PREDICTED EFFECTS OF GROUND ON SOUND RADIATION FROM FACTORIES

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INTRODUCTION

In the literature calculations of ground effect have been dominated by consideration of either point sources or line sources (in relation to traffic noise). Nevertheless there has been some research into the effects of finite source size and directivity in regard to industrial noise sources [1] and to aircraft noise [2]. On the other hand, classical considerations of propagation from finite sources [3,4] such as window panels modelled either as continuous or discrete distributions of point sources of equal intensity have ignored ground effect, while remarking that it should be considered if the length of the propagation path is significant (3). This paper offers results of an initial approach to the problem of predicting noise levels at distances up to several hundred metres from large factory buildings radiating noise from several points or elements of their external envelope. Computer simulations of the field from 3- and 2-dimensional arrays of point sources at 1 m separations are used. The sources are assumed of equal intensity and either totally coherent such that their individual sound pressures may be added or totally incoherent so that individual sound energies are added.

THEORY

The sound field due to each point source is approximated by the acoustic equivalent of the Weyl-van der Pol Formula for the field above a locally reacting boundary [4] in the form

$$P_{tot} = \frac{e^{ikr_1}}{r_1} + \frac{e^{ikr_2}}{r_2}\left[R_p + (1 - R_p)\, F(w)\right] \qquad (1)$$

where r_1 and r_2 are distances from the source and its mirror image in the ground plane to the receiver, respectively. R_p is the plane wave reflection coefficient given by

$$R_p = \frac{\cos\theta - \beta}{\cos\theta + \beta} \qquad (2)$$

where θ is the angle of specular incidence and β is the normalised normal admittance (= 1/Z). F(w) is the boundary loss factor being a complex function of the numerical distance

$w = ikr_2 (\cos\theta + \beta)^2/2$..

Z is calculated as a function of frequency from

$$Z = A(1 + i)/f^{\frac{1}{2}} + iB/f \qquad (3)$$

corresponding to a variable porosity ground model [5], where A and B are constants related to flow resistivity and rate of change of porosity with depth.

Equations (1) - (3) are used to calculate the field due to each source in the array specified by coordinate as indicated in Fig 1, and the pressures or energies are added to give the total field. Subsequently the excess attenuation may be calculated from

$$20 \log \left| \frac{\text{direct field}}{\text{total field}} \right|$$

where the direct field is obtained by adding the direct (inverse square law) contributions from all the sources in the array.

RESULTS

It is straightforward to show that ground interference effects are rapidly annihilated by incoherence. Figure 2 illustrates this for a 2 x 2 m array of four sources. For coherent sources, the ground effect dip is most affected by the array height and depth (in that order). This is illustrated by Figures 3(a) and 3(b). The length (in the YZ plane, see Fig 1) is relatively unimportant since a considerable change in length is required to produce a significant change in the path length difference between direct and ground-reflected sound rays. The prediction for the sound field at a centre line distance of 30 m from the facade of a hypothetical building represented acoustically by a 30 x 250 m rectangular XZ-planar array of 100 coherent point sources each separated by 10 m and at a height of 5 m above the relatively hard ground plane is shown in Figure 4. This shows a substantial and broad ground effect dip between 200 and 800 Hz.

CONCLUSIONS

Clearly more work is required on acoustical modelling of radiative elements of factory shells in terms of size, coherency and directivity. More sophisticated methods of including ground effects through surface area integrations should be explored. Meteorological effects should also be included. Nevertheless at this early stage it may be concluded that ground effect will play an important part in modelling propagation of noise around factories.

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REFERENCES

[1] E J Rathe, J Sound Vib (1969) 10 (3), 472-479.

[2] Z Maekawa, Applied Acoustics (1970) 3, 225-238.

[3] J B Moreland, J Acoust Soc Am (1985) 78, 590-597.

[4] C A Yoerkie and R S Larson, AIAA Journal (1987) 1-13.

[5] K Attenborough, S I Hayek and J M Lawther, J Acoust Soc Am (1980) 68, 1493-1501.

