Resonance: standing waves in jars and pipes

Warin Poomarin and Ian Jacobs: KVIS, Rayong, Thailand

1 Resonance in a jar

Take a cylindrical jar and sing into it.

Find by trial and error the lowest frequency resonance (at around 300 Hz). *Do this yourself so you can hear the resonance clearly*.

Insert a microphone into the bottom of the jar and record the FFT spectrum at resonance.

The lowest harmonic, will have an antinode that is a little outside the open end and a node at the closed end. The one quarter wavelength standing wave will be dominant.

Fig 1 - searchng for resonance.

The threads have been removed from the screw-top jar in figure 1. This was done to remove a slight restriction one cm from the top. It was subsequently found that leaving the jar intact made no measurable difference to the end correction.

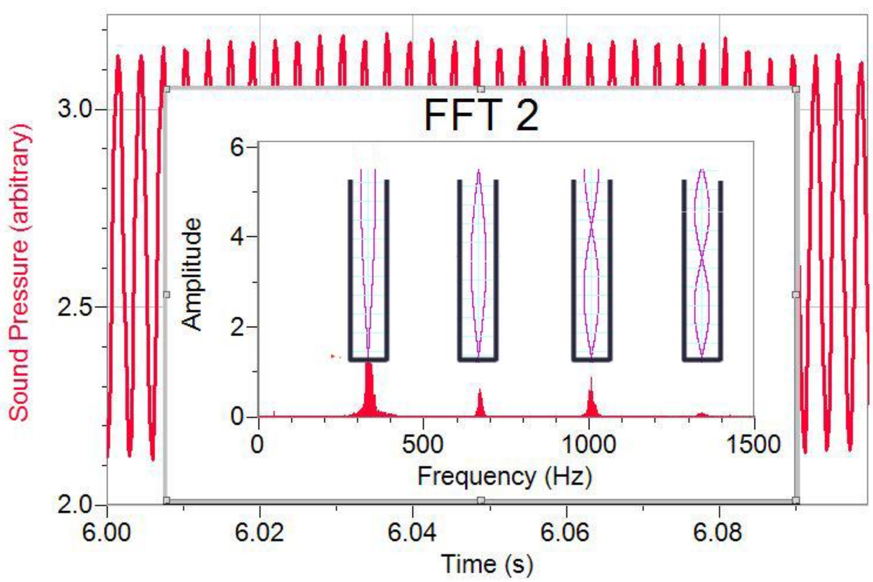

Fig 2 – a typical FFT spectrum at resonance with idealized standing waves.

Resonance occurs at 340 Hz for this jar that is 22 cm deep. Increasing the distance of the mouth from the end of the jar from 1–10 cm reduces the amplitude but makes little if any difference to the resonant frequency. The speed of sound in air is close to 340 m/s and the wavelength of the dominant fundamental is 1.00 m. The end correction at the open end of this wide tube is ~3 cm as shown in figure 2. The end correction is the same for the weak second harmonic. Resonance in long narrow tubes shows only odd harmonics when one end is closed and the other open. In this short wide tube excited by singing, weak odd and even upper harmonics are present.

> **Note:** standing sound waves are longitudinal pressure waves and cannot be easily drawn. Pressure nodes and antinodes in the jar are done with what may be mistaken for transverse wave diagrams. Pressure variations are greatest at a node and energy (figures 1 and 2 above) is transferred to the microphone through a node at the closed end. The intensity of the harmonics reduces with frequency in a regular way in figure 2. Moving the microphone alters that pattern.

Microphone placement

Fig 3 – the microphone is repositioned near the centre of the jar.

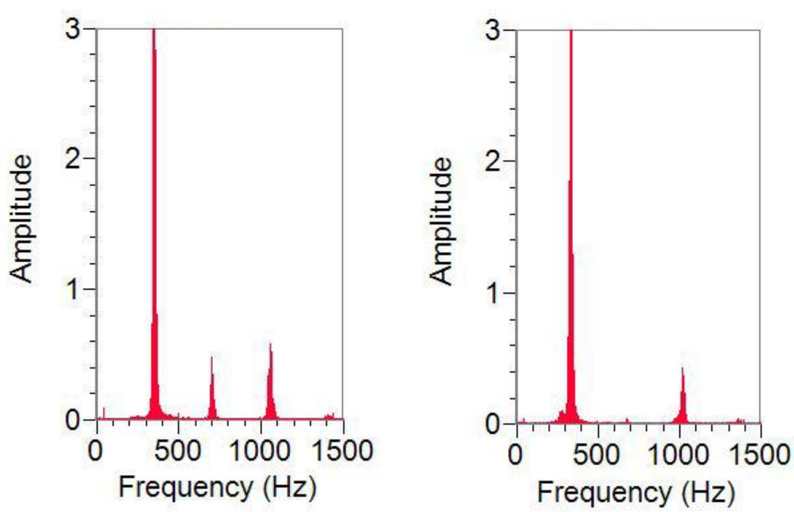

Fig 4 – the second harmonic is almost absent at the centre of the jar.

The microphone (figure 3) is now close to an antinode for the second harmonic and the recorded sound level at 680 Hz is lower than in figure 1 for that reason. Energy is most efficiently added to a standing wave through a node and the reverse is true for recorded sound. In this case the effect was most noticeable when the mouth was 10 cm from the end of the jar and the amplitudes of the resonances were consequently lower.

2 Resonance in a room

If you have an empty tiled room go in by yourself and sing (*eee, ooh, aar*). Raise the pitch of your voice and find the resonant frequency of the room by trial and error. If you can't find an empty room try a bathroom.

3 Resonance in pipes

a Find lengths of flexible plastic drain pipe of different diameters. Cut pipes of the same length.

Hold the pipes to your ear one at a time in a room with ambient noise.
(Turn on air conditioners in an empty room, or try a working classroom.)

Listen carefully to the resonance in each pipe. If the lengths, speed of sound, and end corrections are the same (or very nearly so), the pitch will be the same for each pipe. Can these minor variations be neglected? Coil the pipe. Can you detect any change in pitch of the low few frequency resonance.

b Cut pipes of the same diameter to different lengths.

Listen carefully to resonance in each pipe. Note the dependence of pitch on length.

c Hold the long pipe (1.5 m x 2 cm diameter) against your ear with one hand and swing a metre or so of the pipe in a circular motion with your other hand. Swing it firmly but not too fast. Note the increased loudness of the low droning resonance in the pipe.

Why might the loudness be increased by swinging the pipe?

Note the outflow of air through the pipe against your ear. Inertial forces and the Bernoulli effect may contribute in unequal amounts to this outward air flow.

How could you make an informal estimate of the relative importance of each effect without resorting to pressure or wind velocity measurements?

d Take the longest pipe away from your ear and swing it in a fast circular motion. Note the pitch of the resonance and the presence of upper harmonics.

Swing the shorter pipes and note the dependence of pitch on length.

Note: see *Singing Pipes* in the *Demonstrations* index for a discussion of the mechanism of sound generation and resonance.