Using Modal Analysis to Understand Transmission Line Speaker Enclosure Response Part 4 – Fiber Fill versus Acoustic Foam Lining

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Introduction

The most common forms of damping used in modern TL enclosures are fiber stuffing and/or acoustic foam. Each method of damping comes in different materials, sizes, and shapes but the physical behavior within each method is probably very similar.

In the early days of TL building, long fiber wool was the damping material of choice and mythical performance properties were claimed. Later fiberglass and polyester fiber were also proposed, but long fiber wool always maintained a certain cult like mystique and the claimed sonic superiority was generally accepted as fact among the TL community. After measuring the acoustic output of a straight constant cross-sectional area test TL with long fiber wool or polyester pillow stuffing (in 1999-2000), I found they performed almost the same without any large reduction in the speed of sound, coupling of air and fiber motions, or other magical damping performance preached by the old school TL purists. My conclusion was that fiber stuffing distributed in the enclosure volume acted as a viscous damper for the oscillating air motions, stuffing density determined the level of viscous damping achieved.

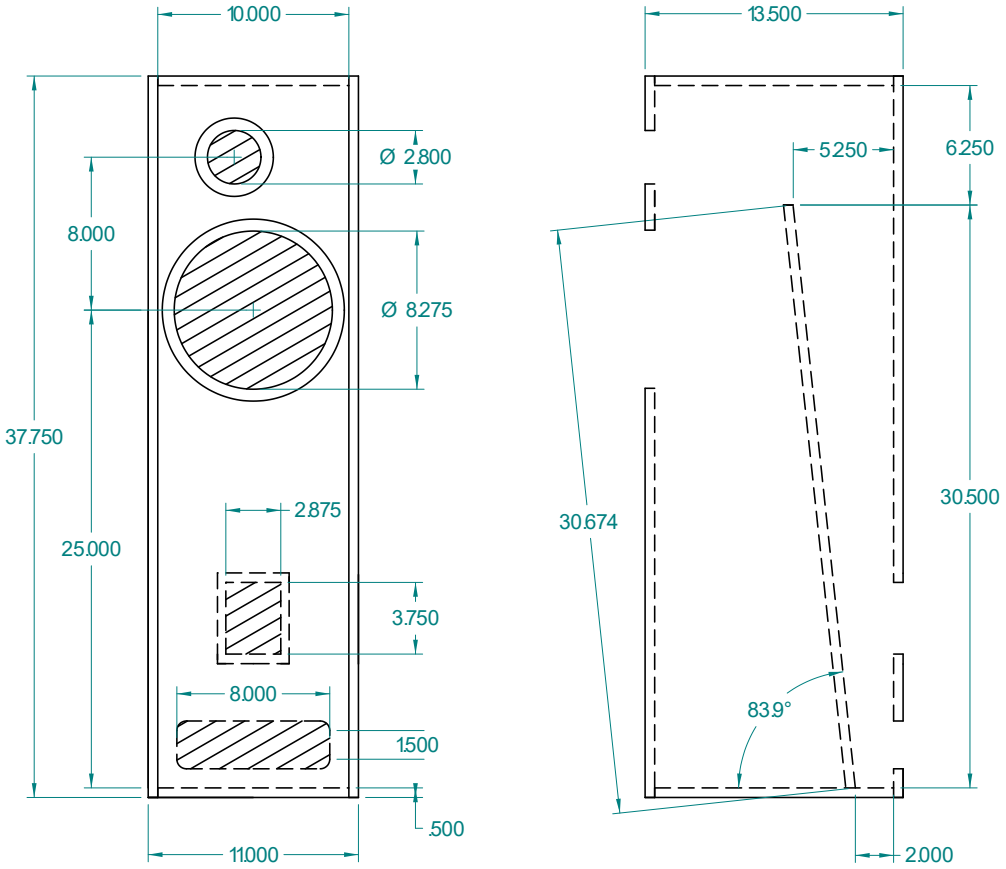
The density, location, and support of fiber stuffing is an arts and crafts project that is not always easy to replicate repeatedly in a manufacturing environment. Current commercial TL designs tend to use an acoustic foam lining attached to the walls of the enclosure. It is easy to control the size and location of the foam pieces leading to a more consistent, repeatable, and efficient manufacturing process. The question that I have often asked myself is how does a layer of acoustic foam acting in parallel with an open volume of air perform as a damping technique compared to the entire volume uniformly filled with fiber stuffing.

