Acoustic Filters for Noise Reduction

Jared Chang

Introduction

- You hate it when your neighbor wakes you with his leaf blower on Saturday.
- Blower noise is particularly irritating due to its broad harmonic spectral content.
- I want to design acoustic filters that would reduce sound levels at specific strategic frequency regions within this broad spectrum.

My Project

- Design filters that would reduce noise at a specified frequencies.
- Measure the power transmission spectrum of each filter.
- Propose possible utilization of these filters toward reducing objectionable sound produced by leaf blowers.

Experiment

- Construct a white noise source in a cardboard box using a waveform generator, audio amplifier and desktop speaker.

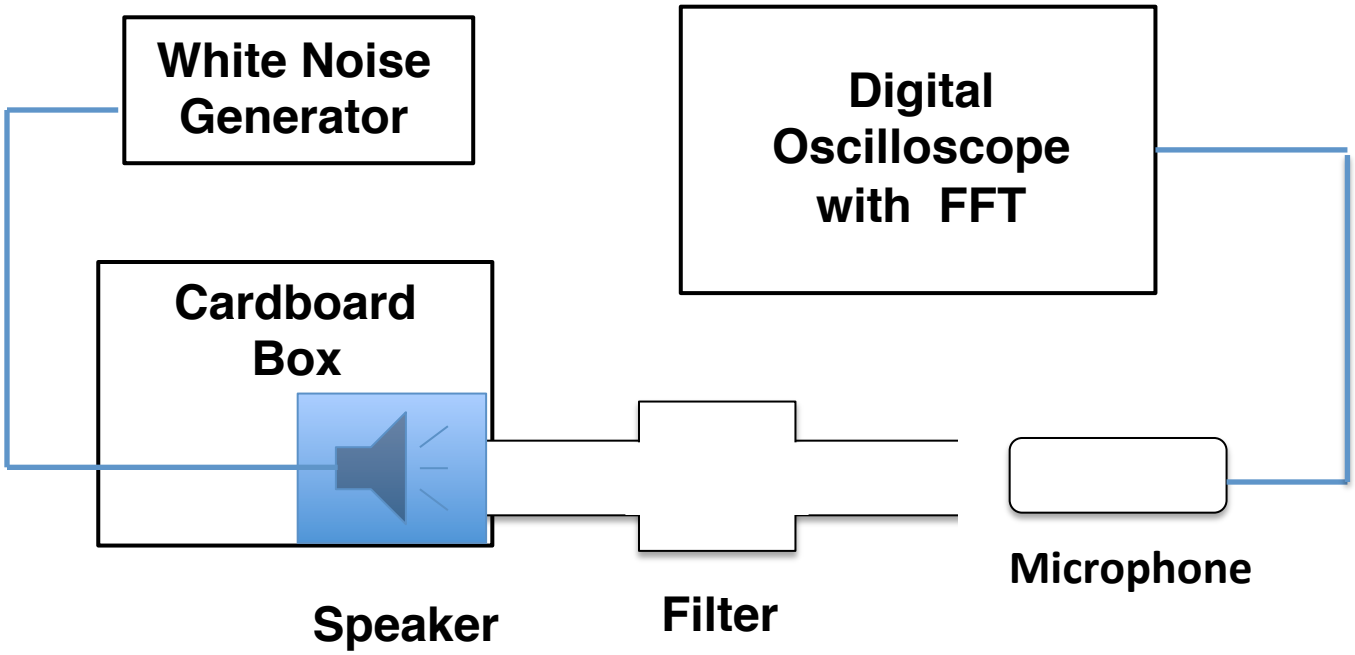
- Use PVC pipe to construct an acoustic transmission line at varying lengths.

- Insert either a Helmholtz resonator or a single cavity low-pass filter into the middle of the line.

Experiment Cont.

- Couple the noise source to one end of the line and position a directional microphone at the other end.
- Use the FFT function on the oscilloscope to derive the sound power spectrum.
- Transfer the data to Excel and graph the spectra.
- Compare the results of each case.

