# 4. Air Resonance

PURPOSE AND BACKGROUND

The concept of *resonance* in a pipe is similar to that of a string. The waves in pipes consist of compressions and rarefactions of the air, with back-and-forth motion of the air molecules in the direction of propagation or against it. The waves in air thus are *longitudinal* waves. In this laboratory we study standing waves in a pipe. They are the result of two waves traveling in opposite directions inside the pipe, with each wave being reflected at the ends of the pipe. In this way the superposition of two waves yields a standing wave, provided that in addition the *resonance conditions* are met.

For a pipe with both ends open, resonance at the *lowest* frequency (*fundamental frequency* or *first harmonic*) occurs when there are anti-nodes of the air motion at the ends – and only there, with a single velocity node at the center, see Figure 1. The motion of air molecules is highest at the anti-nodes and lowest at the nodes. For a pipe with one end closed and one end open, resonance

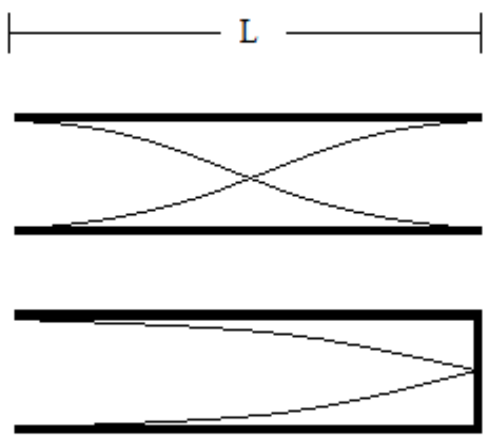


Figure 1: Air molecule displacement in an open and closed pipe.

at the lowest frequency occurs when we have a velocity node at the closed end and an anti-node at the open end. Plotted in Figure 1 is the displacement or velocity of air molecules as a function of position along the pipe. The two curves for each pipe in Figure 1 are one-half period of oscillation apart.

For the pipe with both ends open, we have $L = \lambda/2$ according to Figure 1. For the closed pipe we have $L = \lambda/4$. The fundamental frequency is given by

$$f_1 = \frac{v}{\lambda} = \frac{v}{2L} \quad (\text{both ends open})\,, \qquad f_1 = \frac{v}{\lambda} = \frac{v}{4L} \quad (\text{one end closed})\,, \tag{1}$$

where $v$ is the velocity of sound.

## Questions

THEORY AND EXPERIMENT

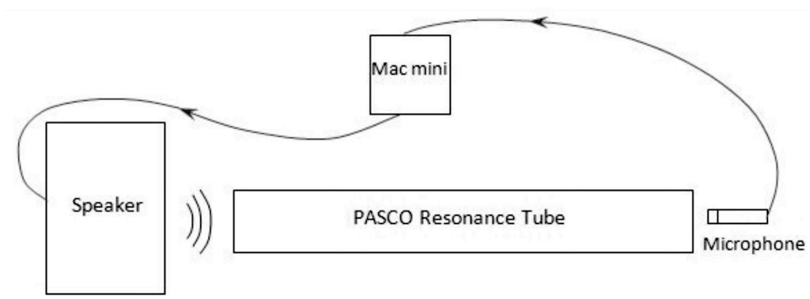


Figure 2:

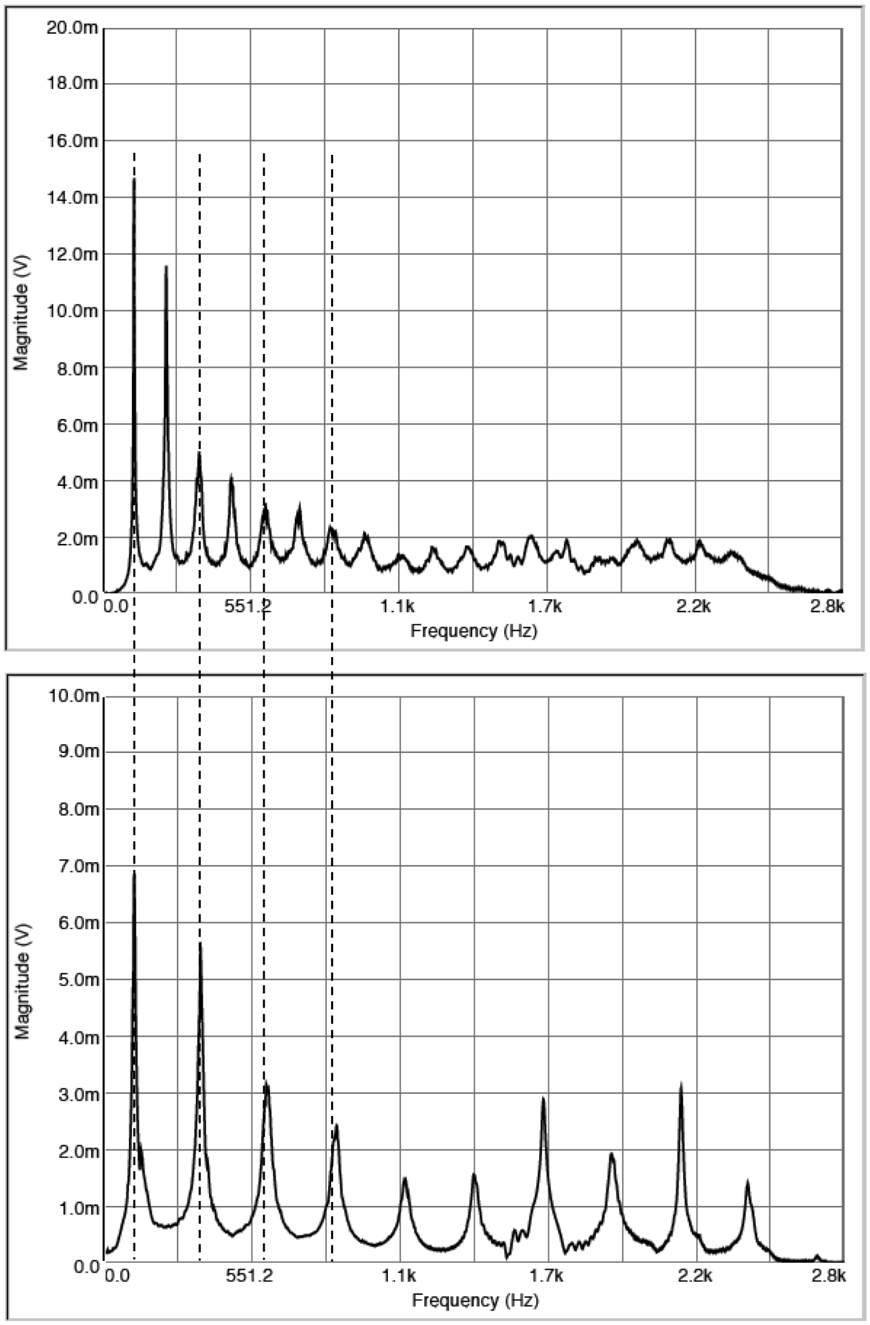
20.0m
18.0m
16.0m
14.0m
12.0m
10.0m
8.0m
6.0m
4.0m
2.0m
0.0
Magnitude (V)
0.0
551.2
1.1k
1.7k
2.2k
2.8k
Frequency (Hz)
10.0m
9.0m
8.0m
7.0m
6.0m
5.0m
4.0m
3.0m
2.0m
1.0m
0.0
Magnitude (V)
0.0
551.2
1.1k
1.7k
2.2k
2.8k
Frequency (Hz)

Figure 3:

