Absorption of Sound by Tree Bark

by

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ABSTRACT

Laboratory tests were conducted with a standing wave tube to measure the acoustic absorption of normally incident sound by the bark of six species of trees. Twelve bark samples, 10 cm in diameter, were tested. Sound of seven frequencies between 400 and 1600 Hz was used in the measurements. Absorption was generally about 5 percent; it exceeded 10 percent for only three samples, and then only at 1250 Hz or above. No general trend was evident in the variation of absorption with frequency.

INTRODUCTION

It has been shown by previous field research that dense forests greater than 50 feet deep provide useful attenuation of noise (*Eyring 1946, Embleton 1963, Cook and Van Haverbeke 1972, Reethof 1973*). However, there is some disagreement on the amount of absorption to be expected. Furthermore, the mechanism of sound attenuation by forests is not well understood. Tree boles may act primarily as scatterers of sound, and the elements that provide the greatest absorption may be soft forest floor, shrubbery, or a combination of these. Once the major absorbing elements are identified, their relative contribution to the overall attenuation of sound can be studied in detail so that forest characteristics and species that will yield the most effective attenuation can be recommended.

This paper describes the initial phase of our comprehensive study of the attenuation of sound by forests. Sound absorption characteristics of bark from trees of six species were studied in the laboratory. There is essentially no literature on the sound absorption characteristics of bark, and none on measurement instrumentation. We plan to examine the sound absorbing mechanisms of various forest elements to determine how these affect the dissipation of acoustic energy in forests. Ground absorption, considered by some to be effective in forests, will be studied next. Attenuation by shrubs and tree canopies will also be examined.

PROCEDURE

The absorption by tree bark of sound of normal (perpendicular) incidence was measured with a commercial impedance tube, also known as a standing wave tube, manufactured by Bruel & Kjaer Instruments, Inc.[1] Cylindrical test samples were cut from slabs, with the natural wood intact behind the bark. Six species were tested: northern red oak (*Quercus rubra* L.), mockernut hickory (*Carya tomentosa* Nutt.), eastern white pine (*Pinus strobus* L.), American beech (*Fagus grandifolia* Ehrh.), eastern hemlock (*Tsuga canadensis* (L) Carr.), and a cork oak (*Quercus suber* L.).

Impedance tubes are used to measure the

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Forest Service or the U. S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

fraction of the incident acoustic energy absorbed by a material. Pure tone sound waves travel down the tube and strike the sample; part of the acoustic energy is absorbed by the material and the remaining energy is reflected and travels back up the tube. The superposition of the incident wave and the reflected wave establishes a standing wave (*Kinsler and Frey 1962*). The amplitude maxima and minima of the standing wave are measured and the absorption coefficient is calculated using the following relationship:

$$\alpha = 1 - \left(\frac{S - 1}{S + 1}\right)^2$$

where α is the absorption coefficient, the ratio of the absorbed to incident acoustic energy, and

S is the ratio of the maximum to minimum acoustic pressures in the impedance tube.

A typical axial pressure pattern is shown in figure 1.

Figure 2 is a schematic diagram of the apparatus. The sample holder is mounted at one end of the impedance tube, which is 10 cm in diameter and 1 m long. A loudspeaker is mounted in a box at the other end of the tube. A frequency oscillator generates selected tones, and a frequency counter monitors the tone sent to the speaker to insure accuracy within ± 1 Hz. A 1/8-inch-diameter microphone probe tube moves in and out along the central axis of the impedance tube. The microphone in the movable carriage at the end of the probe tube monitors the sound pressure of the standing wave. The signal from the microphone goes through a preamplifier to an audio frequency spectrometer, where the absorption coefficient is read from a calibrated scale. The apparatus is shown assembled in figure 3.

The impedance tube is designed for use with normally incident waves and samples with a flat surface. Bark, with its surface irregularities, does not conform to the definition of a flat surface. Therefore, a hard oak slab, an excellent reflector, was placed in the sample holder and its absorption was measured. Then an additional slab was mounted at an angle to simulate one ridge of a bark surface, and absorption was again measured. The results showed excellent agreement, indicating that absorption by bark can legitimately be measured with the impedance tube.