Apparatus Diagram



Low Frequencies Preferentially Penetrate Though Walls

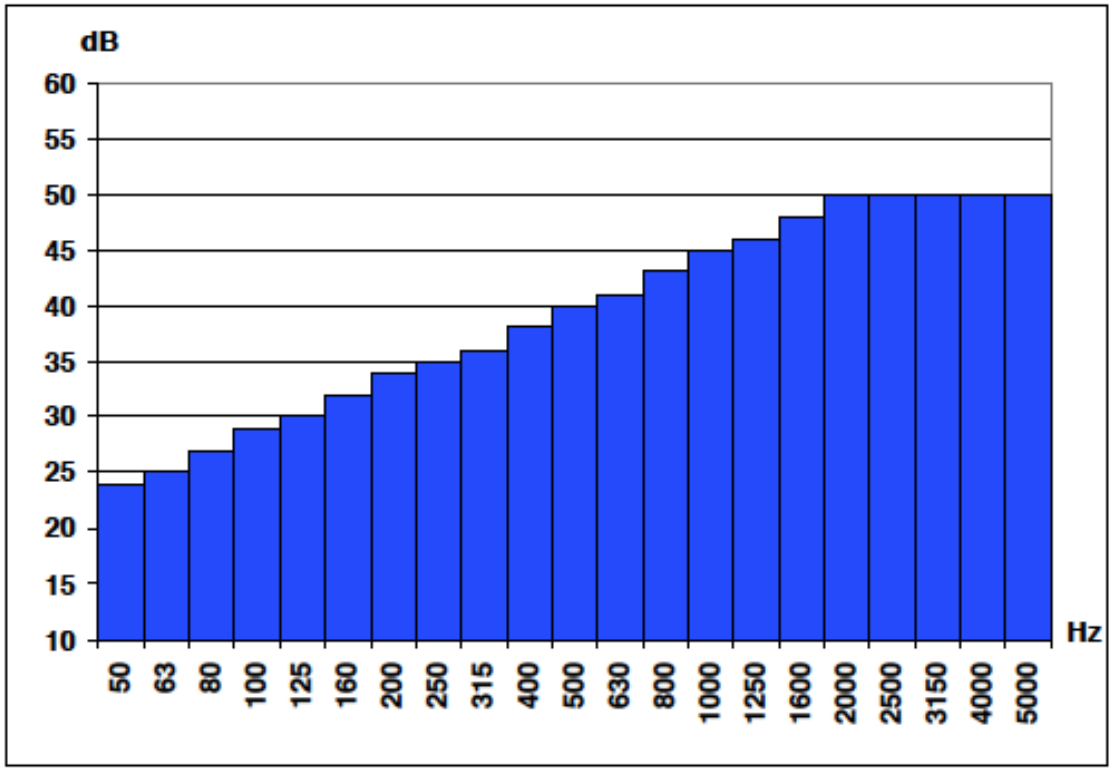


Figure 3. Estimated outer wall transmission loss in 1/3 octave bands.

