# XII. PHYSICAL ACOUSTICS*

Prof. U. Ingard
Prof. R. D. Fay
L. W. Dean III
N. E. Frankel
S. P. Gill
R. L. Greene
R. S. Krupp
G. C. Maling, Jr.
D. C. Montgomery
H. L. Willke, Jr.

## A. SCATTERING OF SOUND BY SOUND

In a previous report (1), the equations for the scattered sound field arising from the interaction of two sound waves were solved for some particular cases. As a first approximation, the frequencies of the waves in the scattered field are the sum and difference of the frequencies of the primary waves. Some of the solutions have been examined experimentally.

Diagrams of the experimental apparatus are shown in Figs. XII-1 and XII-2. Two transducers generate sound pulses that collide at right angles. The sound frequencies are 0.6 mc and 1 mc, and the pulses are approximately 60 μsec long. The use of pulses eliminates any possibility of the two transducers interacting and sending out spurious signals. A receiver is placed in the same plane on a mount so that it can be rotated in an arc about the region where the pulses collide. Another adjustment is provided so that the distance between the receiver and this region can be varied. The pulses are then amplified and displayed on an oscilloscope. The receiver is tuned to the sum frequency, 1.6 mc, and the lowest detectable sound pressure is 0.07 dynes/cm$^2$. The strengths of the 0.6-mc and 1-mc sources are 15,000 dynes/cm$^2$ and 25,000 dynes/cm$^2$, respectively. Calibration measurements for the sources and the receiver have been reported elsewhere (2).

When a glass rod is placed in the region of interaction of the two pulses normal to the plane of Fig. XII-1 some of each pulse is reflected and travels out from the rod as a cylindrical wave. The two cylindrical waves should then interact and, if they are independent of the polar angle, should give rise to a scattered wave whose amplitude is independent of distance from the rod (1). If the diameter of the glass rod is equal to several wavelengths of sound, the reflected waves will not vary strongly with polar angle ($\theta$) except near the shadow zones. Therefore measurements taken at the sum frequency near $\theta = 45°$ should be independent of distance from the interaction region. Measurements for a glass rod, 0.25 cm in diameter, are shown in Fig. XII-3. As expected, the amplitude is nearly constant. The reflected waves are only cylindrical out to approximately 6 cm, at which point they begin to become spherical. We would therefore expect the amplitude of the scattered wave to fall off beyond this point.

---

*This research was supported in part by the U.S. Navy (Office of Naval Research) under Contract Nonr-1841(42). Reproduction in whole or in part is permitted for any purpose of the United States Government.

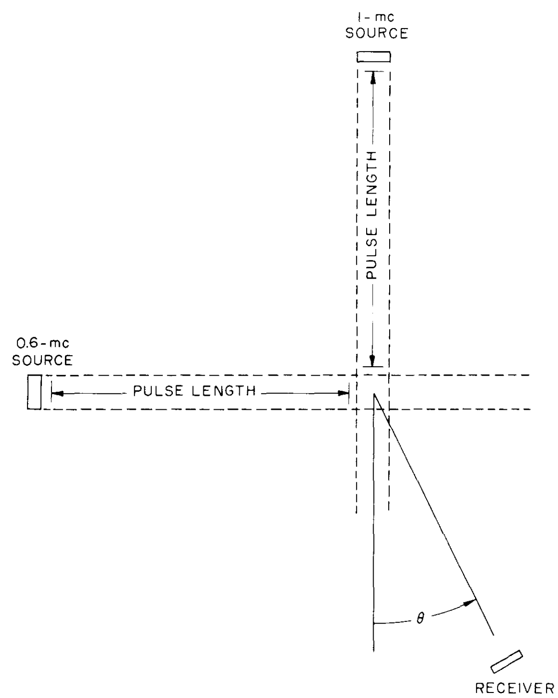


Fig. XII-1. Geometry of the experiment.

