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STUDIES OF OUTDOOR SOUND OVER COMPLEX TERRAIN

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ABSTRACT

The efficiency of screens of various designs and of earth berms should be estimated not only in a still atmosphere but also taking into account the effect of wind. Downwind may severely reduce the insertion loss and this fact should be taken into account in the design phase. A design is only suitable if it provides a relatively high insertion loss under downwind conditions as well as in a still atmosphere. In an attempt to address this problem, scale model results showing the influence of a screen and an earth berm under different wind-conditions will be presented along with theoretical calculations based upon parabolic equation methods.

1 - INTRODUCTION

The efficiency of noise abatement measures, such as noise screens of various sizes and shapes and earth berms, is relatively well known for a still homogeneous atmosphere whereas it is largely unknown under windy conditions. Especially the case of downwind is important since the wind field tends to carry the sound over the screen or berm and thus reduce the insertion effect of the object in question. Measurements of the efficiency of noise barriers when wind is taken into account are very rare. In this work a previously used experimental technique based upon scale models is extended to the more complicated case of wedge shaped obstacles on the ground, i.e. berm shaped barriers. When such barriers are investigated in the presence of wind the scenario becomes very relevant from a practical point of view. The theoretical problems involved in mathematically well founded calculations for such a case are rather formidable, however.

For the case of berms in a still and homogeneous atmosphere, boundary element calculations may be successfully applied whereas the class of parabolic equation calculations is not directly applicable. Parabolic equation methods could be used provided that a conformal transform technique is applied in order to transform the non-flat domain of calculation into a plane one. Direct application of parabolic equation methods to uphill sound propagation is problematic and when it comes to downhill propagation on the far side of the berm the problems become even greater since the key issue becomes one of extrapolation rather than interpolation (as the case was on the uphill side). For the slightly simpler case of a screen there is a problem with the parabolic equation models from a theoretical point of view but in practice efficient solutions exist.

When the flow of air over a simple screen is taken into account, the precise velocity distribution of the wind field in proximity of the screen becomes important. This flow pattern has been investigated experimentally and theoretically by means of solutions to the Navier-Stokes equations. Acoustic calculations based upon parabolic equation solutions to the fundamental acoustic problem of a simple screen on a finite impedance ground, in connection with a realistic wind velocity distribution close to the screen has previously given results in very good agreement with measured data from scale model simulations [1,2].

For the case of an earth berm two problems remain: Firstly to formulate a solution which is accurate in the presence of a wind field, secondly to provide a reasonable estimate of the wind field in the vicinity of the berm.

In the present work only laminar flow is discussed. The case of an earth berm on a grass-covered surface is experimentally investigated taking wind effects into account. Theoretical comparisons with Boundary

Element calculations for no wind and with parabolic equation calculations taking wind into account are provided [3].

The flow around the obstacle plays a very important role in the acoustic effect of the obstacle. A practical approximate scheme has been developed for obtaining suitable flow estimates in the vicinity of a simple screen [2]. This scheme is based upon measured data and results from computational fluid dynamics.

In this work calculations involving flow over earth berm are all based upon calculations for an equivalent simple screen. Obviously, this is a simplification, which introduces deviations between measured and simulated data.

2 - RESULTS

Figure 1 shows the geometry for which a number of experiments have been carried out. The ground could be an outdoor surface covered with vegetation. It is an impedance surface specified by a flow resistivity of 7 $\mathrm{kNsm}^{-4}$and a layer thickness of 0.025 m (full scale) in the Attenborough two-parameter model. All parameters and results are provided in relation to full scale. Figure 2 shows wind data (4m/s). Figure 3 shows results for the no wind condition. Calculations for a simple screen of the same height as the berm are also included. The screen is seen to be more efficient than the berm at low frequencies. Figure 4 compares measured data for downwind (4m/s), nowind, and upwind (2m/s and 4m/s). The strong influence of the wind is apparent. Figure 5 presents comparisons of measured data with simulations for a simple screen of the same height as the berm for upwind, and in Figure 6 such a comparison is carried out for downwind. Two versions of flow simulations are used; one is directly according to [2] and the other treats the flow as if the screen was only 1.5 m whereas the acoustic screen height is maintained at 2m. This reveals the strong influence of the flow pattern close to the screen, since away from the screen the flow is the same in both cases. Figure 7 shows an additional curve for the case where the wedge shaped berm has been covered with the same impedance as the plane part of the ground. The influence of the finite impedance of the wedge is modest, especially at higher frequencies. Figure 8 shows a comparison of measured and simulated data for a simple screen of height 1.5m. In this case the object of measurement is of the same physical shape as is used in the simulations and the agreement is good. Furthermore, the measured results for downwind are seen to be very similar to those presented in Figure 6 for a wedge structure of a greater height, in spite of the marked differences seen for the case of still atmosphere. Hence, a screen is more effective for no wind, but under downwind conditions the berm can be more favorable because of the more benign redirection of the wind caused by the berm.

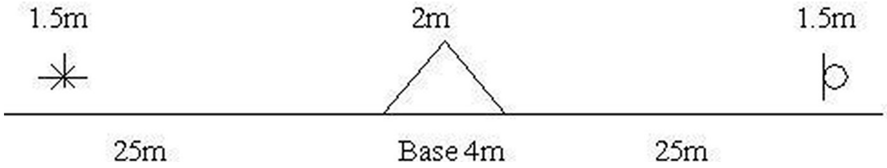

Figure 1: Wedge shaped berm on finite impedance surface; source to receiver distance is 50m.

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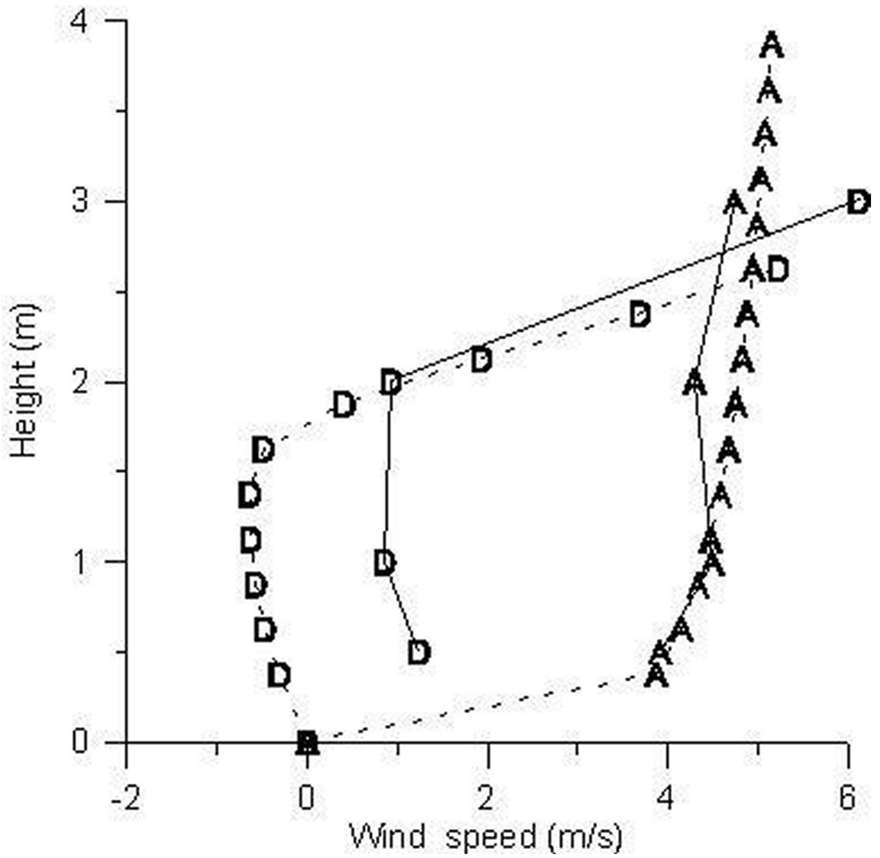

Figure 2: Wind speed for downwind; distance from source: A 9m, D 27m; full curve: measured; interrupted curve: calculated according to 1.5m screen.