Joint Baltic-Nordic Acoustics Meeting 2004, 8-10 June 2004, Mariehamn, Åland

Penetrating Noise Centers at ca. 600 Hz

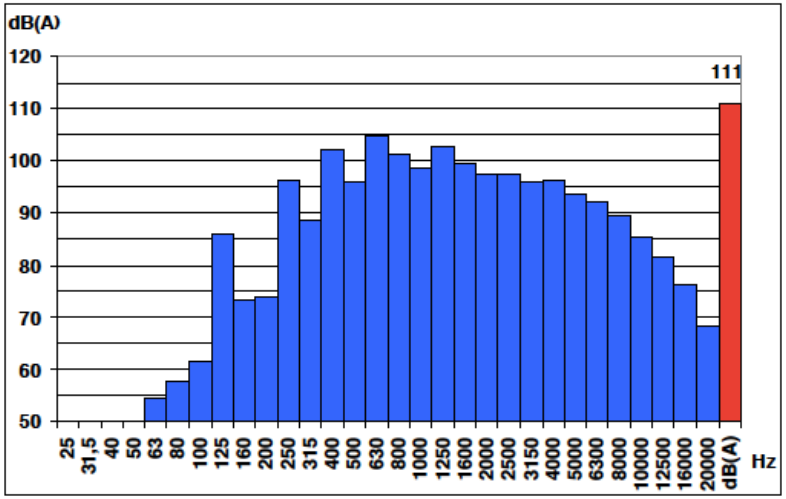