[6] K Attenborough, J Sound Vib (1985) 99, 521-544.

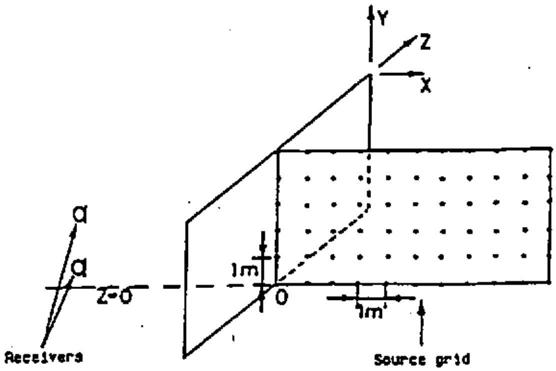

Fig.1 Schematic of source array receiver geometry.

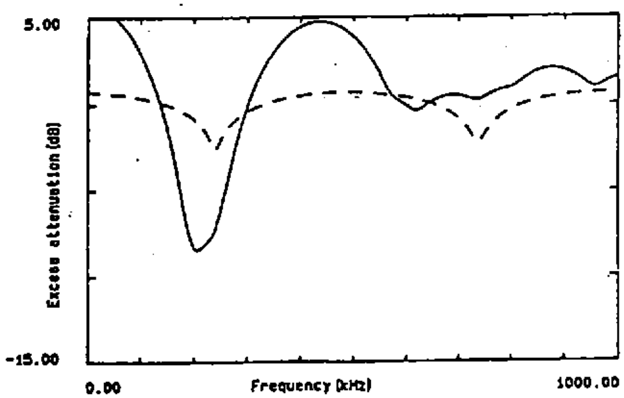

Fig.2 Comparison of excess attenuation spectrum for two different source arrays.
Solid line - coherent 2*2 array.
Broken line - incoherent 2*2 array.
Predictions based on the variable porosity model of ground with flow resistivity =20000000 mks rayls/m, alpha=150/m.
For the 2*2 array source separation = 1.0m. First source is at a height of 3m above ground level and at a range, R of 10.0m.
Receiver at 1.2m.

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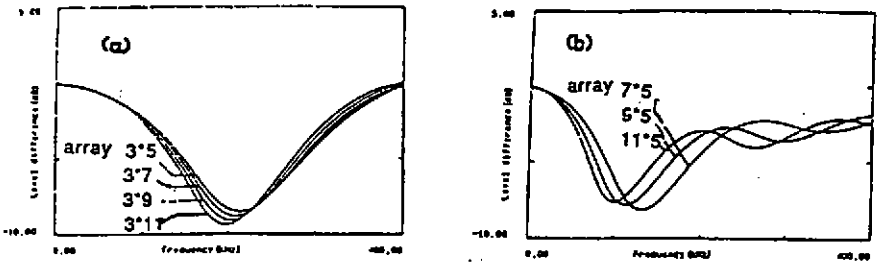

Figure 3 : Sensitivity of ground effect dip to changes in x-y plane coherence point source array size (length) using the variable porosity model of ground with alpha = 150 (1/m) and sigma = 200000 MKS units. Source separation = 1.0m. First source is at height of 3m above ground and at a range of 20.0m. Receivers at 0 & 2m.

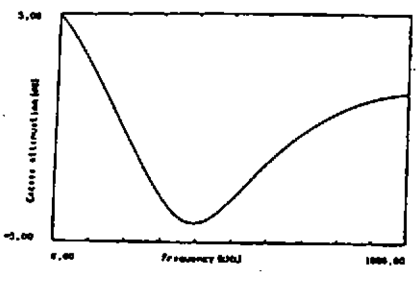

Figure 4 : Excess attenuation spectrum for a large (30m*250m) x-z plane source modelled by an array of 100 coherence point sources. Ground model as in figure 3. Source plane is at height of 5m above ground level and the nearest source is at a range of 30.0m from the receiver. Source separation of 10.0m. Receiver at 1.2m.

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