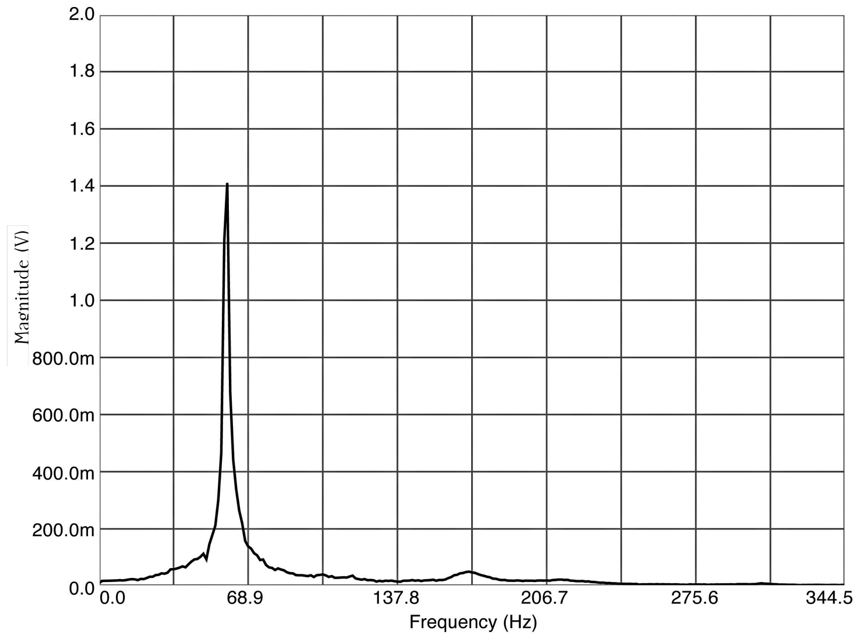


Figure 4:

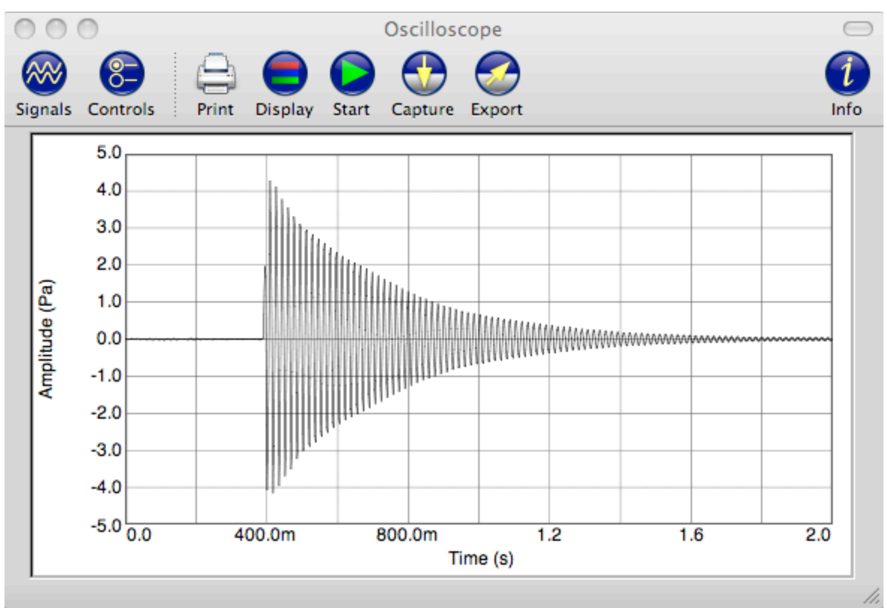


Figure 5:

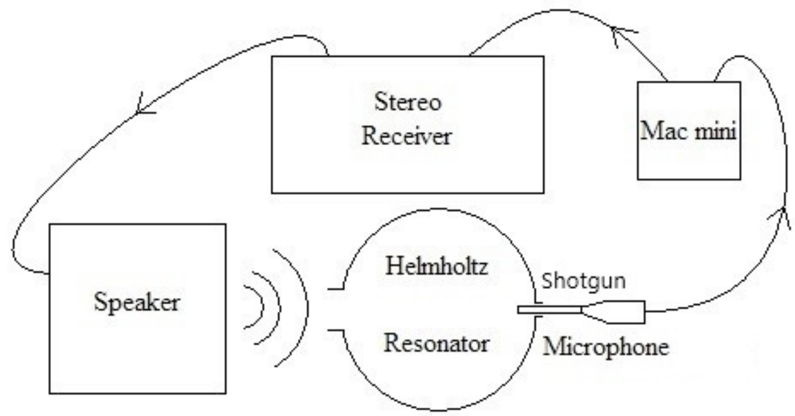


Figure 6:

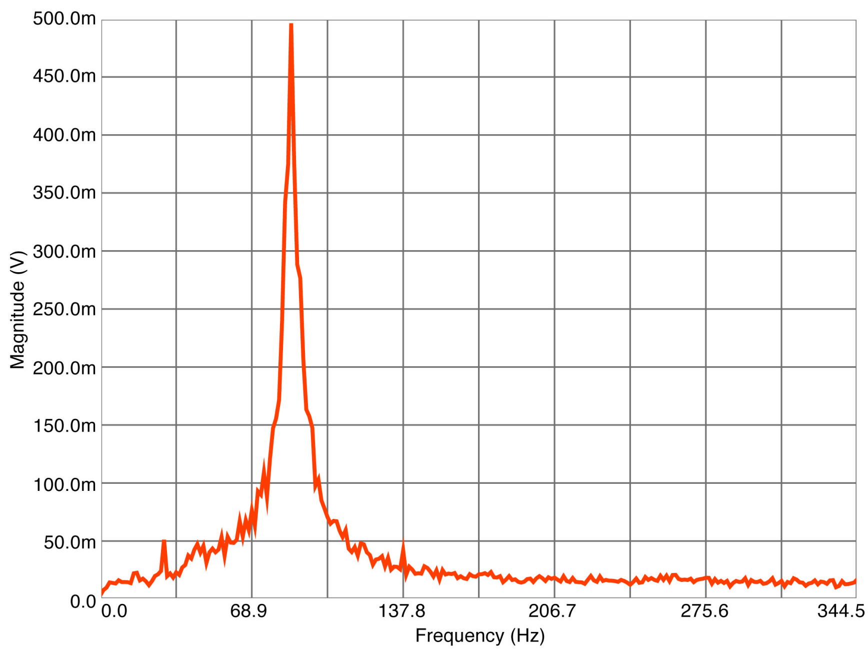


Figure 7:

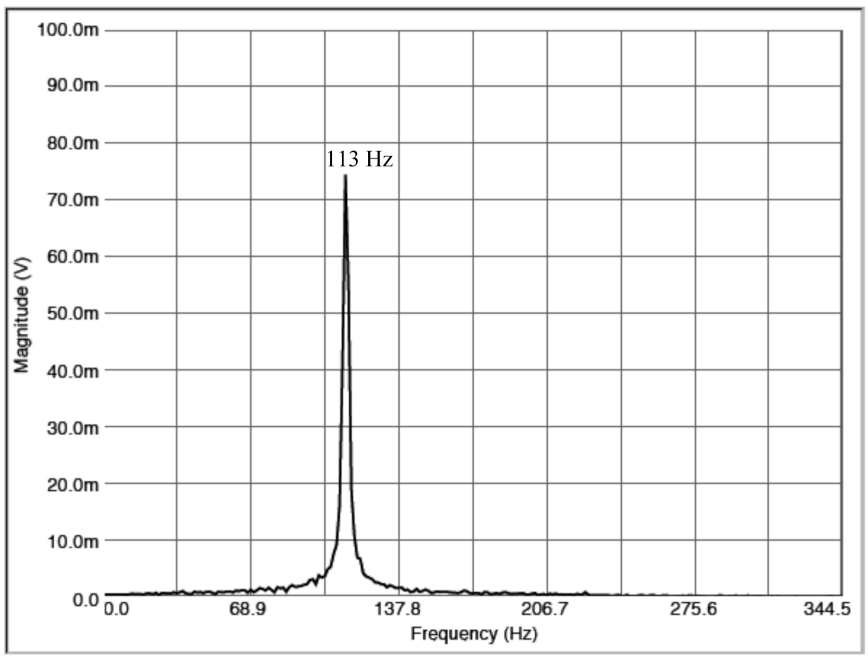
100.0m
90.0m
80.0m
70.0m
60.0m
50.0m
40.0m
30.0m
20.0m
10.0m
0.0
Magnitude (V)
113 Hz
0.0
68.9
137.8
206.7
275.6
344.5
Frequency (Hz)

Figure 8: