A METHOD OF PREDICTING SOUND LEVEL AS A FUNCTION OF DISTANCE FROM AN INCOHERENT RECTANGULAR SOURCE

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A problem frequently encountered by the noise control engineer is the prediction of sound level at a distance from a large rectangular source such as the side of a building. Except when the distance from the source to the observer is much greater than the dimensions of the source, the inverse square law, even when modified to take account of the area of the source, gives very inaccurate results. Sources of this kind are not normally coherent, and the well established data on radiation from pistons are not valid.

Since the dimensions of the type of source considered are much greater than the wavelength of their 'A' weighted spectrum peaks and the distance from the source to observer is many times greater than the wavelength, these sources may reasonably be idealized as incoherent. One may then obtain an expression for the sound level at a distance from the source by integrating the intensity received from an infinite array of infinitessimal points over the plane of the actual source.

Let Q in figure 1 be an observer situated a distance r perpendicular to the plane of ABCD. Let I_s be the sound intensity in front of ABCD at a distance $r \rightarrow 0$. Thus the sound power radiated by the area dx' dy' is given by

$$W_s = I_s \, dx' \, dy'$$

and the sound intensity at Q radiated by a finite rectangular source on the plane of ABCD is given by

$$\int_{y_2'}^{y_1'} \int_{x_1'}^{x_1'} \frac{I_s \, dx' \, dy'}{4\pi h^2} = \int_{\theta_2}^{\theta_1} \int_{\phi_2}^{\phi_1} \frac{I_s \cos\phi \cos\theta}{4\pi(\cos^2\theta + \cos^2\phi - \cos^2\theta\cos^2\phi)^2} d\phi \, d\theta$$

where $\theta_1, \theta_2, \phi_1, \phi_2$ are as shown in figure 2.

Integrating with respect to $d\theta$ and then $d\phi$ gives

$$1)\quad I_r = \frac{I_s}{4\pi}\Big[(\sin\theta_1 - \sin\theta_2)(\sin\phi_1 - \sin\phi_2) + \frac{2}{3^2}(\sin^3\theta_1 - \sin^3\theta_1)(\sin^3\phi_1 - \sin^3\phi_1) + \frac{3}{5^2}(\sin^5\theta_1 - \sin^5\theta_2)(\sin^5\phi_1 - \sin^5\phi_2) + \ldots\ldots\Big]$$

The sound intensity in front of an infinite incoherent plane source is infinite, but for a finite source I_s may be taken as

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the intensity measured at a distance such that $R \ll x$ and $R \ll y$. With the widespread availability of programmable calculators and micro-computers there is no problem in evaluating equation 1 to a high degree of precision, but it is interesting to note that if $R \gg x$ and $R \gg y$ then the second and subsequent terms of the series may be neglected, and the expression becomes (in decibels):

$$2)\quad SIL_r = SIL_s + 10\log_{10}(\sin\theta_1 - \sin\theta_2)(\sin\phi_1 - \sin\phi_2) - 11$$

Table 1 lists the values of $SIL_r - SIL_s$ for a source 10m x 1m and an observer situated on a line normal to the centre of the source. Also shown are the values arrived at by equation 2) and also by the expression

$$3)\quad SIL_r = SIL_s + 10\log_{10}\left(\frac{xy}{4\pi r^2}\right)$$

For large distances, all three equations give the same result: at distances less than the widest dimension large differences occur using equation 3).

r	(1)	(2)	(3)
.015625	-.7995	-4.9736	35.1315
.03125	-1.2890	-4.9800	29.1109
.0625	-1.9836	-5.0055	23.0903
.125	-2.8710	-5.1045	17.0697
.25	-4.0845	-5.4615	11.0491
.5	-5.8703	-6.4983	5.0285
1	-8.3485	-8.5515	-.9921
2	-11.3960	-11.4460	-7.0127
4	-15.1012	-15.1103	-13.0333
8	-19.7774	-19.7784	-19.0539
16	-25.2789	-25.2789	-25.0745
32	-31.1480	-31.1480	-31.0951
64	-37.1290	-37.1290	-37.1157
128	-43.1396	-43.1396	-43.1363
256	-49.1577	-49.1577	-49.1569
512	-55.1777	-55.1777	-55.1775
1024	-61.1982	-61.1982	-61.1981
2048	-67.2187	-67.2187	-67.2187

TABLE 1 Values of $SIL_r - SIL_s$ according to equation (1) (expressed in decibels), equation (2) and equation(3) for values of distance r from a 10 x 1 rectangular source with observer on a line perpendicular to the centre of the source.

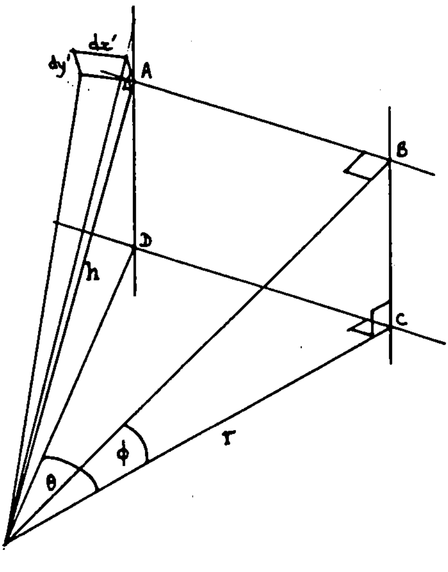

FIGURE 1

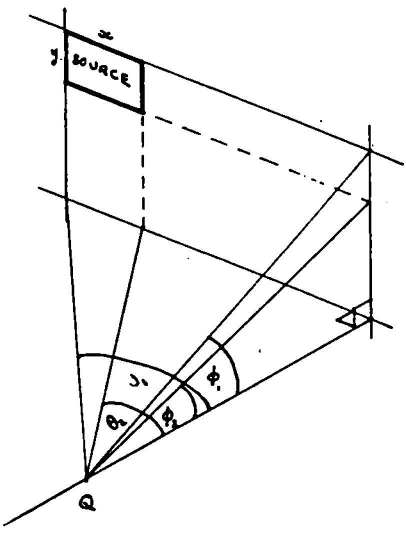

FIGURE 2