Figure 6. Husqvarna 155 B leaf blower

Incident Noise

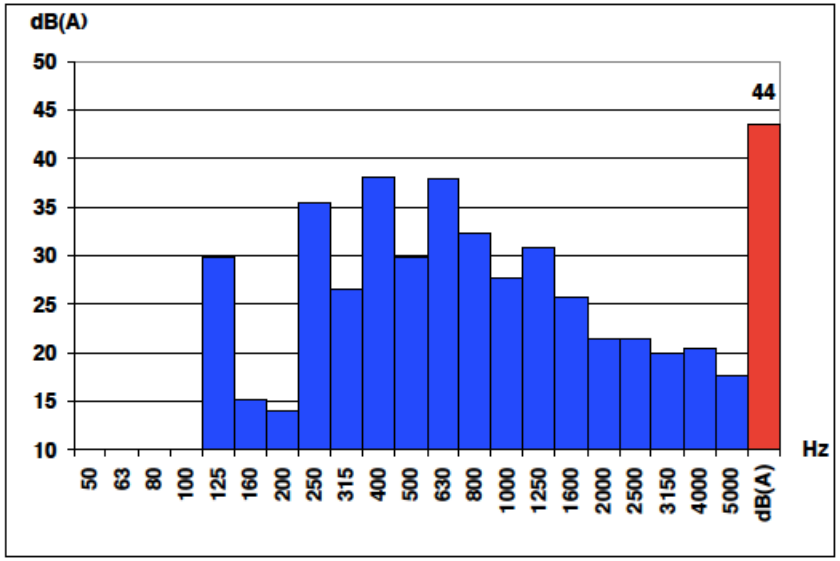
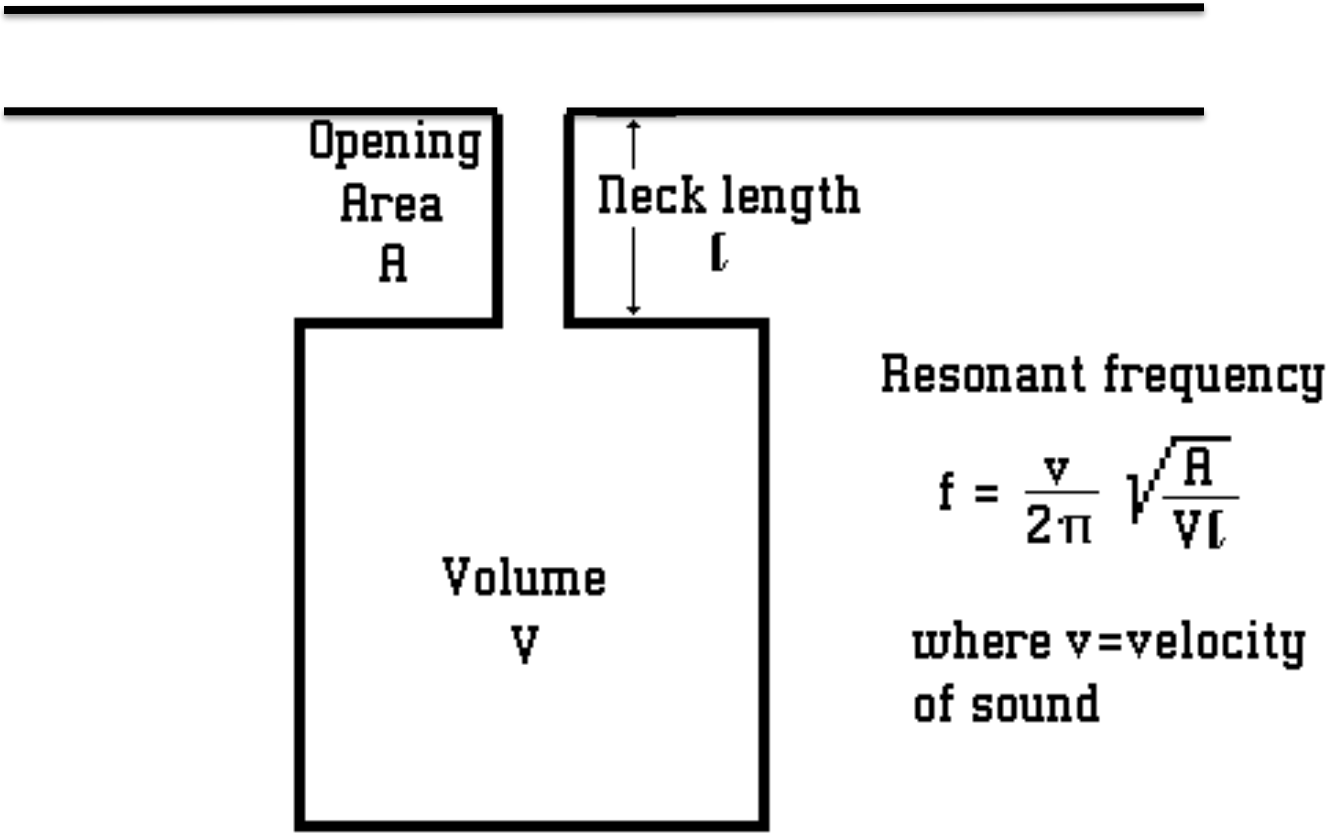