Until now, I have always used polyester fiber stuffing in my TL designs. The intent of this study was to measure the same TL geometry completely empty, filled with polyester fiber stuffing, and lined with acoustic foam to quantify any differences in acoustic performance. No attempt was made to formulate a mathematical model, or apply a documented mathematical model, for a foam lined TL enclosure. MathCad modeling of acoustic foam will need to be a separate task tackled further down the road in my TL modeling development.

The Satori TL Speaker Design

The recently completed Satori TL was used as a test bed for comparing fiber stuffing and acoustic foam damping configurations. Threaded rods and thin foam gaskets applied to the side walls allowed the enclosure to be disassembled and reassembled quickly and easily while still maintaining an airtight seal. Measurements of the electrical impedance and near field SPL of the woofer and terminus were taken for an empty TL, a fiber stuffed TL, and an egg crate acoustic foam lined TL.

http://www.quarter-wave.com/Project13/Project13.html



Sketch of the 5:1 tapered Satori transmission line speaker enclosure. All dimensions are in inches.

Empty, Fiber Stuffing, and Foam

Examples of the Satori TL enclosure just before final assembly.

- Left Picture – Empty TL.
- Center Picture – 0.5 lb/ft^3 of Polyester Fiber Stuffing
- Right Picture – 1.5-inch-thick Egg Crate Acoustic Foam.

Fiber or Foam were applied to the same portion of the TL, approximately the first 3/4 of the tapered TL's length.

Measurement Results

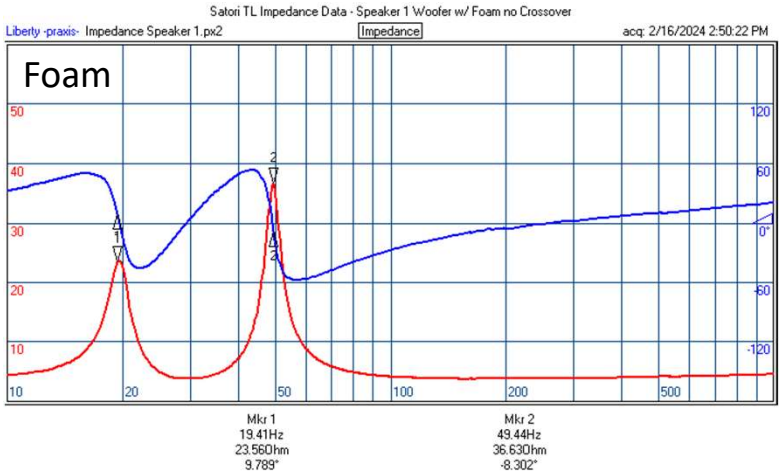
Electrical impedance and near field SPL of the Woofer and Terminus were measured with Liberty Instrument's Praxis software and hardware. In room 1 m SPL measurements, including the passive crossover, were performed with the OmniMic software and hardware

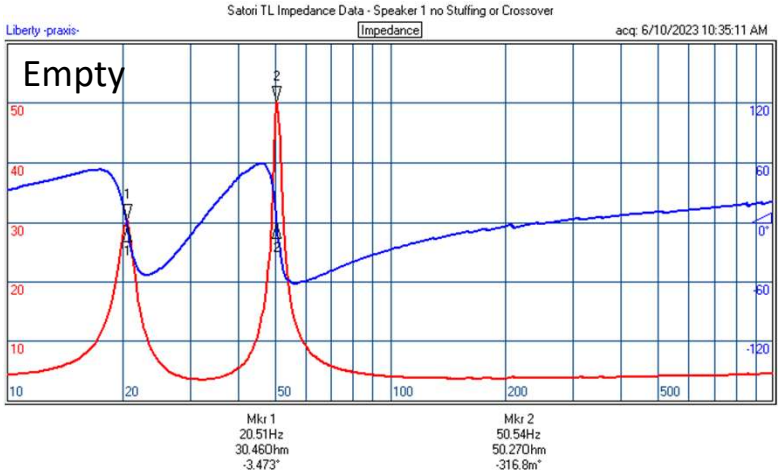
First, electrical impedance measurements were made of the woofer in the TL enclosure with the foam lining but without any crossover. Near field SPL measurements were also made of the woofer and the terminus for the foam lined TL without any crossover. Previously the same measurements of the empty and fiber filled TL were made with the same test set-up.

