Phase Changes in Reflected Sound Waves

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Phase changes in waves are just varied enough and just unfamiliar enough to students to be confusing. The phase changes upon reflection of waves on a string and of sound waves are usually the first to be encountered by students, and can give a bridge to other such changes found, for example, in electromagnetic waves. Before digital oscilloscopes, phase changes in sound waves had to be taken on faith or tested indirectly. Now they are quite easy to show. This note describes an experiment that demonstrates phase changes of a reflected sound pulse in a long air-filled tube. The demonstration also gives an easy and straightforward measurement of the speed of sound, and shows that air temperature matters while pressure does not, as theory predicts.[1]

A positive pulse, about 200 μs in duration, is obtained from a pulse generator. The pulse is fed to an audio amplifier, which drives a speaker fitted into the end of a tube. The tube is a plastic drainpipe, about 4 in in diameter and 10 ft long, a standard product in building supply stores. An ordinary cone loudspeaker is fitted to a wooden ring that slips over one end of the pipe (see Fig. 1). The other end of the pipe can be capped or left open, using a slip-on cap that can be bought with the drainpipe. A small capacitor microphone, the type fitted to circuit boards, is placed into a 1-cm hole drilled into the tube at its center. The amplified pulse is fed to the speaker and also triggers the two-channel oscilloscope sweep. Channel 1 records this input pulse while Channel 2 reads the output of the microphone. Figures 2(a) and (b) show

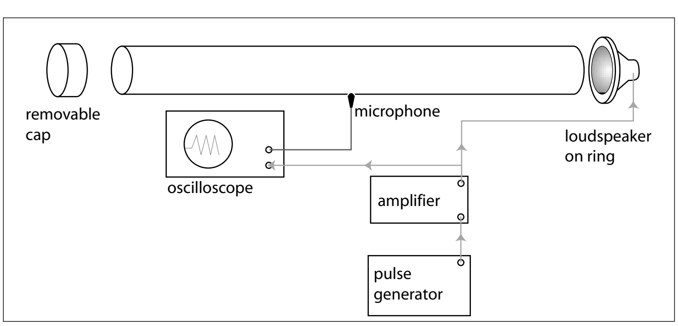

Fig. 1. Setup for demonstrating phase changes in reflected sound waves.

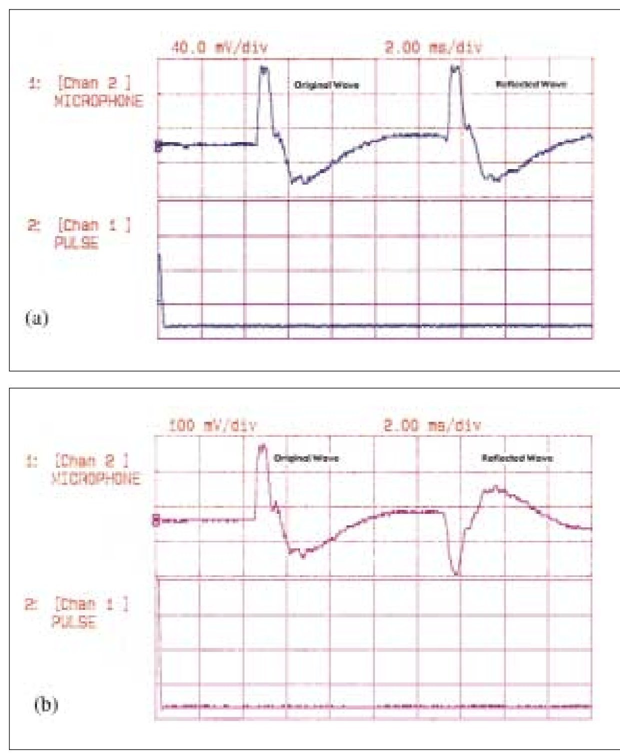

Fig. 2. (a) Closed tube. The upper trace shows the pulse after it has left the speaker and traveled halfway down the tube (some overshoot is evident as the speaker cone returns to its rest position). The reflected pulse mirrors the original pulse quite well. (b) Open tube. The trace in Channel 2 shows phase inversion of the reflected pulse. The pulse has been rounded somewhat by dispersion, pointing out that the mechanism of fluid boundary reflection is different from reflection at a solid boundary.

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typical oscilloscope traces. With a sweep duration of about 20 ms, the input pulse is shown at the left in Channel 1, while in Channel 2, and about 5 ms to the right, one sees the pulse, which has left the speaker and is now at the microphone, about halfway down the tube. About 9 ms later, in Channel 2, one sees the reflected pulse that has come back to the location of the microphone.

Students are often surprised to see that phase inversion of the pressure wave occurs with the tube open, not closed, and also to see that the amplitude of the reflected wave is not much less with the tube open than with it closed. This is where the realization occurs that wave reflection is somewhat more interesting than may have been thought.

Reference

1. Eugene Hecht, *Physics, Alegebra/Trig*, 3rd ed. (Brooks/Cole, Pacific Grove, CA, 2003), pp. 389–390.

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