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SOUND FIELD OF A MOVING SOURCE IN THE VICINITY OF FINITE IMPEDANCE WALLS

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INTRODUCTION

Sound fields created by moving sources near impedance reflectors occur in spaces with a surrounding surface area combined of different segments and in the open, in the vicinity of ground - which is a case typical to the atmospheric acoustics. The theory was applied here to computer simulation in order to trace acoustic phenomena which appear during the motion of the sound source in such environments.

It is well known from investigation of sound propagation from a source near ground that four waves define this propagation. These are the direct wave, the reflected wave, the ground wave and the surface wave. In our analysis the two first dominant waves are considered, and it is shown that application of images is possible. Hence the classical formulation used for calculation of sound fields, due to a source moving along an arbitrary orbit, may be applied as a fundamental solution, useful also for definition of the acoustic field in the presence of reflectors.

FORMULATION AND SOME EXAMPLES

A. Linear motion of a source along x-axis :

The wave equation which describes the acoustic pressure field p(x,y,z,t) due to a moving excitation point of strength q(t) :

(1) $$\nabla^2 p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = -\frac{\partial}{\partial t}[q(t)\delta(x-vt)\delta(y)\delta(z)]$$

With a velocity potential ψ we have $p = \partial\psi / \partial t$ and the resulting wave equation is :

(2) $$\nabla^2 \psi - \frac{1}{c^2}\frac{\partial^2 \psi}{\partial t^2} = -q(t)\delta(x-vt)\delta(y)\delta(z)$$

the solution of which is :

(3) $$\psi(r,t) = \frac{q[t - \frac{R}{c}]}{4\pi R\,(1 - M\cos\theta)}$$

See figure 1 . Hence :

(4) $$p = \frac{1}{4\pi}\frac{q'[t-(R/c)]}{R(1-M\cos\theta)^2} + \frac{q}{4\pi}\frac{(\cos\theta - M)\,V}{R^2(1-M\cos\theta)^2}$$

B. Calculation of R :

At the moment of sound radiation towards a control point P the source is positioned at $r(t_e)$, and $t_e = t - R / c$. The distance R between the radiation point and the control point is :

(5) $$R^2 = [x - x_s(t-\frac{R}{c})]^2 + [y - y_s(t-\frac{R}{c})]^2 + [z - z_s(t-\frac{R}{c})]^2$$

and for motion along the x - axis :

(6) $$R = \frac{1}{1-M^2}[\, M(x - Vt) \pm \sqrt{(x-Vt)^2 + (1 - M^2)\, r^2}\,]$$

with

(7) $$r^2 = y^2 + z^2 \quad ; \quad M = \frac{V}{c}$$

Which, for supersonic propagation yields two solutions. See figure 2. Figure 3 illustrates the situation where a source moves along a straight line at the velocity of 100 m/s, and the source frequency of 150 Hz.

C. Sources in the vicinity of reflecting surfaces.

The wave equation (2) should be satisfied together with the following boundary equation :

(8) $$[\frac{1}{c}\frac{\partial}{\partial t} - \xi\frac{\partial}{\partial y}]\, \Psi(x,y,z,t) = 0$$

With : $\xi = Z_s / \rho c$. However, in order to satisfy the boundary conditions an additional potential field, which is created by an image source may be used as a replacement. If the source moves in parallel to a plane reflector, at the distance h , the result is :

(9) $$\psi(x,y,z,t) = \frac{q_0}{4\pi}\exp(-ik\gamma^2(ct - Mx))\, [\frac{\exp(ik\gamma^2 R_1)}{R_1} + r\,\frac{\exp(ik\gamma^2 R_2)}{R_2}]$$

with

$$\gamma^2 = 1/1\text{-}M^2$$

(10) $$R_1 = \sqrt{(x - Mct)^2 + ((y - h)/\gamma)^2 + (z/\gamma)^2}$$

$$R_2 = \sqrt{(x - Mct)^2 + ((y + h)/\gamma)^2 + (z/\gamma)^2}$$

and the reflection coefficient :

(11) $$r = \frac{\xi(y + h) - \gamma^2(R_2 + M(x - Mct))}{\xi(y + h) + \gamma^2(R_2 + M(x - Mct))}$$

See figure 4 for a motion in the vicinity of such a surface.

MOTION OF A SOURCE BY FINITE REFLECTORS

Using again the image source as an approximation for the finite reflectors, it becomes only a problem of timing, as may be observed from figures 5a and 5b.

MOTION OF A SOURCE ALONG A CURVED PATH

The equation of motion in this case is :

(12) $$\nabla^2 p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = -\frac{\partial}{\partial t}[\, q(t)\, \delta(x-\int v_x dt)\, \delta(y-\int v_y dt)\, \delta(z-\int v_z dt)\,]$$

See figure 6. It's solution depends on the distance R between the radiation point $r_s(t_e)$ and the control point O(x,y,z,t) given by equation (5).

The technical problem is the definition of the location $r_s(t_e)$. In cases of complicated orbits the location should be defined by using the integration :

$$r_s(t_e) = \int_0^{t_e} v(r,t)\, dt \qquad (13)$$

This integral is to be solved by numerical methods.

List of Figures

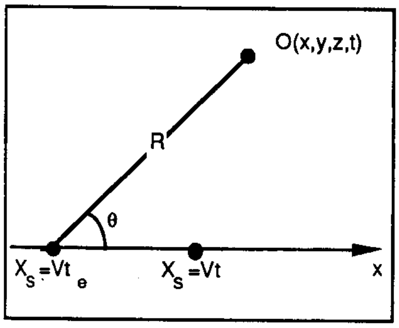

Figure 1

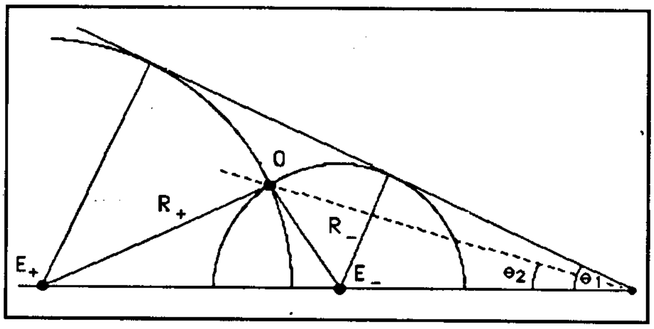

Figure 2

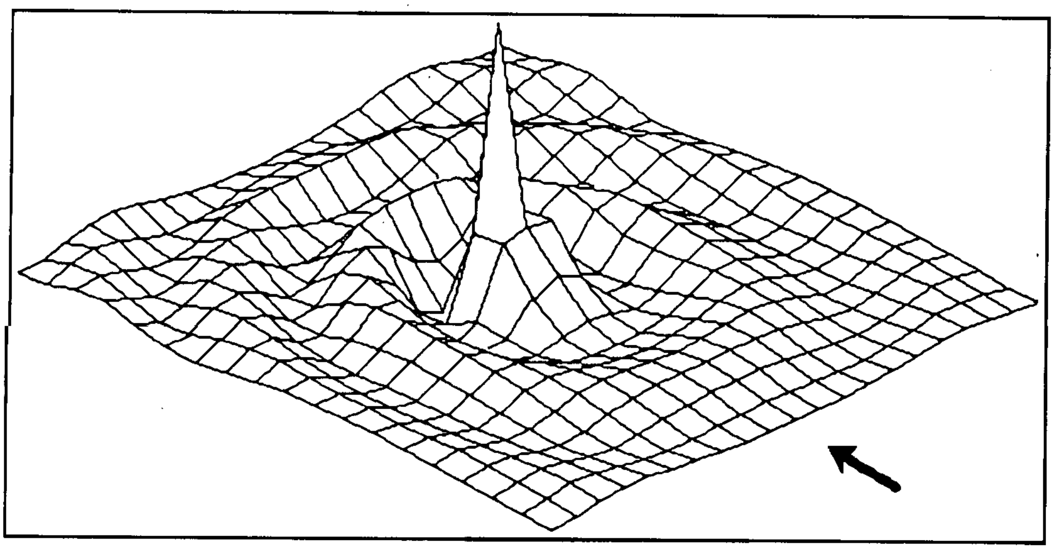

Figure 3

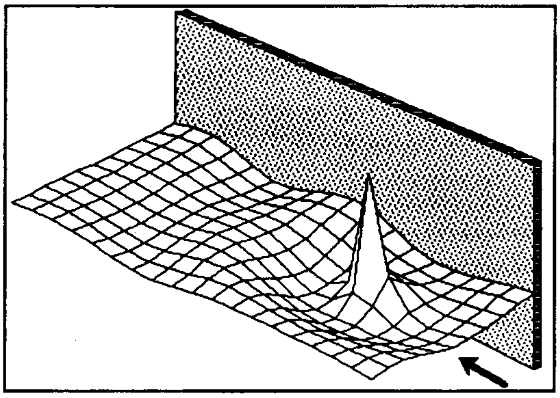

Figure 4

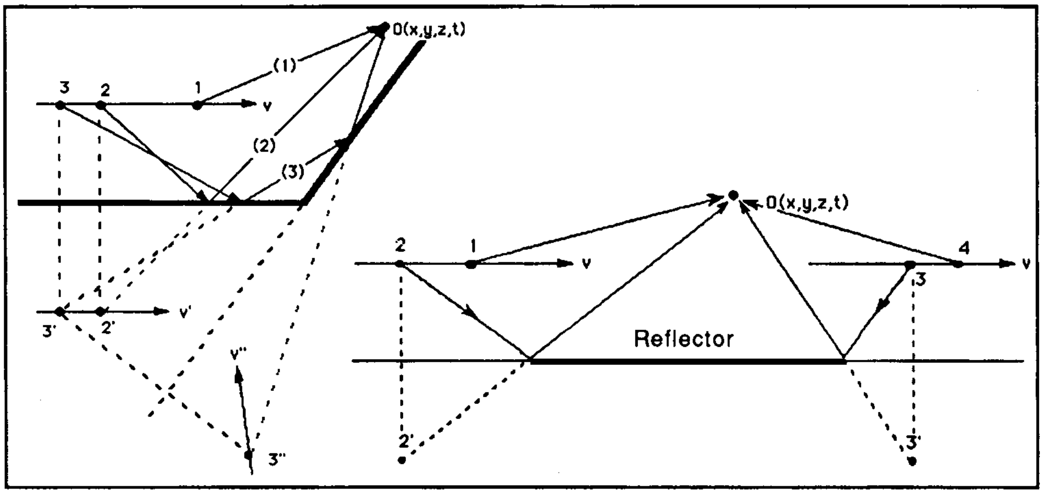

Figure 5

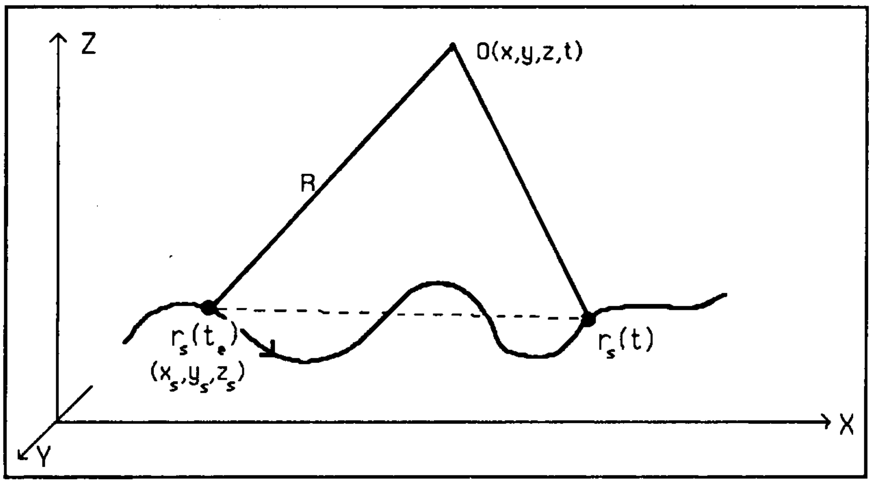

Figure 6