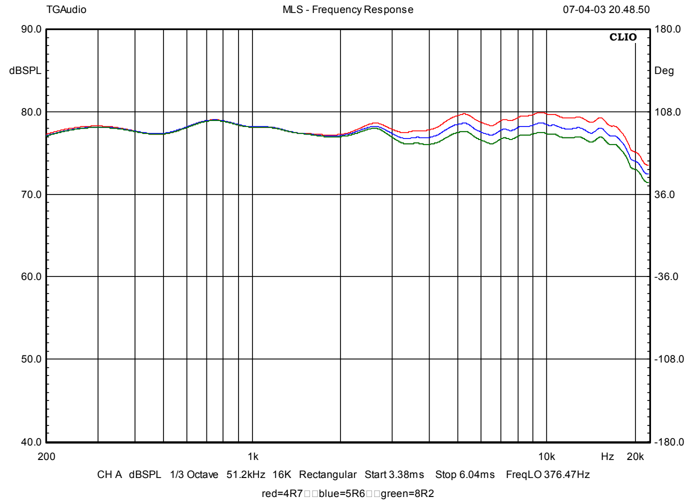

Fig.6. Tweeter series resistor, red = 5R6, blue = 6R8, green = 8R2. I use 8R2.
The choice is yours.

New tweeter for the 2.5 clone

After introducing the 2 kHz notch filter to the original crossover (v2) design and also introducing a slightly modified filter (v3) in order to smooth frequency and phase response in the upper midrange, still people have been complaining about the sibilant nature of the upper registers. I have defended the 8513 tweeter, being such a proven design, and have hesitated to make any changes to the tweeter as this would most certainly for good take us away from the ProAc Response 2.5 sound with its strengths and weaknesses.

However, I cannot ignore the fact that a number of my recordings linger on my CD-shelf as long as the clones are in place in my living room, this mostly being records of vocal music.

But first a short story on the tweaks that have been conducted in order to get to the decision of introducing a new tweeter.

DAMAR coating

A series of near field measurements of the 8535 were done in order to localize cone break-up and not surprisingly the dust cap is responsible for some serious cone break-ups that create a significant bump at 2 kHz (fig. 1) (same place as the bump created by the crossover).

Two layers of DAMAR coating were applied to the center dome and this to some extent smoothed the frequency response in the upper midrange (fig. 2) and also above 10 kHz. Subjectively this had a positive effect on the overall perceived sound.

Damping the 8535 Dust Cap (diyaudio.com), Darryl Nixon and Troels Gravesen.

Recent experiments by Troels Gravesen have demonstrated that there are advantages in applying damping to the dust cap of the clone's 8535 mid-bass driver. Troels has been working on the resonance problems of the 8535 which he found has "a major intrinsic bump at 3 KHz". In Troels' words, ". . . the coating seems to remove some edginess in the midrange with a more smooth performance and tolerance towards difficult recordings".

The substance used is Damar varnish, which can be obtained from artists' supply shops. The picture attached is from Troels and is of Damar as sold in Denmark. The following is reported with Troels' permission, together with quotes from his e-mails to me.

"As a start you may apply a coating until the dust cap is soaked and leave it there as long as it is not applied outside the dust cap. The effect should be there in a couple of hours . . .

"At the beginning of applying the DAMAR the somewhat porous dust cap readily absorbs the varnish and I continued to apply DAMAR until the surface appeared shining. This doesn't mean 'flooded' with liquid, so 'soaked' may be a little overstated. Actually the amount of DAMAR applied is moderate. I should have applied it in mikrolitre quantities to give recommendations. However, after drying the application is hardly visible. After 1 hour I repeated the application with a final coat of 'less than first time'. After 1 week I don't measure altered performance, so I guess the treatment is stable over time. If the coating is to be removed the dust cap is soaked with turpentine and absorbed with Kleenex tissue."

