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SOUND REDUCTION BY A FINITE BARRIER OF ARBITRARY SHAPE

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Introduction

This paper describes a technique for the prediction of sound attenuation afforded by an arbitrarily shaped screen of finite dimensions. In order to illustrate effectively this technique, a basic model is assumed which comprises a two dimensional barrier placed between a monotonic point source of sound radiating spherical waves and the monitoring position at which the sound pressure level (SPL) predictions are to be made. Further, this ocnfiguration is assumed to be constructed in free field surroundings, so that minimal considerations are given to calculations which are extraneous to the essential purpose of the work. The basic model may of course be extended to simulate more realistic surroundings (for example reverberant conditions, by invoking the method of images, and random sources of noise, by extending the frequency analysis).

The paper therefore concentrates on the edge diffracted wave field and the analysis is based on a Fresnel-Kirchhoff diffraction integral which is a surface integral over the area of the screen. The technique employed is to subdivide the surface of the barrier into a number of rectangular elements and the diffraction integral is solved separately on each element.

Theoretical studies in published work have been approximate and also restricted to rectangularly shaped barriers. (1 to 3) This paper presents a rigourous theoretical approach to the calculation of attenuation of sound due to finite barriers. The theory leads to final explicit expressions for the sound attenuation due to the screen. A computer program has been developed which performs the numerical calculations on input of the parameters relating to the configurations of source, barrier and monitoring position. viz frequency and position of source, position of receiver, the SPL at unit distance from the source, and the dimensions and positions of each element in a subdivision of the barrier.

Formulation of the SPL equations at a Monitoring Position

It will be necessary to determine both the SPL at the monitoring position P with the barrier removed and the SPL reduction, or attenuation, due to the insertion of the barrier between the source S and the monitoring position P.

Since the point source is assumed to operate at monotonic frequency and the surroundings are free field, the complex disturbance at the point P with the barrier omitted is given by the spherical wave equation (4) in the form:

$$U_{WOB}(P) = \frac{Ae^{ik\bar{s}\bar{p}}}{\bar{s}\bar{p}} \qquad (1)$$

Where $U_{WOB}(P)$ is the disturbance at P in the free field
SP is the distance from S to P, $k = 2\pi/\lambda$ where
λ is the wave length, and A is the amplitude at unit distance from S.

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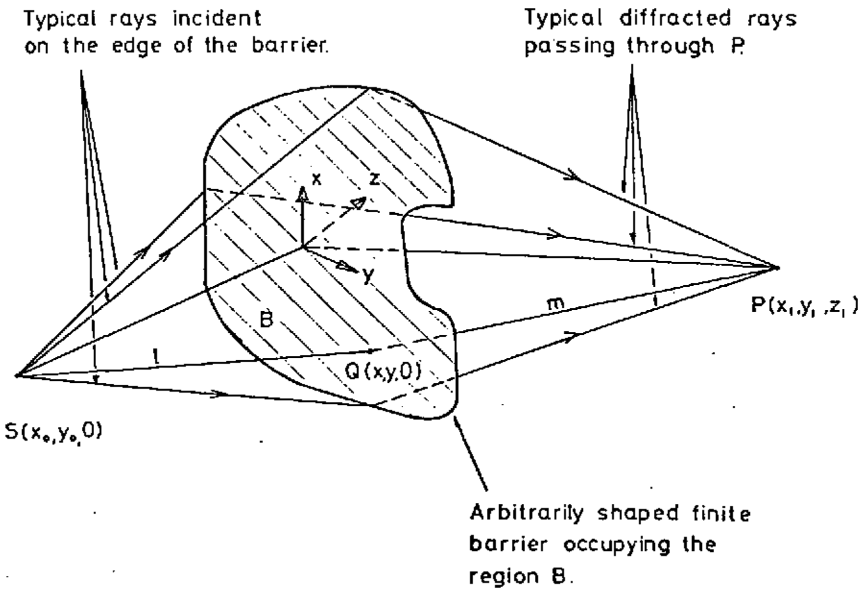

FIG 1 DIFFRACTION AROUND THE EDGE OF THE BARRIER AND THE CO-ORDINATE SYSTEM Oxyz

A Cartesian co-ordinate system is chosen with O_{xy} defining the plane of the barrier see figure 1. With the barrier in position, the disturbance at P will be due to any sound received directly from S in addition to that due to diffraction round the edge of the barrier. Let B be the region in the x-y plane occupied by the barrier. Then, by Babinet's principle (5), the complex disturbance $U_B(P)$ at P in the presnece of the barrier is given by:

$$U_B(P) = U_{WOB}(P) - U_B(P) \qquad (2)$$

where $U_{WOB}(P)$ is given by equation (1), and $U_B(P)$ represents the Fresnel-Kirchhoff diffraction equation (6) given by the following

$$U_B(P) = -\frac{A_i}{2\lambda}\iint_B \frac{e^{ik(l+m)}}{lm}\,[\cos(n,\ell) - \cos(n,m)]\,dS \qquad (3)$$

Where ℓ and m are the distances from S and P respectively to the variable point Q on B (Fig 1) and (n,ℓ) and (n,m) are the angles made by S and P with the normal to the plane at Q. In view of equation (1) it remains to solve equation (3) in order to determine $U_B(P)$. However, the integral is not immediately applicable to the region B due to conditions imposed on the dimensions of the area of integration (6). This problem is overcome by subdividing the region B into smaller elemental regions $R_1, R_2, \ldots R_n$, the areas of which do allow the application of the diffraction equation see figure 2.

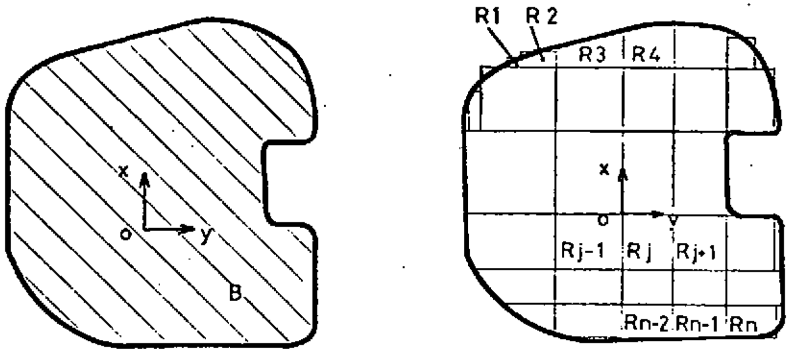

FIG 2 SUBDIVISION OF THE REGION B INTO ELEMENTAL RECTANGULAR REGIONS R_j, j = 1, 2, . . . n.

Equation (3) may be written as:

$$U_{\bar{R}j}(P) = -\frac{2A_i}{L_jM_j}\left[\cos(n,L_j) - \cos(n_jM_j)\right]e^{ik(L_j+M_j)}I_j \qquad (4)$$

where
$$I_j = \frac{e^{-ik(L_j+M_j)}}{4}\iint_{R_j} e^{ik(\ell+m)}\,dS \qquad (5)$$

and L , M , (n,L) and (n,M) are defined in (7)

Now $SPL_{WOB}(P)$ at P with the barrier removed is derived from equation (1) and is given by

$$SPL_{WOB}(P) = SPL_1 - 10\log\bar{SP}^2 \qquad (6)$$

where SPL_1 is the SPL at 1 m from S in free space and the attenuation $SPL_{RED}(P)$ due to inserting the barrier between S and P is given by:

$$SPL_{RED}(P) = SPL_{WOB}(P) - SPL_B(P) \qquad (7)$$

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where $SPL_B(P)$ is the SPL monitored at P with the barrier in position. $SPL_B(P)$ is derived from $U_B(P)$. This enabled a computer program to be written which calculated SPL_{WOB}($SPL_B(P)$ and $SPL_{RAD}(P)$ for any given configuration with the basic parameters as input data.

Summary

A theoretical investigation into noise reduction due to an arbitrarily shaped finite barrier in free space using rigourous diffraction theory has been carried out. The method used the technique of subdividing the barrier into elemental regions to enable a solution of the Fresnel-Kirchhoff integral. The final expressions for the SPL and attenuation at the monitoring position are given in terms of the basic parameters of the configuration of source, barrier and monitoring position. These parameters were used as input data for a computer program for the SPL calculations. The method is suitable for extension into more generalized surroundings other than the free field.

References

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