Figure 14. Husqvarna 155 B leaf blower

Heard Indoors

Joint Baltic-Nordic Acoustics Meeting 2004, 8-10 June 2004, Mariehamn, Åland

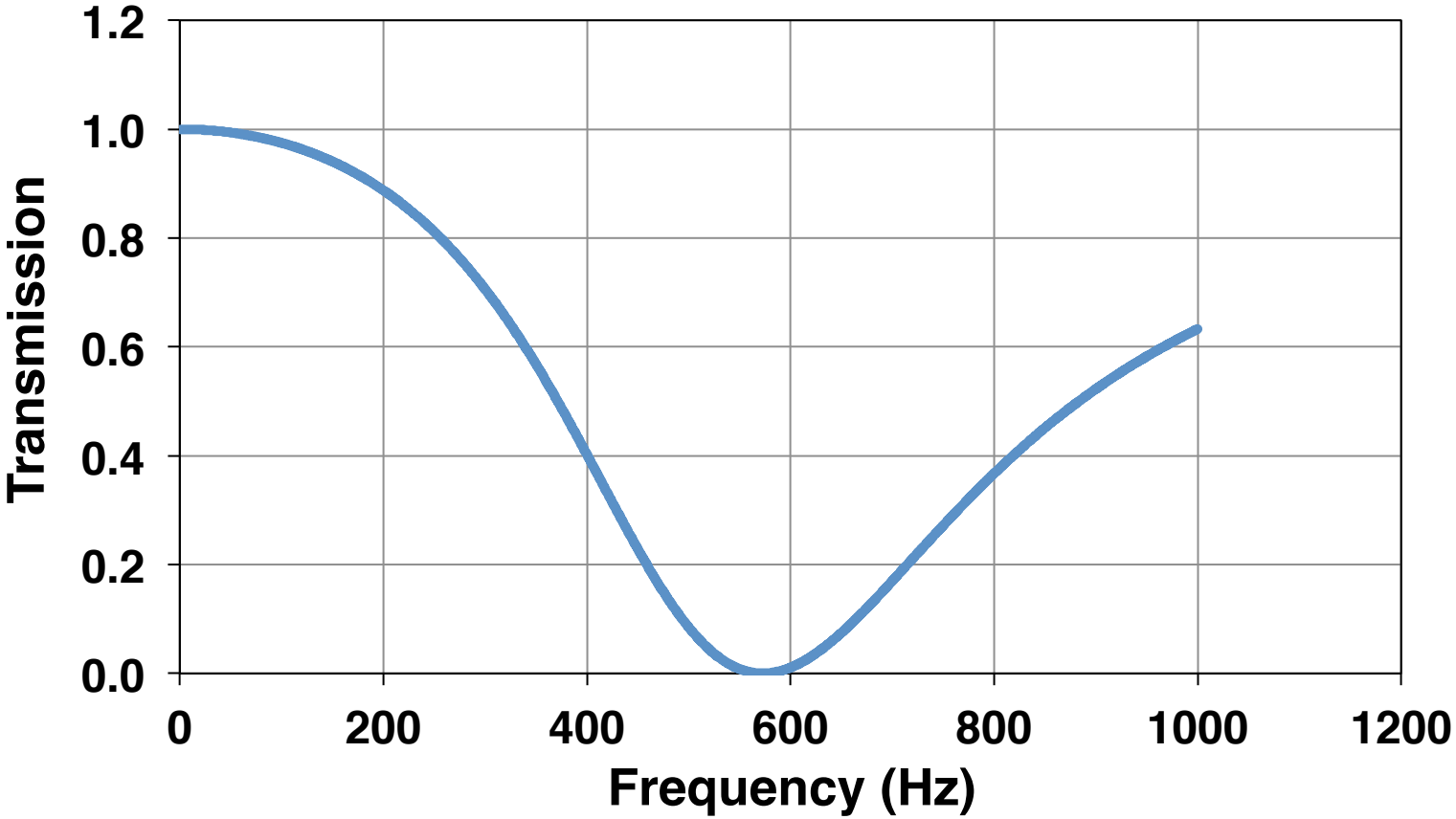
Helmholtz "Resonator" Parameters



Helmholtz Resonators Equations

- $F = W_o/(2Pi)$
- $W_o = c[A/L_{eff}*V)]^{0.5}$
- $T_n = [1+([c^2]/(4S^2)*[(w*L_{eff}/A)-(c^2/[w*V])]^{-1}$
- T_n = Power Transmission
- S = Cross section of the duct
- F = Frequency (Hz)
- W_o = Angular Frequency (rads/s)
- C = Speed of sound at sea level 343 [m/s]
- A = Cross section of resonator (m^2)
- L_{eff} = Effective neck length (m)
- V = Volume (L)

