Influence of absorbing materials on the damping of harmonic resonances in a transmission line type enclosure.

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2025

Introduction:

The following article is not scientific material. It's a collection of examples of amateur prototypes, their measurements, and ideas to document the effects of various sound absorbing materials and the damping of harmonic resonances in transmission line type loudspeaker enclosures.

I conducted my first tests a dozen years ago, on simple test enclosures. In 2016, I provided measurements of a Scan Speak 18W/8545 speaker mounted in a PVC pipe.

www.flickr.com/photos/25191222@N04/albums/72157666139277692/

This simple experiment shows that the use of polyurethane foam makes it possible to significantly lower the resonance of a 1/4 tunnel relative to an enclosure without damping material, while quite effectively damping the harmonic resonances of the tube.

I also tested the behavior of the foams in a small Taper enclosure (a transmission line with a tapered cross-section), in which the foams behaved similarly to the PVC pipe tunnel, giving quite different results from damping with polyester fleece, which is often used in transmission line speaker designs.

www.flickr.com/photos/25191222@N04/albums/72157666286978835/

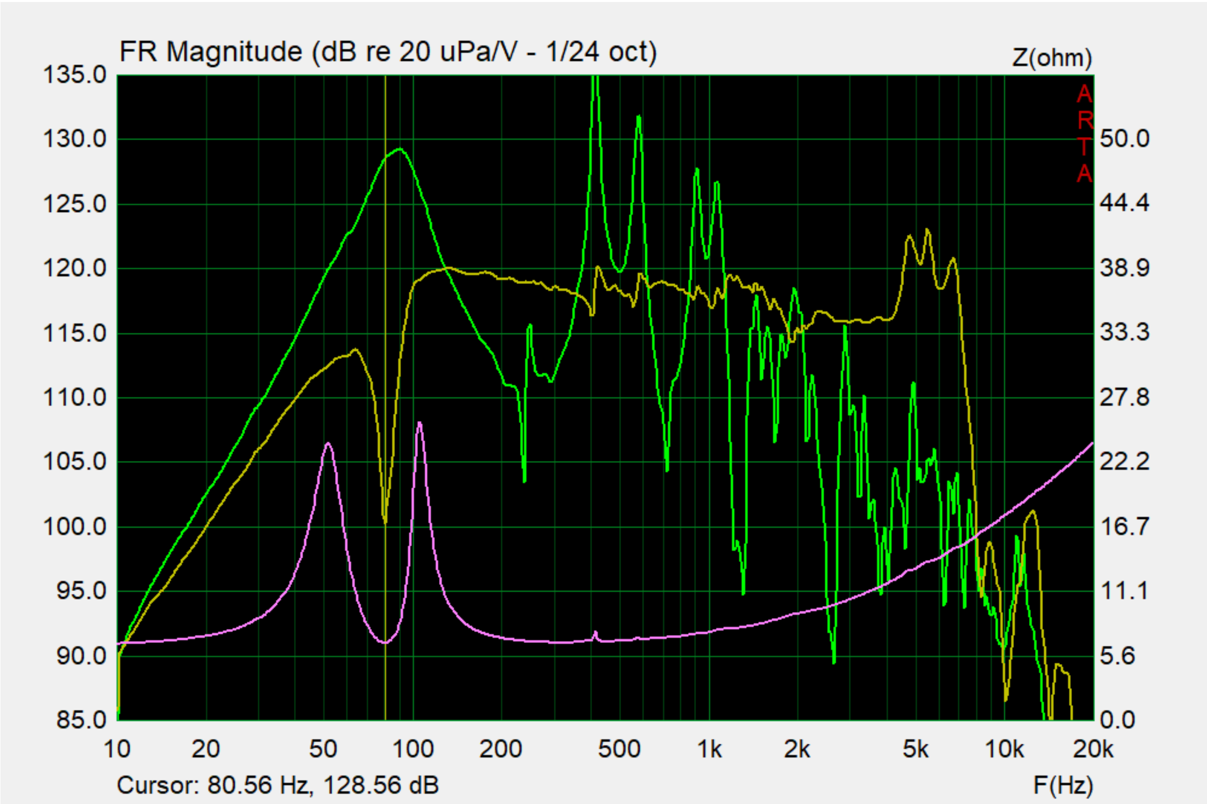
The test enclosure:

For the following measurements, I built a simple design with a constant section of 125 x 125 mm and a tunnel length of 1000 mm. The driver used for the test is a Visaton W130 S 8 Ohm, which I mounted at an offset of 350 mm, which is approximately an offset of 1/3 of the total tunnel length. In this publication, I will only present measurements of the transmission line, without simulating its analog in computer software.

I made frequency response and impedance measurements for each damping variant, starting with an enclosure without absorbing material.

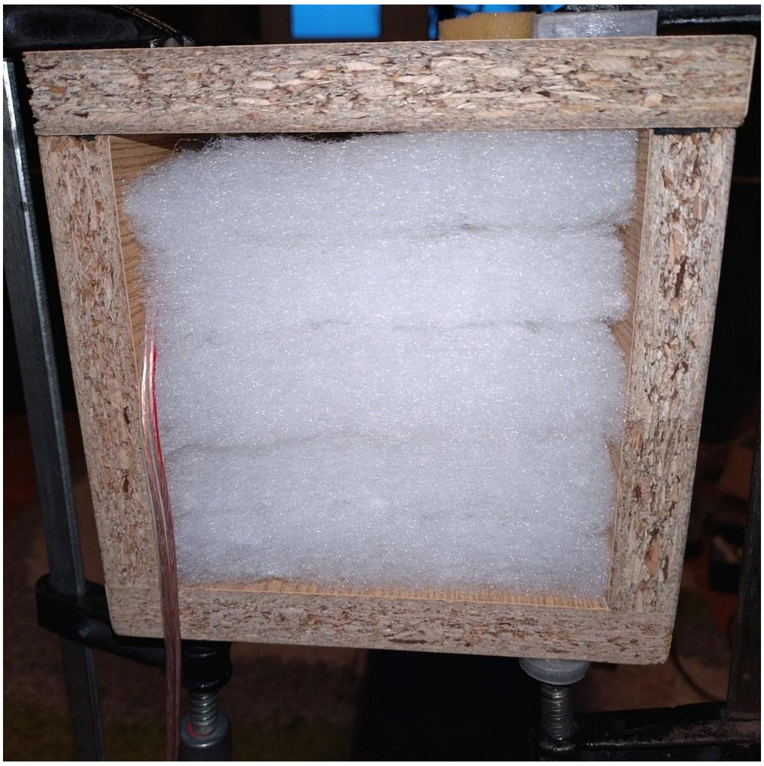
The measurements show the frequency response of the speaker and tunnel in the near field, as well as the impedance.

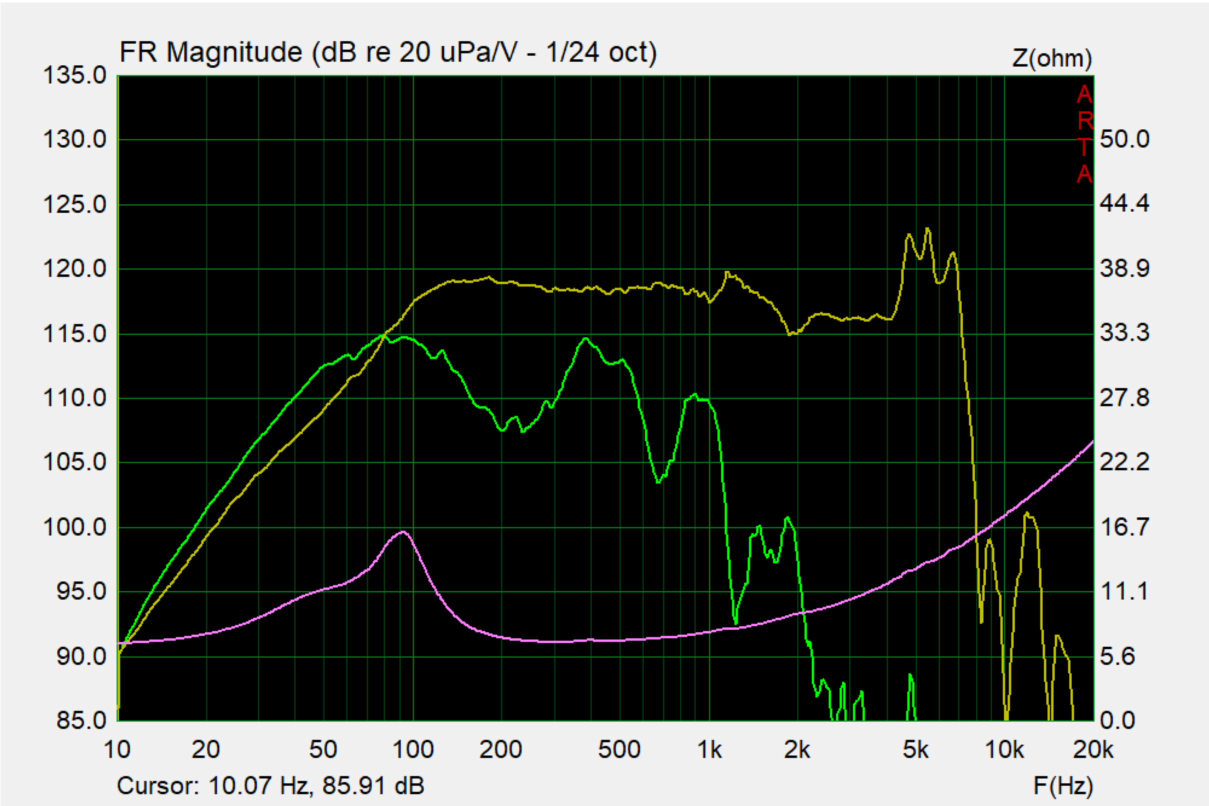
Measurements of the empty enclosure:



The quarter-wave resonance of a 1000 mm long tunnel is 80 Hz.

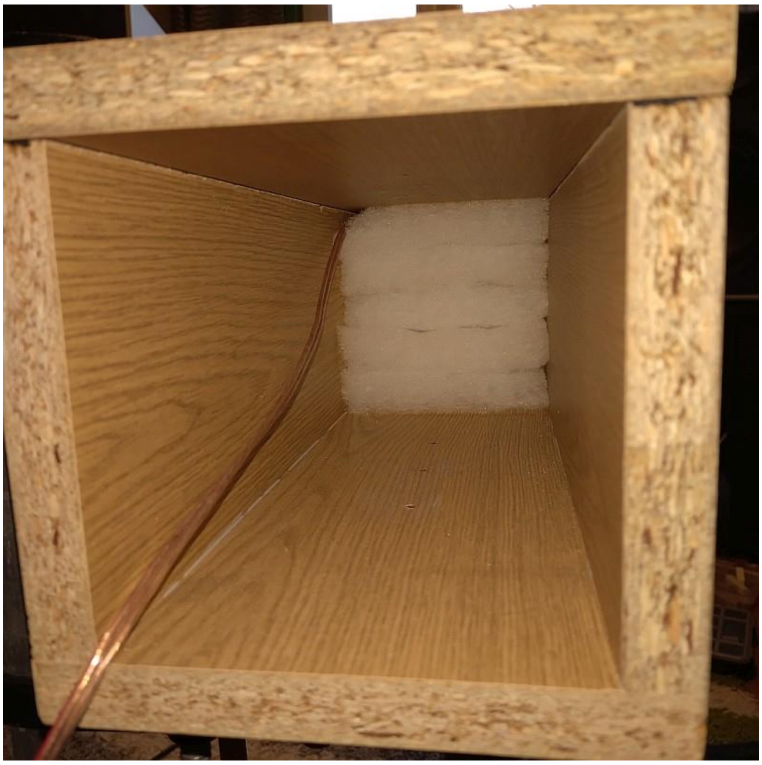
Enclosure dampened with Polyfill fiber, with a density of 300 g/m2 along the entire length of the tunnel. Total weight of the fiber material 185 grams:

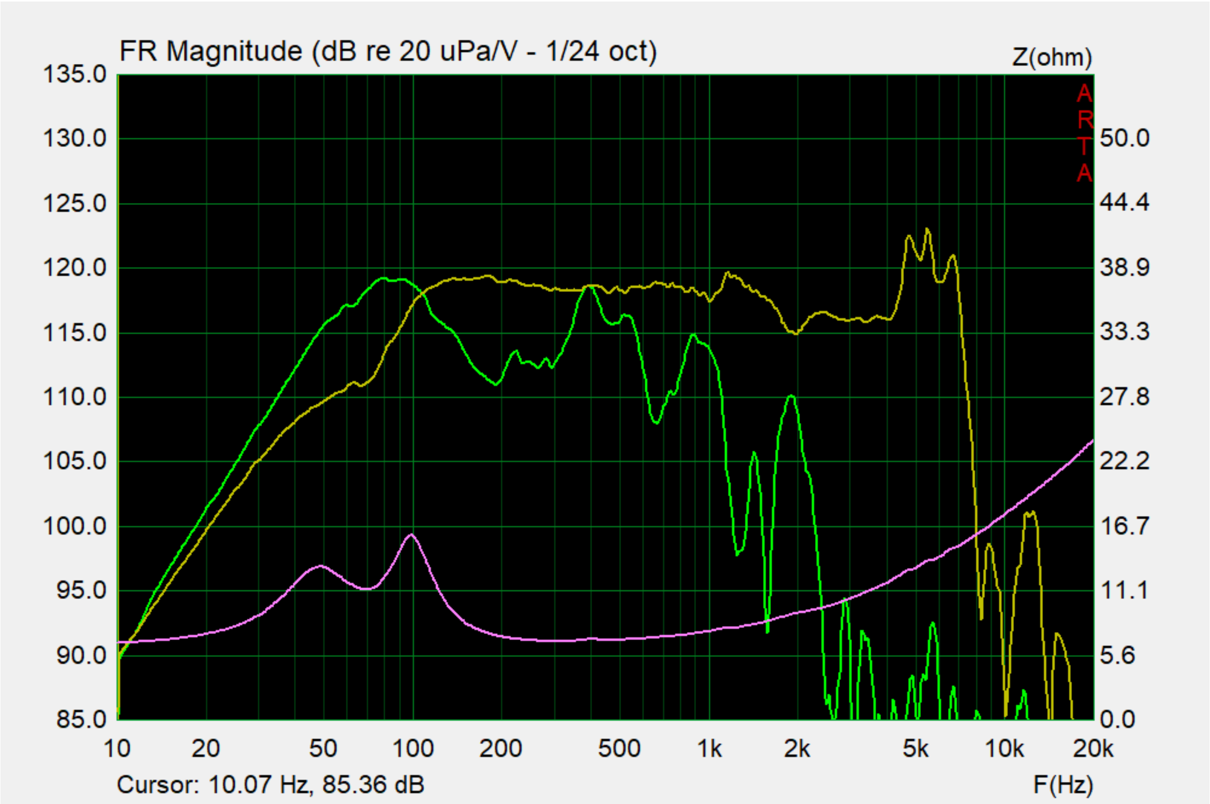




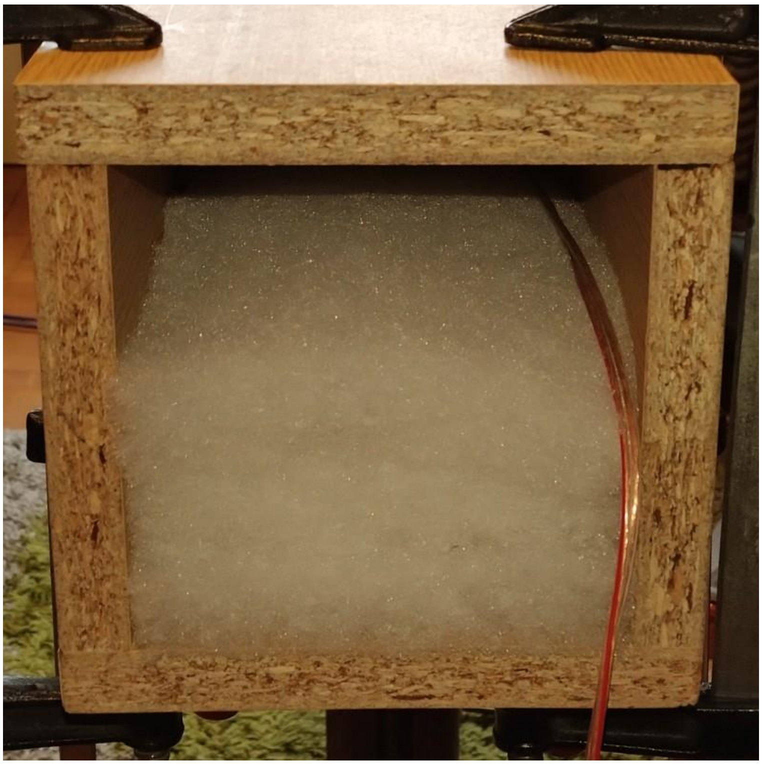
Zdjęcie 1

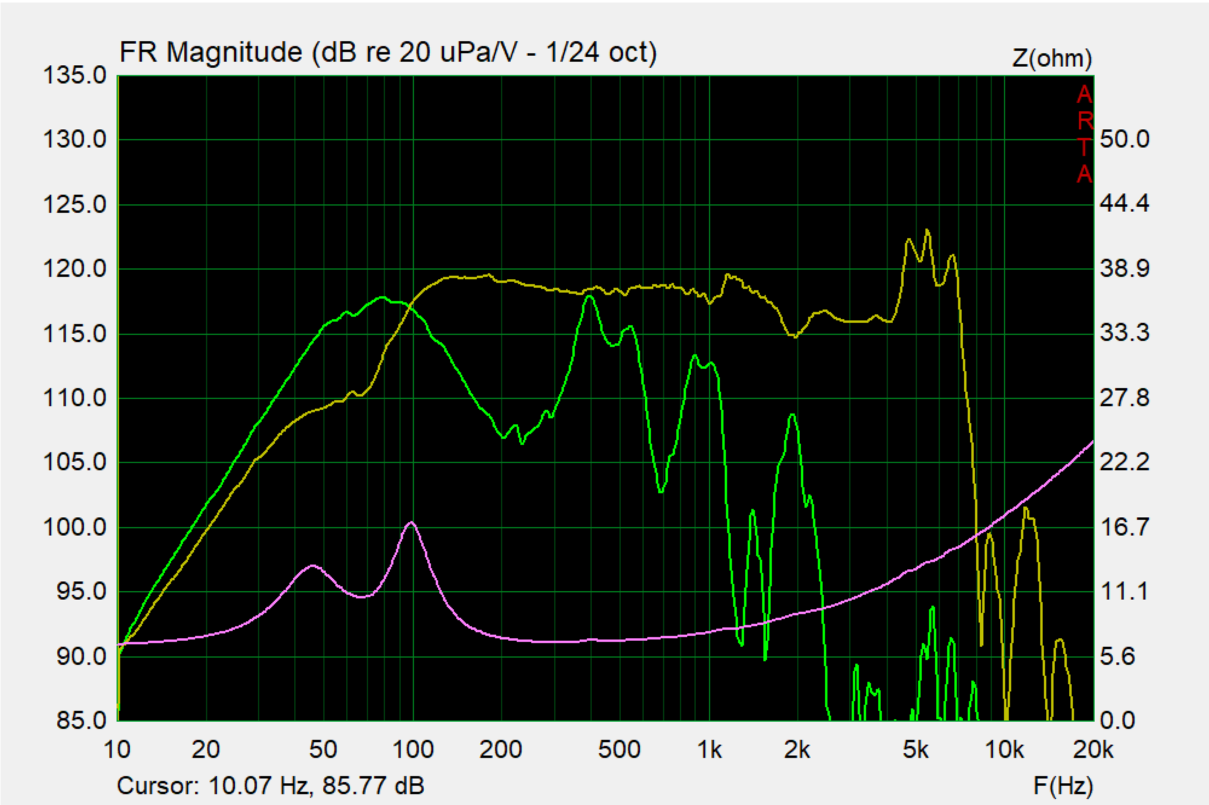
Enclosure dampened with Polyfill fiber with a density of 300 g/m2 along the length of 70 cm of the tunnel, from the beginning:



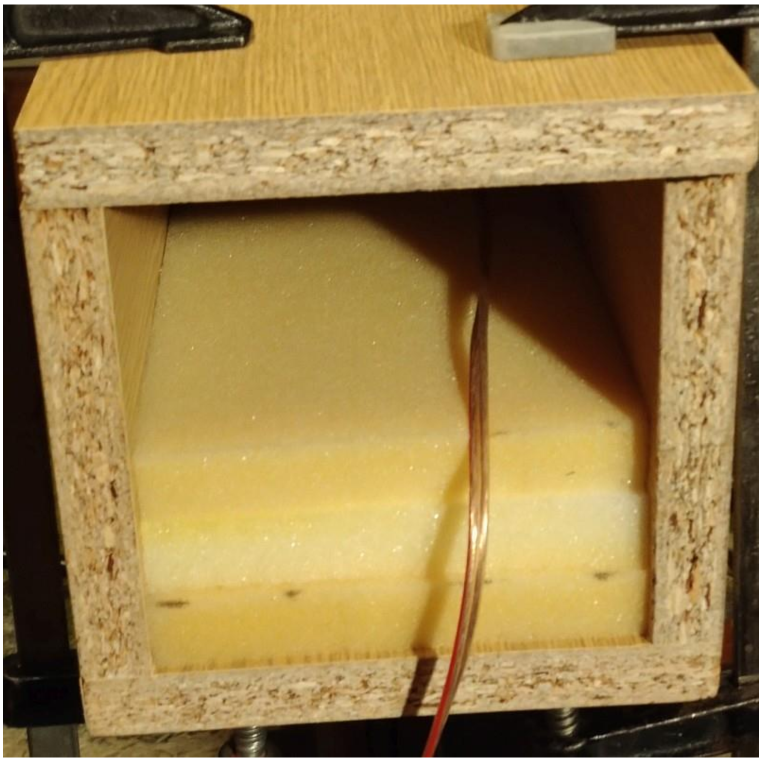


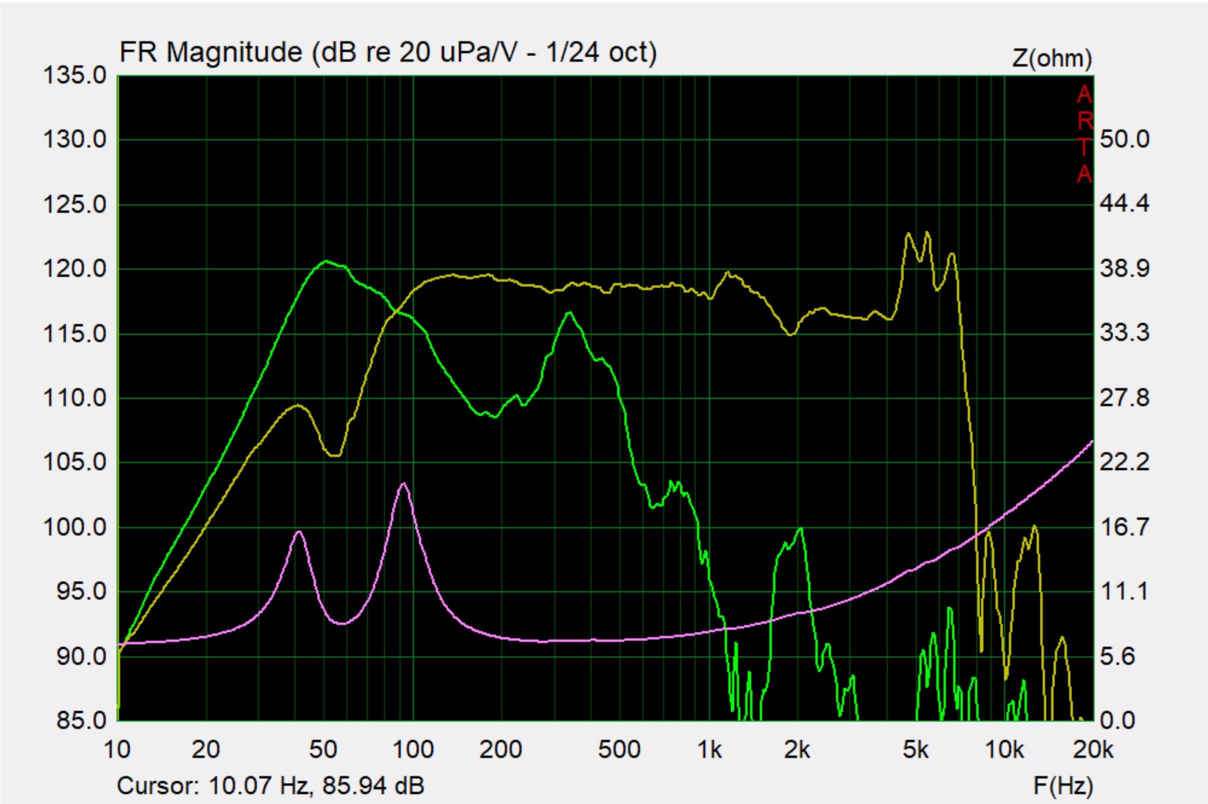
Enclosure dampened with 3 pieces of Polyfill fiber, with a density of 300 g/m2 along the entire length of the tunnel:



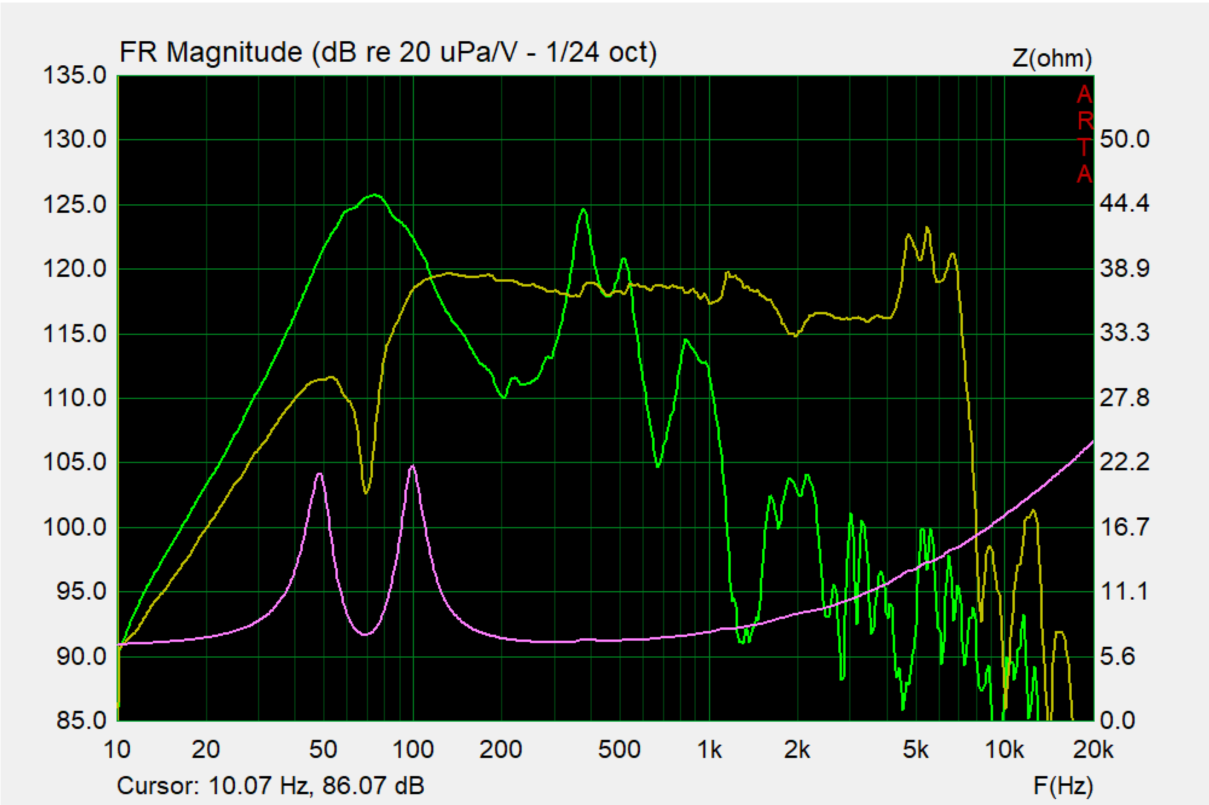


Enclosure damped with T18 18kg/m3 polyurethane foam. Three pieces of 2 cm thick along the entire length of the tunnel:

