Further Acoustic Muffler Sound Transmission Measurements

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Reference for previous work: http://www.patarnott.com/pdf/MufflerPaperArnottAWMA.pdf.
A new prototype acoustic muffler was prepared by Art and Scott, as shown in Figs. 1 and 2.

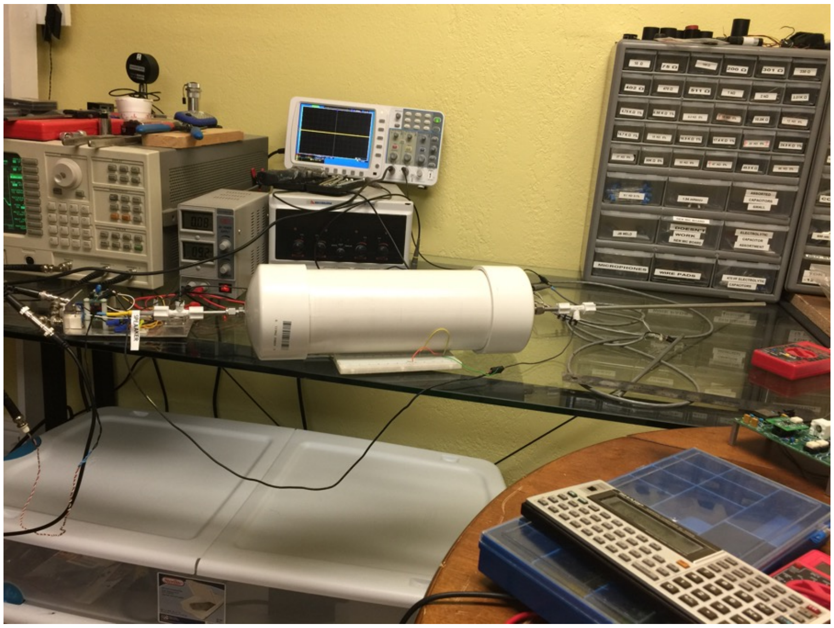

Figure 1. System used for measuring sound transmission through the muffler.

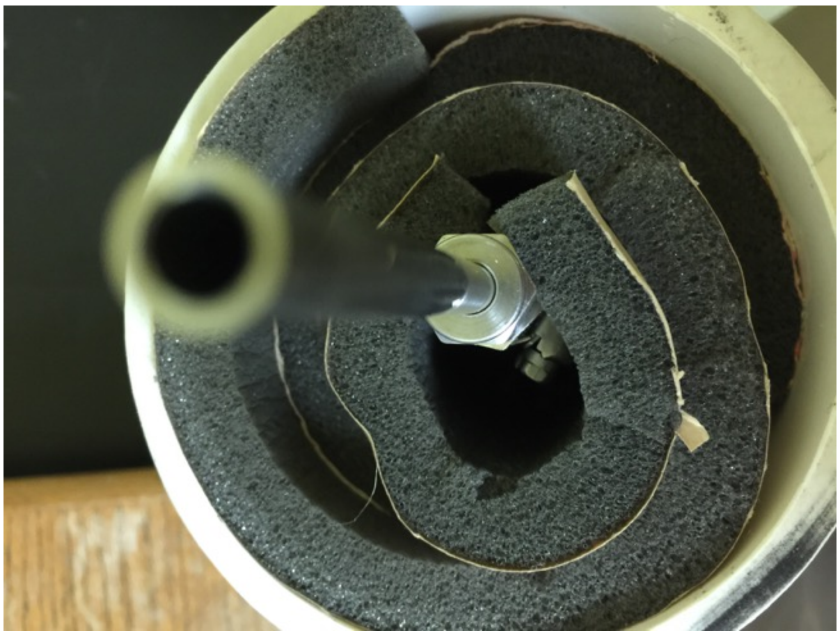

Figure 2. Foam used in the muffler for some measurements.

