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THE ACOUSTIC IMPEDANCE OF THE FOREST FLOOR

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INTRODUCTION A significant contribution to the attenuation of traffic noise through forest belts is due to absorption at the forest floor. The two floors examined in the present study (beneath stands of red pine and mixed hardwoods) have a layered structure. The lowest layer consists of mineral soil and above this can be found vegetable matter in various stages of decomposition. The vegetable matter can be divided into two other reasonably distinct layers: an undecomposed surface layer over a layer of humus in an advanced state of decomposition. Measurements of normal surface impedance are compared with the predictions, from the conceptual model shown in Figure 1. These predictions are obtained from the relevant formula {1} which requires in addition to the surface impedance of the underlying mineral soil knowledge of the characteristic impedance and propagation constant of the humus layer. Three methods of estimating these quantities are outlined and compared.

SURFACE IMPEDANCE MEASUREMENTS. Measurements were made of the standing wave ratio and positions of the first two pressure minima in a vertical standing wave tube the lower section of which was driven into the ground to a depth of 150-200 mm over the frequency range 200 Hz to 1.8 kHz. After the initial set of measurements on the (relatively) undisturbed floor, the two successive upper layers were removed as carefully as possible and the impedance measurements were repeated. Corrections were made for the acoustic centre of the 4mm (I.D) probe tube and for air attenuation along sound paths within the impedance tube.

Samples of the undecomposed litter layer and of the humus layer were removed carefully and transported to the laboratory to enable use of Pyett's two-thickness method {2} and of direct measurement to determine characteristic impedances and propagation constants for these layers over the frequency range 315 Hz to 1.8 kHz. The direct measurement technique used a sample of adequate thickness to approximate an 'infinitely-thick' or semi-infinite layer. The sample was considered 'infinitely-thick' when there was no change in the standing wave ratio with and without a rigid termination.

EMPIRICAL MODELS. Following measurements made upon a large number of fibrous acoustic materials Delaney and Bazley {3} have produced empirical power-law relationships between flow resistance frequency and characteristic impedance or propagation constant. In order to check the usefulness of these relationships for the purpose of the current study flow resistance measurements for both the litter and the humus layers were made using an apparatus devised by Kilmer {4}. (See Table 1.) Power law curve fitting to measured impedance values was attempted using the measured flow resistances.

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DISCUSSION AND CONCLUSIONS. Evidence to support the adoption of the model shown in Figure 1 for the red-pine forest floor includes (i) the relatively small flow resistance offered by the surface litter layer, (ii) the difficulty in obtaining any pertubation of the standing wave ratio in the rigidly-terminated impedance tube with the introduction of up to 250 mm thickness of litter, (iii) values of attenuation constant near to zero and phase constant near to that of air were calculated by Pyett's methods from rigid-backed layer impedance measurements and (iv) in situ impedances calculated from measurements taken with and without the surface litter layer (but assuming in both cases that the surface position was that of the surface of the humus layer) are very similar. This evidence suggests that the surface litter layer is approximately acoustically transparent and thus in the model of Figure 1 it is appropriate to identify the upper layer with the humus layer. Furthermore, inspection of calculated impedance values of the mineral soil (see for example Figure 2) indicated that, although it is comparatively high the impedance of the soil is finite and thus a model that replaces the lower medium in Figure 1 by a rigid backing would not be adequate. This is true for both of the sites studied. Far from being acoustically transparent the litter layer underneath the mixed hardwood stand was found to have similar characteristics i.e. impedance (and flow resistance) to the corresponding humus layer. Thus predictive modelling purposes the two layers were lumped together so that (again) the model shown in Figure 1 was relevant.

The values of characteristic impedance and propagation constant calculated from measured flow resistance and Delaney and Bazley's empirical formulae were not found to compare well with values deduced from impedance tube measurements. Other more appropriate power law regressions were obtained. However as a consequence of the considerable scatter in the measured data both characteristic impedance and propagation constant were fitted by straight-lines as well as they were by power-law relationships. A possible explanation for this discrepancy could follow from the substantial difference between the porosities (see Table 2) of interest here and those of the materials studied by Delaney and Bazley.

Use of values of characteristic impedance and propagation constant for the humus layer in theoretical expressions relevant to the model shown in Figure 1 produce predictions of normal surface impedance that lie essentially within the scatter of in situ measurements (Figure 3).

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$Z_o = \rho_o c_o$	air
$k_1 = \alpha_1 + j_1\beta_1$ $Z_1 = R_1 + jX_1$	organic layer
$Z_2 = R_2 + j\,X_2$	mineral soil

Figure 1 Conceptual Model

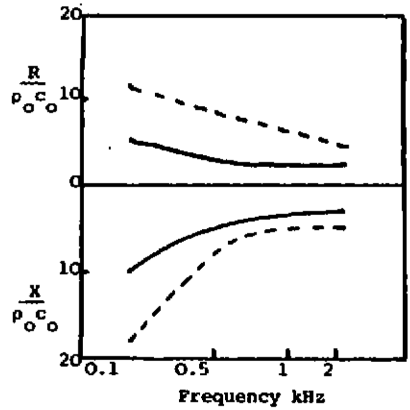

Figure 2. Surface Impedance of red pine floor with (——) and without (- - - -) humus.

Table 1. Measured Flow Resistance (cgs Rayls)

Layer	Red Pine		Mixed Hardwood	
	Mean	S.D.	Mean	S.D.
litter	0.92	0.90	41.59	33.80
humus	49.63	24.03	32.54	25.64
mineral soil	1350	426	486	170

Table 2 Porosities and Depths (cm)

Layer	Red Pine		Mixed Hardwood	
	Porosity	Depth	Porosity	Depth
litter	0.86	3.4	0.81	1.9
humus	0.51	2.0	0.5	3.4
soil	0.28	-	0.3	-

Figure 3 Measured (o) and predicted (X) values of normal surface impedance