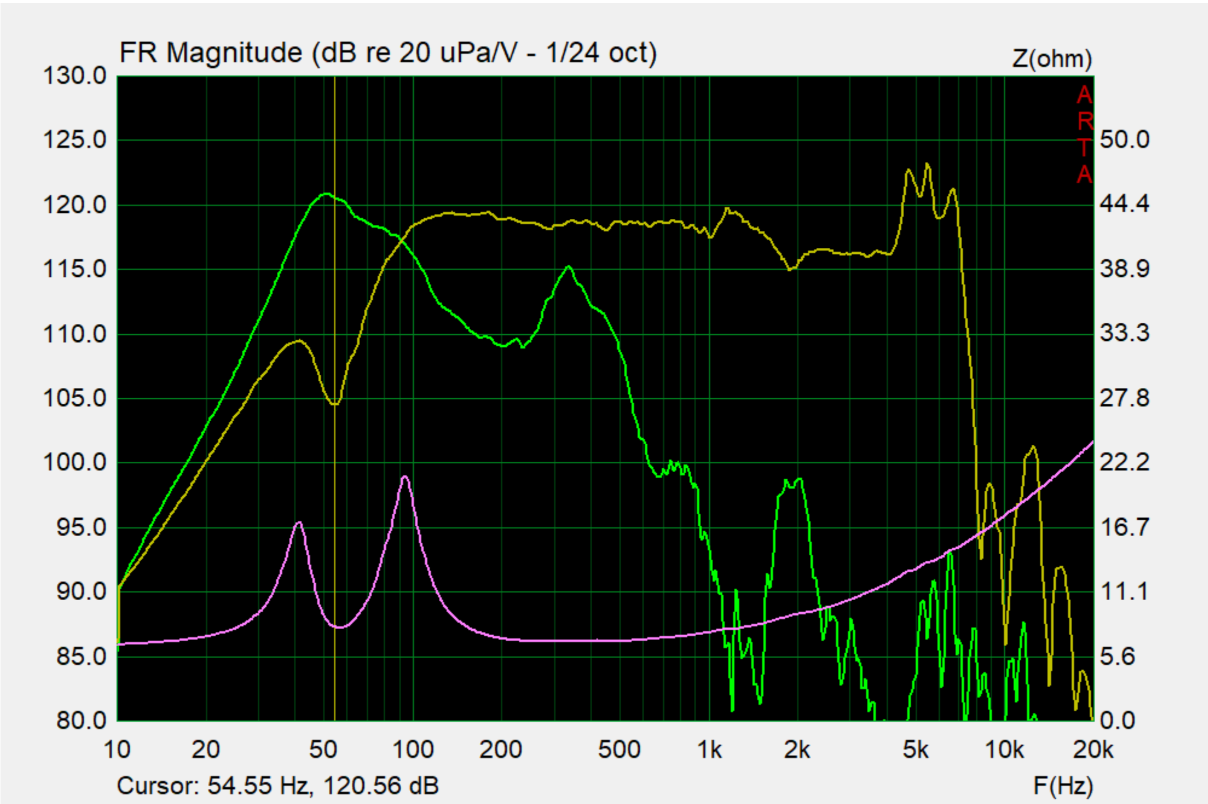




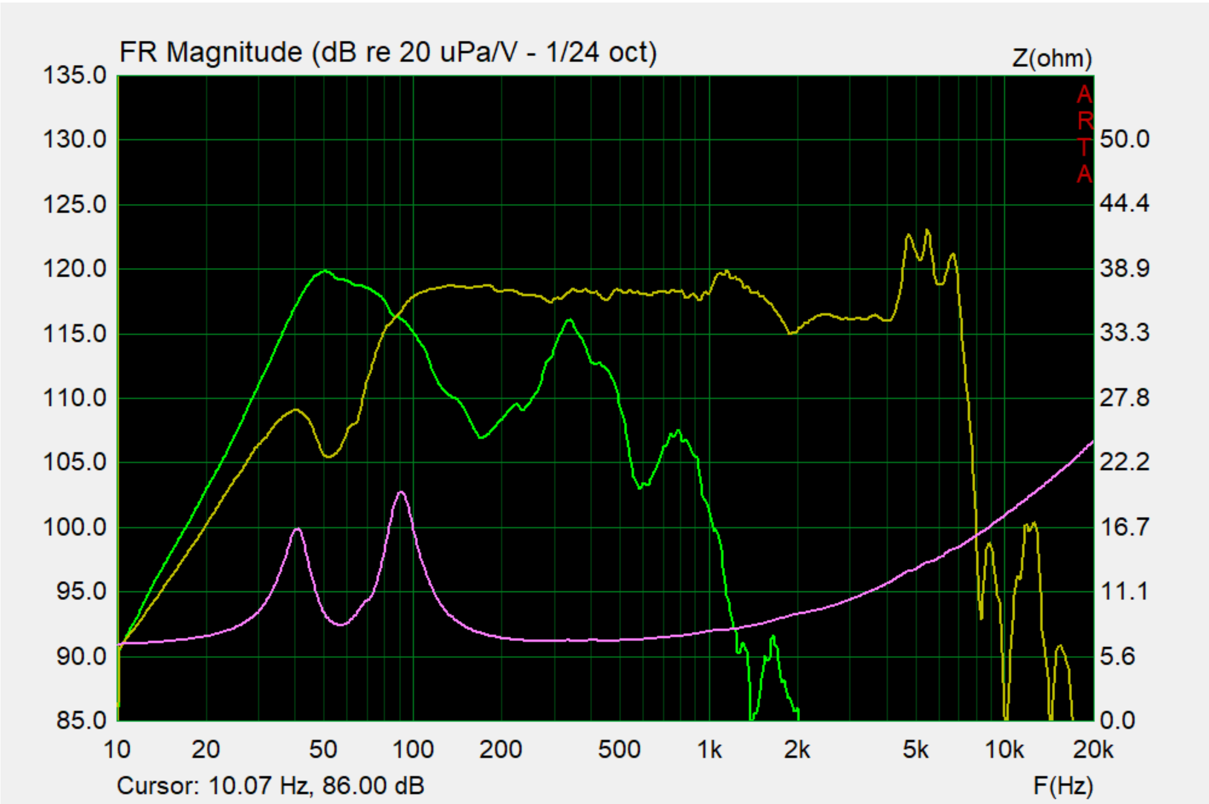
Enclosure dampened with T35 35kg/m3 polyurethane foam with a thickness of 3 cm:



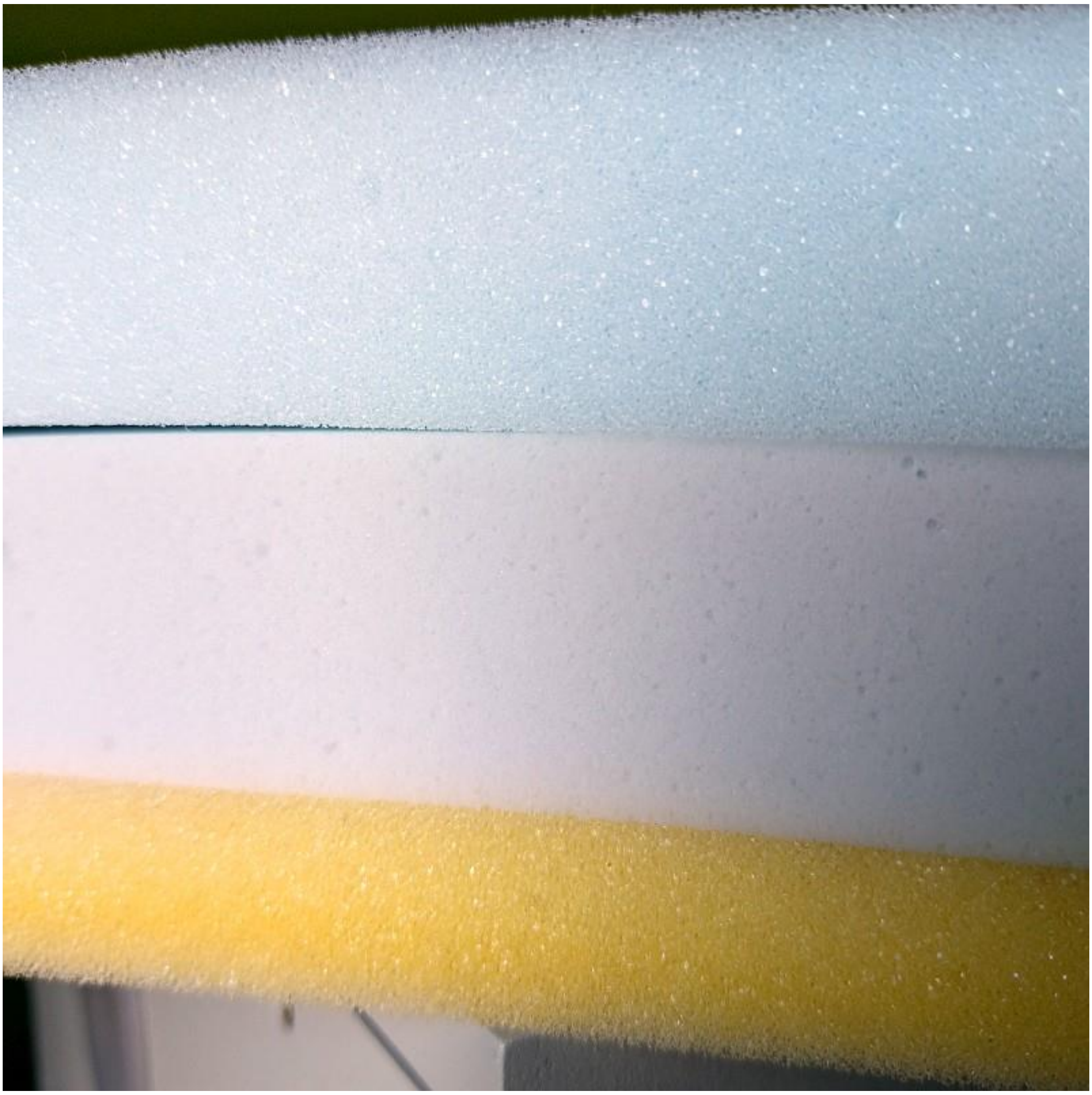
Enclosure dampened with T35 35kg/m3 polyurethane foam, 6 cm thick:



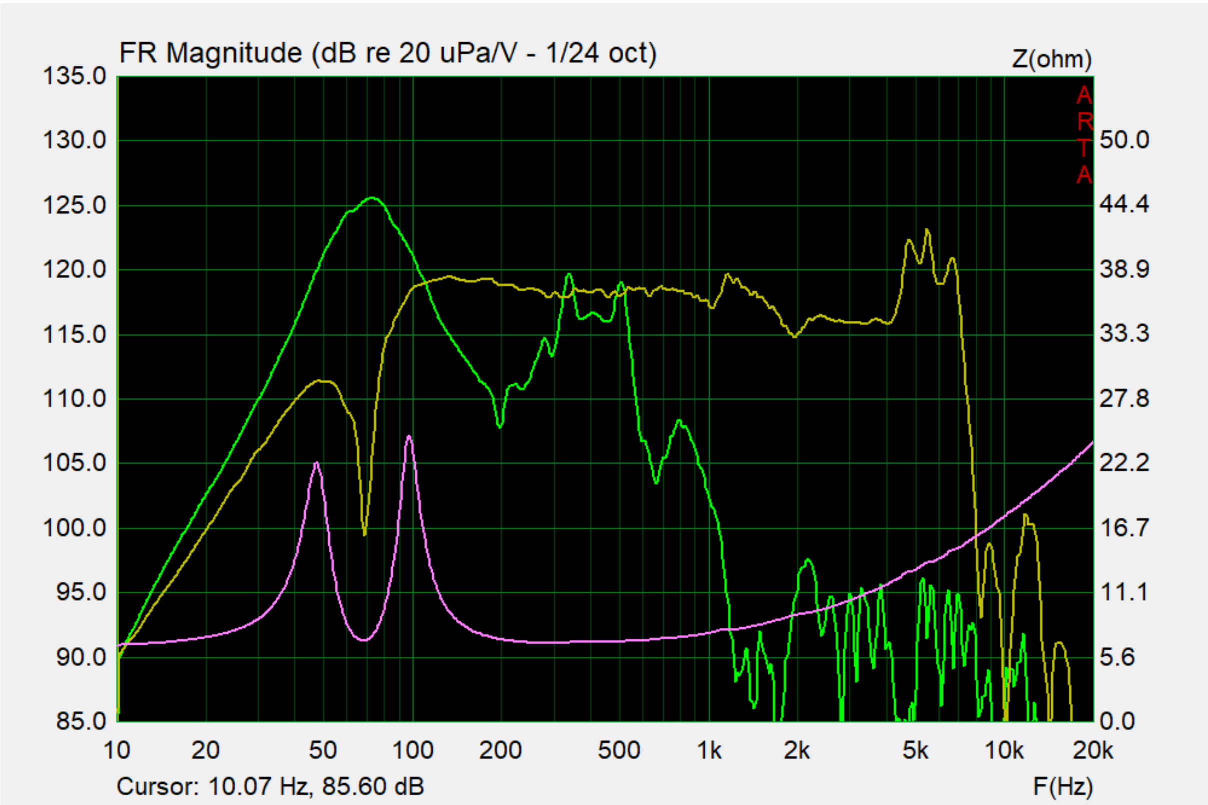
Enclosure dampened with T35 35kg/m3 polyurethane foam, 3 cm thick, on opposite sides of the enclosure:



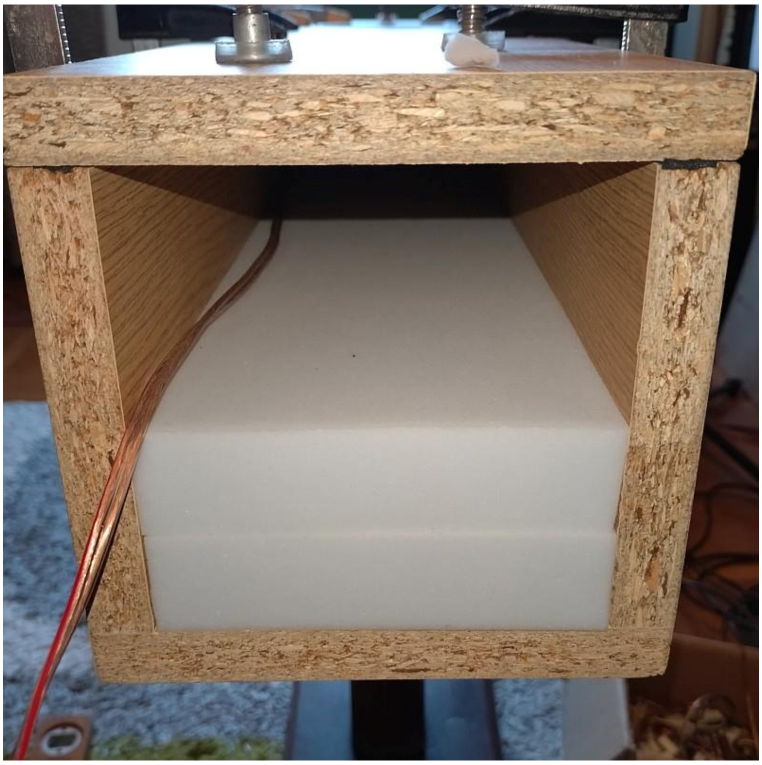
BASF Basotect, a melamine foam that I have not used to date, has come to the consumer market relatively recently. It is used to improve room acoustics, rather than as a damping material in speaker enclosures. The same foams are also known as a “magic sponge” for cleaning various surfaces, without the use of detergents. Compared to polyurethane foams, it is much harder, prone to mechanical breakdown. It is noticeably denser even than T35 polyurethane foam, but much lighter than it. The photo below shows (from the top) T35 polyurethane foam with a thickness of 3 cm, Basotect melamine foam with a thickness of 3 cm and T18 polyurethane foam with a thickness of 2 cm.

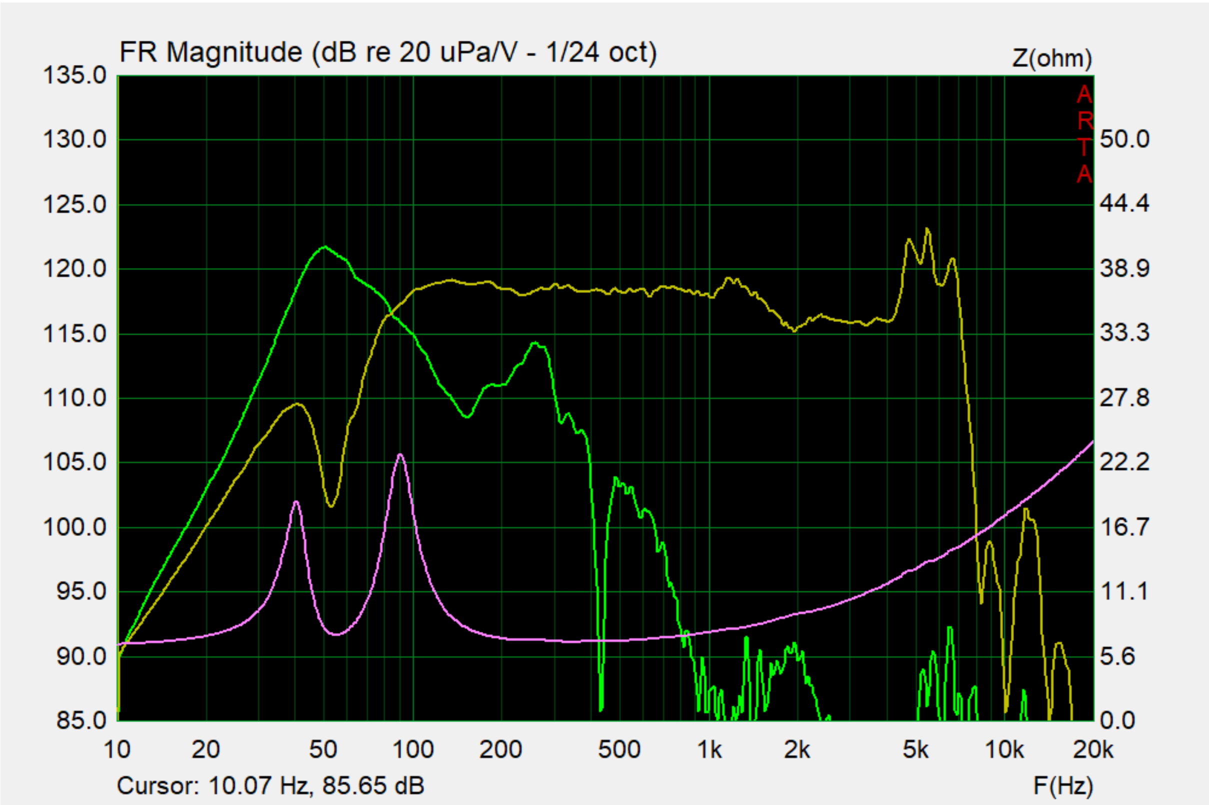


Enclosure dampened with Basotect foam, 3 cm thick, along the entire length of the tunnel:

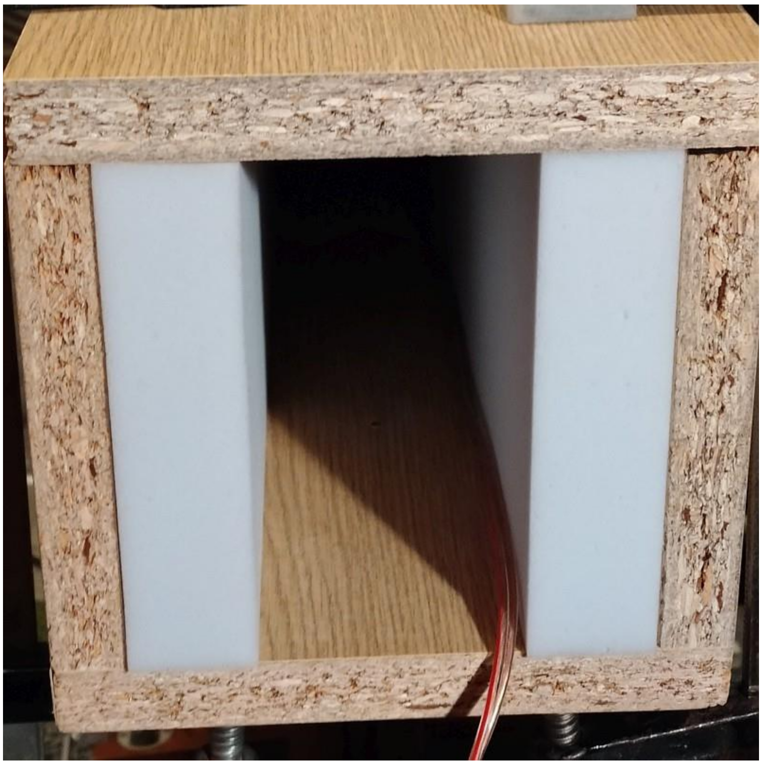


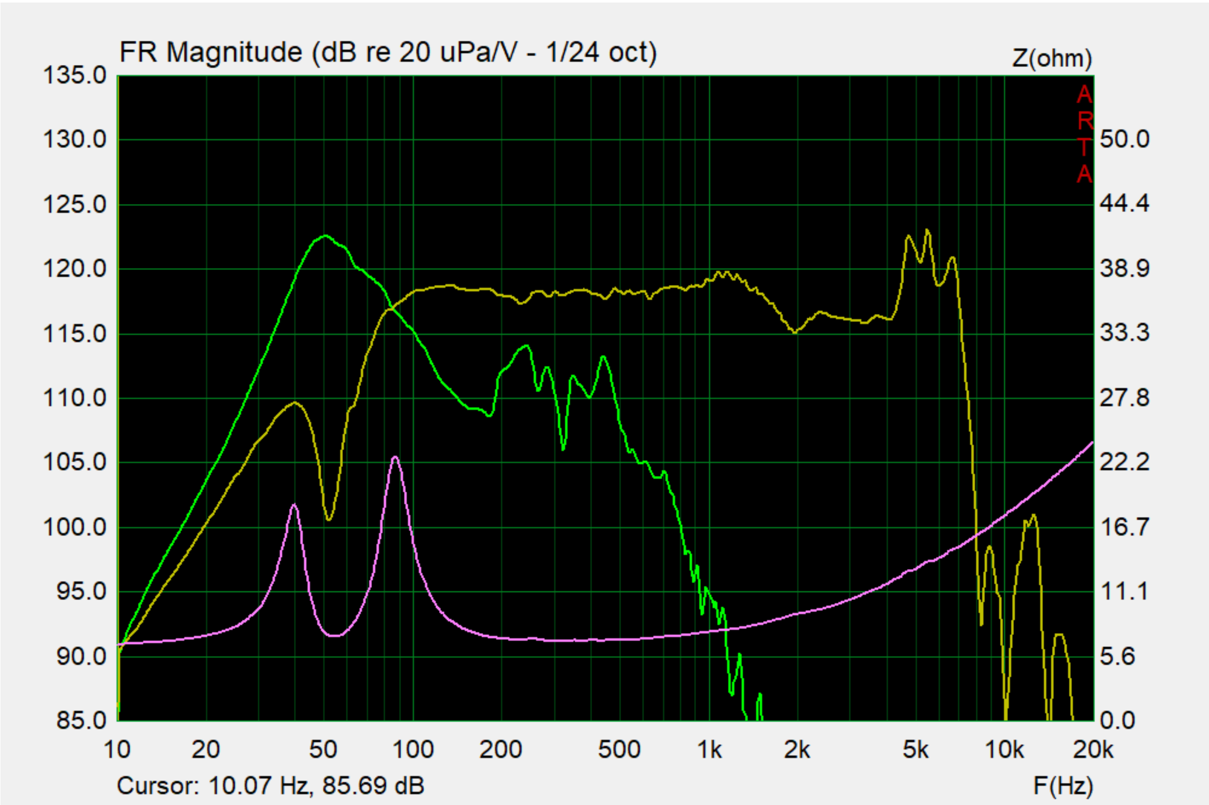
Enclosure dampened with Basotect foam, 6 cm thick, along the entire length of the tunnel:



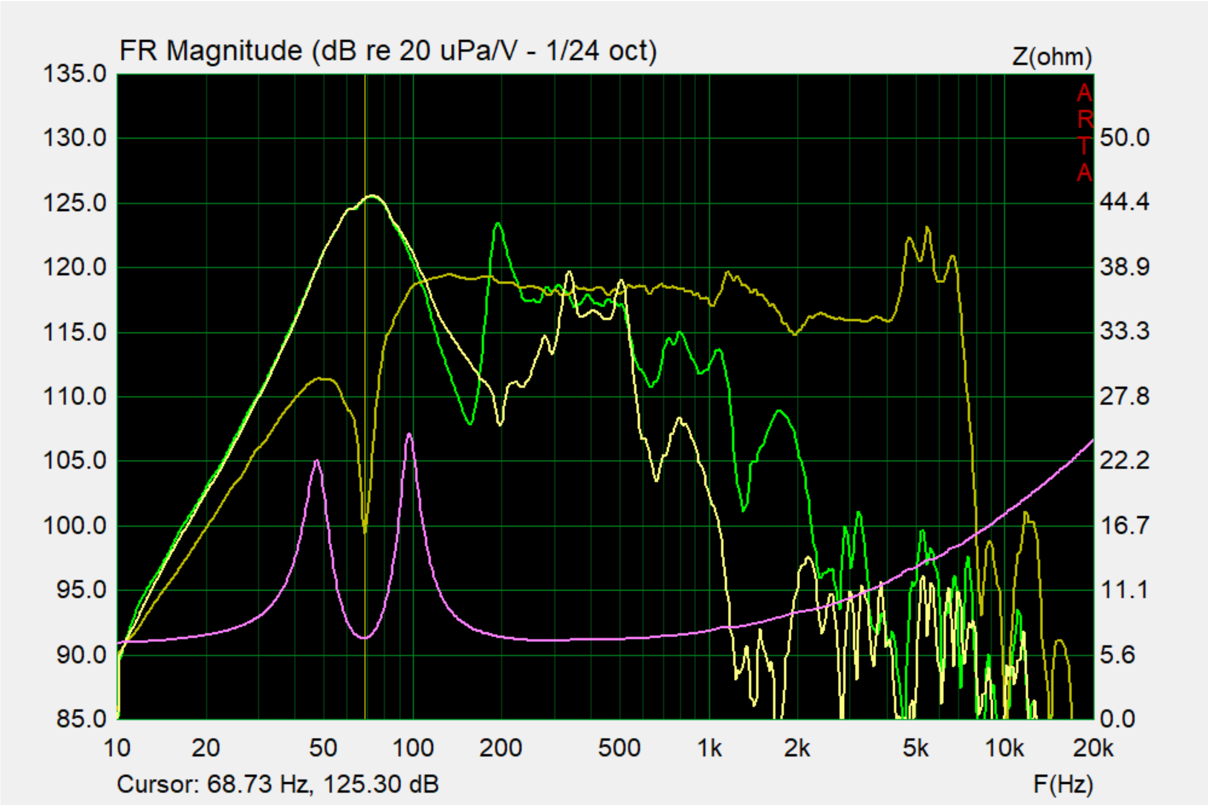


Enclosure dampened with 3 cm thick Basotect foam, on opposite sides, along the entire length of the tunnel:





When I presented my measurements of a PVC pipe filled with polyurethane foam on the subject groups, some commenters said that the lowering of the pipe's resonance was caused by the foam changing the cross-section of the tunnel, which would create something like a bass reflex tunnel at the end of the tunnel. Some commenters wrote that the foam acts like a tunnel with a tapered cross-section, making it possible to lower the tube's tuning. Both of these hypotheses are partially true, because in both cases we are dealing with, an increase in air mass at the end of the tunnel, which results in a lower resonance. However, there is only open-pored foam in the tube, which allows air to flow through. So what is behind the lowering of tuning when using foam? There is a hypothesis that talks about air molecules, “trapped” in the pores of the foam, which, excited to vibrate by the speaker, form a larger moving mass together with the foam, so that, the resonance of the tunnel can be lowered. If such an assumption were to be taken as fact, the sheer amount of foam in the tunnel would be of greater importance than the place where it is located, and this is the experiment I decided to conduct. I compared a 3 cm thick Basotect foam, lined along the entire length of the tunnel, and two Basotect foams, also 3 cm thick, but laid only in the first half of the tunnel:



In the above screen shot, the green color measurement is the response of the tunnel with the Basotect applied to the first part of the tunnel. As you can see, the resonance of the enclosure is exactly the same (68 Hz, relative to 80 Hz for an empty enclosure) as in the variant with Basotect 3 cm along the entire length of the tunnel. Only the bandwidth of the higher harmonic frequencies is noticeably different. The lack of damping from the middle, to the end of the tunnel does not allow effective absorption of wave resonances.

I think this simple example disproves the hypothesis of added mass by narrowing the tunnel port (BR), or Taper-like enclosure action.

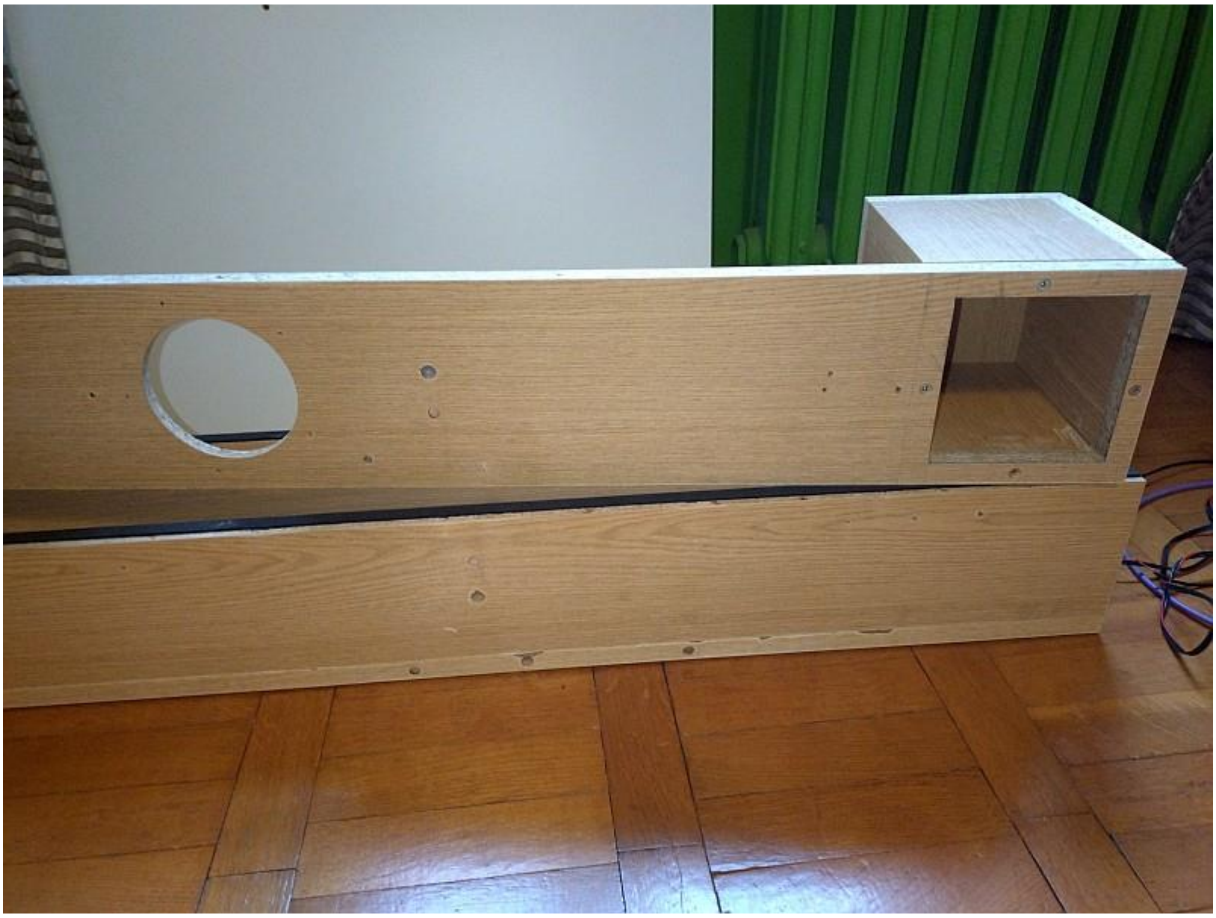
Quarter-wave damper:

Over the course of several decades, every transmission line designer has had to deal with damping the unwanted wave resonances created in enclosures of this type. In an ideal world, a transmission line would offer effective quarter-wave resonance, and the perfect damping material would absorb all the rest of the acoustic bandwidth that introduces unwanted distortion. Various tunnel geometries, driver offsets have a significant impact on optimizing the tunnel's efficiency, while suppressing its harmonic resonances. In addition, the use of the right absorbing materials, their quantity, and their place in the tunnel has a significant impact on the final result. Thanks to modern computer simulation methods, we can achieve more than optimal results.

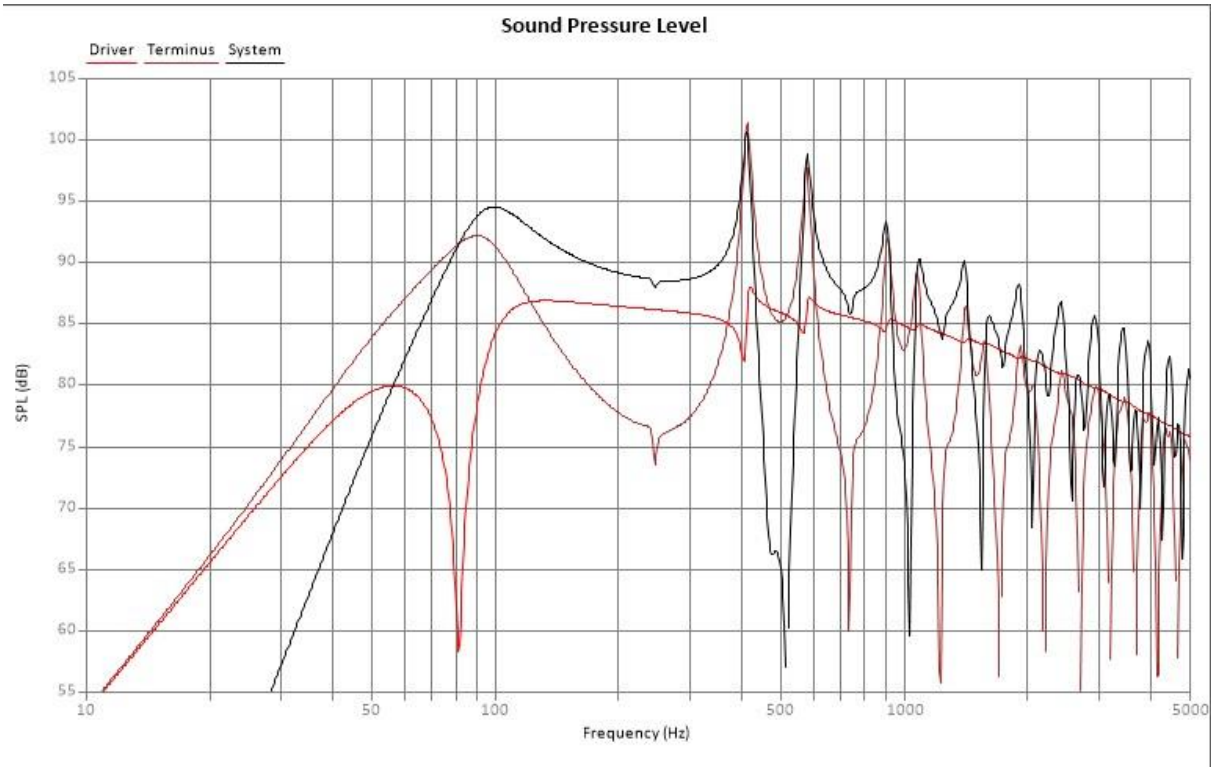
An interesting solution that was not uncommon in various projects is the Helmholtz resonator, which, tuned to a certain frequency, was able to minimize the harmonic resonance of the transmissive line. This type of resonator is usually used at the beginning of the tunnel, or near the offset of the speaker.

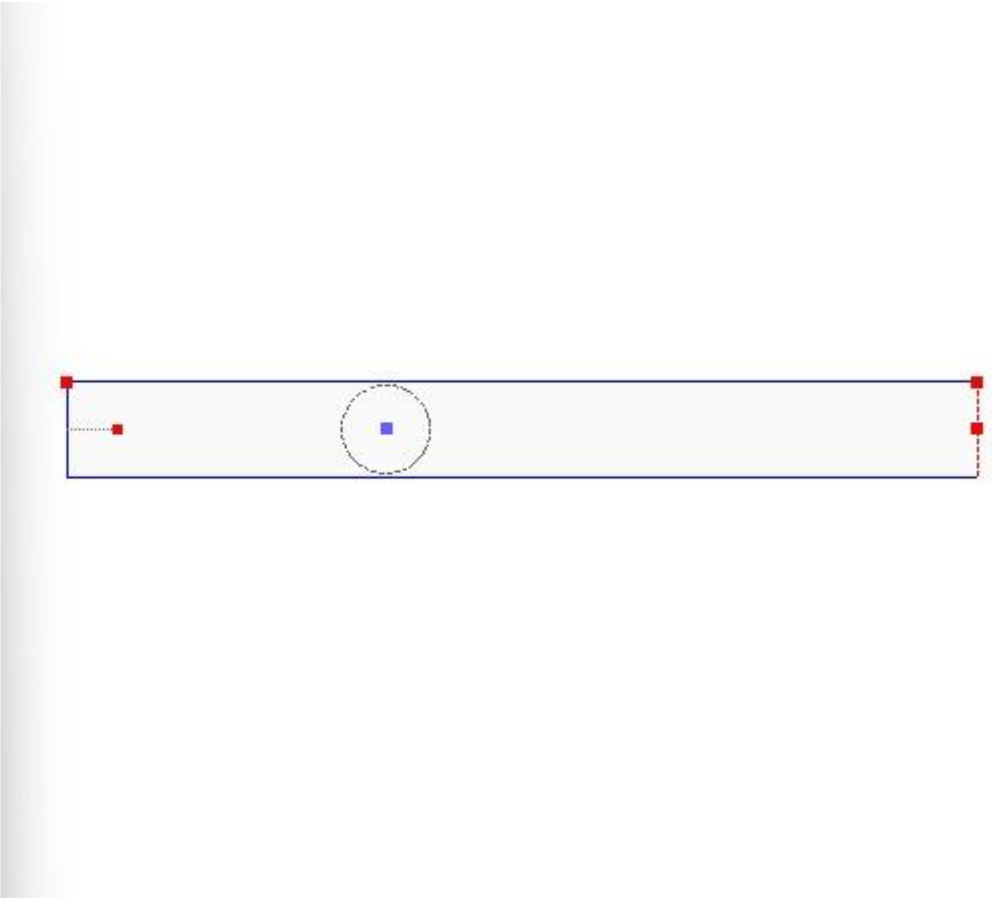
Using computer simulations, I checked the potential utility from such a resonator, placed at the end of the tunnel, but using a quarter-wave resonator rather than a Helmholtz resonator. The principle of the attenuator is simple.

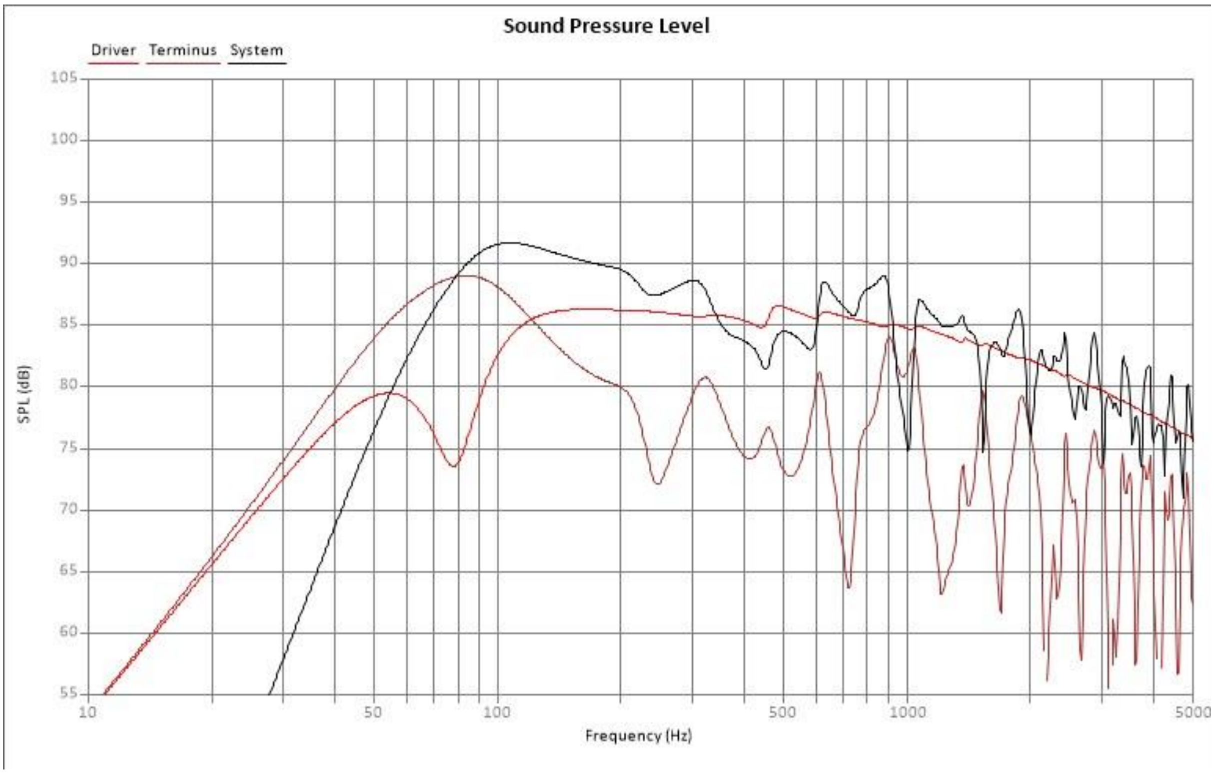
In the Visaton test enclosure, I wanted to attenuate the resonance around 490 Hz, using a quarter-wave damper. The 490 hz sound wave is about 70 cm long, and its quarter-wave will be about 17.5 cm. To the enclosure, I added a short tunnel with a length of 18 cm.

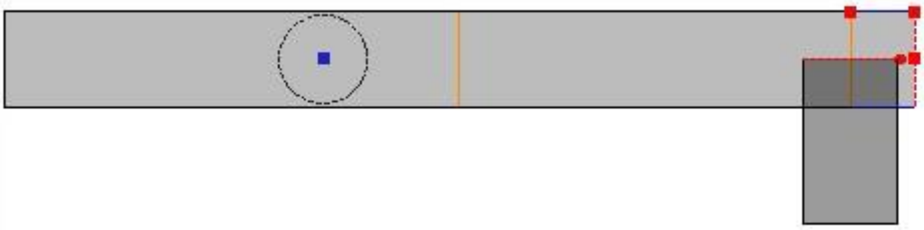


Simulation of an attenuator in Leonard Audio Transmission Line software:

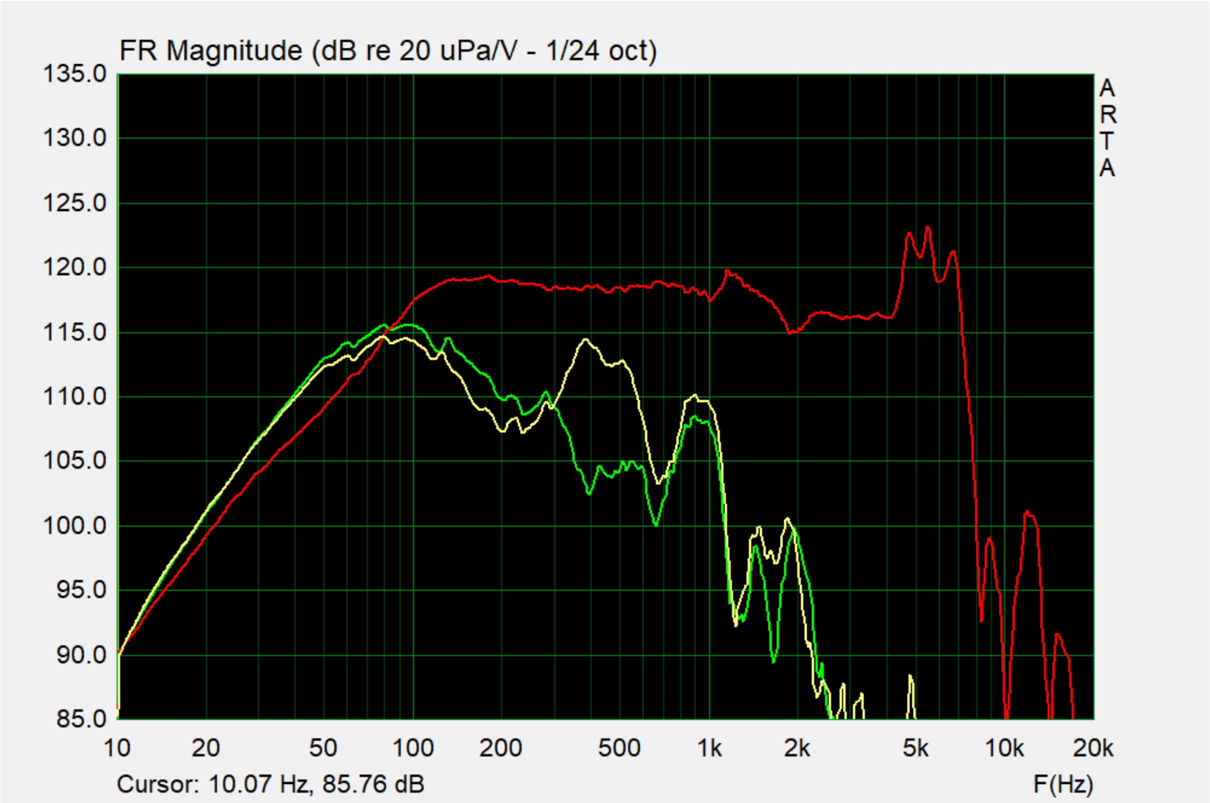




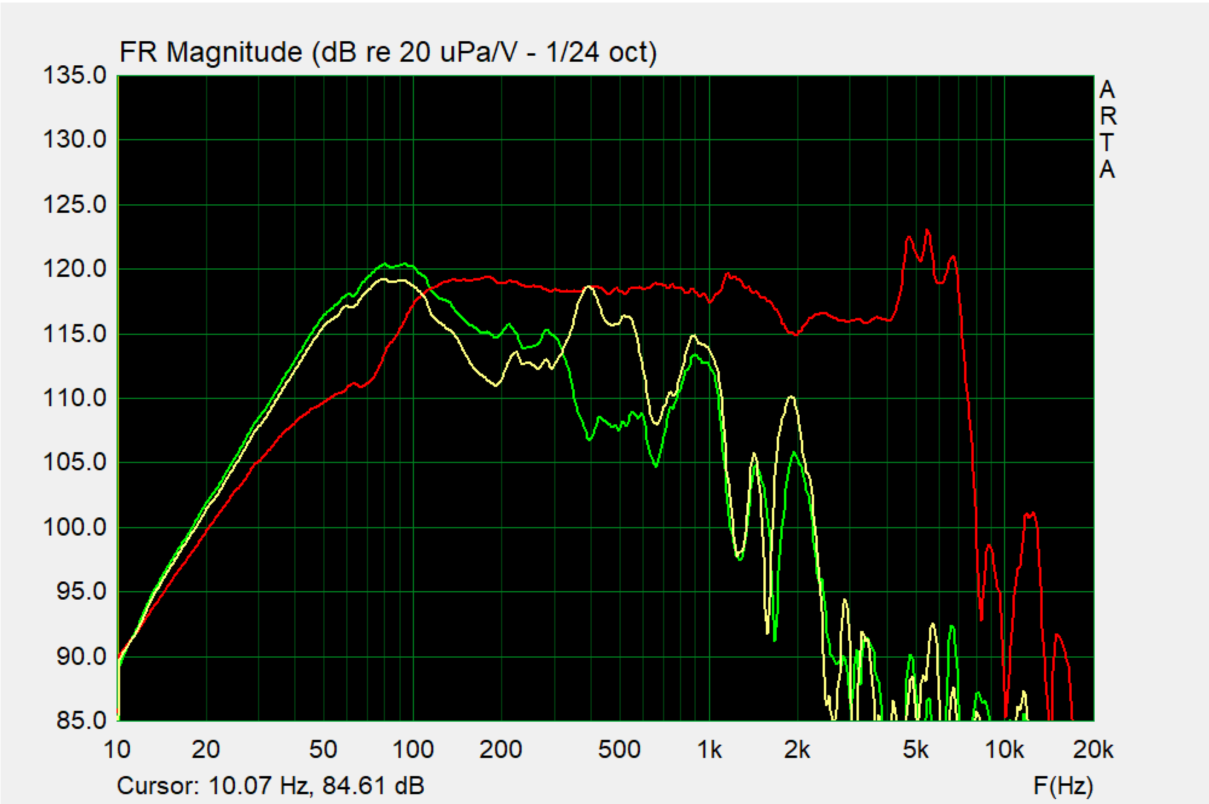

Sound Pressure Level
Driver
Terminus
System
105
100
95
90
85
80
75
70
65
60
55
SPL (dB)
10
50
100
500
1000
5000
Frequency (Hz)



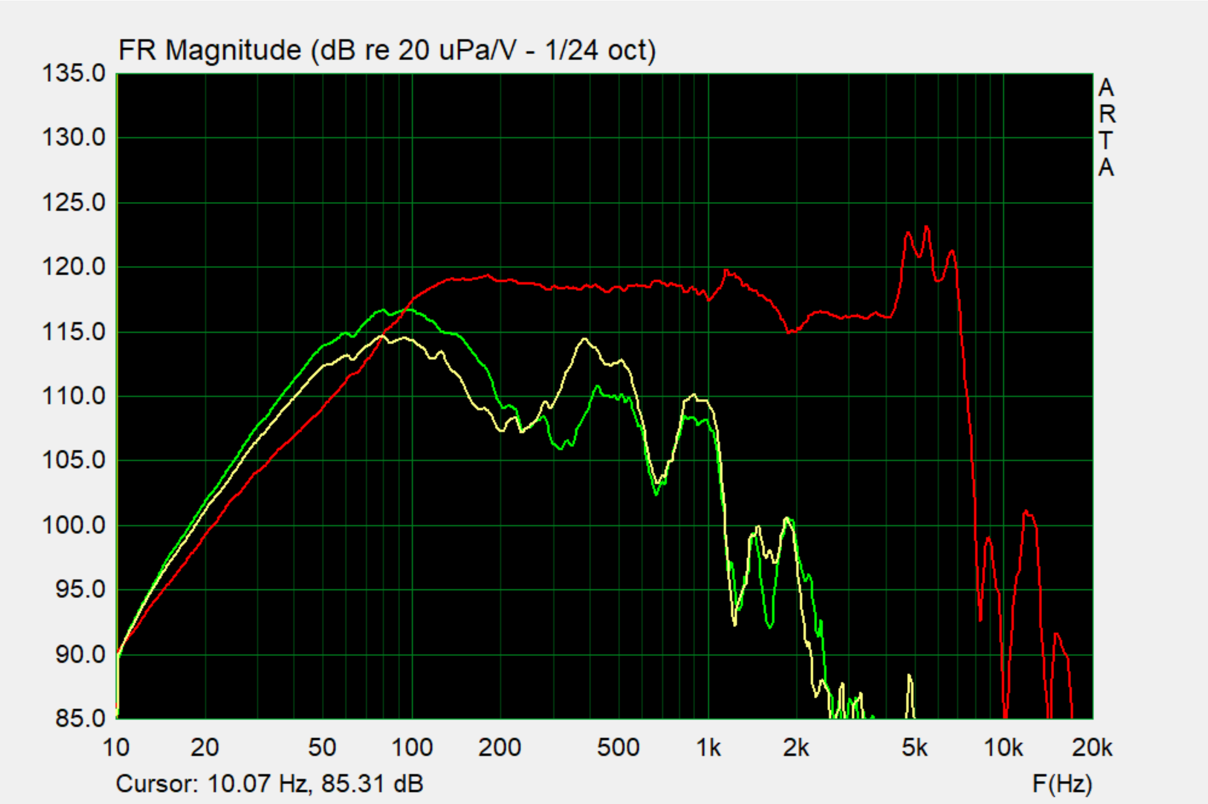
Measurements of the performance of the damper in an enclosure damped with 300 g/m2 polyester fiber the entire length of the tunnel. Damper filled with Polyfill fiber. NOTE: I will only present the measurement of the tunnel with the damper. The red measurement of the driver response is illustrative. Green measurement - tunnel with damper. Yellow measurement - measurement without damper:



Measurements of the performance of the damper in an enclosure damped with 300 g/m2 polyester fiber over a length of 70 cm of tunnel. Damper filled with the Polyfill fiber:

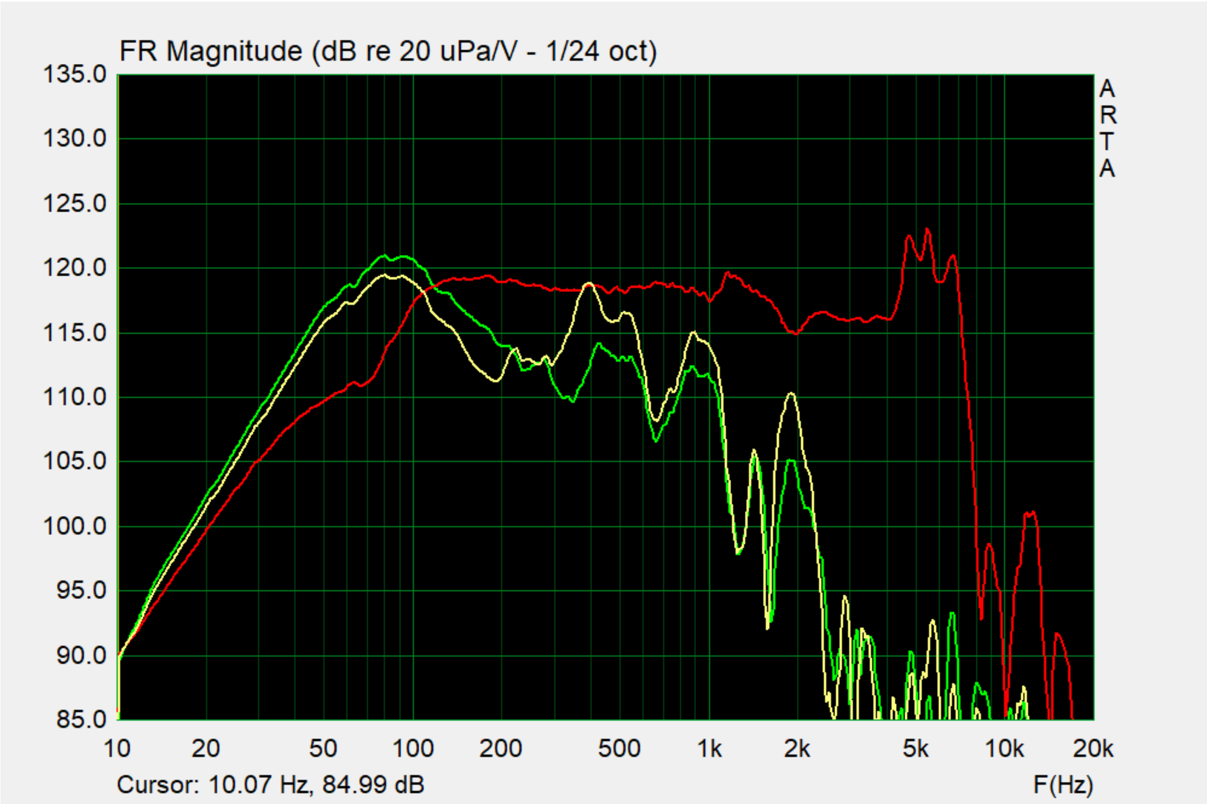


Measurements of the performance of the damper in an enclosure attenuated with 300 g/m2 polyester fabric over the entire length of the tunnel. Damper filled with T18 foam:



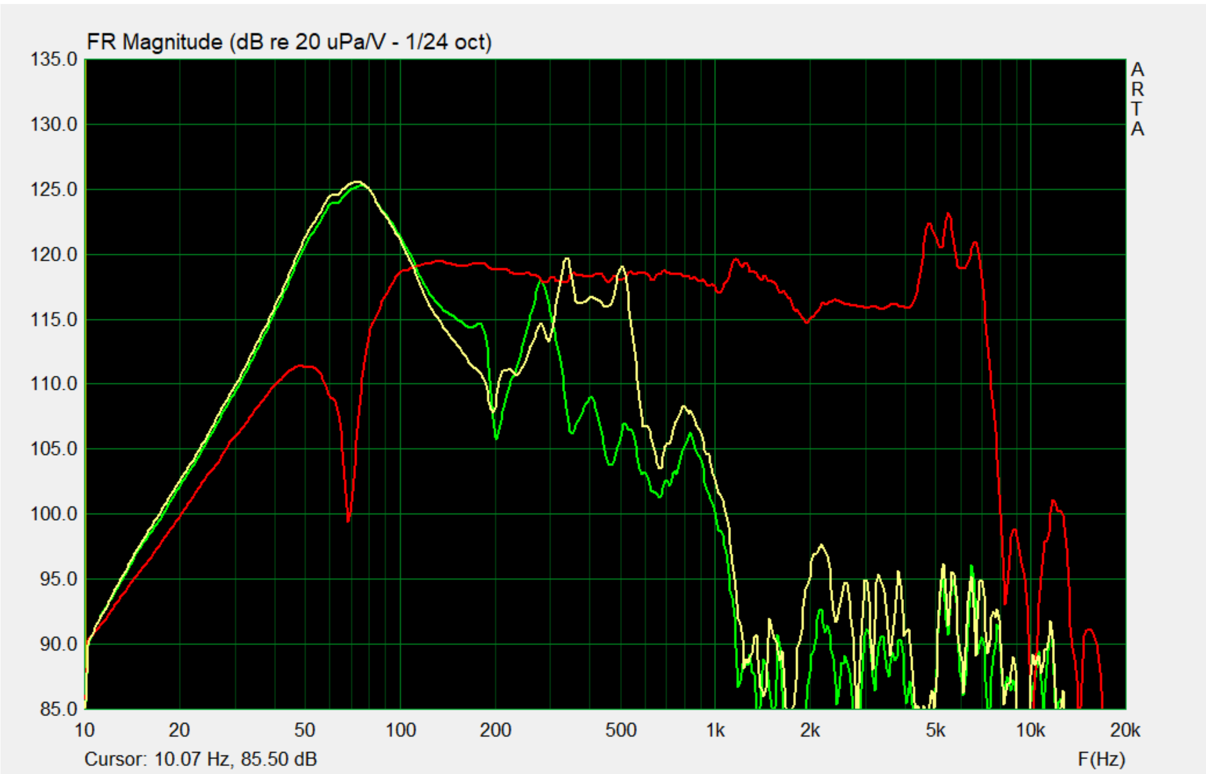
The use of foam in the damper caused it to be out of tune, lowering its operating frequency, making it not as effective as the polyester fiber damping variant. The use of foam in the TL tunnel does not lower only the quarter-wave resonance, but also its harmonic resonances!

Measurements of the performance of the damper in an enclosure damped with 300 g/m2 polyester fiber over a length of 70 cm of tunnel. Damper filled with T18 foam.:

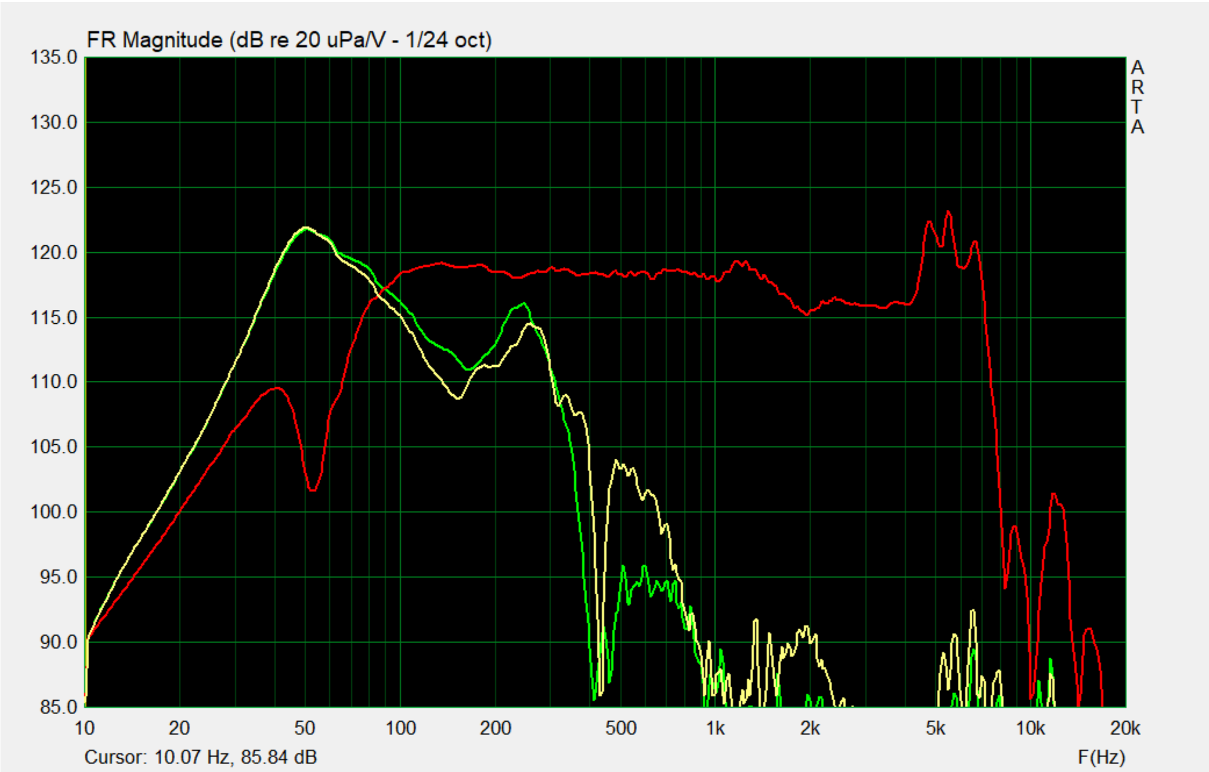


Similarly, in this case, the damper action is ineffective, by using T18 foam in the resonance chamber.

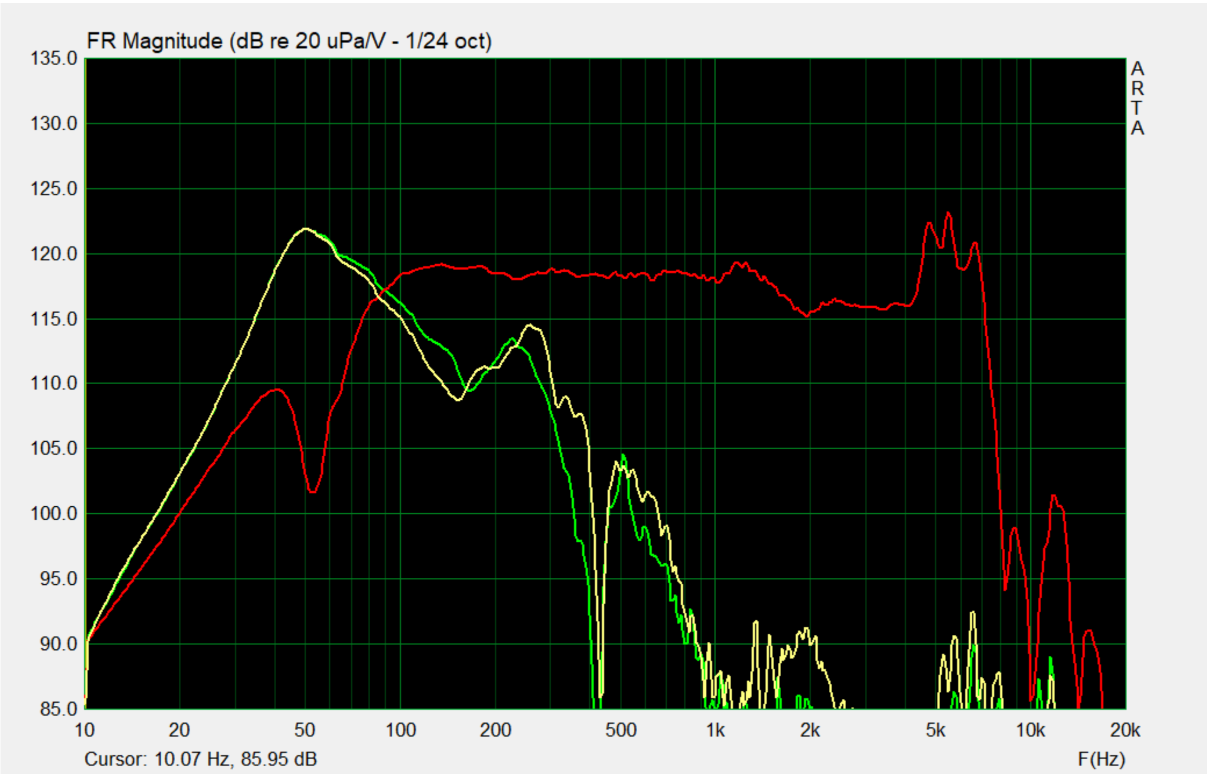
Measurements of damper performance in an enclosure damped with Basotect 3 cm foam, along the entire length of the tunnel. Damper filled with Polyfill fiber:



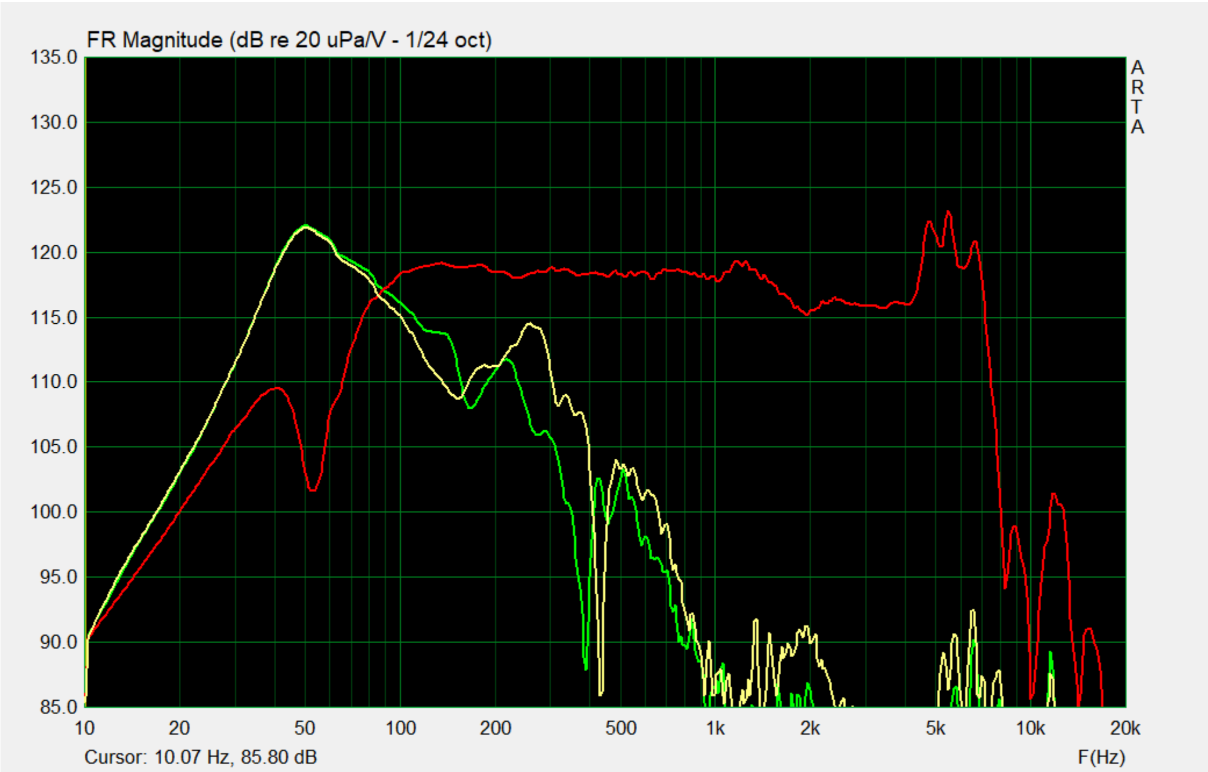
Measurements of damper performance in an enclosure damped with Basotect 6 cm foam, along the entire length of the tunnel. Damper filled with Polyfill fiber:



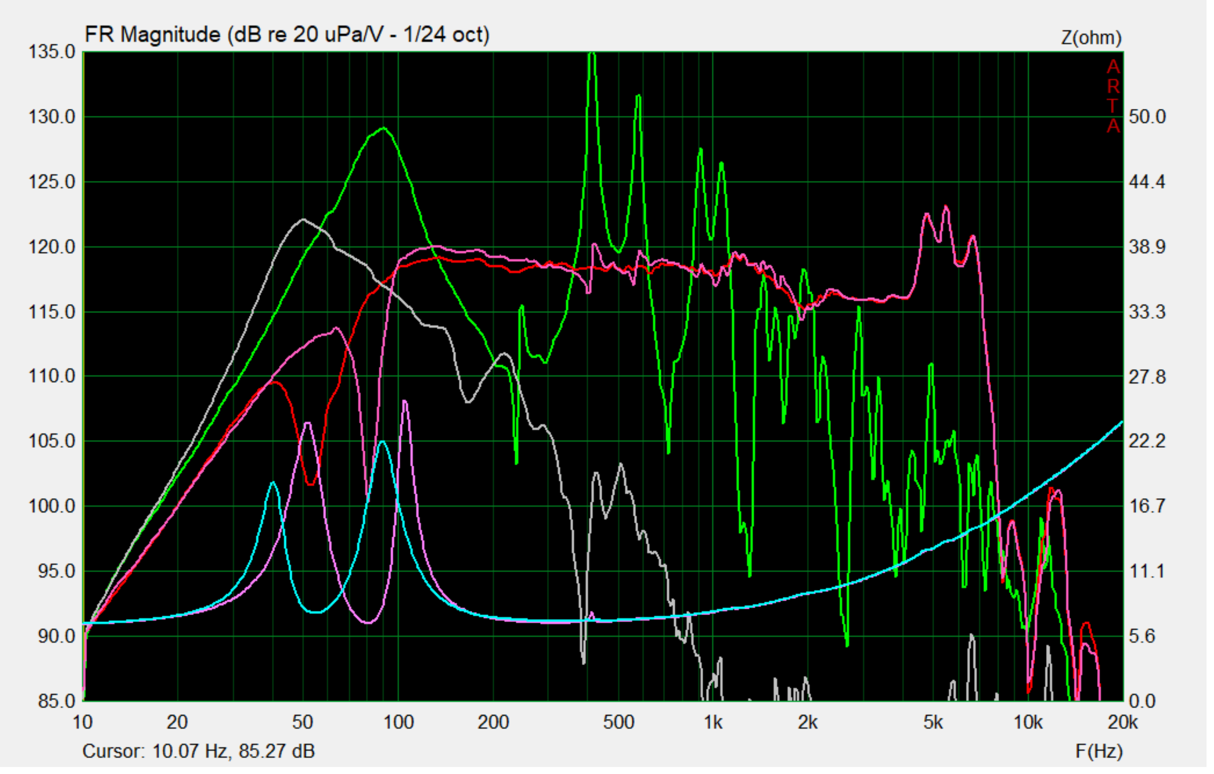
Measurements of damper performance in an enclosure damped with Basotect 6 cm foam, along the entire length of the tunnel. Damper filled with T18 foam:



Measurements of damper performance in an enclosure damped with Basotect 6 cm foam, along the entire length of the tunnel. Damper filled with Basotect:



The last measurement is a comparison of the response of an empty tunnel with an enclosure damped with Basotect foam and with a resonance damper added, which is also damped with Basotect foam:



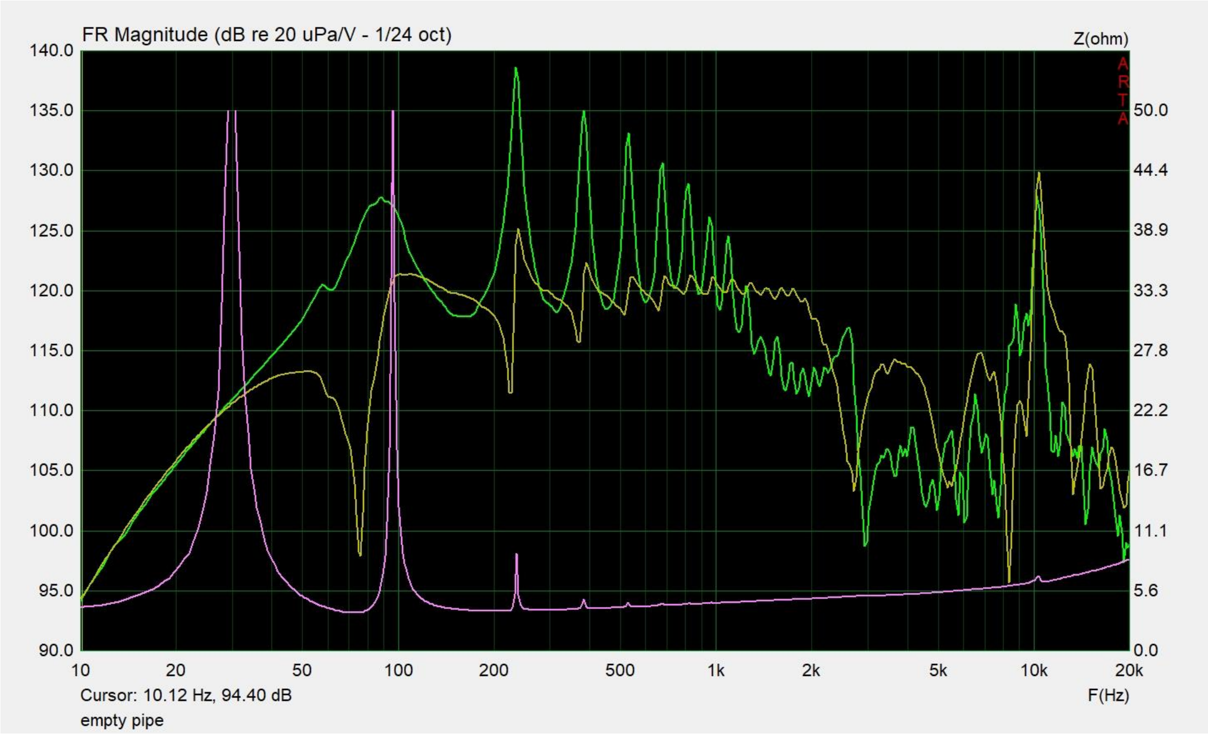
Here we can see that even such a simple TL, which is far from suboptimal in terms of tunnel geometry, after using Basotect foams and a resonance damper achieves performance that cannot be replicated using popular polyester damping. We tuned the tunnel, which is only 100 cm long, with Basotect foams to about 53 Hz. The attenuation of harmonic resonances can be considered very effective.

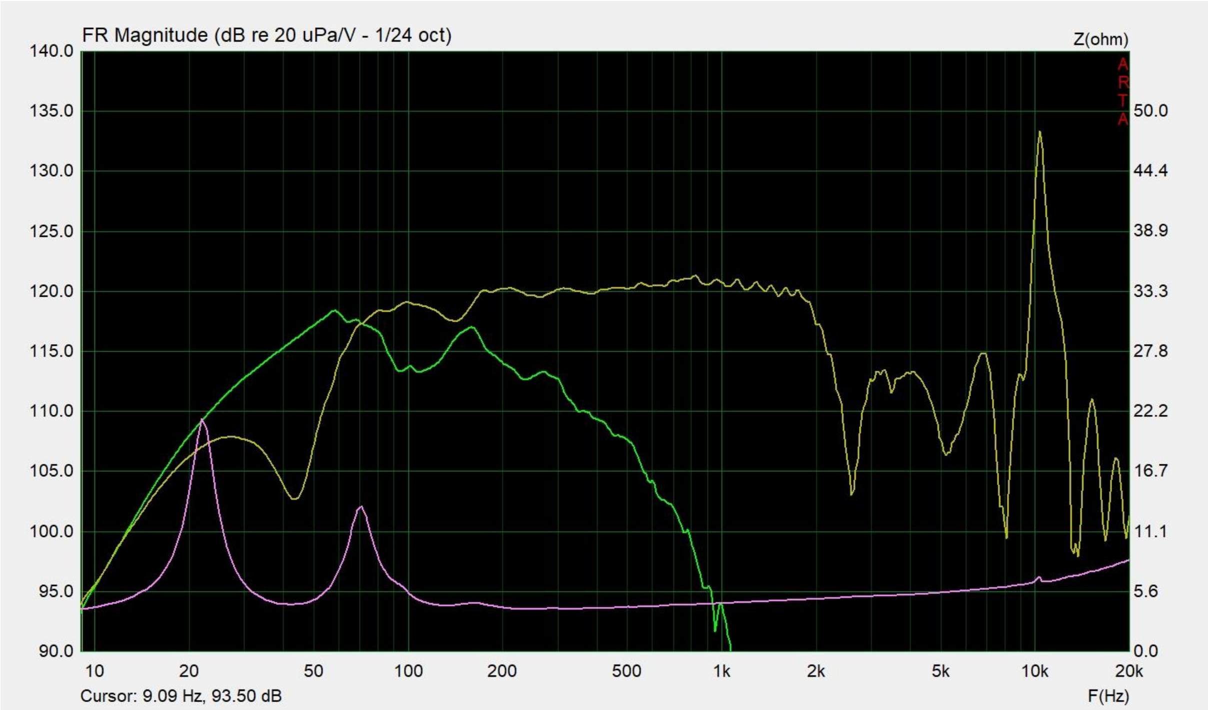
It is also worth mentioning that the cross-sectional area of the tunnel occupied by the foam is almost 50% . Despite this, we get a very high radiation efficiency of the tunnel, and at the same time harmonic resonances are well absorbed by the foam.

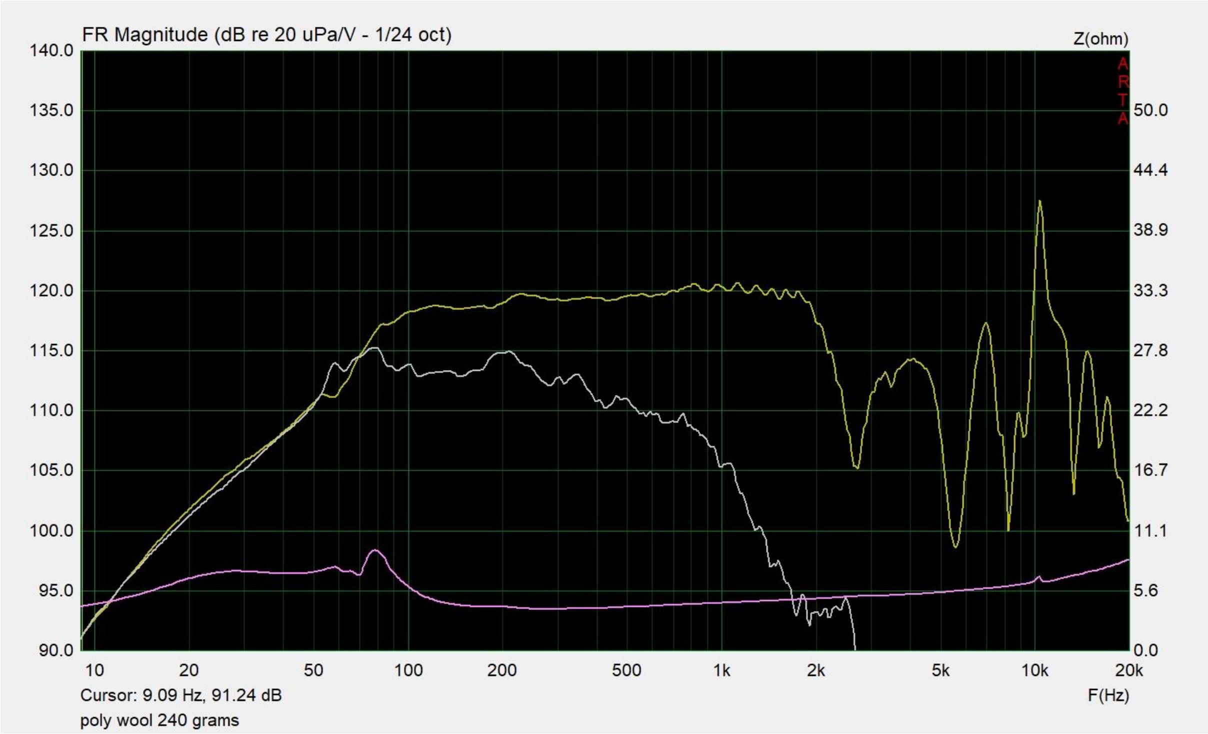
Conclusions:

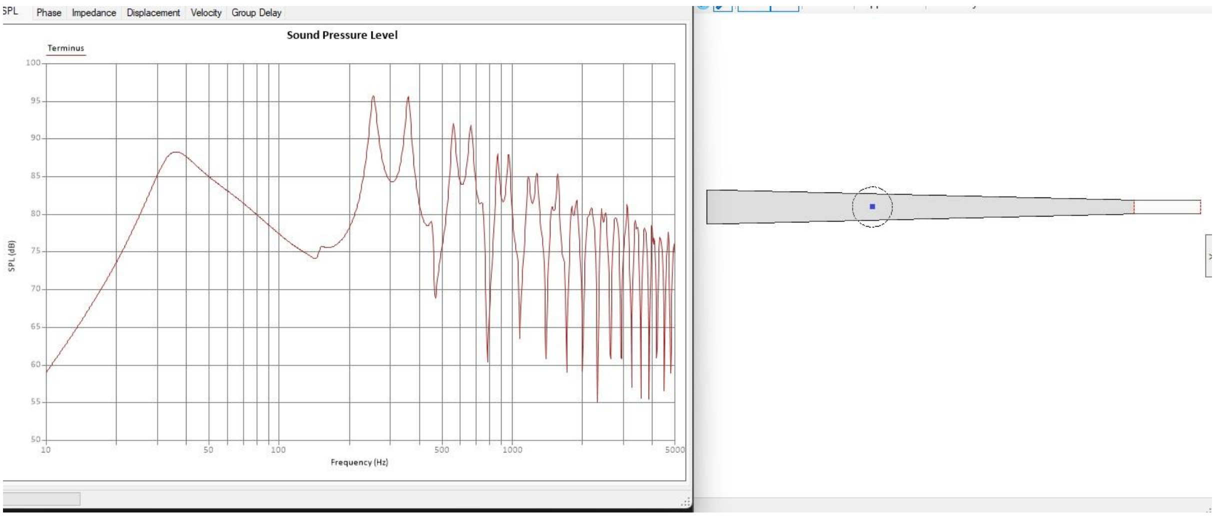
1. 1. open-pore acoustic foams and polyester fleece are by no means interchangeable materials. Their performance in the TL enclosure is completely different, and the proper use of these materials requires different application and placement in the enclosure.
2. the fundamentals of a good TL enclosure design are proper designed tunnel geometry and speaker offset.
3. The transmission line damped with foams (especially Basotect foam) more resembles a Bas reflex enclosure in its operation. Quarter-wave resonance is strongly marked, impedance peaks are weakly dampe.
4. Using software for simulation of enclosures with transmission line damped with polyester fiber (spreadsheets MJK, Hornresp, SpicyTL, TLwrx, Akabak, AJHorn...) we are able to predict the performance of the actual enclosure with good accuracy. None of the simulation programs known to me has the ability to simulate the behavior of Basotect foams. Only SpicyTL offers the ability to simulate TL with polyurethane foams.
5. 5 It is impossible to say definitively which form of TL damping is better. Both variants of damping have their own strengths and weaknesses, and certainly each will find its use in specific conditions.
6. I think the above tests will encourage other builders to do their own testing and thinking, as they break some myths that have been floating around over the years in various sources, articles, online forums, etc.