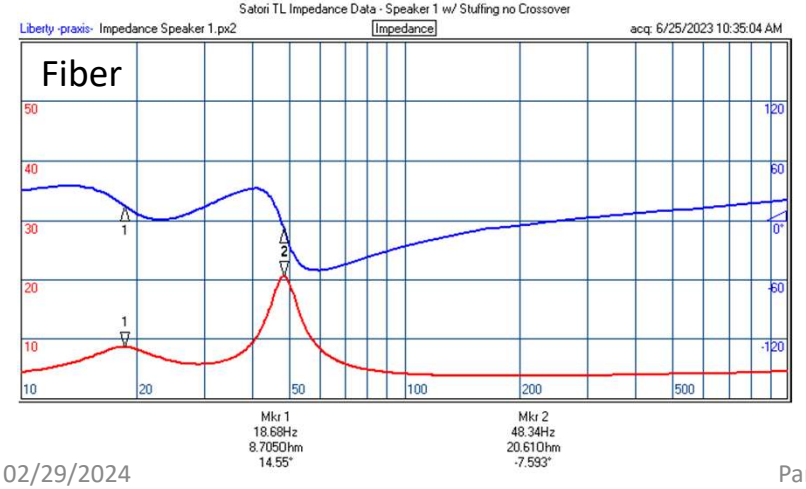
Second, in room 1 m SPL measurements of the completed speaker with the acoustic foam lining were made with the passive crossover. Fiber stuffing measurements already existed and were available for comparison. Missing are in room 1 m SPL measurements of the empty TL, an oversite on my part.

Comparing the measurement results helped quantify the differences between the empty, fiber stuffed, and acoustic foam lined TL. Care must be taken when comparing results to differentiate between what is a result of inserting damping material versus what is caused by the tapered TL's folded geometry.

