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SOUND PROPAGATION OVER GROUND WITH A BARRIER - SOME METEOROLOGICAL EFFECTS

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INTRODUCTION

It has been known for long that the state of the atmosphere influences sound propagation outdoors. Absorption, reflection, refraction and scattering due to turbulence are examples of different phenomena that take place. If some kind of barrier is present between source and receiver diffraction of sound occurs. When studying sound propagation outdoors one has to consider all these phenomena. Their interactions are very complex and their effects are not easily separated. Many models treating diffraction by a barrier on ground have been outlined, e.g. Thomasson [1]. Ray tracing methods have been used to take into account the refraction effect, but without any barrier. A modification of the Thomasson model is made here in an attempt to include the refraction effect. Simultaneous meteorological and acoustic measurements were made over bare and snow-covered grassland. A broad-band point source was placed near a barrier and sound levels on different distances and at two heights were reeorded.

MEASUREMENT SITE AND METHODS

The measurements have been made at the flat and grassy area of the Marsta Meteorological Observatory, 59°55' N, 17°35' E Gr., about 11 km north of the city of Uppsala.

A metal barrier, 51.9 m long and 2.6 m high, was erected and a sound source was placed 12.5 and 25 m from it at 1.25 m height. The sound source was a petrol-driven electric generator that had its exhaust pipe replaced by a horn. As shown in Larsson and Israelsson [2] it can be regarded as a point source. The sound was recorded at 25, 50 and 100 m from the source at 1.25 and 4.0 m height. The recording time was 5 minutes. Before, and sometimes after each measurement period the background sound level was recorded for 1.5 minutes.

The meteorological measurements were made in an adjacent 10 m high mast. Wind speed and temperature were measured at 0.5, 1.6, 3.8 and 10.0 m height. Wind direction was taken at 10.0 m height. The meteorological parameters were sampled every 10 s by means of a Microdata 1600 L data logger. Air pressure and humidity were taken from the routine observations made by the Observatory personnel.

The sound recordings were analysed in 1/1-octave bands using a B & K 2131 Digital Frequence Analyzer. For each octave band the sound level was checked and rejected if it was not at least 10 dB higher than the background level. For the meteorological parameters mean values were calculated for each measurement period. All computations were made using a computer at the Uppsala University Data Center.

MEASUREMENT RESULTS

The wind- and temperature gradients are very important meteorological parameters for the propagation of sound over ground with a barrier. These gradients cause refraction of the sound rays, which influences the sound level.

By using the following formula for the radius of curvature R for horizontal sound rays a facile parameterization of the refraction phenomena can be deduced:

$$R = \frac{c\left(1 + \frac{u}{c}\right)^2}{\frac{10}{\sqrt{T}}\frac{\partial T}{\partial z} + \frac{\partial u}{\partial z}} \qquad (1)$$

where T, u, $\frac{\partial T}{\partial z}$ and $\frac{\partial u}{\partial z}$ are the temperature in K, wind component velocity in ms^{-1}, and their vertical gradients in Km^{-1} and s^{-1} respectively; c is the sound velocity in calm air corresponding to the temperatue T. The inverted value, 1/R, has been used as an external parameter describing refraction in the atmosphere for near horizontal sound rays [2]. Negative 1/R-values indicate that the sound rays are bent upwards and positive values indicate downward bending.

An example of the results from the field measurements is given in Fig.1. The 1/R-value has been calculated for every measurement. The material has been divided into nine 1/R-intervals. The limits of intervals 3-6 are given at the bottom of Fig.2.

The insertion loss given in Fig.1 is deduced by subtraction of the mean sound pressure level with the barrier from the value without the barrier for the same ground, 1/R-interval, distance and heights of source and receiver. The sound levels are reduced to conditions with no atmospheric absorption, *i.e.* no attenuation due to humidity.

From Fig.1 we can see that the insertion loss mostly decreases with greater distance and lower 1/R-interval. The insertion loss for the

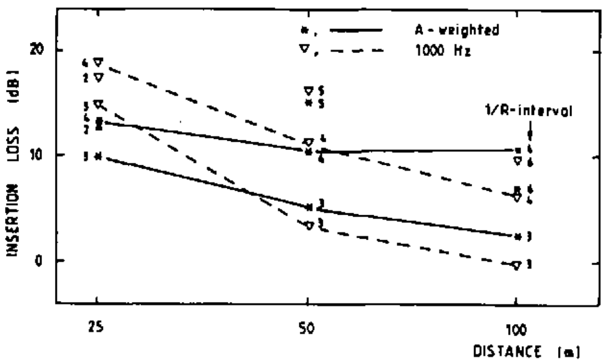

Figure 1. Mean insertion loss versus distance source-receiver for different sound ray curvature (1/R). Distance source-barrier: 12.5 m. Source and receiver height: 1.25 m. Snow-covered ground.

1000 Hz octave band tends to zero for the 1/R-interval no.3 at the distance 100 m.

A barrier reduces the sound level for moderate distances behind it. For greater distances the reduction diminishes. Even small changes in refraction, *i.e.* weather conditions, influence the insertion loss considerably, *e.g.* 10 dB at 100 m.

MODEL RESULTS

The model outlined by Thomasson [1] treating diffraction by a barrier on an impedance boundary was modified by calculating "virtual" source and receiver positions as functions of the curvature of the sound rays, Eq. 1, so as *e.g.* positive curvature "raises" the source and the receiver. The technique is thouroughly described in Hallberg et al [3]. The ground admittance was measured by Thomasson. An example of the results from the model is given in Fig.2.

We see that the modification of the model seems to be able to simulate effects of changing curvature, *i.e.* changing refraction. The model values are calculated for discrete frequencies, while the measured ones are octave band values. However, the model sound level for the middle frequency is a good approximation of the mean model sound level within the bands.

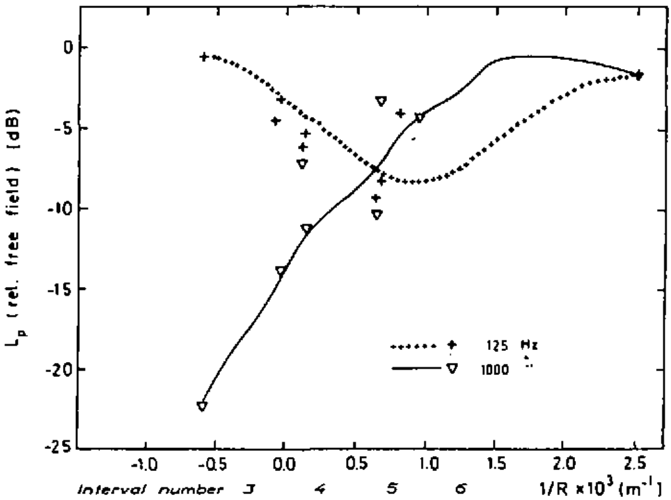

Figure 2. Measured and model values of sound level relative free field versus sound ray curvature (1/R). Distance source-barrier: 12.5 m. Distance source-receiver: 100 m. Source and receiver height: 1.25 m. Ground: grassland.

ACKNOWLEDGEMENT

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