Modes in a Cavity

In this experiment, you will measure some of the properties of resonant cavities using a loudspeaker excited by a white-noise generator and a microphone (Figure 1).
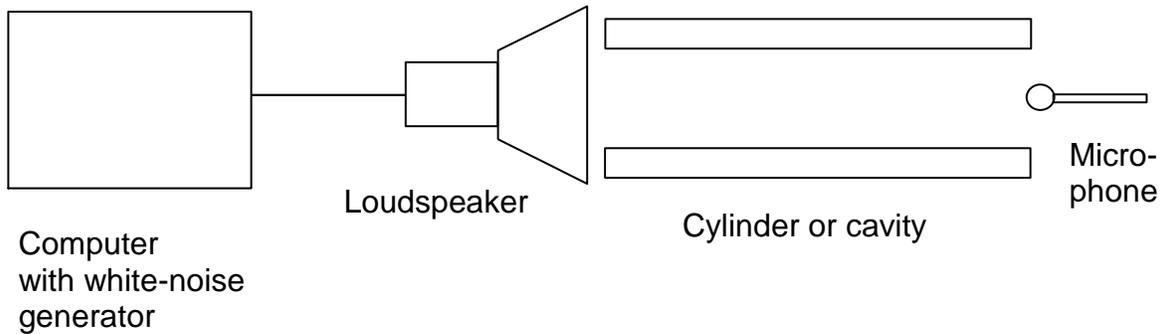

Figure 1. Schematic of the acoustics experiment, showing the computer, loudspeaker, cylinder or resonant cavity, and microphone. The output of the microphone is returned to the computer for processing.

Instructions. Devise a series of experiments to measure the *frequency response* of the microphone–loudspeaker combination, and the aluminum tubes or rectangular cavity. Plot the frequency response as a semilogarithmic graph (logarithmic units on the vertical axis, linear frequency on the horizontal axis; that is what you get from the program. The program will also average many scans to get a fairly smooth frequency response.) If you know the frequency response of the amplifier–loudspeaker, how do you calculate the frequency response of a cavity?

Calculate the expected frequencies and compare them to the measured peaks. Perform an error analysis and see whether the expected frequencies agree with the measured frequencies within experimental uncertainty.

If you are analyzing a cylinder, note that the boundary condition at the ends of the cylinder is soft, and there is an end correction approximately equal to 0.6*R*, where *R* is the radius of the cylinder, if the cylinder is *open* at both ends. Use the three cylinders of equal length and *verify whether the end correction is correct and whether it varies with frequency or radius.* See, for example, http://www.phys.unsw.edu.au/jw/pipes.html, and http://www.phys.unsw.edu.au/jw/musFAQ.html#end . You may also experiment with changing the axial position of the loudspeaker or the microphone, or with closing the microphone end of the cylinder. In your report, you might want to compare the frequency response of one of the tubes with that of a square or triangular wave.

To visualize some standing waves in a cylinder, go to http://www.falstad.com/modebox/, increase the width, decrease the height, and begin with 400. Note, however, that Falstad shows the acoustic pressure, rather than the amplitude of motion of the particles, so he shows a

maximum at the walls, whereas the amplitude there is a minimum. The amplitude is what we usually think of when we deal with EM waves.

If you are analyzing a rectangular or cubic cavity, Google "cavity mode" and see, for example, http://www.silcom.com/~aludwig/Physics/Main/Cavity_modes.html . Articles on modes in microwave cavities are equally relevant (why?).   To visualize some cavity modes, go to http://www.falstad.com/modebox/ and set it initially for 110 mode. See note above. Falstad has a lot of other splendid applets you might find useful.

In your report, check whether the measured frequencies correspond to those you predict. Some boxes have openings (for the microphone) in different locations; *see if the frequency response changes (in amplitude) when you put the microphone into corresponding openings in different boxes and explain why*. Note also that in a cubic box several modes may give the same frequency (110, 011, and 101, for example); what do you think will be the effect of this *degeneracy* on the frequency response of the box?

Check to see whether all modes are excited equally, whether your experiment concerns a box or a tube. To do so, you will have to plot the frequency response of the microphone–speaker combination in the absence of the box or tube. Note that the vertical scale is in decibels.