Electrical Impedance

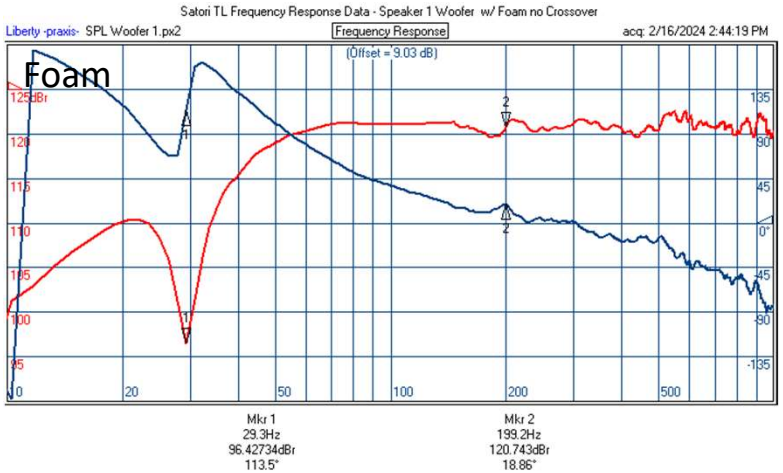


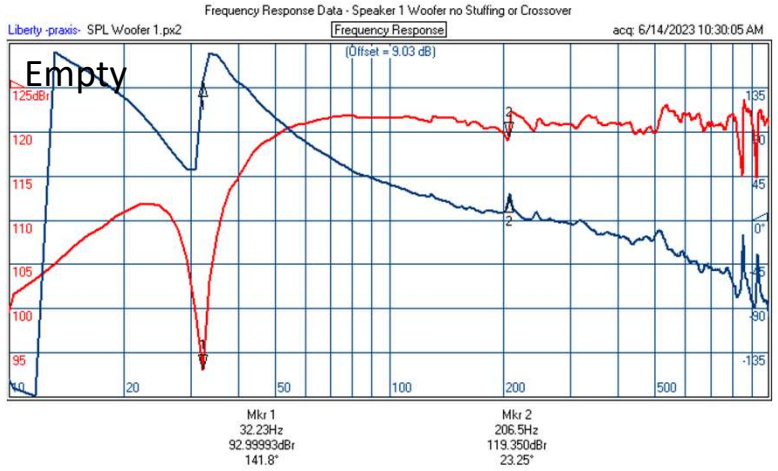


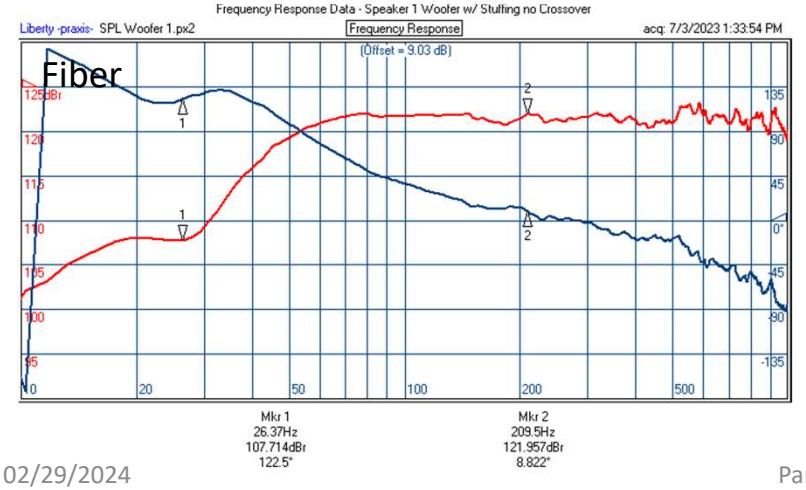


The locations of the double humped impedance peaks, and the null between, in the frequency domain behave as expected. Adding damping material lowers the frequencies and the magnitudes of the peaks. It is interesting that the foam lined TL's impedance curve is close to the empty TL's result. Fiber filling provides significantly more damping of these first two resonance peaks.

