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IN SITU AND LABORATORY MEASUREMENTS OF GROUND IMPEDANCE

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1. INTRODUCTION

Outdoor sound propagation is not only influenced to a great extent by meteorological factors like air temperature and humidity and wind speed but also by the surface along which the sound is propagating (1,2,3). Because of the increasing application of outdoor sound models used to predict the noise load of a certain traffic road on neighbouring residential quarters (4,5), there is a great need for measured values of acoustic characteristics of all kinds of soil surfaces, both artificial ones like lawns and natural ones like forest floors. Until now most theoreticians have taken grass covered surfaces as the softest natural surfaces (5).

This paper describes the principles and experimental results of two methods of acoustic impedance measurement of natural and semi-natural surfaces. The first one is known as the inclined track method, which enables us to measure impedances in situ in outdoor measurements; the second method comprises the use of a short sound pulse with which impedances of large soil samples on a hard backing in an anechoic room can be measured. Essentially this last method can also be used outdoors.

2. THE INCLINED TRACK METHOD

For the determination of the acoustic softness of a soil only two figures have to be measured. All impedance measurements are aimed at getting these parameters as accurate as possible. They are the amplitude and phase of the complex reflection coefficient (R), defined as the ratio between reflected sound pressure and incident sound pressure at the reflecting surface.

In inclined track measurements the reflection coefficient is calculated from the sound interference pattern on a straight line with a constant inclination (in our case of 20 degr.)(6). This pattern is caused by interference of the direct and the ground reflected waves. The reflection coefficient, however, also depends on the geometry of the experimental set-up, and in order to arrive at a more universal description of the acoustic characteristics of soil, the normalised acoustic surface impedance (Z) has to be extracted from R. In doing this great care has to be taken of the choice of the model relating Z to R. A number of these models exists (see 1 and 2 for reviews). In our measurements with short distances between source and receiver (up to 17 m) the simple relation $R=(Z\cos\alpha-1)/(Z\cos\alpha+1)$ is satisfactory (7). Here α is the angle of incidence, the complement of the angle of inclination.

The actual measurements were carried out with pure tones above different forest floors and grass-fields. Although two microphones would be sufficient to calculate Z, we used 30 measuring points to compensate for the inaccuracies of the measuring positions. The influence of those on the impedance values is well described in the literature (8,9). Z was determined for each of the 22 frequencies separately by means of fitting a sound field model to the measured sound pressure levels with the real and the imaginary parts of Z as fitting-parameters. In the model the sound speed was corrected for air temperature and humidity, and the frequency characteristic and directionality of the loudspeaker were used to calculate the sound pressure relative to the free field. The differences between calculated and measured sound pressure values were on the average 1,5 d. at each microphone. Typical results of two surfaces are shown in Fig. 1. These are in agreement with recent findings of other investigators (8), who have also found that the real parts of the impedances hardly vary with frequency, while the imaginary parts decrease with increasing frequency.

3. THE SOUND PULSE TECHNIQUE

Because natural soils are inhomogeneous the impedances of small soil samples, for example measured with an impedance tube (10,11), will probably show little relation with the impedance of the infinite outdoor soil surface. To get an average impedance we therefor applied

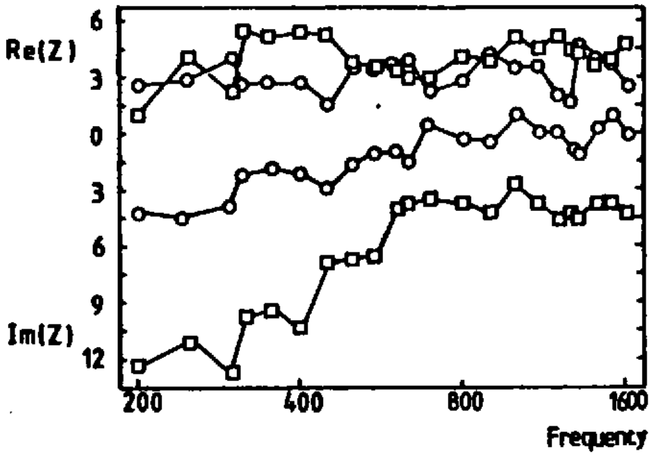

Fig.1. The real (upper two curves) and imaginary (lower two curves) parts of the normalised surface impedances of a bare sandy soil with some heather and low grasses (squares) and of a spruce forest floor covered with a carpet of fir needles and dead twigs (circles).

a pulse sound method. A short pulse was directed perpendicularly at a reflecting surface and by comparing the amplitudes and the phases of the direct and the reflected pulses the surface impedance could be calculated with a formula taking the spherical character of the waves into account (12).

As reflecting surfaces we used layers of dried sharp sand with thicknesses ranging from 0 to 0,13 m on a hard backing of 2 mm sheet steel measuring 1X2 m. A typical result is shown in Fig. 2, quite similar to the findings of Dickinson (6). In theory, the surface impedance varies with layer thickness (13) and only when the layer is infinite the surface impedance in this experimental set-up can be compared with the outdoor situation. We found, however, that at e.g. 2 kHz the sound is absorbed mainly in the upper 90 mm of sand, because the measured Z did not change at thicker layers. Another complicating factor is the edge effect caused by the finite surface of the sample (14). This limits the use of this method to sound with a wave length smaller than the diameter of the sample, when it is applied in an anechoic room, but not outdoors. It should be noted that comparison of the two figures is not allowed, because the soils were not the same, nor were the angles of incidence or the dimensions of the reflecting samples. Further investigations have to be carried out to make a comparison between the methods possible and to improve them so as to make them valuable tools in the research of the relation between biological and physical soil parameters and acoustics.

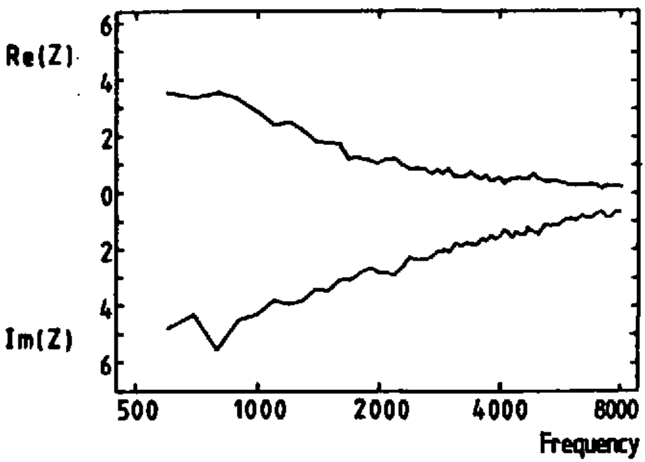

Fig.2. The real(upper curve) and imaginary (lower curve) parts of the normalised surface impedance of a layer of 0,13 m of dry sharp sand on a hard backing.

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