So Why is Acoustic Foam not as Effective as Fiber Stuffing?

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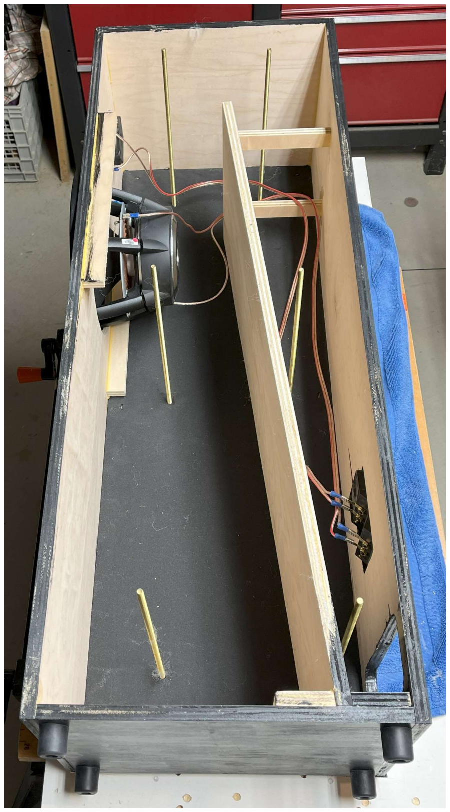
Introduction

The results presented in Part 4 of my series of presentations about the Satori TL design surprised me. I had expected that acoustic foam would have as big an impact as fiber stuffing on damping the higher harmonics of the TL's tuning frequency. While the acoustic foam did provide some damping, it was not nearly as effective or as easily adjustable as the fiber stuffing.

Thinking about these results, and looking at the two materials and installations, I have a few thoughts (no math or physics as proof, just some speculations) on why the damping methods performed so differently.