Near Field Woofer SPL

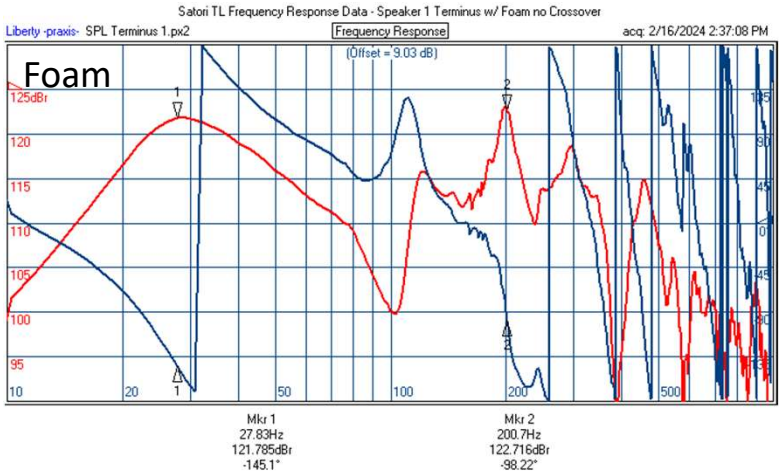


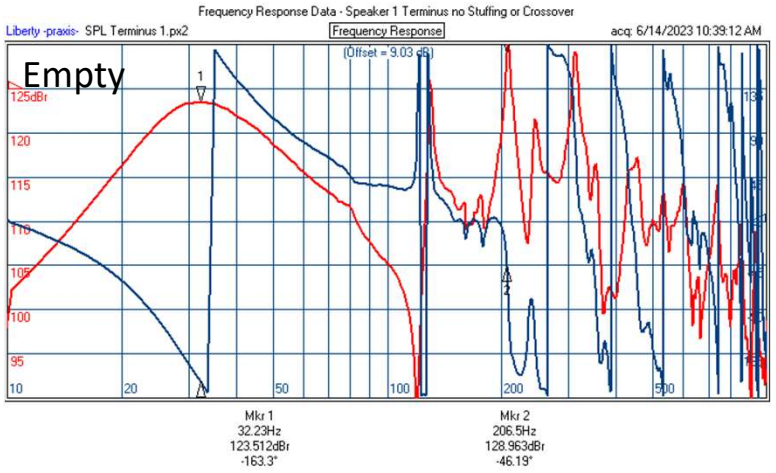


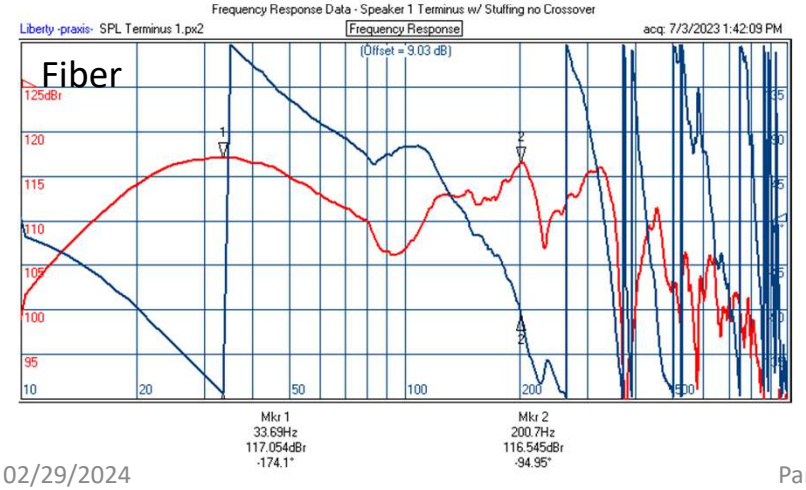


The tuning frequency for the TL, as determined from the first deep null, does not change dramatically between the empty and the damped enclosure. Damping lowers the tuning slightly and the strength of the standing wave as evident by the depth and width of the driver's null in the measurement results. There is no indication of a dramatic reduction in the speed of sound often claimed in TL folklore.

Near Field Terminus SPL



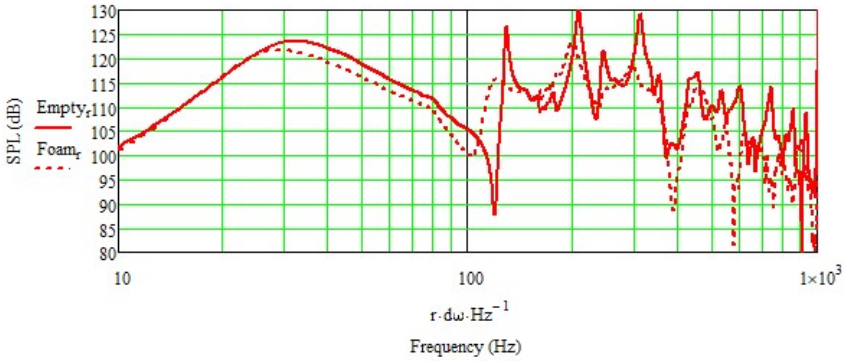


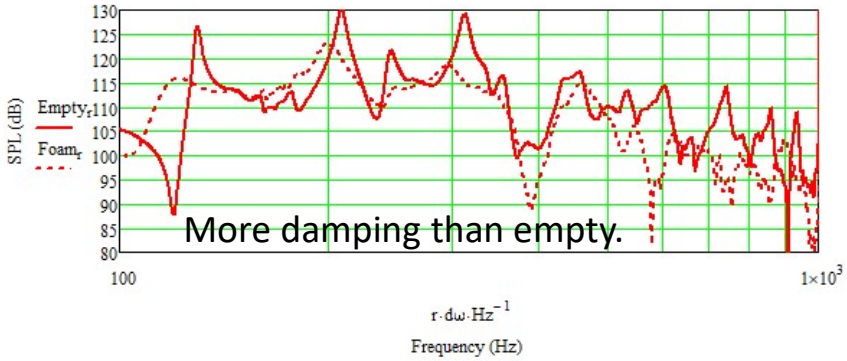


The terminus SPL output determines the speaker's bass performance, just like the port's output in a BR enclosure. The empty and the foam lined TLs have sharper SPL peaks at the tuning frequency, these curves are similar to a BR port's output. The fiber filled TL has a suppressed and rounded bass response, a less resonant behavior. Also, the fiber filled TL does a much better job of controlling the output from the higher quarter wave resonances.

