inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 2.4

NORD 2000. EFFECTS OF DIFFRACTION IN THE NEW NORDIC PREDICTION METHODS FOR ENVIRONMENTAL NOISE

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Keywords:
OUTDOOR SOUND PROPAGATION, DIFFRACTION, ENVIRONMENTAL NOISE

ABSTRACT
It is important to correctly model the effects of diffraction in a modern environmental noise prediction method. The new Nordic prediction methods shall be able to evaluate noise barriers of different types and combinations, both in order to determine the insertion loss and to compare different configurations of barriers. This paper presents the solutions chosen for the new Nordic prediction methods. Since the methods must be computationally effective, all models used are analytical solutions, sometimes somewhat modified. A simple thin screen is dealt with using a combination of diffraction theory and the spherical reflection coefficient. For wide screens, such as earth berms, and multiple screens, the diffraction coefficients of the different edges are combined, and a larger number of ray paths are taken into consideration. The method handles scattering by turbulence into the shadow zone behind a barrier by using the scattering cross-section of the turbulence. Refraction is dealt with by modifying the diffraction and reflection angles and for long ranges by adding ray paths that pass above the barrier.

1 - INTRODUCTION
The quality of a modern environmental noise prediction tool is very much influenced by the way it handles diffraction. Without proper treatment of complex situations involving natural and constructed noise barriers, no conclusions about the effects of different noise reducing measures can be drawn.
Complex situations can be handled by numerical methods, but they are too slow to be used in a prediction tool. Exact analytical solutions exist in a few simple cases, but can be combined in order to get a more complete solution. The Nord 2000 project has taken such an approach, and this paper describes how the effects of diffraction have been included in the method. A number of field measurements have been made in the project in order to verify the chosen models, and a few comparisons are included here.

2 - SINGLE EDGE DIFFRACTION
Single edge diffraction is handled by an analytical diffraction solution for an infinite rigid wedge by Hadden and Pierce [1]. This solution is combined with the effects of impedance sides using a method described in [2], where the spherical reflection coefficient of the wedge side is combined with the diffraction coefficient. The ground effect is introduced by using a method inspired by the Fresnel zone method for calculating the effect of impedance jumps suggested by Hothershall.
An interesting case is a very low screen. When the screen becomes sufficiently small in comparison with the wavelength it can no longer be considered as infinite when calculating the diffraction coefficient. This can be handled with various numerical methods, but no applicable analytical solutions exist. It is therefore necessary to introduce a modification to the basic theory in order to reduce peculiar effects for very low screens. In the Nord 2000 model there are three criteria for when a screen situation is no longer calculated using diffraction theory, and they are all dependent on the frequency. First and foremost the screen height must be larger than a fraction of the wavelength. Secondly the screen height must be larger than the Fresnel zone width at the screen, and thirdly the screen must have an influence on the propagation, i.e. break the line of sight.

The single screen model has been verified successfully against numerical calculations, model experiments and full-scale measurements. A full-scale measurement result will be discussed in section 5.

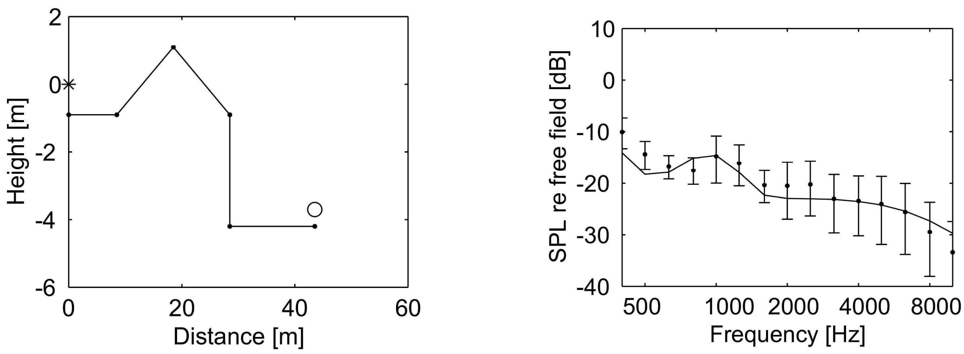
3 - MULTIPLE EDGE DIFFRACTION

Multiple diffraction is important for wide barriers, or for situations where more than one barrier is important for the screening effect. The basic principle used is the method described in [2], where single diffraction coefficients are combined in order to yield the multi edge diffraction coefficient. The total effect of diffraction and ground effect is again calculated by a method inspired by the Fresnel zone method.

The number of necessary calculations increases rapidly as the number of diffracting edges increases, therefore should a more complex shape be reduced to a situation with fewer edges. For most purposes two or three diffracting edges will be sufficient in order to get a good prediction.

The problem with low barriers is exactly the same as in the single edge case, and the same criteria can be used for when the screening becomes significant.

A full-scale outdoor measurement is compared to predictions in figure 1. The impedances of the surfaces were measured or estimated, and the result is presented between the third octave bands 400 Hz to 10 kHz. Two edges give an important contribution to the diffraction, and there is a reasonable agreement for high frequencies. For low frequencies the background level affects the measurements, which makes them unreliable. Note that the error bars are big for high frequencies due to unstable atmospherical conditions during the measurement.



(a): Geometry, * indicates the source position, and o the receiver.

(b): Solid is the predicted level and error bars indicate the 95% confidence interval of the measurements.

Figure 1: Comparison between measured and predicted sound pressure level relative free field in a multi-edge diffraction case.

4 - EFFECTS OF TURBULENCE

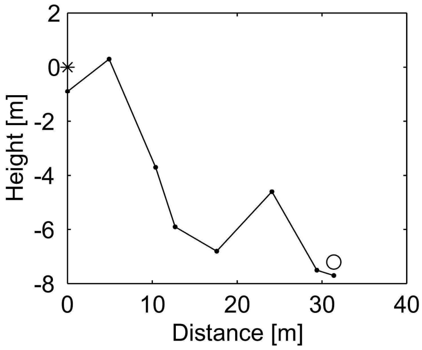
Many authors have investigated the effect of atmospheric turbulence on the insertion loss of barriers. In principle turbulence scatters sound into the shadow zone of the barrier, mainly at high frequencies. In the Nord 2000 model this effect is handled by using the scheme developed by Jens Forssén [3], which uses the scattering cross section of the turbulence to estimate the scattered sound power.

An example is presented in figure 2, where a measured double wedge situation is compared to predictions with and without turbulence. In a case like this the effects of turbulence will be very important at high frequencies.

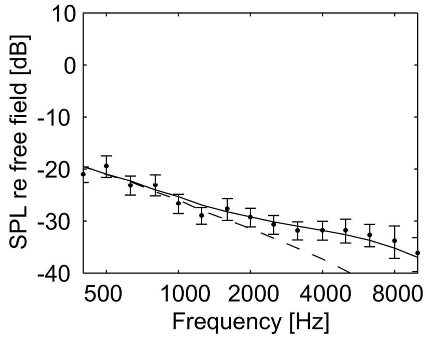
5 - DIFFRACTION AND REFRACTION

The effects of refraction become more and more important as the distance between source and receiver increases. These effects are twofold; firstly the diffraction angles are changed by the curvature of the sound rays and secondly rays may exist that pass above the barrier. A good summary on how to approximated these effects in ray acoustics is given in [4], and a similar method has been introduced into the Nord 2000 model.

In figure 3 a measurement under strong upwind conditions is displayed. The predictions shown are without refraction, and by using a linear sound speed gradient to modify the diffraction angles. Again the higher frequencies are where the accuracy is affected the most. For low frequencies the background



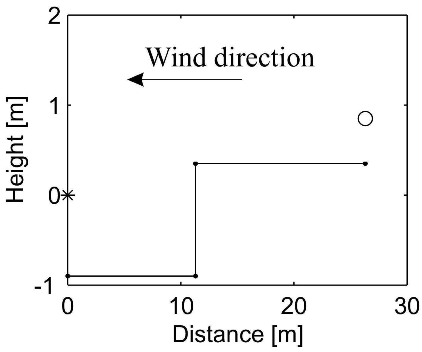
(a): Geometry, * and o indicates the source and receiver position respectively.



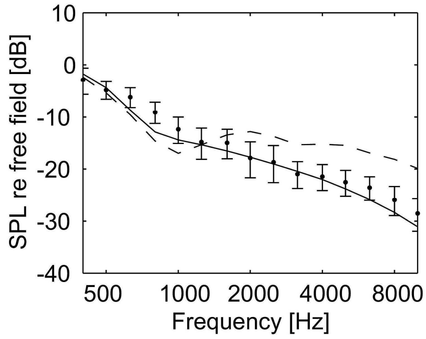
(b): Solid is the predicted level, dashed predicted without turbulence and error bars indicate the 95% confidence interval of the measurements.

Figure 2: Comparison between measured and predicted sound pressure level relative free field in a case where scattering by turbulence is important.

level was high due to wind-induced noise at the microphone, which makes the measured results unreliable there.



(a): Geometry, * and o indicates the source and receiver position respectively; there is a strong wind in the negative x-direction.



(b): Solid is the predicted level, dashed is predicted without refraction and error bars indicate the 95% confidence interval of the measurements.

Figure 3: Comparison between measured and predicted sound pressure level relative free field in a case where refraction is important.

6 - CONCLUSIONS

- In order to get good predictions of noise levels in situations were diffraction is important, the effects of refraction and scattering by turbulence should be included.
- A model combining the above effects with the ground effect and effects due to unstable atmospherical conditions can give good results compared to full-scale measurements.

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