The varnish sold under the "Damar" brand name in my own country is produced by the company Art Spectrum, and the 100mL bottle I obtained looks physically different. Also, the consistency of the substance is obviously thicker than that sold in Denmark. Applying it as Troels recommended did not produce the same visual results he described. The varnish did not really soak into the dust cap as I applied it, but produced a shiny appearance from the outset. Nevertheless, I went ahead and applied a moderate amount. It took several hours to dry, though it remained slightly sticky in places even 18 hours later. (Mind you, it had been raining here for several days, so that may explain the drying time.) It eventually soaked in to a large extent, though there were still some shiny patches. I reported this to Troels and he recommended the following:

"If your Damar batch seems to be rather thick I'd hesitate to apply a second layer of coating. Maybe one additional layer at the 'center of the centerdome', like 2 cm diameter. Uneven distribution of coating is usually a good thing in disturbing resonances."

My listening tests produced similar results to Troels'. There is a small but definite reduction in midrange edginess, giving a slightly cleaner sound in what I consider to be the clone's main problem area. This benefits "difficult" recordings in particular, so if you are troubled by the clones' midrange this is a highly recommended mod. Just don't expect miracles! The effect is subtle.

The important thing is that you don't apply too much (though the coating is reasonably easy to remove with turpentine if you do) – and that you DON'T get any on the cone itself. (Troels did try damping the cone with Damar, but the results were very negative.)

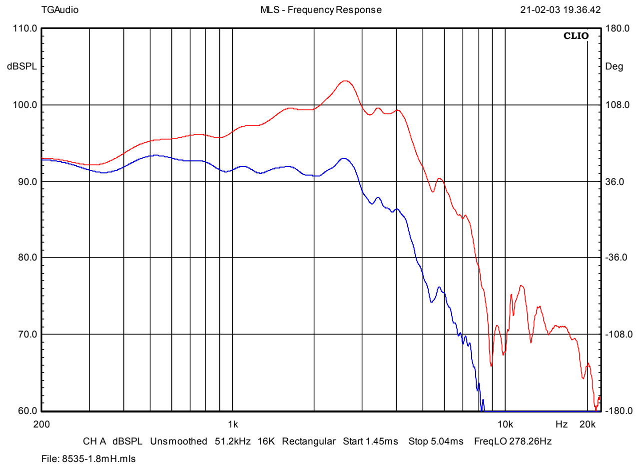

Fig.1, red = 8535 in cabinet, no crossover. Blue = 1.8 mH in series with 8535. No smoothing.

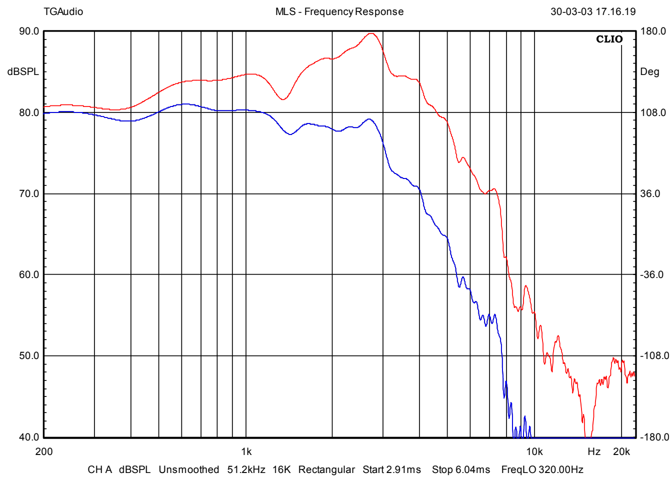

Fig.2. Red = 8535 after DAMAR coating, no filter. Blue = 8535 after DAMAR coating + 1.8 mH.

Identifying the source of sibilance

First the clones were cut off below 100 Hz by a 6 dB filter and supplemented by a subwoofer in order to significantly reduce cone movement and ease the burden put on the 8535 by having to reproduce everything from 30 Hz to 3 kHz.
This did not in any way reduce the sibilant nature of the highs. Excessive cone movement does not seem to be a severe limiting factor for the 8535 in order to truthfully reproduce the sensitive midrange except when played at very high level.

Secondly a 3-way construction was tried introducing a Vifa PL11MH coated midrange at 500–3000 Hz. This is indeed a very good midrange and I wouldn't hesitate to use this in some other construction. This did not – much to my surprise – in any way change the sibilant nature of the highs! After this there was only one thing left to do: 'Thanks to the 8513 tweeter for all the hours we have spent together, but out you go!'
Having a pair of ScanSpeak 9500s, this was an obvious choice for a new pair of tweeters.
I have removed the magnetic oil in the voice coil gap of the 9500s. Otherwise no tweaks.