Helmholtz Modeled Spectrum



Simple Low – Pass Filter

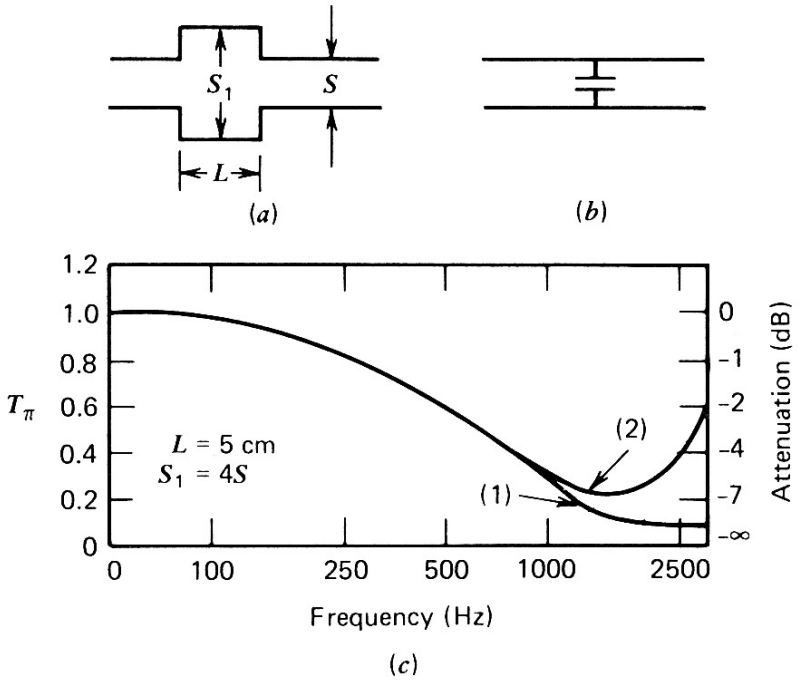


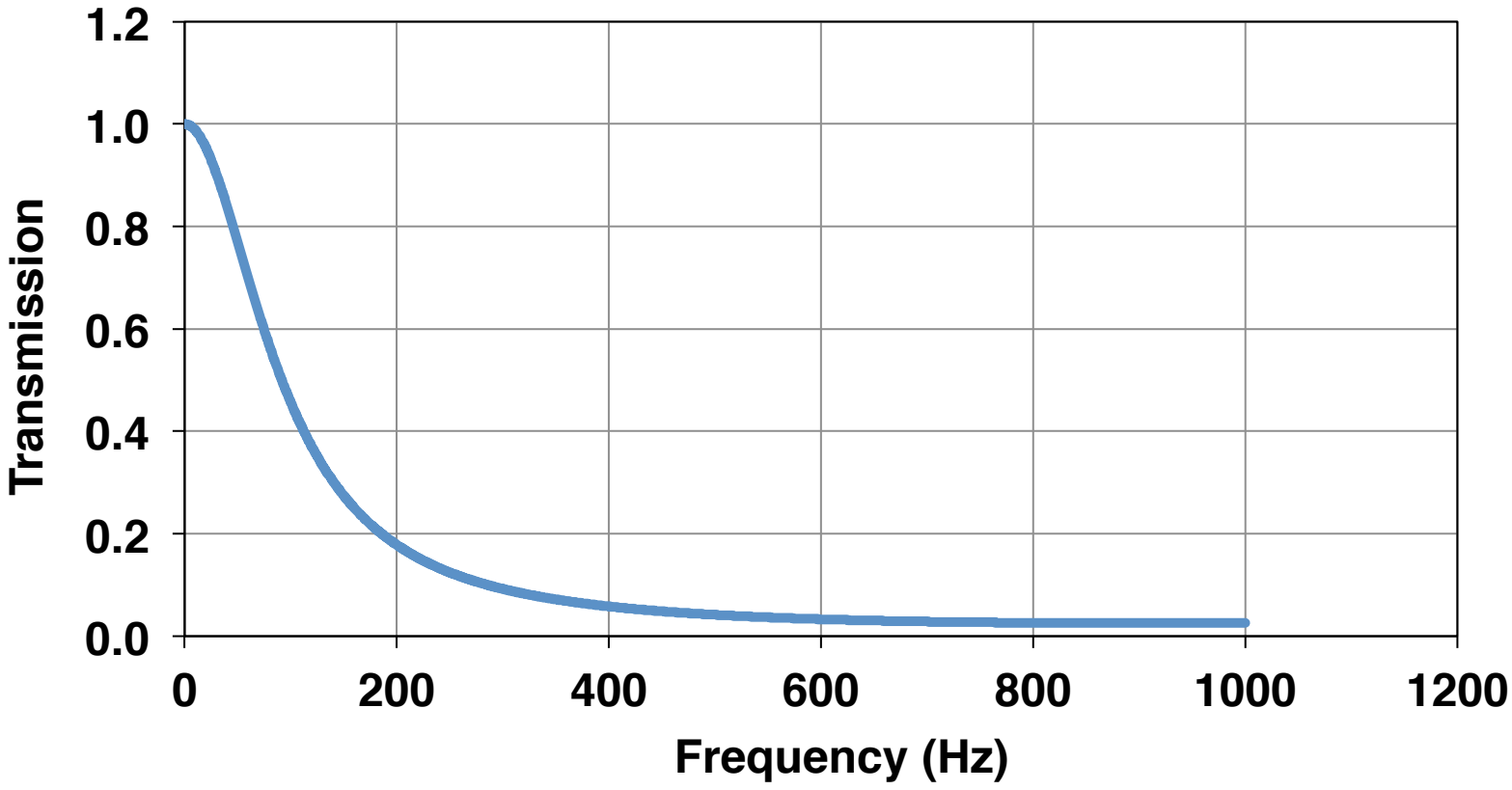
Fig. 10.6. *(a) Simple low-pass acoustic filter. (b) Analogous electrical filter. (c) Power transmission curves for filter (a).*