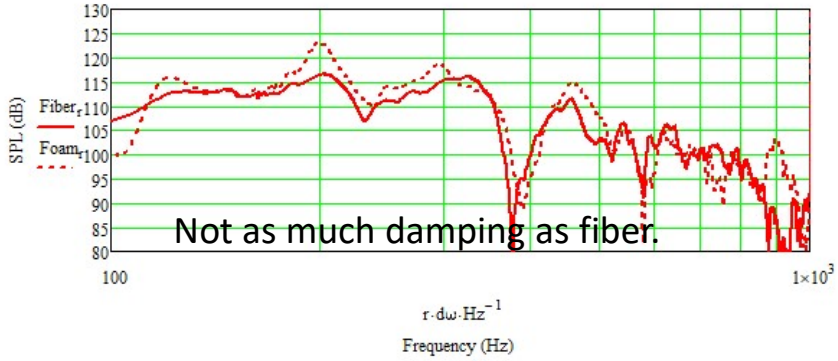
Near Field Terminus SPL Comparisons

Empty (solid red line) versus Foam (dashed red line)



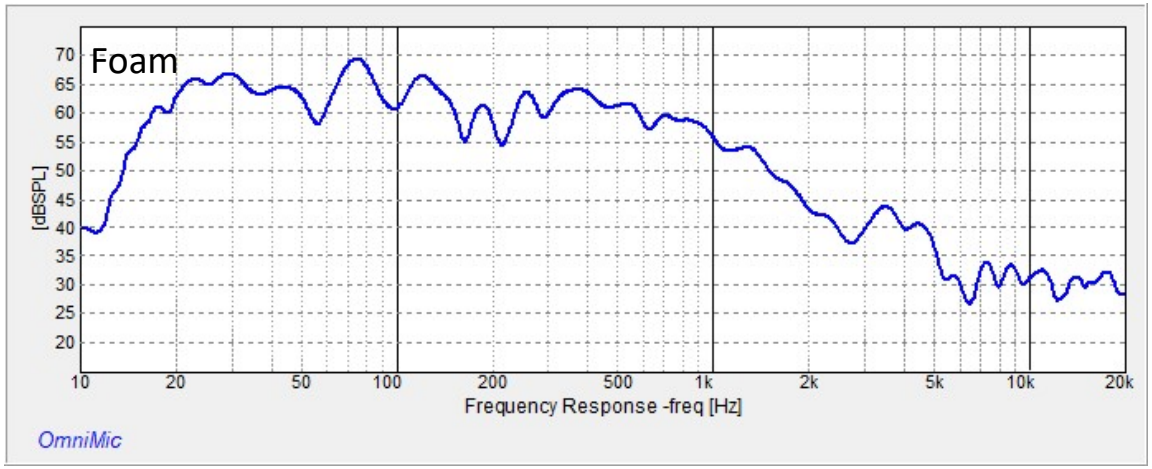


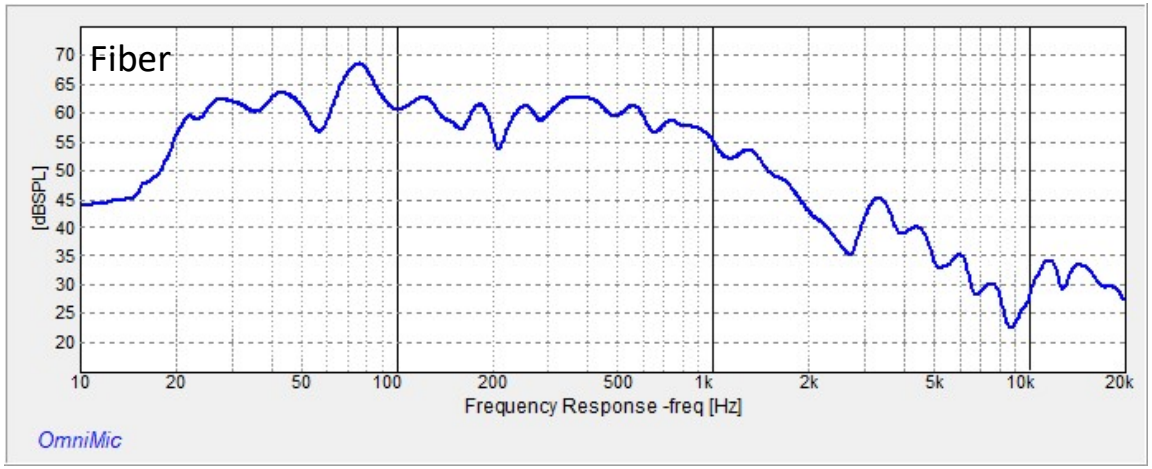
Fiber (solid red line) versus Foam (dashed red line)



Terminus output at the tuning frequency is almost 5 dB higher for the foam lined compared to the fiber filled TL, a nice result. At higher frequencies, foam lining does not provide as much damping as the fiber filled TL but is still better than an empty TL, a compromise result.