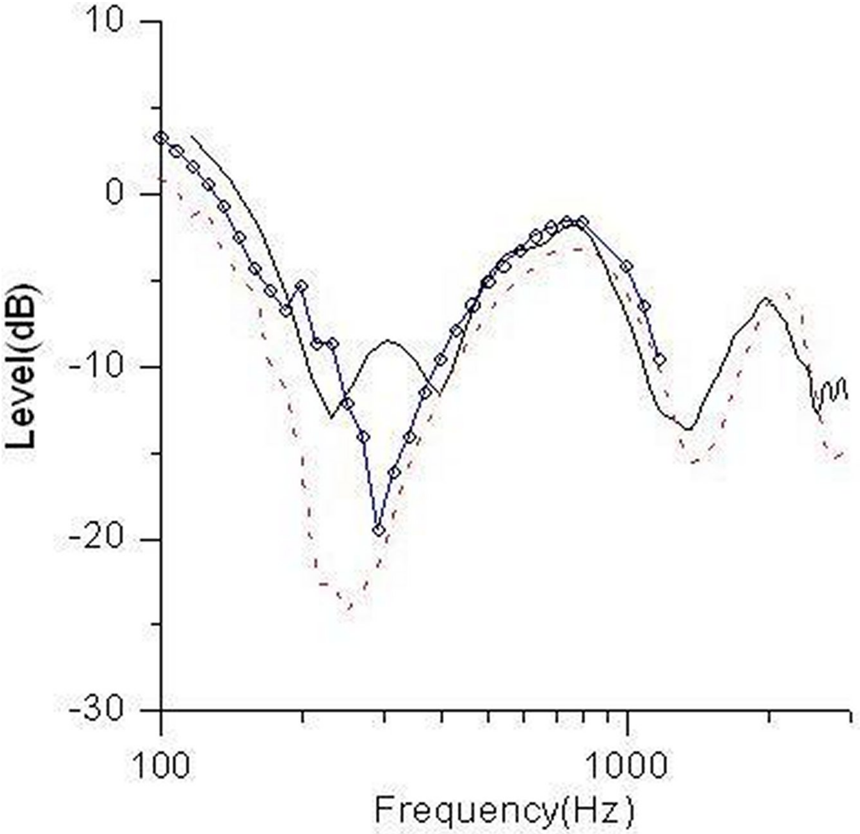

Figure 3: Measured data for berm for no wind, full curve; BEM calculation for berm, circles; PE calculation for simple screen, interrupted curve.

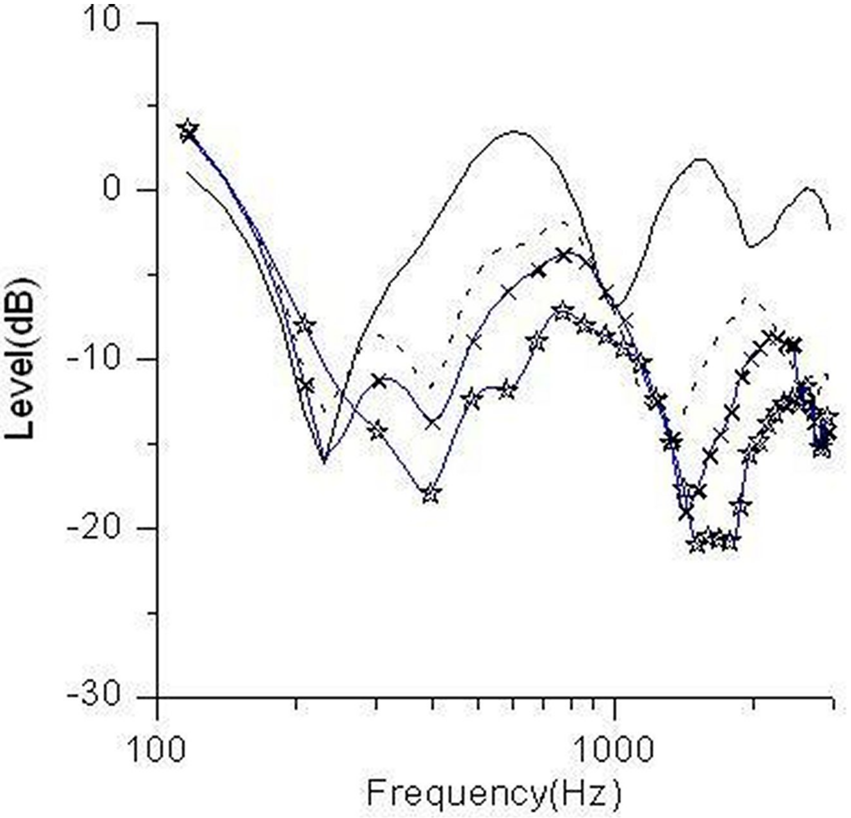

Figure 4: Measured data for berm under downwind conditions, full curve; no wind, interrupted curve; and upwind 2m/s and 4 m/s.

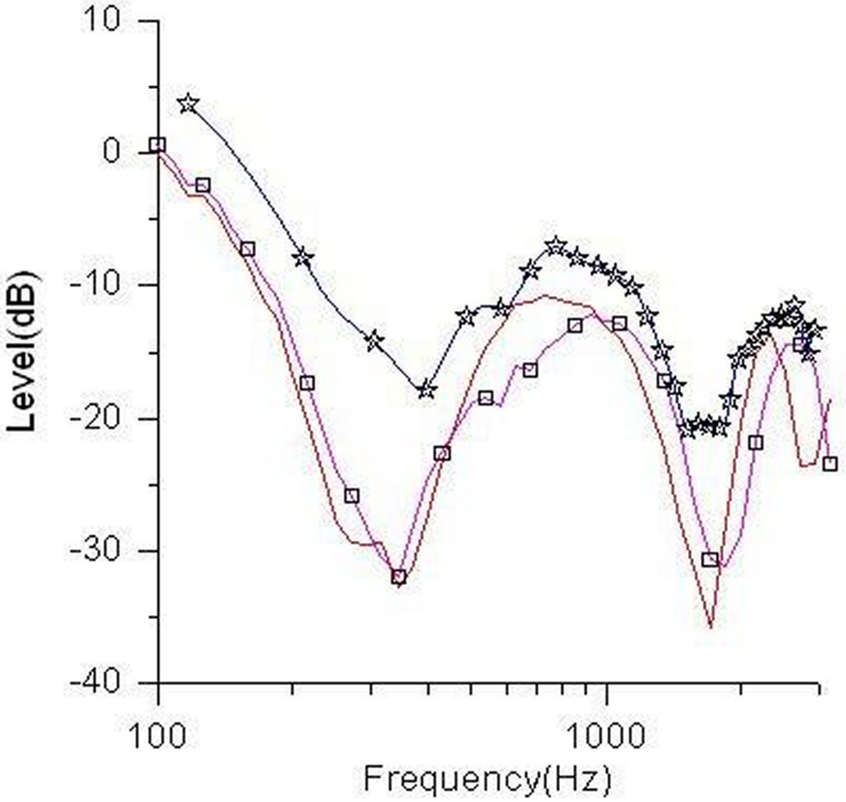

Figure 5: Measured data for berm under upwind conditions, -4m/s (stars) and PE simulations for equivalent screen (simple full curve); curve marked by square symbols shows PE data when the flow is estimated for a screen of only 1.5m height.

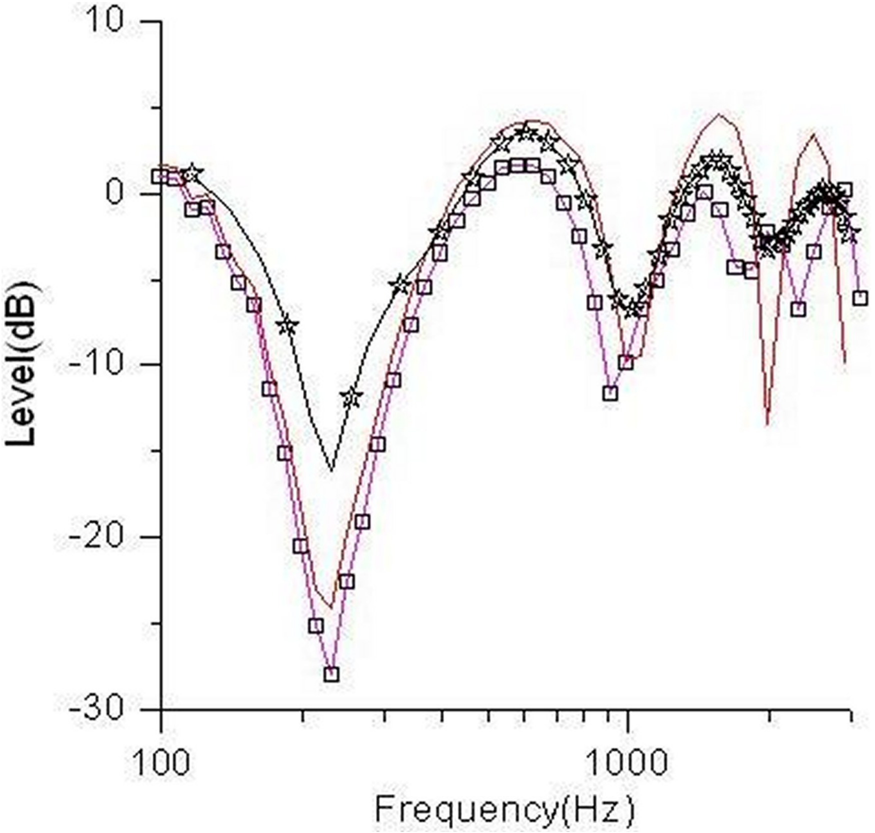

Figure 6: Equivalent to Fig. 5 but for downwind.