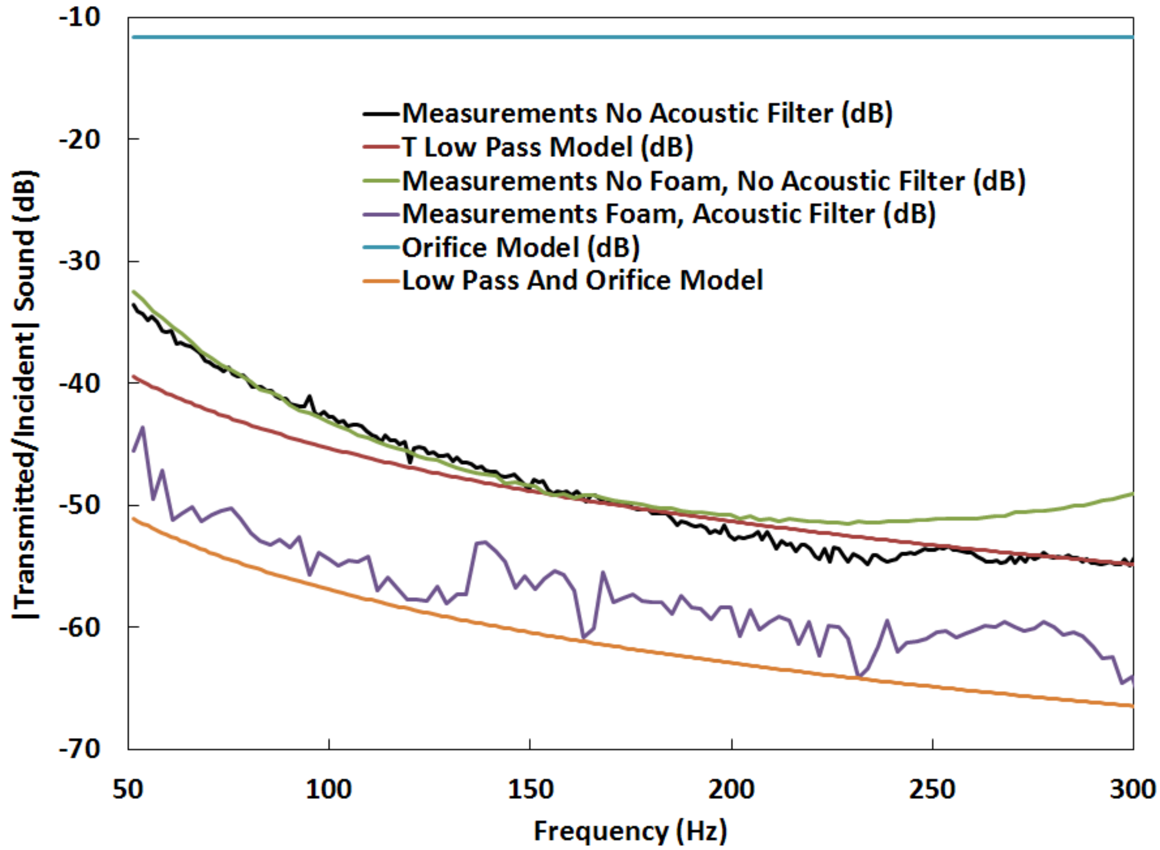

Figure 3. Summary of sound transmission measurements.

Figure 1 shows the muffler (white PVC tube), dynamic signal analyzer (left, with green screen), speaker, and two mics (in the center of the small white tees). Figure 2 shows the most effective foam packing for the measurements reported here.

Figure 3 summarizes the results for the frequency range to 300 Hz. The black curve is transmission through the muffler with no acoustic resistor, showing about a 45 dB reduction of sound at 150 Hz. The purple curve shows a 55 dB reduction of sound when both the acoustic resistor and muffler are used. Interestingly, the green curve shows the transmission when no foam is used in the muffler, showing that the muffler acts as a low pass filter, and that the screen used as sample line through the muffler causes attenuation. The acoustic foam has an effect on sound reduction above about 185 Hz, but not much of an effect at lower frequency.