For proper impedance tube measurements the sample must be properly seated in its holder. This presents no problems for flexible materials, because they make good contact with the surface of the holder, leaving

Figure 1.—A typical axial pressure pattern of the standing wave in the impedance tube.

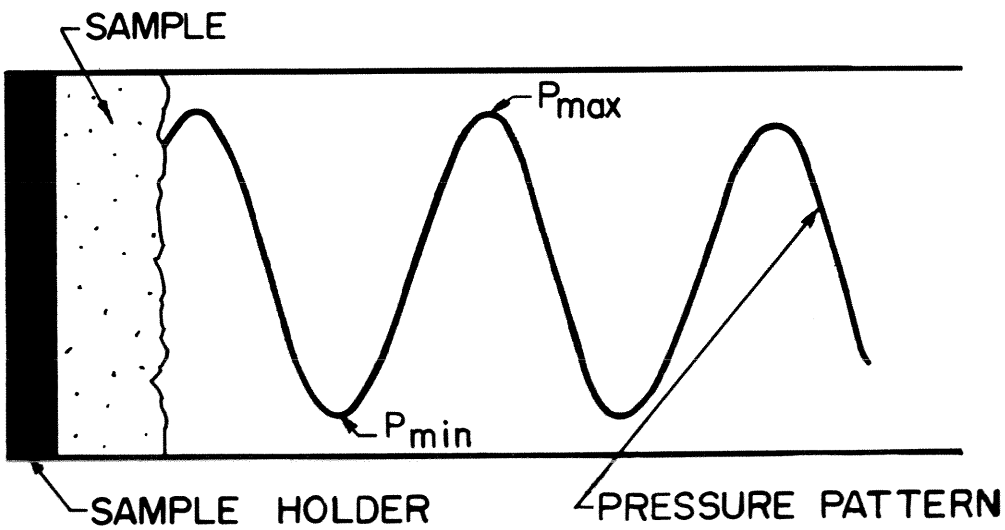


Figure 2.—A schematic diagram of the impedance tube apparatus.

