Propagation of Noise over and through a Forest Stand

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This research was supported in part by funds provided by the Northeastern Forest Experiment Station through the Pinchot Institute for Environmental Forestry Research, Consortium for Environmental Forestry Studies.

ABSTRACT.—Measurements of the two-dimensional acoustic field in a forest resulting from a source located outside the forest indicated that the attenuation pattern near the ground is significantly different from the pattern higher up in the forest. The patterns of attenuation support the recent theory that the forest floor is the main absorber of acoustic energy in the forest.

SOUND RADIATING from a point source decreases in sound pressure level (SPL) 6 dB for each doubling of distance due to spherical spreading of the wave front. Any additional reduction in SPL due to the presence of ground, vegetation, buildings, etc. is usually referred to as excess attenuation.

Measurements of excess attenuation within 10 feet of the forest floor indicate that the reduction in SPL due to the presence of the forest is approximately 6 dB per 100 feet of forest *(Bjornson 1971, Herrington 1974, McLaughlin 1975)*. These same studies indicated that the variation in SPL near the forest floor was not characteristic of the acoustic field in the forest at higher levels. The objective of our study was to describe the acoustic field within and over a forest stand in a vertical plane parallel to the propagation of sound from a point source.

METHOD

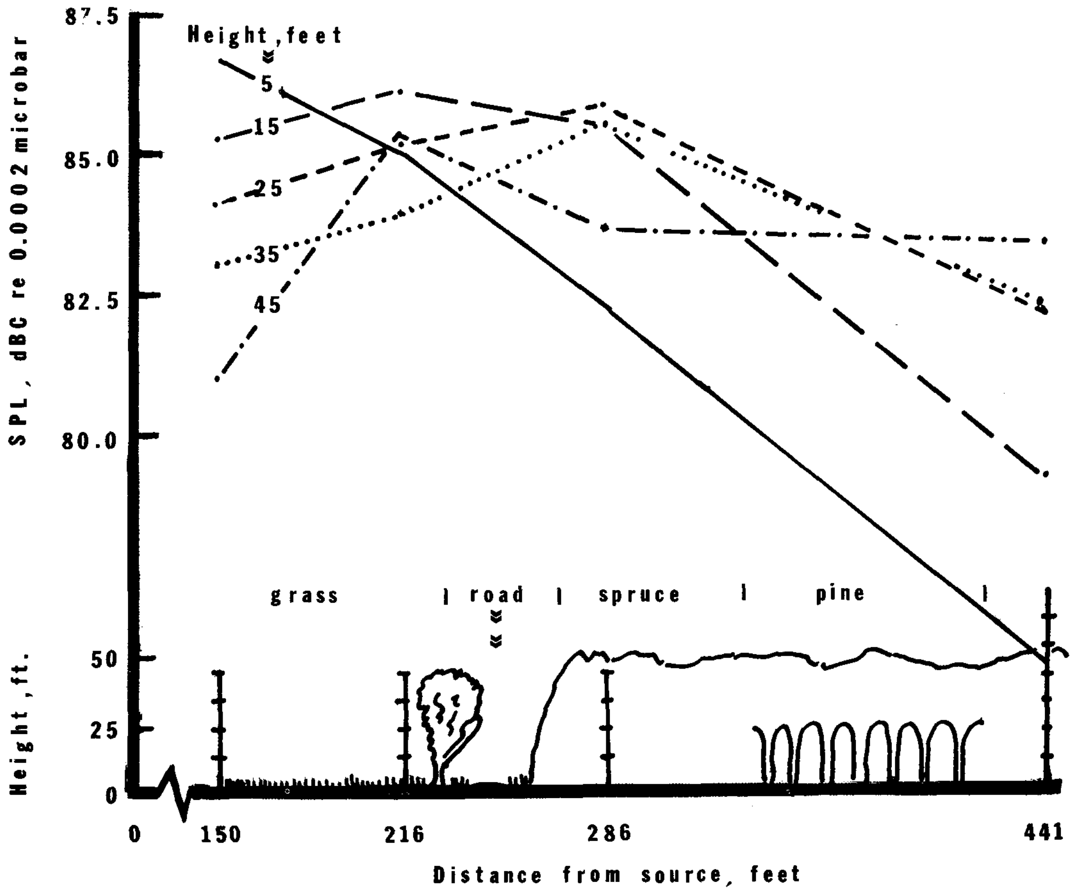
Wide-band pink noise (a spectrum of noise with equal energy per octave of frequency) was broadcast from a folded-horn speaker toward the edge of a coniferous plantation (fig. 1). Along the axis of propagation, five towers were erected. Two of these towers were located outside the forest, one was located on the edge of the forest, and two were located within the forest.