The red curve in Fig. 3. shows the model for a low pass filter for the transmission, excluding attenuation by the screen. The model is discussed at https://en.wikibooks.org/wiki/Acoustics/Filter_Design_and_Implementation, and makes use of the geometry show in Fig. 4, taken from this reference.

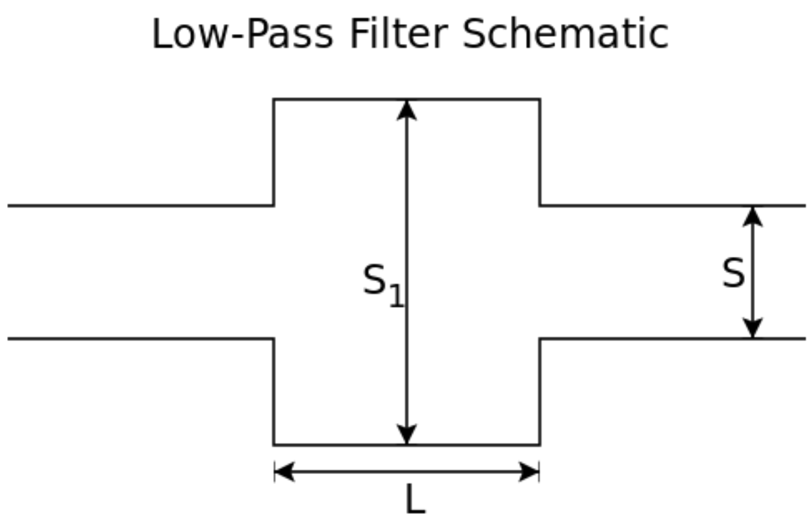

Figure 4. Model for the muffler as a low pass acoustic filter. L is the muffler length and S is cross sectional area.

The equation for acoustic power transmission through the muffler in Fig. 4 is

$$T_\pi \approx \frac{1}{1+\left(\frac{S_1-S}{2S}kL\right)^2}, k = 2\pi c / f \quad , \qquad (1)$$

where *k* is the wavenumber given in terms of the speed of sound *c* and frequency *f*. Figure 4 and Eq. (1) are from https://en.wikibooks.org/wiki/Acoustics/Filter_Design_and_Implementation.

The orifice transmission model makes use of the same geometry of Figure 4, though S>S1, so the center section of length L is of smaller diameter than the tubes on either side. The orifice model assumes acoustic reflection at the right boundary between S1 and S, and the continuity of volume velocity for a lossless system to give

$$T_\pi \approx \left[\frac{2}{\sqrt{\frac{S}{S_1}}+1}\right]^2 . \qquad (2)$$

This model is untested, subject to verification. The more general modeling approach described in http://www.patarnott.com/pdf/MufflerPaperArnottAWMA.pdf provides a reasonable fit to measurements, but is a much more complex numerical solution.