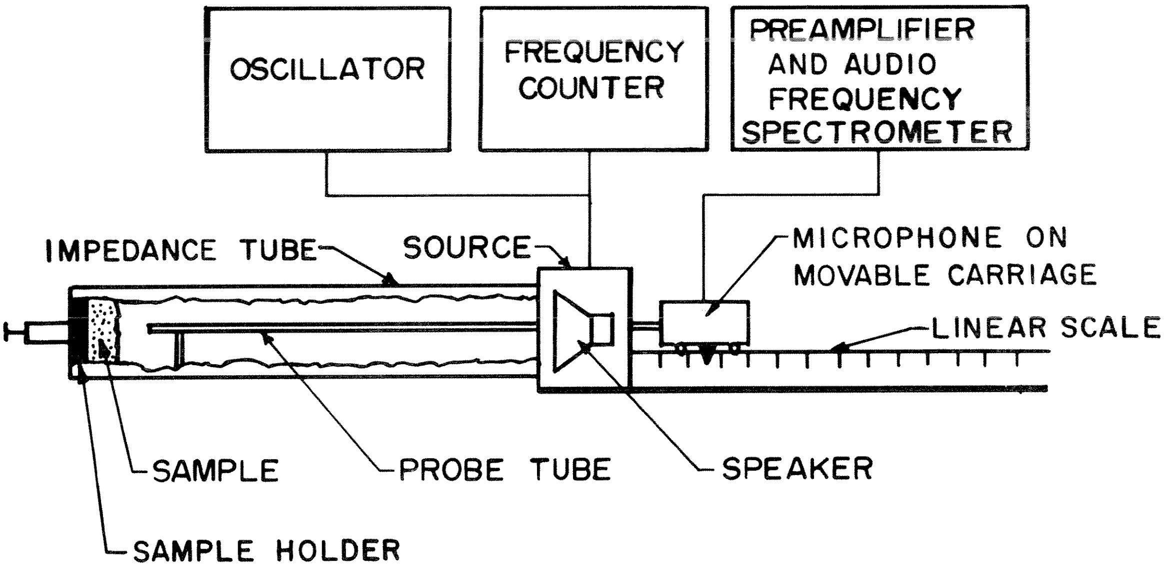
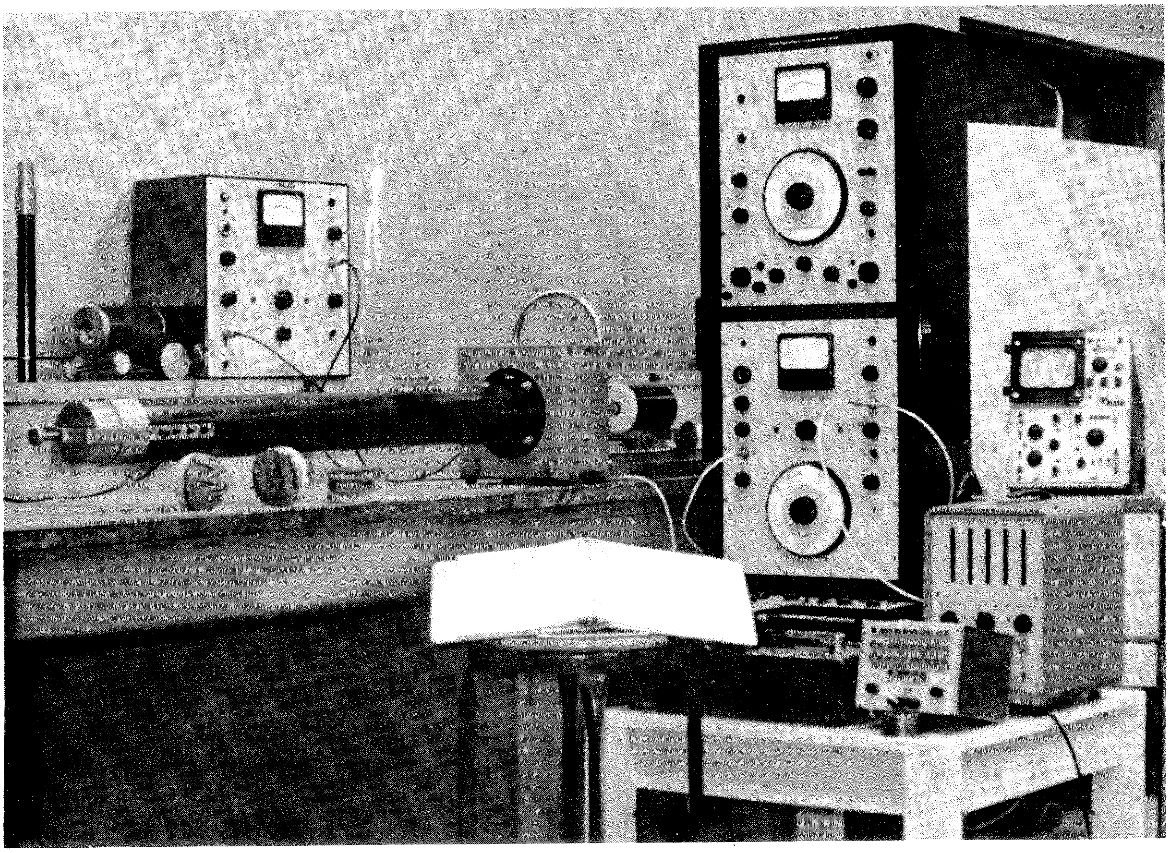


Figure 3.—The impedance tube, instruments, and several samples.



no room for air gaps in which sound would be absorbed. But with wood, problems arise. If the sample is turned on a lathe so that there is just enough tolerance for the sample to be inserted and removed, there is a finite thin ring of air between the sample and holder. The flow resistance of the air passages will provide acoustic absorption, resulting in erroneous absorption coefficients. And the gap allows the sample to vibrate, which also may produce errors.

We tried various ways of holding the sample. Bolting it in place and using various sealers and putties improved results. However, the best method we discovered was to pour liquid paraffin into the sample holder, insert the sample, and let the paraffin solidify to form a seal. Care was taken to assure that the paraffin did not fill any bark crevices.