L. E. Kinsler et. Al. “Fundamentals of Acoustics”, John Wiley, 1982 p238.

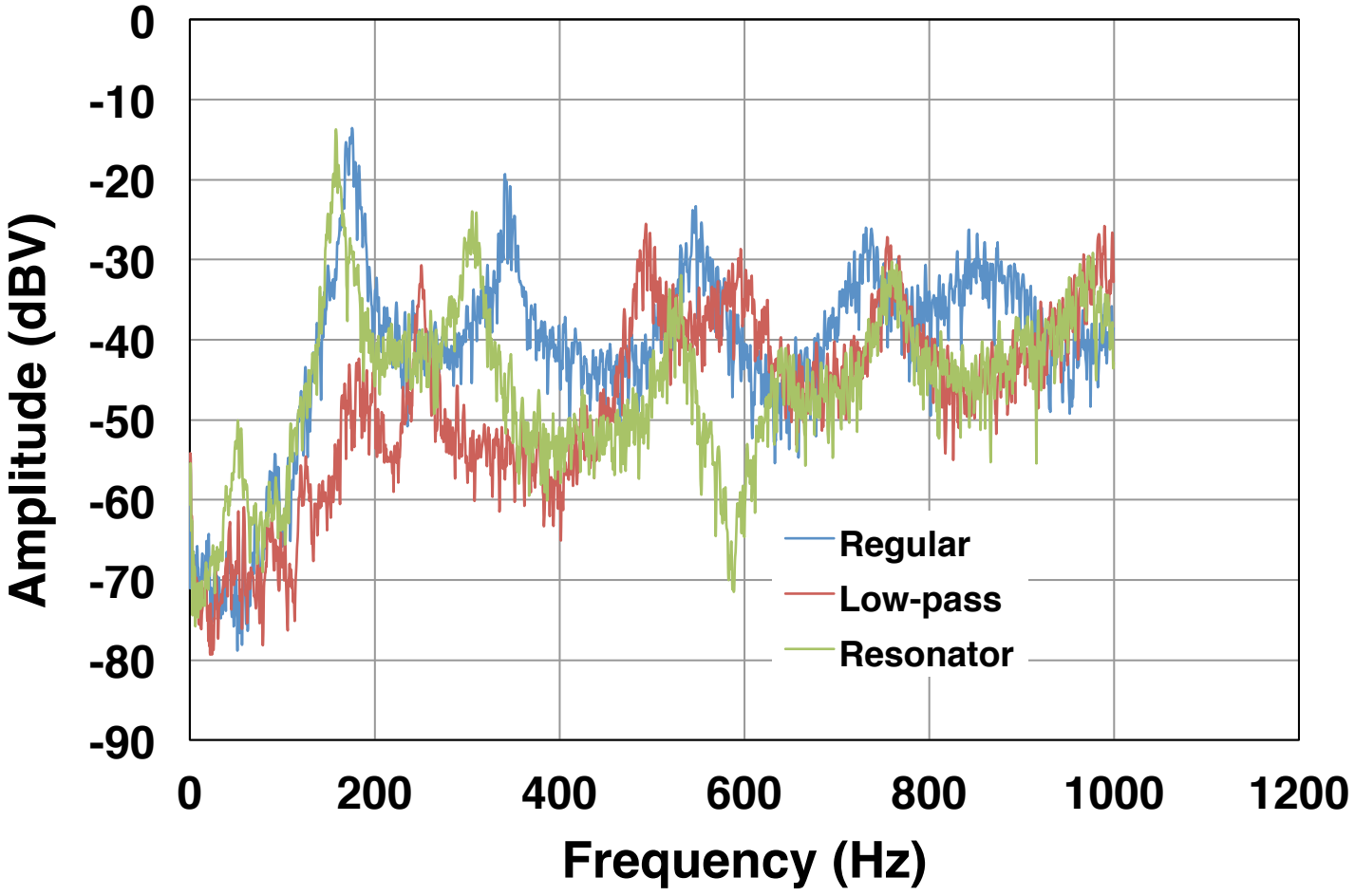
Low-Pass Power Transmission Equation

- $T_n = 4/[4(\cos[k*L])^2+[S_1/S+S/S_1]^2*(\sin[kL])^2]$
- T_n = Power Transmission
- K = Wavenumber
- L = Length of expanded chamber
- S_1 = Cross section of enlarged chamber
- S = Cross section of the duct