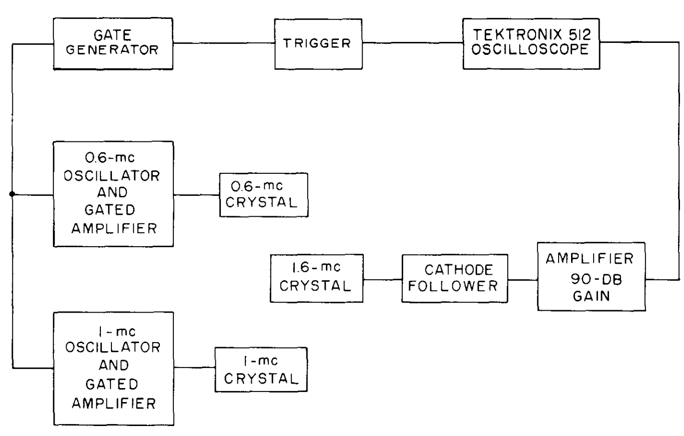


Fig. XII-2. Block diagram of scattering-experiment equipment.

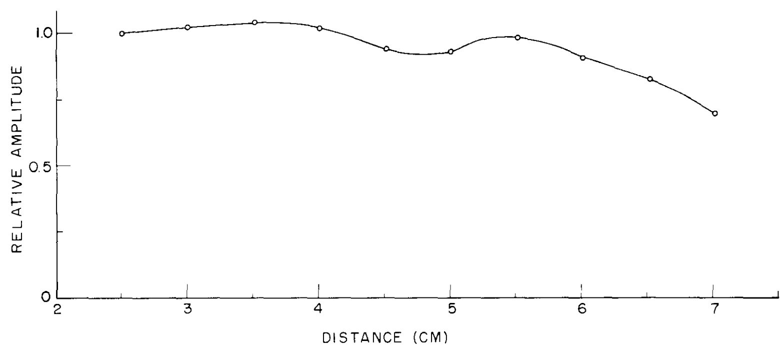


Fig. XII-3. Amplitude of scattered wave versus distance from glass rod at $\theta = 45°$.

When no objects are placed in the region of interaction of the pulses, scattered waves should be observed at various angles (1). Thus far, the sensitivity of the receiving equipment has not been sufficient to detect these scattered waves. However, if a slight motion is imparted to the medium (water, in this case) strong signals that fluctuate in time with a period comparable to the period of the gross motion of the medium are observed. These signals appear at all angles. We have not yet determined whether the motion of the water is directly responsible for the generation of these scattered waves, or whether the convection of temperature gradients or of small bubbles through the interaction region is responsible.

L. W. Dean III

References

1. L. W. Dean III, Scattering of sound by sound, Quarterly Progress Report No. 56, Research Laboratory of Electronics, M.I.T., Jan. 15, 1960, p. 167.

2. L. W. Dean III, Scattering of Sound by Sound, Ph.D. Thesis, Department of Physics, M.I.T., January 1960.

## B. SOUND ATTENUATION IN ALUMINUM RODS

Measurements of excited extensional vibrations in small cylindrical aluminum rods that are held free at both ends have been carried out. The decay of the vibrations in time after the excitation has been turned off is a measure of the attenuation of sound in the sample. The experimental technique used is similar to that of P. G. Bordoni (1).

The rods are 2S0 commercial aluminum, 99 per cent pure, 2.56 inches long, and 0.5 inch in diameter. Measurements on several different rods at room temperature give values for the resonant quality factor Q of from $6.7 \times 10^3$ to $20 \times 10^3$. No appreciable change in damping occurred because of externally mounting the rods either on or slightly off their nodal plane. The differences in damping can only result from the different structural composition of the rods.

N. E. Frankel, R. L. Greene

## References

1. P. G. Bordoni, Elastic and anelastic behavior of some metals at very low temperatures, J. Acoust. Soc. Am. 26, 495-502 (1954).