Construction of a new crossover

LP-section: You can reuse most of your components from the v3 crossover in this new filter. The 1.8 and 0.47 mH coils are the same. The capacitor has been raised to 8.3 uF (6.8+1.5) and a 2R2 resistor has been added to the capacitor giving a smooth roll-off for the 8535. The point of crossover is intended to be around 3 kHz, as I'm now confident that the 8535 will do well all the way to this point and I want to maintain the 8535 handling as much of the midrange as possible.

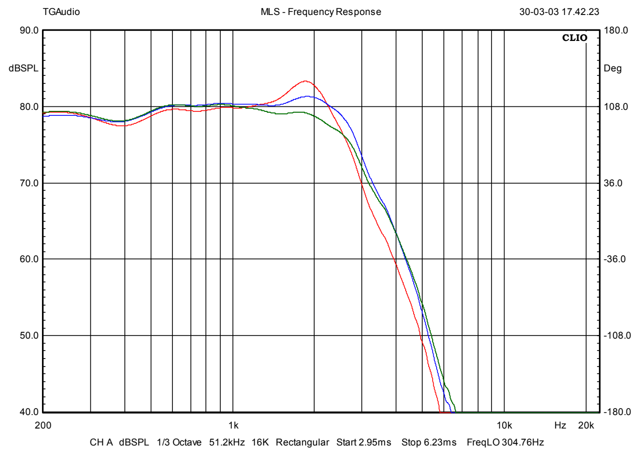

Fig. 3. 8535 roll-off with various filters:
Red = 1.8 mH + 8.3 uF + 0.83 mH
Blue = 1.8 mH + 8.3 uF + 0.47 mH
Green = 1.8 mH + (8.3 uF+2R2) + 0.47 mH. All 0.33 oct. smoothing.

The basic 3rd order crossover topology is maintained in order to give best possible phase response in the crossover region.
As can be seen, the need for the 2 kHz notch filter is eliminated by this approach.

HP-section:

Not much to say about this part. No problem in making the 9500 roll off at 3 kHz. See schematics, fig. 4 and response curves fig. 5 and 6.

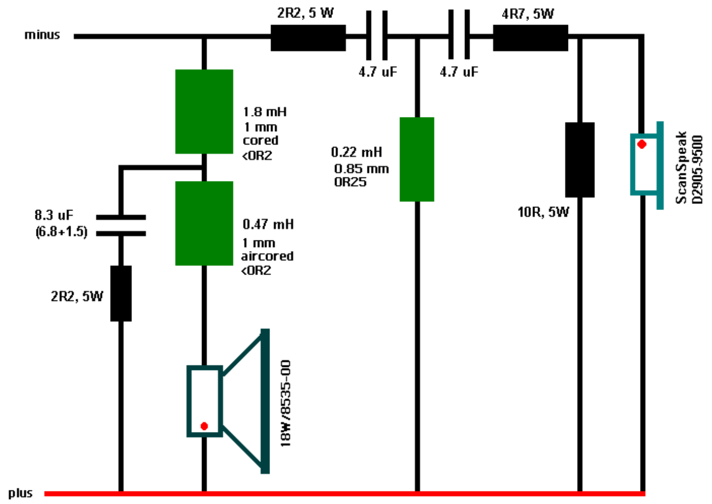

Fig. 4. Crossover schematics for 8535+9500.

Fig. 5 displays the frequency response from the drivers with the new filter and with same polarity a dip is seen at crossover frequency.

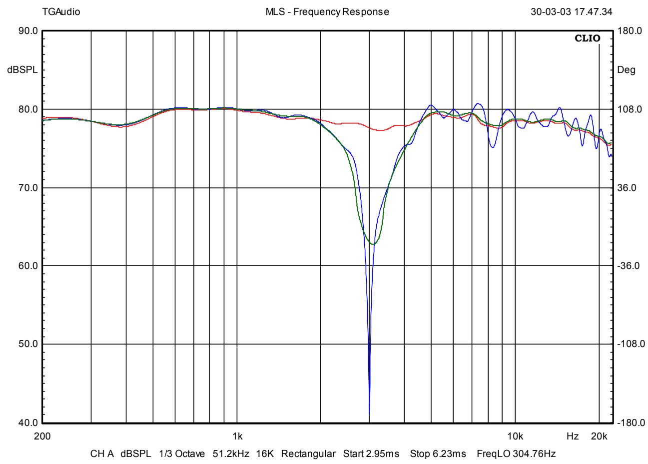

Fig. 5. Red = frequency response with inverted polarity, 0.33 oct. smoothing. Green = same polarity, 0.33 oct. smoothing. Blue = same polarity, no smoothing. All measurements performed at tweeter height, 1 meter distance.

I'm quite sure tweeter level will be an issue and the 2R2 can be changed from 1–2.2 ohms resistance without affecting point of crossover.

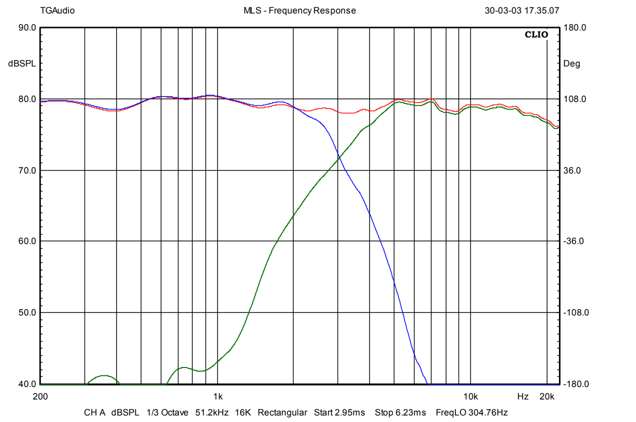

Fig. 6. Roll-off of both drivers with new filter.

Graphic presentation of new crossover for bi-wiring:

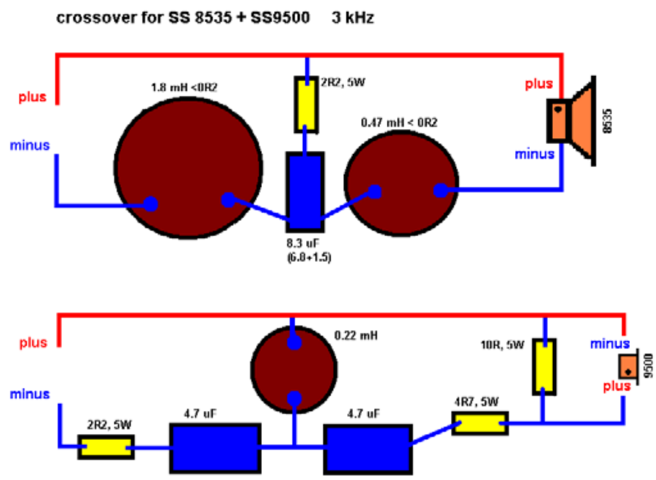

Fig. 7. Crossover schematic, layout for bi-wiring.

Sonic evaluation of modified 2.5 clone

2.5 clone with ScanSpeak D2905-9500 tweeter.

The 9500s have the ability to bring forward the best qualities in the 8535s and the word that first comes to my mind is coherence. To my ears the 8535 has a kind of old-fashioned full-range sound, yet in a completely other league than the old PHILIPS 9710 'full'ranger' or the like.
It has its 'virtues' in terms of a rather robust midrange that is quite demanding on your choice of recordings. It is rather merciless on poor recordings and inadequate electronics and will probably always be so.

With the new tweeter in place the degree of transparency rises considerably and we know how much the low end adds to the sense of transparency, and the 8535 has that ability, so we are close to getting it all from this modest two-way floorstander. Quite amazing. The new design appears to give a slightly more distant perspective and for sure the sibilant, whizzer sound is gone.

I think that the elimination of the notch filter by redesigning the LP section does a great deal to enhance transparency. Notch filters can 'solve' acute problems, but I still have the feeling they can add some obscure/subtle phasiness to the region affected.
Looking at the CSD data from the region where the notch filter works, it looks like we have to look over a hilltop to spot the start of the transient, meaning that despite having an apparent flat frequency response it seems as if the energy is slightly delayed (page 6, latest v5) in the region affected by the notch filter.
Ideally we want only the forefront of the sound wave to hit the ear followed by an immediate decay within the first 0.5 milliseconds.