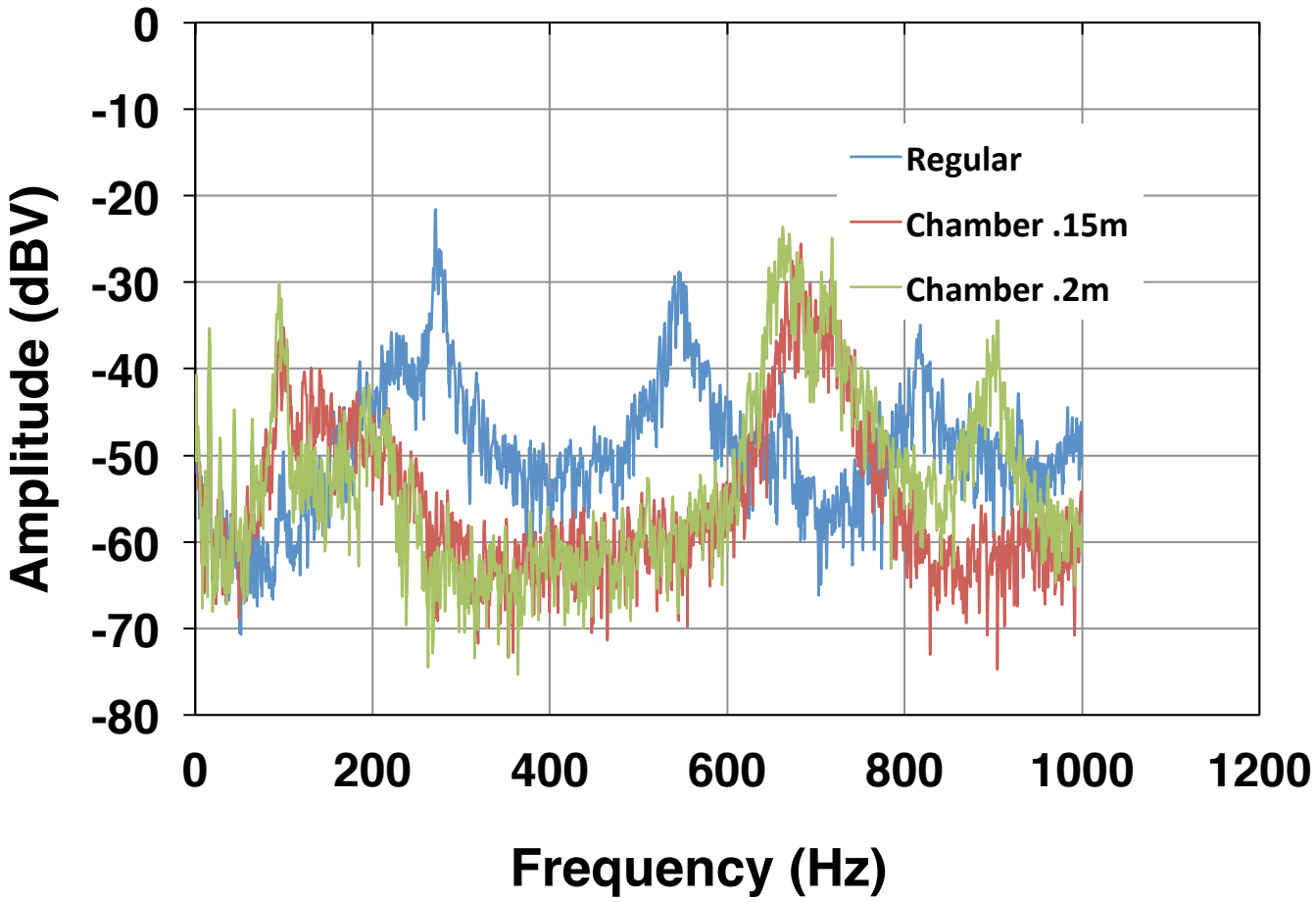
Low - Pass Modeled Spectrum



Resonator vs. Low-Pass Filters



Comparison of Two Different Low Pass Filters



Conclusions

- Both filters reduced noise > 20 dB in the targeted frequency range.
- The Low-Pass filter had a wider bandwidth overlap with the target noise spectrum.
- Filters would only effect sound that is transmitted through the duct and not emitted from the motor or fan blades.

Future Directions

- Scale up the low pass filter to the physical dimension necessary for use on leaf blower pipe and deploy on a real leaf blower.
- Appraise the ergonomic impact.
- Explore the possibility of designing a low-pass filter incorporated into an intake manifold designed for the blower fan.

Acknowledgements

- Summit Education Foundation for generous support.