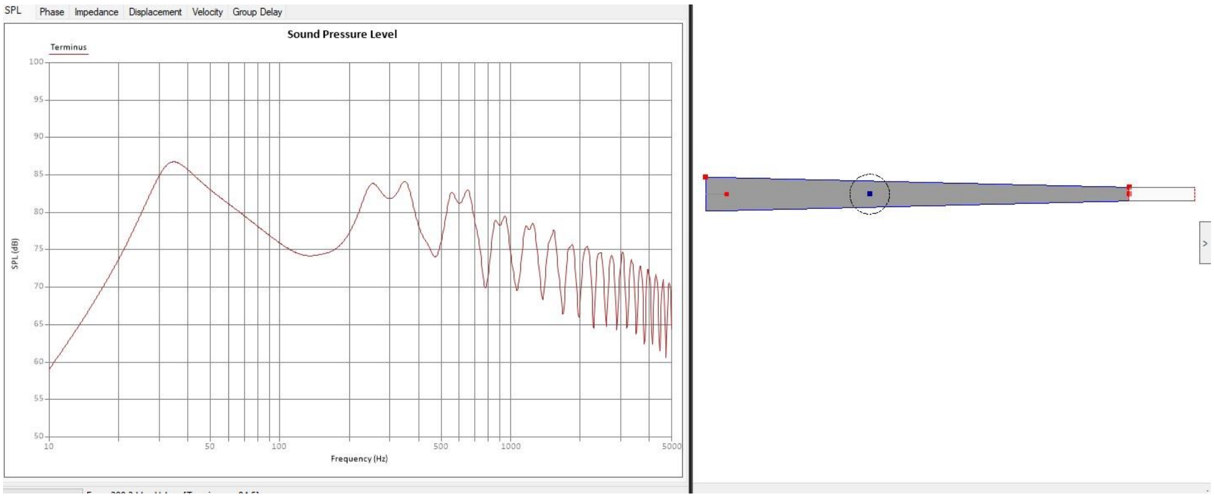
Some additional measurements and designs:


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
Z(ohm)
ARTA
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
50.0
44.4
38.9
33.3
27.8
22.2
16.7
11.1
5.6
0.0
10
20
50
100
200
500
1k
2k
5k
10k
20k
Cursor: 10.12 Hz, 94.40 dB
F(Hz)
empty pipe


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
Z(ohm)
ARTA
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
50.0
44.4
38.9
33.3
27.8
22.2
16.7
11.1
5.6
0.0
10
20
50
100
200
500
1k
2k
5k
10k
20k
Cursor: 9.09 Hz, 93.50 dB
F(Hz)


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
Z(ohm)
ARTA
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
50.0
44.4
38.9
33.3
27.8
22.2
16.7
11.1
5.6
0.0
10
20
50
100
200
500
1k
2k
5k
10k
20k
F(Hz)
Cursor: 9.09 Hz, 91.24 dB
poly wool 240 grams


SPL
Phase
Impedance
Displacement
Velocity
Group Delay
Sound Pressure Level
Terminus
100
95
90
85
80
75
70
65
60
55
50
SPL (dB)
10
50
100
500
1000
5000
Frequency (Hz)


SPL
Phase
Impedance
Displacement
Velocity
Group Delay
Sound Pressure Level
Terminus
100
95
90
85
80
75
70
65
60
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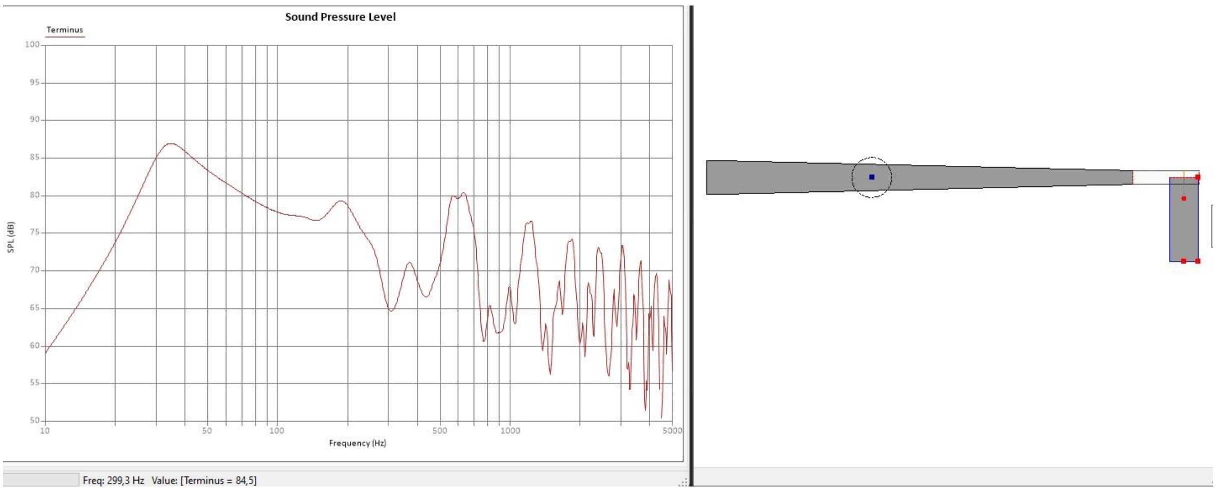
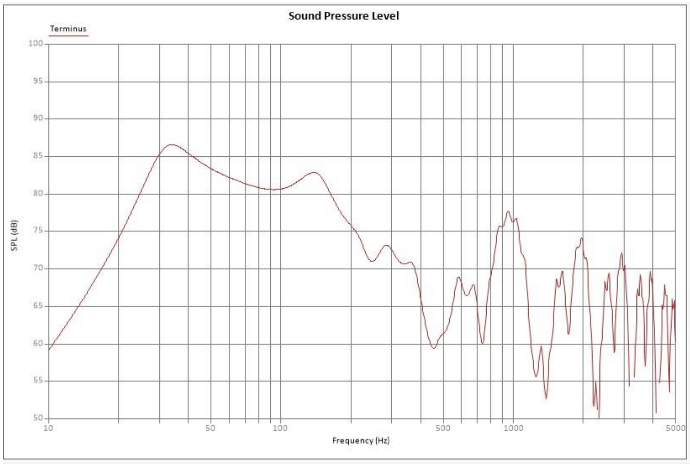
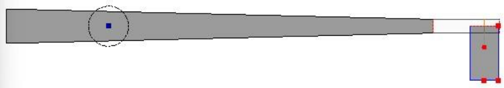
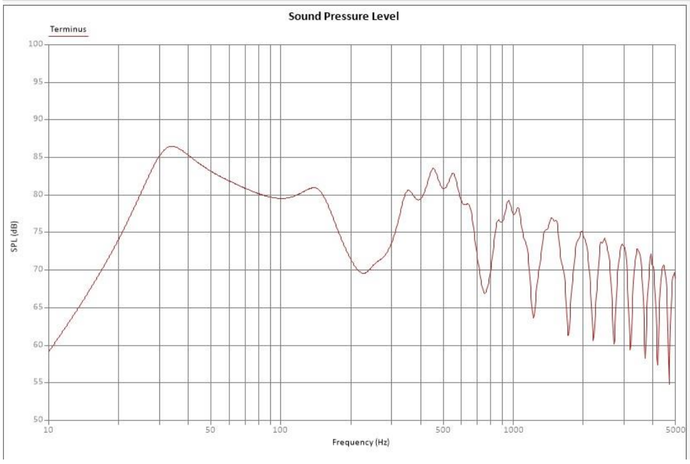
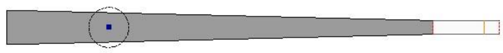
50
SPL (dB)
10
50
100
500
1000
5000
Frequency (Hz)

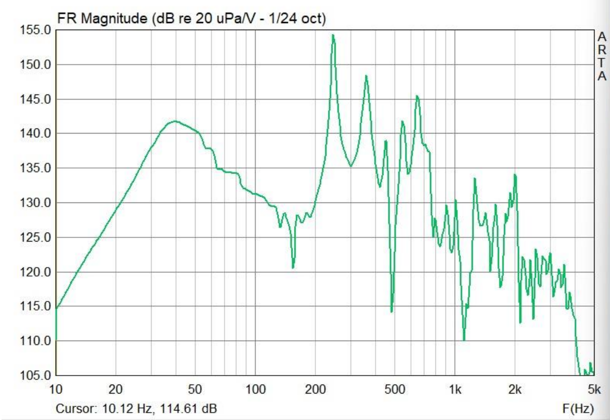

Sound Pressure Level
Terminus
100
95
90
85
80
75
70
65
60
55
50
SPL (dB)
10
50
100
500
1000
5000
Frequency (Hz)
Freq: 299,3 Hz Value: [Terminus = 84,5]

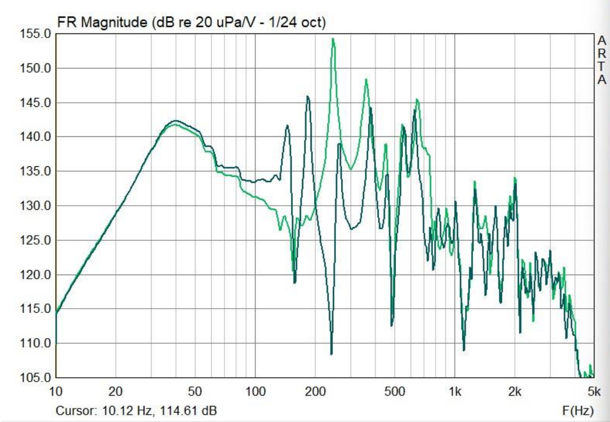

Sound Pressure Level
Terminus
SPL (dB)
Frequency (Hz)

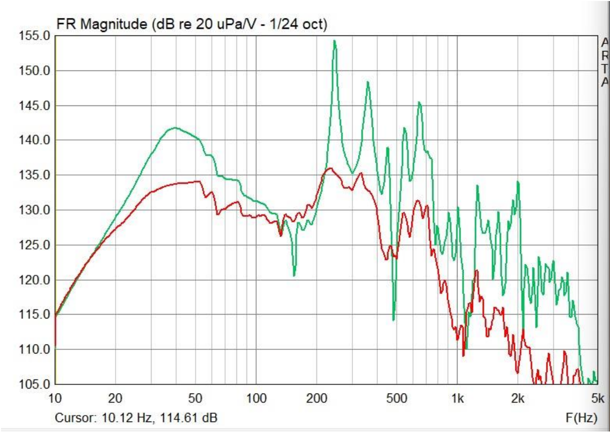


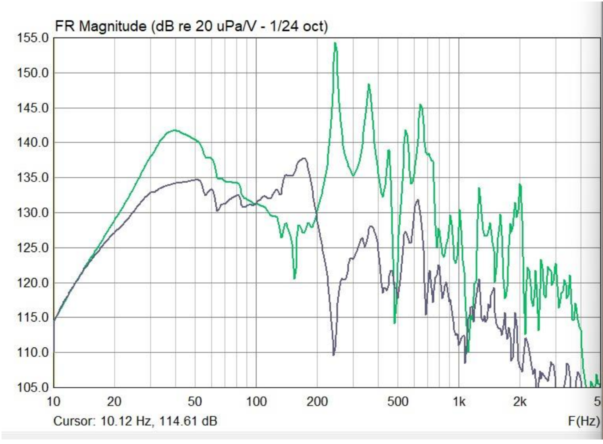

Sound Pressure Level
Terminus
SPL (dB)
Frequency (Hz)

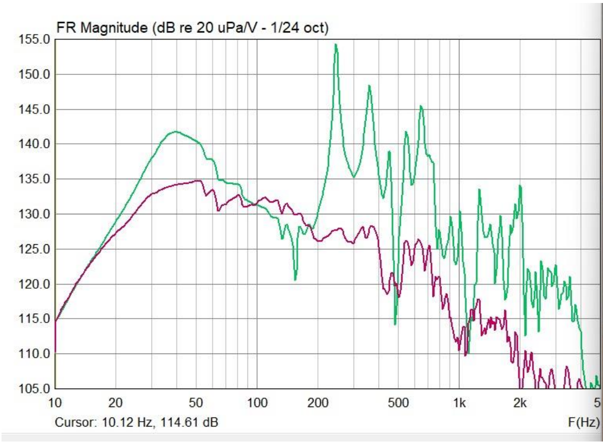


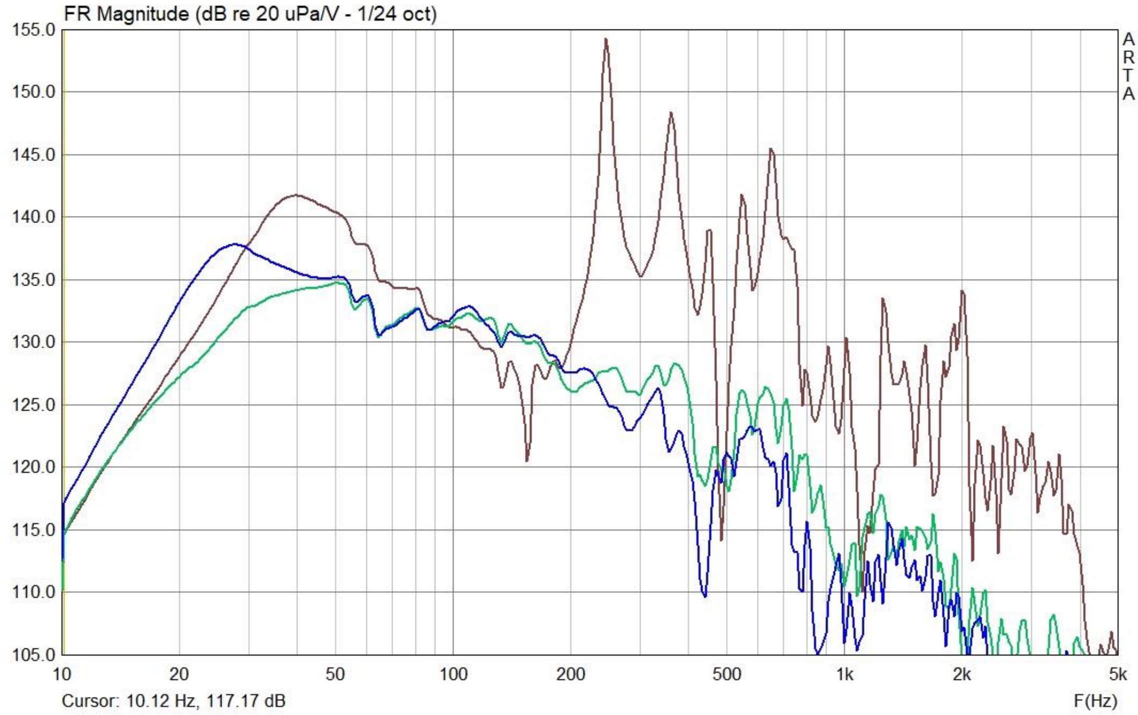

FR Magnitude (dB re 20 uPa/V - 1/24 oct)
ARTA
Cursor: 10.12 Hz, 114.61 dB
F(Hz)


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
ARTA
Cursor: 10.12 Hz, 114.61 dB
F(Hz)


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
10
20
50
100
200
500
1k
2k
5k
Cursor: 10.12 Hz, 114.61 dB
F(Hz)


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
10
20
50
100
200
500
1k
2k
5
Cursor: 10.12 Hz, 114.61 dB
F(Hz)


FR Magnitude (dB re 20 uPa/V - 1/24 oct)
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
10
20
50
100
200
500
1k
2k
5
Cursor: 10.12 Hz, 114.61 dB
F(Hz)



Blue - polyurethane foam

Green - polyester fabric

Brown - empty enclosure