The 9500s seem to have a slightly recessed high end (> 10kHz) compared to the 8513s, despite having a very flat frequency response, and I believe this is a very common observed phenomenon with most 1" soft-domes.

The Final 2.5 Clone, the "sibilance" problem

1st WARNING:
I have recently (May 2003) acquired my third pair of 18W8535-00 drivers, and much to my surprise these drivers were heavily coated on the rear of the membrane.
These drivers were meant for a three-way construction so they perform as expected, but for those who buy this new batch of drivers from ScanSpeak it appears that they will not perform in accordance with all the material that has been published until now regarding the 2.5 clone.
Due to the coating they will have an earlier roll-off characteristic and will require modifications to the crossover.

2nd WARNING
The tweaks suggested in the following paper deal with the D2010-8513 tweeter.
You will have to dismantle the driver and –

- remove the ferrofluid
- damp the pole piece
- coat the membrane with DAMAR resin
- if you haven't coated the dust cap on the 8535 driver you will have to perform this operation also
- do minor modification to the V6-crossover

If you feel uncomfortable with finer mechanics you may ruin your 8513 tweeters.
The tweeter is a delicate construction, but with proper care you can easily dismantle the construction and perform the tweaks.

The reason for these tweaks is sibilance:
Definition:
Sibilance: "Essy". Exaggerated "s" and "sh" sounds in singing, caused by rise in the response around 6–10 kHz.
See: http://www.linkwitzlab.com/images/graphics/sd-qulty.gif

Before proceeding I have to thank Darryl Nixon, Australia, for an extensive mail exchange on the phenomenon of sibilance and in particular the less than appropriate performance of the 8513 tweeter.

The phenomenon characterised by the word "sibilance" has proven more than difficult to deal with in the case of the 8513 tweeter. If we stick to the definition literally, we should be able to solve the problem by adjusting the response in the critical area.
Various attempts have been tried in order to alter the frequency response in the 4–10 kHz region by changing the crossover and introduce notch filters, etc. But none of these changes gave results worth pursuing. The sound from the tweeter still sounded awful on a number of especially vocal recordings.
If you make a search on the web on the word "sibilance" you get quite a number of hits, mostly aimed at recording engineers on how to avoid excessive sibilance by choice of microphones or electronics. You can even buy a "de-esser" piece of electronics to solve the problem!

From the work done on the 8513 tweeter, it becomes apparent that what we perceive as sibilance is not necessarily only derived from excessive response in certain areas but also from some intrinsic qualities of the tweeter. Actually the response is quite flat.
I have done numerous comparative tests with the CLIO measuring system on various tweeters and found no apparent poorer performance of the 8513 tweeter, so I will not be able to tell you by measurements why the 8513 tweeter is inferior as is or why the suggested tweaks make it sound so much better.

But I'll stick my neck out and claim a significant improvement in performance for those discerning listeners who like vocals, strings and brass instruments.

Most likely the 8513 tweeter holds some obscure IM distortion that on poorer recordings makes you hold your hands to your ears.
The tweaks will change the performance to a level not far away from the ribbon tweeters that currently are my reference for best tweeter performance.

At the same time you will have to adjust tweeter level to produce a frequency response at +/– 1.5 dB from 400–17,000 Hz. That is with the V6.1 crossover with 8R2 or 9R0 to the tweeter.
However, the tweaks will enhance performance from whatever crossover you may hold.

I have recently heard the real ProAc Response 2.5 speakers and had the impression that the tweeter was well balanced to the bass driver but the midrange hardness and relatively poor midrange/tweeter resolution was much the same as what characterises the clone. I had a hard time believing that this tweeter would have ~ 5 ohm series resistor to the tweeter. With 5 ohm to the tweeter the clone sounds just awful.
I don't care how many reviewers have praised the successful integration of drivers in the Response 2.5 and apparent midrange smoothness. The speakers had a slightly smeared midrange with less than proper resolution and image focusing compared to other speakers and what can be achieved from the described tweaks. I'm also sure that some will say "goodbye ProAc sound", and except for the bass, that's just what it's all about.