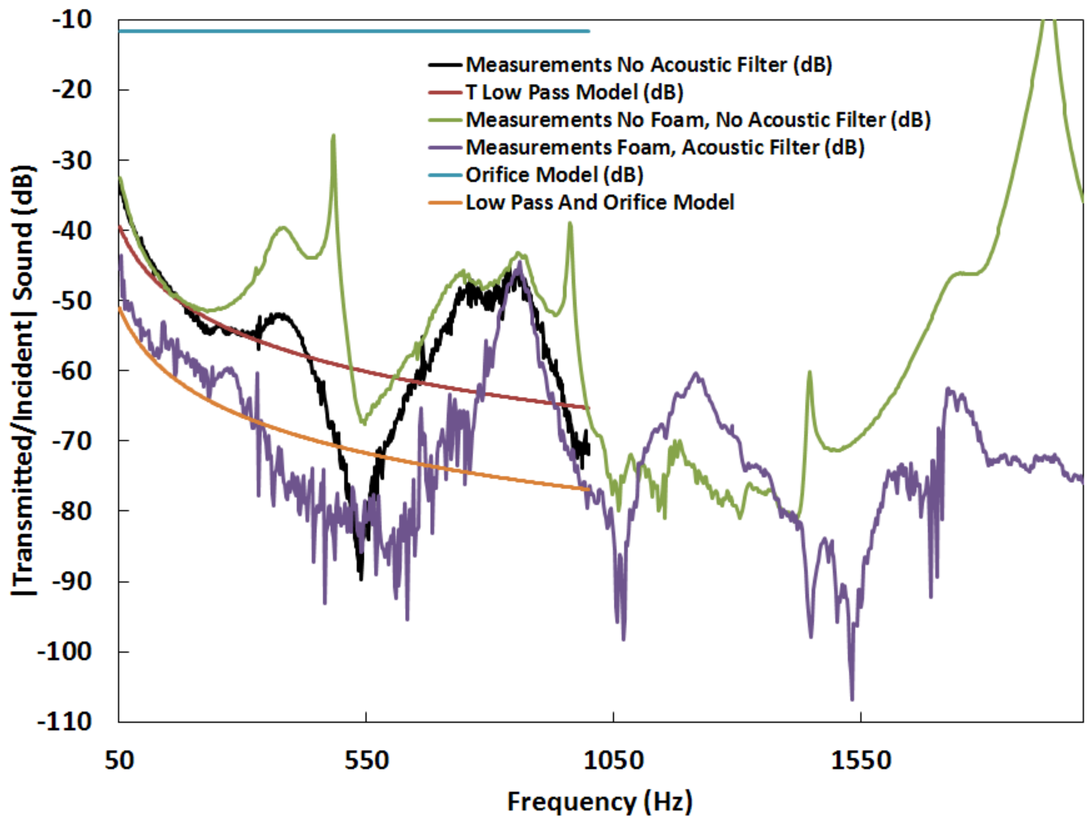

Figure 5. Measurements and model over a wider frequency range.

Figure 5 shows the measurements and models over a wider frequency range. Note that the measurements with the acoustic foam and acoustic reflector (purple curve) show very low sound transmission at 550 Hz, though the measurements with no acoustic filter (black curve) shows a narrow stop band at this frequency. This stop band is likely due to an acoustic pressure node at the position of mic 2 (right most mic) in Fig. 1 due to the length of tubing used (about 30 cm) with a pressure minimum at the right due to the open tube boundary condition. Other stop bands and resonance in the purple and black curves are likely due to this tube as well. In previous measurements reported in http://www.patarnott.com/pdf/MufflerPaperArnottAWMA.pdf, a 25' coil of copper tubing was used as a termination to minimize the effect of sound coming back into the system. Note that the muffler with no foam in it (green curve in Fig. 5) has strong resonances and stop bands due to lack of attenuation of sound by the foam. An empty muffler would be suitable for only low frequency sound attenuation.

Figure 6 shows acoustic transmission through a Helmholtz resonator stop band style filter, with acoustic resistor, compared with that of the acoustic muffler and resistor combination shown also in Fig. 5. The acoustic muffler/resistor combination is much better at lowering transmitted sound than the Helmholtz resonator.

