SOUND PROPAGATION IN FORESTS.

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1. INTRODUCTION.

Sound propagation in forests is studied by physicists and biologists. The aims of this research are: Firstly, to understand sound absorption in air and sound propagation above acoustically hard and soft soil surfaces, secondly, the noise pollution abatement in town and landscape planning, and finally, the constraints of the (natural) environment on animal vocalization and communication. Regarding the existing literature three sound propagation patterns in vegetations are described:

a. A pattern showing a slight, more or less constant, increase in sound absorption with increasing frequency from 0,023-0,23 dB/m at 100 Hz to 0,26-0,83 dB/m at 10 kHz found in different tropical vegetations (4) and an increase from 3 dB/100 m at 400 Hz to 25 dB/100 m at 5 kHz in temporate vegetations (23);
b. A pattern with a constant, frequency-independant excess attenuation in the low and mid frequency range of about 20 dB/100 m up to 2 kHz and an increasing excess attenuation with increasing higher frequencies (3);
c. A pattern showing two excess attenuation maxima in the low and the high frequency range of sound and a poor or even none excess attenuation in the midfrequencies (1,2,6,7,20 and 22).

A more complete review of this field of research can be found in reference 15. Since there seems to exist a disagreement in the different results, our laboratory started a number of experiments to investigate the complex processes of the interactions between forests and sound propagation.

2. ANALYSIS OF THE PROBLEM.

Forests, vegetations or plant communities are complex acoustic media when compared to air and the atmosphere or some defined materials, since three major components are found in a forest: air, ground surface and plant material, which act upon each other.

The ultimate scope of all investigators is to understand the propagation of sound waves through this complex system and it is logical, therefore, that experiments are carried out over rather long distances up to a few kilometers. The measured sound pressure levels are a summation of air absorption, as a result of the meteorological conditions in the investigated vegetation, which differ markedly from the conditions over level soil surfaces without trees and shrubs (5,11,21 and 24); the ground reflection and absorption, that differs from grass covered soil surfaces (2,8 and 13) and the acoustic properties of the plant material itself. However, to understand and explain the causes of the sound propagation results found over short and long distances, knowledge must be gathered concerning the influences of the different parts of the total complex medium on the sound propagation and attenuation patterns.

Therefore, it will be evident from this analysis that a great number of different experiments must be performed to obtain a good understanding, explanation and ultimate solution of the sound propagation in forests.

3. EXPERIMENTAL APPROACH.

3.1. Macro-level.

To obtain results for general use, i.e. excess attenuation values for noise abatement planning and frequency spectra for animal communication phenomena, we started our research in the late sixties with experiments on the macro-level. We measured the sound pressure levels versus the frequency at different source-receiver distances up till 100 m and we called the total of attenuation values and the frequency spectra the acoustic climate of a plant community. Those investigations were carried out in semi-natural forests (12) and in plant monocultures and plant communities (17). During the acoustic measurements meteorological data were collected inside the forests and in their surroundings. The temperature and relative humidity data are used to correct the measured sound pressure levels for air absorption, and the windspeed and winddirection are monitored in order to decide wether or not acoustic measurements could be performed.

Meanwhile,we focused on the reflection and absorption characteristics of the forest soil surfaces and other ground surfaces, since a part of the acoustic climate and the propagation pattern in a plant community occurred to be determined by the soil surface of that particular vegetation.

3.2. Micro-level.

As pointed out earlier,the soil surface and the plant organs influence the acoustic climate. To investigate the acoustic properties of those forest-components at a micro-level, i.e. with very short source receiver distances, experiments were carried out in an anechoic chamber. The sound propagation was measured in "model" forests existing in a number of small plants grown in buckets in a greenhouse. This kind of experiments offers the opportunity to investigate the net influence of plant material on the sound field, since the ground effect can be avoided (14).

A pulse sound method is developed to investigate the acoustic properties of soil surfaces (9). Finally a combination of this pulse method with a laser-Doppler-vibrometer system offers the possibility to investigate the vibration patterns of plant leaves and the

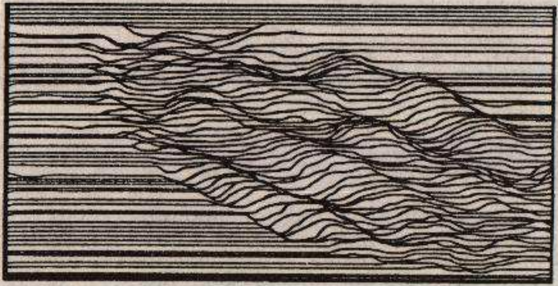

Figure 1.
Vibration velocity pattern of a _Vinca minor_ (periwinkle) leaf in a sound field of 3290 Hz at 120 dB sound pressure level.

acoustic properties of these plant organs in combination with their reflective characteristics (16 and 18). Figure 1 shows the vibration velocity pattern of a plant leaf in a sound field as is found with a laser interferometer scanning system (18).

4. STATE OF THE ART AND FUTURE DEVELOPMENTS.

What can be concluded for this moment concerning the sound propagation patterns referred to in chapter 1? From the increasing amount of results in this field it becomes clear that none of the three patterns is fully correct or totally false, since the measured patterns depend on the condition of the air during the experiment, the soil surface and the plant material on the one hand and on the other hand on the experimental arrangement of the source and the receivers. For, the height of the source and the receivers above the soil surface has consequences for the influence of the ground effect on the sound propagation pattern.

The use of models (10) which can be modified for temperature and windspeed gradients in forests as well as for the correct soil surface impedances will help to find the correct propagation patterns. From these modelstudies and the emperical data of the experiments on both macro and micro-level a better understanding of the sound propagation and attenuation in forests will be possible.

One should be very careful in using absorption-measures like dB/ft, dB/100 ft, dB/m or dB/100 m, since it is evident that the sound propagation in forests is influenced not only by linear processes. The hypothesis to use belts of vegetation as better noise abating structures than full grown vegetations (19,22) could not be confirmed in our investiations (17). Also more research on the influence of meteorological conditions in forests on the sound propagation need to be done to offer more and better emperical data to understand and calculate the air absorption in forests more complete.

5. ACKNOWLEDGMENT.

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