In Room Woofer SPL at 1 m w/ Crossover and 1/12th Octave Smoothing





As expected, from the near field measurements, the foam lined TL extends lower in frequency but at the expense of some additional roughness between 100 Hz and 300 Hz.

The fiber filled TL has a rolled off low end and somewhat of a smoother SPL response between 100 and 300 Hz.

The key difference is the very low frequency response. In the room, the foam lined TL produces a few dB's more bass output, compared to the fiber filled TL, starting at 100 Hz and extending down to ~20 Hz. This is a combination of less viscous damping by the foam lining and some low frequency room reinforcement.

Pro's and Con's

Using fiber stuffing in a TL requires careful measurement and placement to get the desired stuffing distribution along a line with a changing cross-sectional area. As stated earlier, this can become an arts and crafts project to get the right distribution and hold the fibers in place. But the density, uniform or changing along the length, is infinitely adjustable and easily locally modified by scooping out or inserting in a handful or two of fiber material.

Using acoustic foam to line a TL is quick, easy, and repeatable. Cut the pieces to size and stick them to the walls of the enclosure. Since the thickness of the foam is the same for each piece, local adjustability is not as easy. In a tapered TL with a foam lining, the percentage of the cross-section taken by pieces of foam increases along the length. Without returning to an arts and crafts project, cutting the width of each piece to achieve a uniform volume split, the adjustability of the foam content along the length is limited to step changes resulting from inserting or removing foam layers.

Back calculating a fiber density equivalent to the damping provided by the foam lining yielded 0.05 lb/ft^3, 1/10th of the stuffing density in the fiber filled TL. For this TL configuration, the fiber stuffing was 10 times more effective at damping the TL's higher harmonics compared to the foam lining.

Listening Impressions

The foam lined TLs were returned to my listening room, set up in the same positions as the fiber stuffed version, and using the same crossover (passive). Listening to my collection of test CDs, I found that the foam lined TLs sounded stronger with respect to bass extension and output but not as tight as the fiber stuffed configuration. The fiber filled TL rounded off the lowest bass response producing a dryer less resonant bass performance.

The additional roughness between 100 and 300 Hz, noted in the foam lined TL's in room SPL measurement, was not obviously audible. The bass performance becomes a matter of taste, a dry tight bass achieved with fiber stuffing versus a deeper and slightly more resonant bass produced by the foam lining. Right now, for this tapered TL design, I am leaning towards the foam lined damping as a better approach. Maybe working with a reduced and nonuniform distribution of fiber stuffing I might be able to converge the two approaches. Or a combination of foam and fiber might be an option to address the different frequency regions, fundamental tuning and higher harmonics. At some point, the changes in sound from tweaking the damping would probably still be measurable but not audible. The beauty of a TL design is the infinite adjustability of the bass performance.

Key Take Aways from Part 4

- Fiber stuffing seems to be a much more effective and an infinitely adjustable option for damping TL enclosures compared to using pieces of acoustic foam lining the enclosure walls. But foam does the job, maybe better is the enemy of good enough in this case.
- I may have totally missed the boat and picked an acoustic foam that is limited for the task of damping a TL, but I still saw some advantages using this acoustic foam. If somebody has a different acoustic foam and the same types of measurements for an empty, fiber filled, and foam lined TL that contradict or improve on my findings I would be very interested and willing to acquire the foam, repeat my testing, and present different results. Send me the measurements and a link to a source for the alternate foam.
- Looking at some of the manufactured TLs lined with acoustic foam, I noticed that they also tend to have more folds or other geometric departures from a straight monotonically tapered TL. These geometries may act to suppress the higher harmonic standing waves, in other words the geometry is more responsible for the low-bass and mid-bass performance than the method of damping.
- A MathCad model that includes an acoustic foam lined TL option is still needed to continue studying the potential damping schemes using fiber stuffing and/or acoustic foam lining. The task has been added to my TL model to-do list.

References

The Foam Factory : https://www.thefoamfactory.com/

Material Data Sheet : https://www.thefoamfactory.com/acousticfoam/pdf/Foam-Factory-1-5-Acoustic-Eggcrate-Foam.pdf