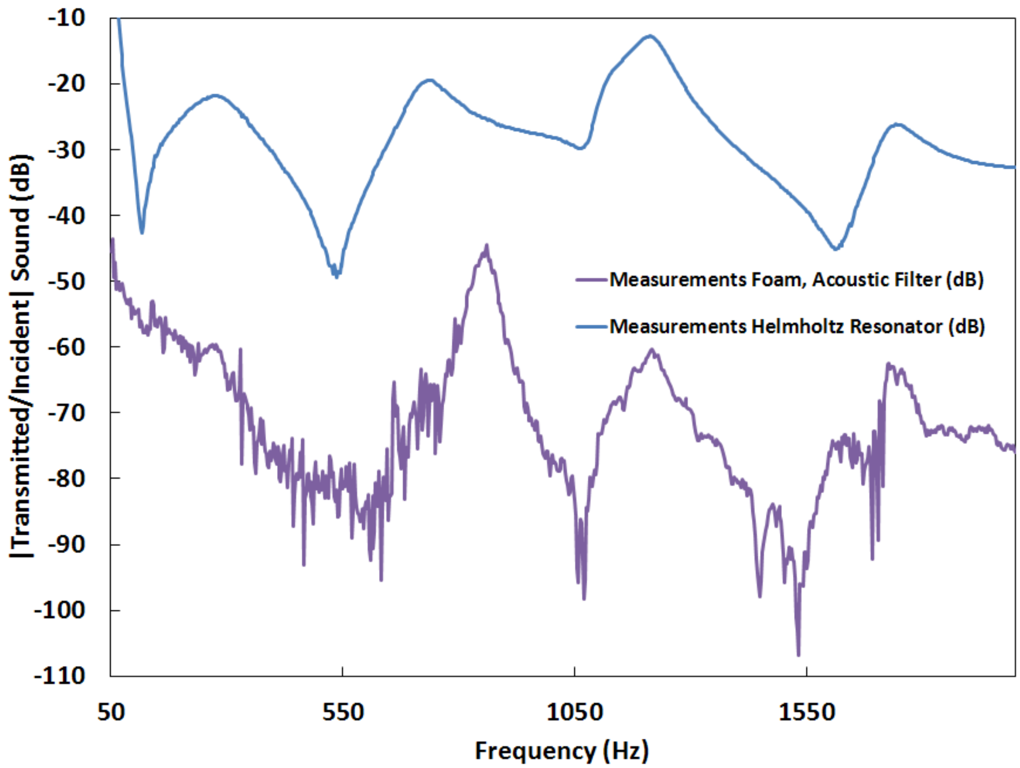

Figure 6. Comparison of the transmission of a Helmholtz resonator stop band filter followed by the acoustic resistor and the acoustic muffler with the acoustic resistor.

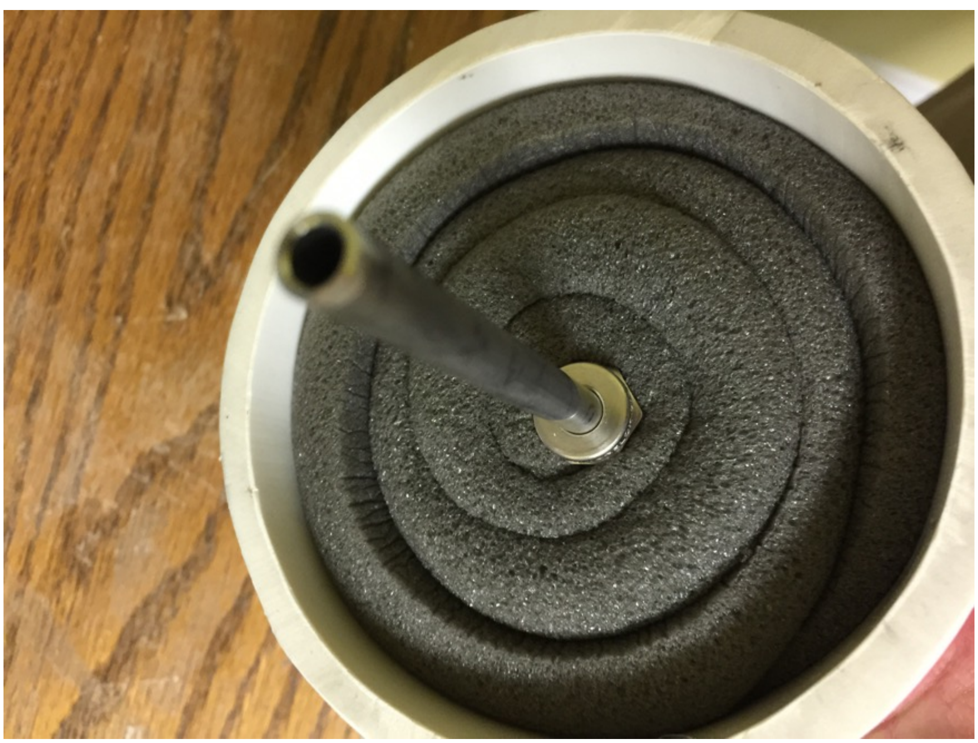

Figure 7. Photo of tightly stuffed foam. 'Thick' foam was wrapped around the screen for this test.

Figure 8. Photo of a thick foam layer at the PVC wall. The screen was left out for this photo.

Figure 9 shows transmission spectra for the muffler foam fillings shown in Figs. 7 and 8. The black curve (Fig. 7 filling) shows that the compacted foam begins to act more like a rigid termination rather than a sound dissipater as much less sound attenuation is noted.

The single thick foam layer foam filling of Fig. 8 gives the red curve spectrum in Fig. 9, showing the most attenuation of all tested for the mid frequency range between 600 Hz and 1550 Hz. However, there is a an undesireable ‘shoulder’ in the transmission spectrum at around 200 Hz.

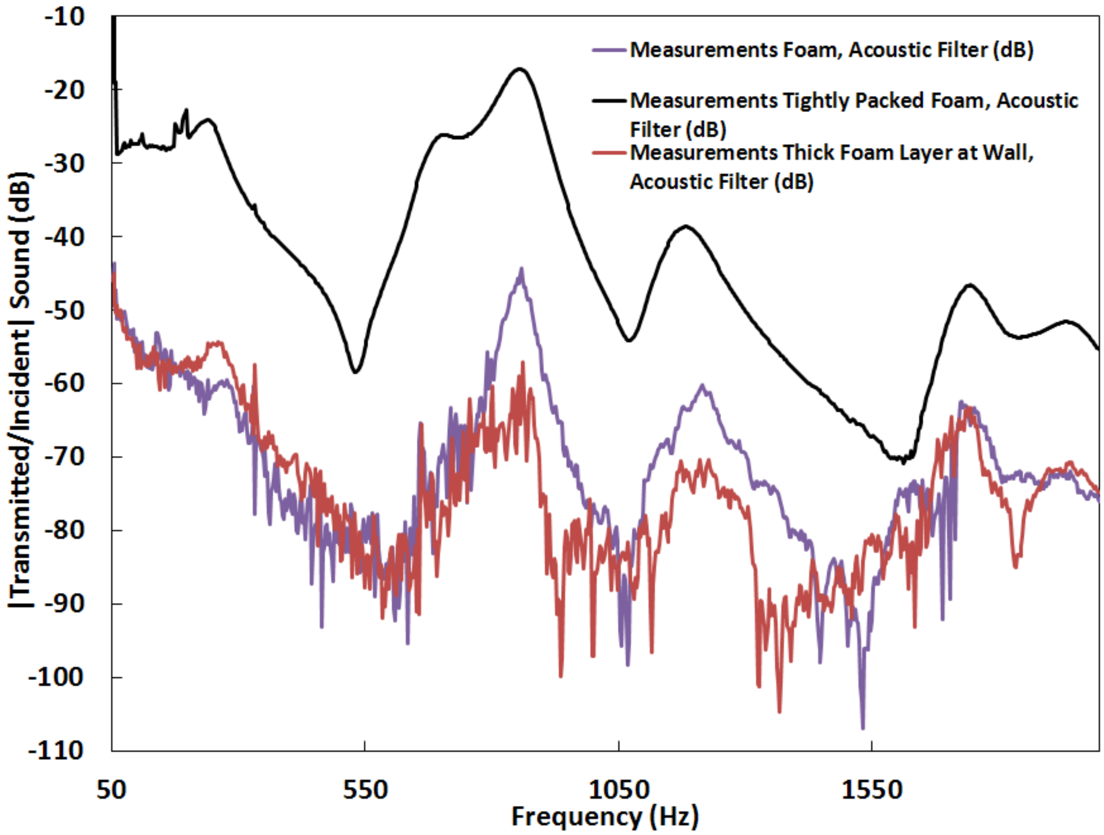

Figure 9. Transmission spectra for the acoustic muffler packings shown in Fig. 2 (purple curve); Fig. 7 (black curve); and Fig. 8 (red curve).