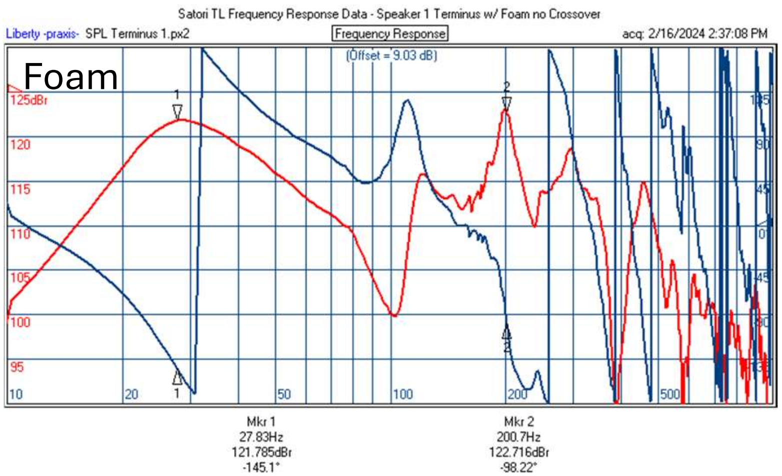
Empty, Fiber Stuffing, and Foam

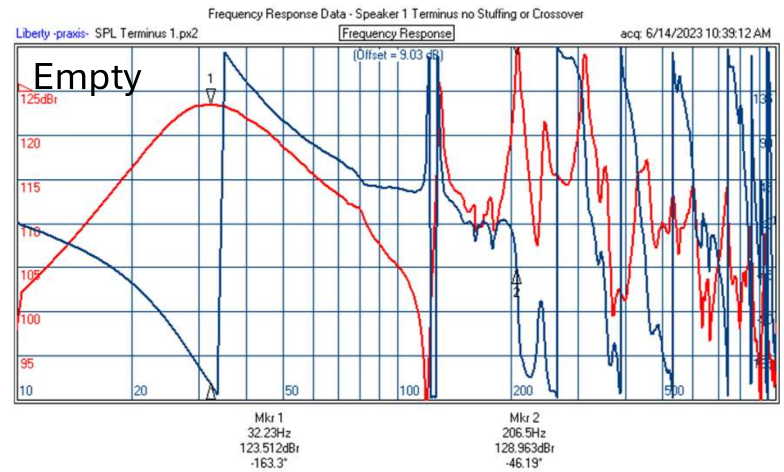


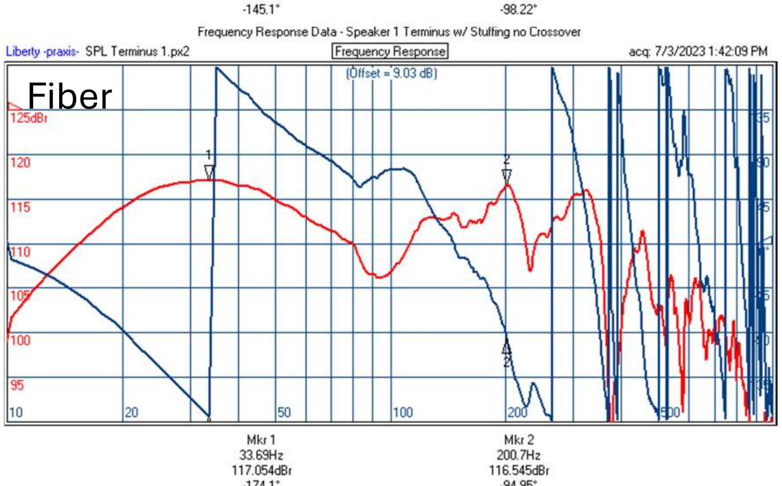
Examples of the Satori TL enclosure just before final assembly. Fiber or Foam were applied to the same portion of the TL's length, approximately the first 3/4 of the tapered enclosure.

The installation and amount of each damping material is typical of TL designs seen on the Internet, commercial or DIY. This is not an apples-to-apples comparison of the same amount of each material but a comparison of typical applications.

Near Field Terminus SPL







The terminus output determines the speaker's bass performance. Comparing the foam and fiber plots shows that a 0.5 lb/ft^3 density of fiber significantly reduced the peaks and dips compared to an acoustic foam lining. To replicate the peaks and dips of the acoustic foam required the stuffing density in the fiber model to be reduced by a factor of 10 to 0.05 lb/ft^3. A fiber density of 0.05 lb/ft^3 is extremely sparse.

Why the Large Difference in Performance?

Acoustic foam is typically used to attenuate unwanted noise. In recording studios, it's applied to the walls and ceiling to cut down on reflections (reverberation) and provide a non-resonant neutral performance space. It is also used around mechanical equipment to control operational noise transmitted into the surrounding environment, for example lining an enclosure placed over a noisy mechanical printer in an office setting. These applications and environments are very different compared to the standing waves generated along the folded path of a transmission line enclosure.

To demonstrate these different applications, the following two scoping examples are presented.

Example 1 : Sound Booth for Recording

Given a room lined with acoustic foam containing a musician playing their instrument. An instrument is naturally loud, assume the SPL reaching the walls is on the order of 90 dB. This SPL can be converted into an oscillating pressure and oscillating air displacement using the following calculations.

First Calculation for Pressure

$SPL := 90$ dB

$2 \cdot 10^{-5} \cdot Pa \cdot 10^{\frac{SPL}{20}} = 0.632\,Pa$ pressure

Second Calculation for Displacement

for a plane wave

$z = p / u = p / (j\,\omega\,x) = \rho \times c$

$x = p / [\rho \times c \times (j\,\omega)]$ displacement

Free Air

for 90 dB at 100 Hz

$$\frac{0.632 \cdot \mathrm{Pa}}{\rho \cdot c \cdot j \cdot 100 \cdot \mathrm{Hz}} = -2.417i \times 10^{-3}\,\mathrm{mm}$$

for 90 dB at 500 Hz

$$\frac{0.632 \cdot \mathrm{Pa}}{\rho \cdot c \cdot j \cdot 500 \cdot \mathrm{Hz}} = -4.833i \times 10^{-4}\,\mathrm{mm}$$

for 90 dB at 1000 Hz

$$\frac{0.632 \cdot \mathrm{Pa}}{\rho \cdot c \cdot j \cdot 1000 \cdot \mathrm{Hz}} = -2.417i \times 10^{-4}\,\mathrm{mm}$$

Oscillating displacements are calculated for a SPL of 90 dB at three different frequencies. The sound waves arriving at the foam are traveling normal to the wall. into the surface of the acoustic foam. The exposed surface area of the foam is larger than the projected area because of the egg crate or pyramid shaped profile.