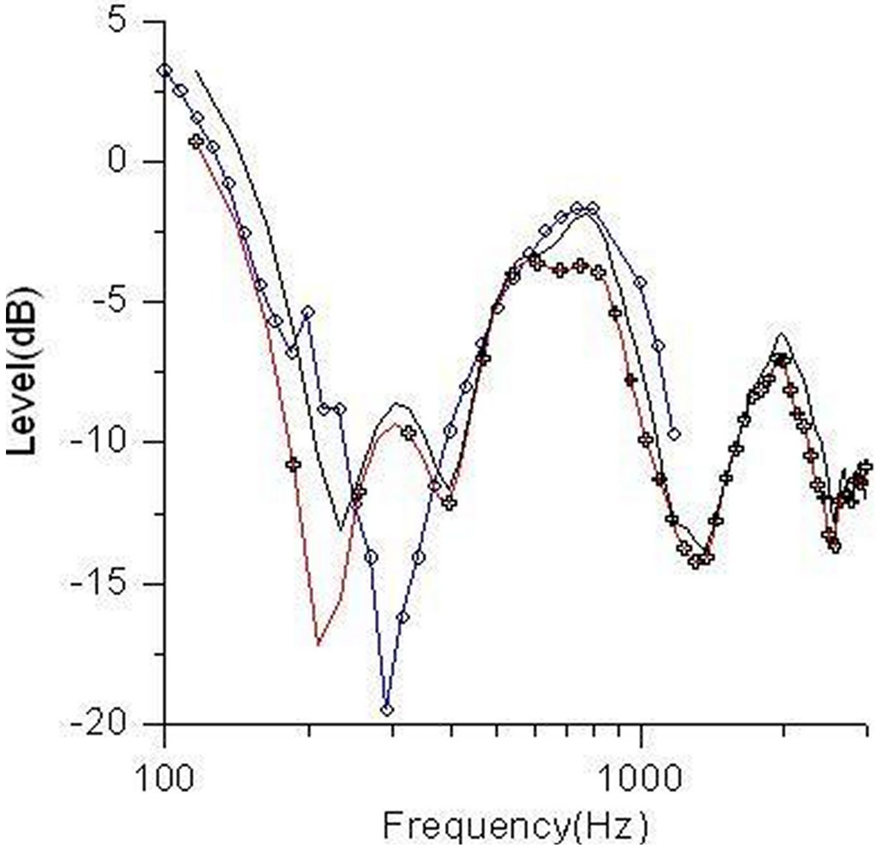

Figure 7: Impedance study: measured data for hard wedge, full curve; measured data for finite impedance wedge, curve with pluses; BEM calculations for hard wedge, curve with circles.

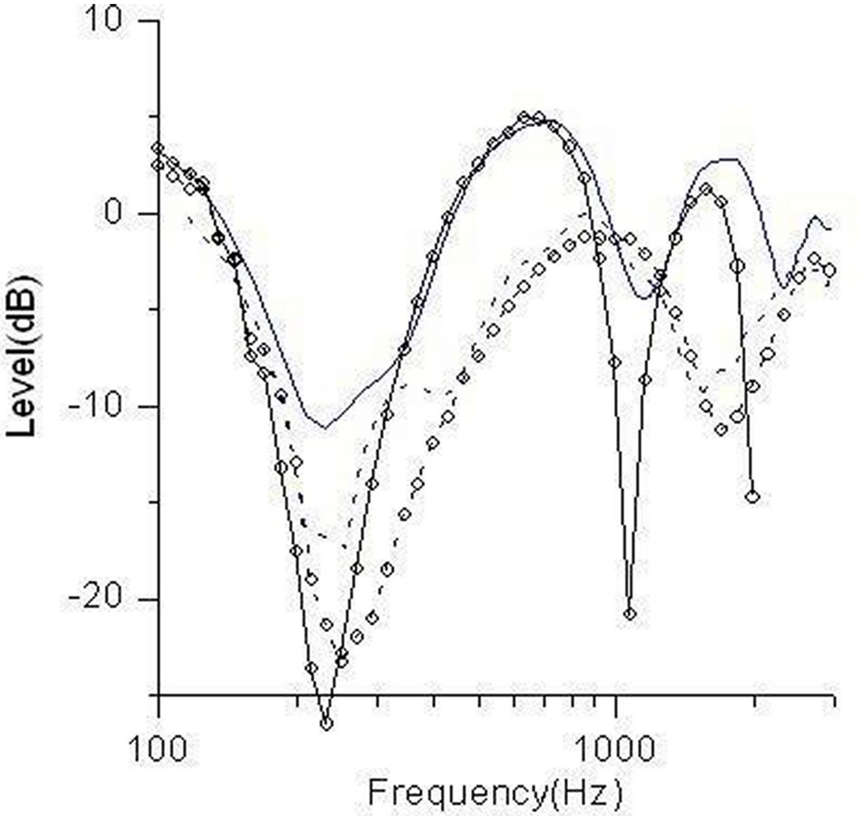

Figure 8: Wedge replaced by 1.5m screen measured under 4m/s and 0 m/s conditions (interrupted curve); circles are PE simulations.