Microphones, which were attached to pulley systems on each tower, were used to measure the sound pressure level at the heights indicated (fig. 1). The pink noise (signal) received at each microphone was recorded on magnetic tape at the test control center. Both ambient noise—that is, the noise naturally present in the environment—and the signal were measured for each tower-height combination during 14 field-measurement periods. These periods were approximately 30 minutes in length. The field measurements were made under a wide range of meteorological conditions during the summer of 1974. The recorded data were subsequently analyzed on a real-time analyzer, using an averaging time of 128 seconds. In this fashion the acoustic field in a vertical plane containing the axis of propagation was determined.

For each measurement, meteorological data (temperature and temperature profile, wind and wind profile, relative humidity and solar radiation) were also recorded.

The forest consisted of a plantation made up of parallel bands of Norway spruce *(Picea abies)* and red pine *(Pinus resinosa)* 1-chain (66 feet) wide, ori-

Figure 1.—Excess attenuation at five heights for acoustic energy propagating over and through a forest edge. Included is a diagram of vegetative features along the path and the location of the towers from which measurements were made.



ented at an angle of 20 degrees to the axis of noise propagation. The spruce presented a very dense tangle of dead branches below the live crown, while the pine was naturally pruned to a height of approximately 30 feet. The edge of the plantation was defined by a road and a partial row of deciduous trees (fig. 1).

RESULTS AND DISCUSSION

Figure 1 shows the average corrected SPL at several heights as a function of distance into the plantation. Corrected SPL was calculated by adding to the recorded data the loss due to spherical spreading of the wave front (6 dB per doubling of distance). Thus, a horizontal line in figure 1 would indicate no excess attenuation.

SPL increased with height at the 150-foot tower and showed a mixed pattern at the plantation edge (216 feet). Measurements of the directivity of the horn used to generate the acoustic signal indicated that this increase in SPL with height was not due to directivity of the speaker. The conclusion, therefore, is that this pattern must be due to reflection of acoustic energy from the edge of the forest. The generally increasing SPL between the 150-foot and 216-foot towers supports this contention. At a height of 5 feet there was little foliage at the edge, and there was a decrease in SPL at the 5-foot height between these points. The further increase in SPL between the 216-foot and 286-foot towers for heights of 25 and 35 feet may also be due to reflection of acoustic energy, but this is less clear than for the edge condition.

Within the forest there is a steady and rapid decrease in SPL at the 5-foot height. At higher elevations, however, the pattern is not as clear. The 45-foot height, which was just about at the top of the canopy, shows very little attenuation with distance; while the levels measured within the canopy do show some attenuation with distance. The 34-foot level, which was distinctly within the closed portion of the canopy, showed the strong attenuation between 286 and 441 feet from the source.

Two-way analysis of variance (height and distance) of the corrected SPL data showed, as might be expected, that total attenuation increases with the distance from the source. The analysis of variance also showed that there was significant variation of the attenuation pattern with height and that there was a significant interaction between height and distance. Grouping of the data in the analysis of variance procedure showed that there was no significant difference between the attenuation patterns at the 15-, 25-, 35- and 40-foot levels, but that there was a significant difference between the attenuation pattern at 5 feet and at the higher levels. That is, the pattern of attenuation near the ground is not the same as that which exists at 15 feet and above.

Based on their measurements of the acoustic absorptivity of bark, Reethof *et al. (1975)* have proposed that tree stems and branches are scatterers of acoustic energy and that absorption takes place mainly at the ground surface. Our results plainly support this argument and indicate further that there may be some attenuation in the thickest part of the canopy also.

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