Looking closely at the surface of acoustic foam, openings much larger than these displacements can be seen with the naked eye. It is not hard to envision these small sound waves penetrating the foam and any reflections back into the room being significantly attenuated. Attenuation increases with frequency as the oscillating displacement decreases while at the same time the oscillating velocity increases. The damping provided by the porous foam is viscous, it acts on the oscillating air velocity hitting and penetrating the foam and not on the oscillating pressure at the foam’s surface.

For me, this simple approximate explanation of the physics makes a lot of sense.

Example 2 : Standing Waves in a TL

Given a TL speaker producing 90 dB at a 1 m listening distance. At the TL tuning frequency, and all the higher harmonics, a standing wave is generated along the length of the TL. The waves are oscillating axially in the length direction and the oscillations of pressure and velocity have sinusoidal profiles. For selected frequencies, the oscillating axial air displacements are calculated in Part 2 Attachment 2 of the Satori TL presentation. To get a feel for the oscillating pressure, velocity, and displacement profiles along the TL length review each page of plots in Part 2 Attachment 2.

The foam is applied as a lining along the TL's walls so the air in the center of the cross-sectional area is empty, free space. Air motion is parallel to the foam surface, across the egg crate or pyramid shaped profile.

Satori TL Results from Part 2 Attachment 2 (Empty)

Tuning Frequency at 32 Hz

220 Pa ----> j x 7.43 mm

3/4 Mode at 131 Hz

67 Pa ----> j x 0.30 mm

5/4 Mode at 222 Hz

307 Pa ----> j x 0.69 mm

7/4 Mode at 315 Hz

208 Pa ----> j x 0.31 mm

11/4 Mode at 494 Hz

76 Pa ----> j x 0.07 mm

The peak oscillating displacements are calculated for peak pressures at five different frequencies. The pressures represent local maximums and vary as a sinusoid along the length of the TL, they are uniform across any cross-section. At the foam boundary, the sound waves are traveling parallel to the surface of the foam so the only interaction between the sound wave and the foam is along the outer perimeter of the TL's central open-air volume.

At the surface of the foam, the oscillating displacements are initially much larger than the porous openings. The displacements are a factor of 1000 more than the previous example. As frequencies increase the magnitude of the displacements decrease approaching and eventually falling below the size of the porous openings. For the most part, the oscillating displacements are large and essentially parallel to the foam's textured surface, it is hard to envision these sound waves penetrating the foam matrix. There is some damping attenuation with increasing frequency as the oscillating displacements decrease but it still seems somewhat inefficient considering the much larger open-air volume along the center of the TL path

For me, this simple explanation of the physical differences also makes a lot of sense.

Final Thoughts on Foam and Fiber Damping

Acoustic foam lining is a light porous material, the pores forming the matrix are very small. Damping of acoustic sound waves is achieved by oscillating velocity passing into and interacting with the material matrix before being reflected back into the environment. If you place your mouth on the flat back side of egg crate acoustic foam and blow the back pressure is huge, very little if any air easily passes through the acoustic foam exiting the other side. This is why I think “larger” oscillating displacements are mostly unaffected and not controlled well by acoustic foam. I am left wondering if the literature models for acoustic foam are based on very small signal interactions that are not applicable at the levels seen inside a TL enclosure. The parallel open-air volume, at each cross-sectional area, would also tend to short the foam lining at lower frequencies, a much lower impedance parallel path for oscillating air to travel.

On the flip side, fiber damping fills the entire air volume with a much larger spacing between the fibers making up the tangled matrix. Larger oscillating air displacements can easily move through the tangle and interacting to provide viscous damping for the oscillating air velocity. Fiber stuffing is extremely efficient at controlling the standing waves generated in a TL and is infinitely adjustable with respect to placement and local density.

Acoustic foam has its place in the TL toolbox, it is easy and quick to consistently apply for a pair of TL enclosures. I am still using it in my Satori TL design with very satisfactory results. In the future, I will probably return to fiber stuffing but at a much-reduced density compared to the original 0.5 lb/ft^3 fiber density.

Did I use the wrong acoustic foam? I doubt it. The porosity of a foam would need to be very large for it to compete with fiber stuffing. Foam does not appear to be a magic solution for TL design, and I doubt there are significant differences in the performance of different acoustic foam types or materials.