Our first tests, with no sealer and with the sample not bolted in place, produced absorption coefficients as high as 46 percent. Repeated tests with paraffin-held samples showed absorption coefficients of less than 10 percent. Tests with paraffin alone in the sample holder showed no significant absorption by the paraffin. The absorption coefficients obtained from samples sealed with paraffin were repeatable within 0.01.

Freshness of the bark was of concern, and that measurements were made to determine whether dried samples would yield absorption coefficients different from those of bark on live trees. We obtained several freshly cut bark samples and tested them immediately. The absorption of dry and fresh samples were similar. It was concluded that the moisture content of bark does not significantly alter its absorption. Therefore, our tests, made on dried bark samples obtained from mature trees, were assumed to be representative of natural conditions in the forest.

The 1-meter-long impedance tube is normally capable of providing reliable absorption data at frequencies as low as 125 Hz. However, the presence of irregularities in bark surfaces made it advisable to record the maximal and minimal acoustic pressures at a greater distance from the sample than is required for testing smooth materials (*Skudrzyk, 1971*). This increased the lower limiting frequency, which is dependent on the length of the impedance tube available for measurement, to 400 Hz. The upper limiting frequency, 1600 Hz, was determined by the diameter of the tube.

RESULTS AND DISCUSSION

The absorption coefficients of samples of red oak, mockernut hickory, and white pine are plotted against frequency in figures 4, 5, and 6, respectively. Each figure shows the results for three samples, each checked for repeatability. The absorption coefficients found in repeated tests of each sample seldom differed by more than 0.01. The absorption coefficients for all samples of the three species were less than 0.10, except for hickory, which had absorption coefficients between 0.02 and 0.23 at frequencies above 1250 Hz. The wide variation in this species correlated well with differences in bark thickness; a thin-barked sample consistently gave low values. The high absorption of mockernut hickory bark may be due to its shale-like layers with spaces between them. The spaces may allow individual layers to vibrate, transforming the incident acoustical energy into mechanical energy. This probably accounts for the high absorption.

After tests on oak, hickory, and white pine, we looked for bark characteristics that might alter the absorption of sound, and selected three other species for testing. These species were American beech, eastern hemlock, and a cork oak. The results are shown in figure 7. The hemlock sample had a higher absorption coefficient than the beech or cork oak, but all were less than 0.10.

CONCLUSION

The absorption coefficients of the six species we tested are quite low and largely independent of frequency. The small variation in absorption among the samples shows that sound attenuation by forest trees is little affected by bark characteristics, unless it is highly sensitive to differences in bark absorption.

Although each tree bole absorbs only a

Figure 4.—Absorption of normal-incidence sound by bark of northern red oak.

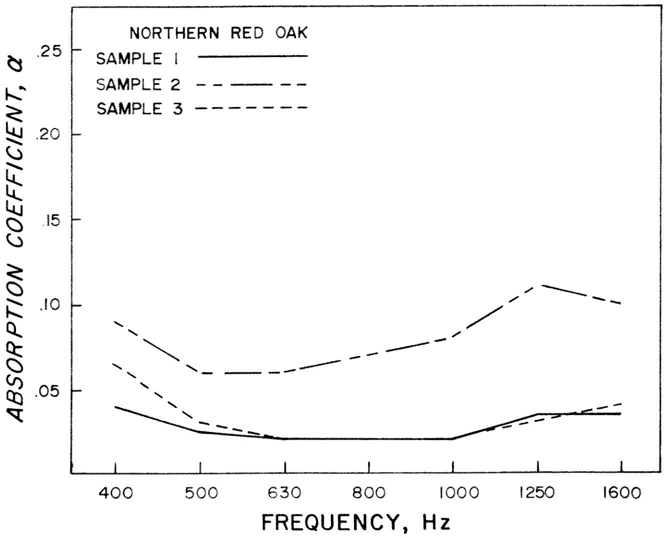


Figure 6.—Absorption of normal-incidence sound by bark of eastern white pine.

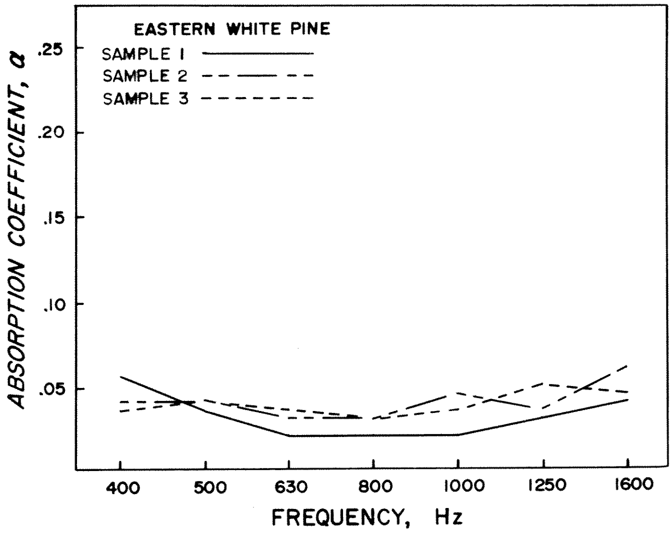


Figure 5.—Absorption of normal-incidence sound by bark of mockernut hickory.

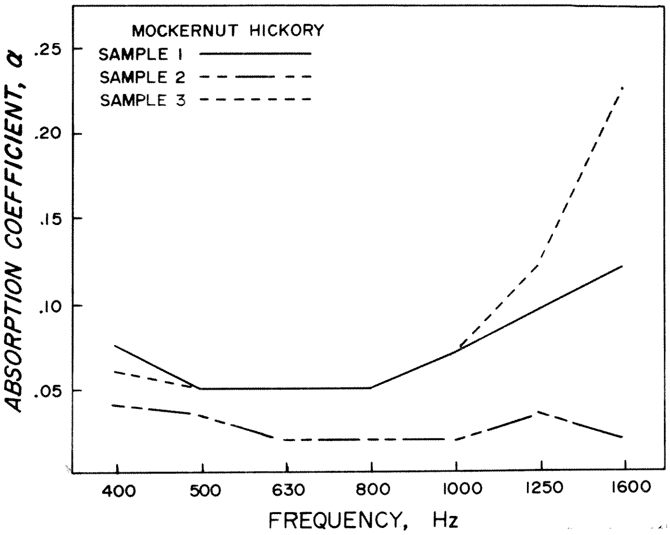
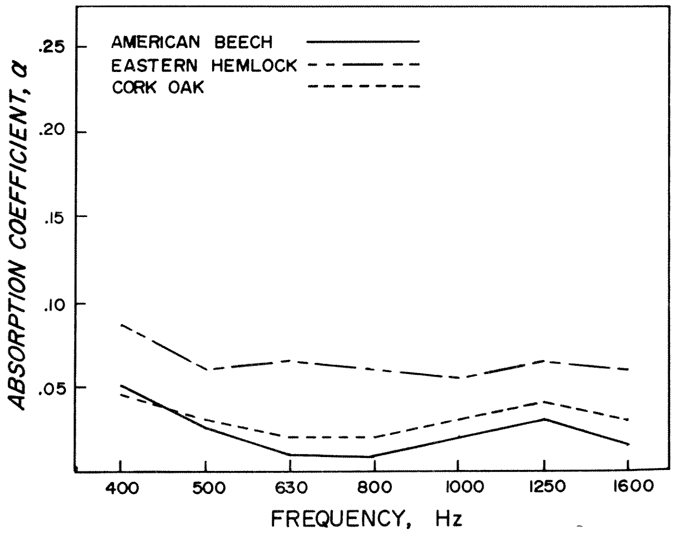


Figure 7.—Absorption of normal-incidence sound by bark of American beech, eastern hemlock, and cork oak.



small fraction of the energy of the incident wave, the effect is repeated as the sound wave is scattered from one tree to another. We do not know how the total absorption by bark compares with that of shrubs, foliage, branches, or the canopy as a whole. It can be assumed that the scattering process makes the sound available to more surface area and therefore gives the ground and the other forest elements more chances to absorb the acoustic energy.

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