A RAPID BARRIER HEIGHT CALCULATION METHOD

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One of the difficulties in designing a barrier to attenuate sound levels outdoors is that although it is easy to calculate the attenuation a certain barrier height will give, it is not so easy to reverse the process to determine what barrier height is necessary to provide a certain attenuation.

The attenuation provided by a Barrier is recognized (1,2) as being a function of the Path Length Difference (PLD) or that extra distance sound is obliged to travel due to the presence of the barrier, see Fig. 1.

$$PLD = a + b - d \tag{1}$$

$$PLD = \left[(H_B-H_S)^2 + (SB)^2\right]^{1/2} + \left[(H_B-H_R)^2 + (BR)^2\right]^{1/2} - \left[(H_R-H_S)^2 + (SB+BR)^2\right]^{1/2} \tag{2}$$

Once the PLD has been calculated it must be converted to Fresnel number form by either knowing the frequency of the sound being attenuated or, for a broad band source by assuming a representative frequency.

$$\text{Fresnel Number } (N) = \frac{\text{frequency}}{565}\ PLD\ (ft) \tag{3}$$

Once N has been calculated then the attenuation can be obtained from curves as shown in Fig. 2 for either a point or line source.

The problem with reversing this procedure is that although the PLD required to give a certain attenuation is easily found, determination of the barrier height required to give this PLD is not so simple, primarily due to the "heavy" quality of Eqn. (2). As a first stage in simplification of Eqn. (2) it was rewritten as follows:

$$PLD = SB\left[1 + \left|\frac{H_B-H_S}{SB}\right|^2\right]^{1/2} + BR\left[1 + \left|\frac{H_B-H_R}{BR}\right|^2\right]^{1/2} - (SB+BR)\left[1 + \left|\frac{H_R-H_S}{SB+BR}\right|^2\right]^{1/2} \tag{4}$$

The approximation

$$(1+X^2)^{1/2} = 1 + \frac{X^2}{2} \qquad (5)$$

was then used to simplify Eqn. 4 still further. Such an approximation is acceptable for barrier calculations as although PLD is a small difference between larger numbers the quantities represented by X^2 are usually small in barrier work. Any errors which do arise can be easily compensated for as is shown later.

Using the approximation of Eqn. 5 in Eqn. 4 necessitates some straightforward if rather tedious algebraic manipulation but eventually a simple quadratic equation for PLD in terms of the barrier height emerges.

$$PLD = A.\, H_B^{\,2} + B.\, H_B + C \qquad (6)$$

where

$$A = \frac{SB + BR}{2.\, SB.BR}$$

$$B = -\left|\frac{H_S}{SB} + \frac{H_R}{SR}\right|$$

and

$$C = \frac{1}{2}\left|\frac{H_S^{\,2}}{SB} + \frac{H_R^{\,2}}{SR} - \frac{(H_S-H_R)^2}{SB+BR}\right|$$

This equation can of course be solved very simply using the general solution for a quadratic equation.

$$H_B = \frac{-B + \sqrt{B^2-4A(C-PLD)}}{2A} \qquad (7)$$

The usual negative sign in front of the square-root is ignored as although it is a possible algebraic solution acoustically it is not, the receiver being in the "bright zone". Eqn. 6 applies for a "thin" barrier but can be easily modified to apply to a "thick" barrier (assuming the PLD concept still applies) such as a continuous row of buildings made up of garages or townhouses. For such a thick barrier (of thickness T) only C is altered as follows:

$$C = \frac{1}{2}\left|\frac{H_S^{\,2}}{SB} + \frac{H_R^{\,2}}{SR} - \left(\frac{H_S-H_R}{SB+T+BR}\right)^2\right|$$

BR is measured from the rear face of the barrier to the receiver.

In order to simplify the calculation of PLD from the required attenuation the approximations shown in Fig. 3 can be used. These were deliberately chosen to be pessimistic for high values of Fresnel Number to counteract inaccuracies resulting from the use of the approximation in Eqn. 5. This should make the method accurate to within 1 dB even for higher values of PLD. The equations shown on Fig. 3 can easily be reversed to give PLD in terms of the attenuation:

For a point source $$\text{PLD} = \frac{565}{\text{frequency}} \cdot 10^{0.18\,(\text{attenuation}-10.7)} \qquad (8a)$$

For a line source $$\text{PLD} = \frac{565}{\text{frequency}} \cdot 10^{0.12(\text{attenuation}-13.0)} \qquad (8b)$$

By way of example, for traffic noise, a commonly used representative frequency is 500 Hz (3).

A complete calculation sheet is shown in Fig. 4 and a worked example shown in Fig. 5.

To demonstrate the accuracy of the method, for the example presented in Fig. 5 (which represents a fairly extreme case with a relatively high barrier) the attenuation resulting from the 27 ft. barrier was calculated in the usual way.

$$\text{PLD} = 5.13 \text{ ft}$$

$$\therefore N = 4.53 \text{ (for traffic noise)}$$

$\therefore$ Attenuation = 14.14 dBA

As 15 dBA was asked for, the method is within 0.6 dB, however if the actual line source curve in Fig. 2 is used then 15 dBA of attenuation is in fact achieved. This indicates that errors due to the approximation inherent in Eqn. 5 are less than 1 dBA and counteracted by assuming the pessimistic attenuation curves shown in Fig. 3.

Of course, the usual restrictions for barrier calculations apply to this method, the barrier should be sufficiently long or wrapped around the receiver at the ends and be massive enough to avoid sound transmission through it. Also, no more attenuation should be asked for than the maximum indicated by the two curves shown in Fig. 2.

To conclude, it is felt that this method provides a simple, rapid and convenient procedure for calculating the barrier height to provide a required sound attenuation with acceptable accuracy.

References

1. Z. Maekawa, "Noise Reduction by Screens", Memoirs of Faculty of Engineering, Kobe University, Japan 11, pages 29-53, 1965.

2. U.J. Kurze and Y.S. Anderson, "Sound Attenuation by Barriers" Applied Acoustics, Vol. 4, pp. 56-74, 1971.

3. "Acoustics Technology in Land Use Planning", Ontario Ministry of the Environment, Canada, 1977.

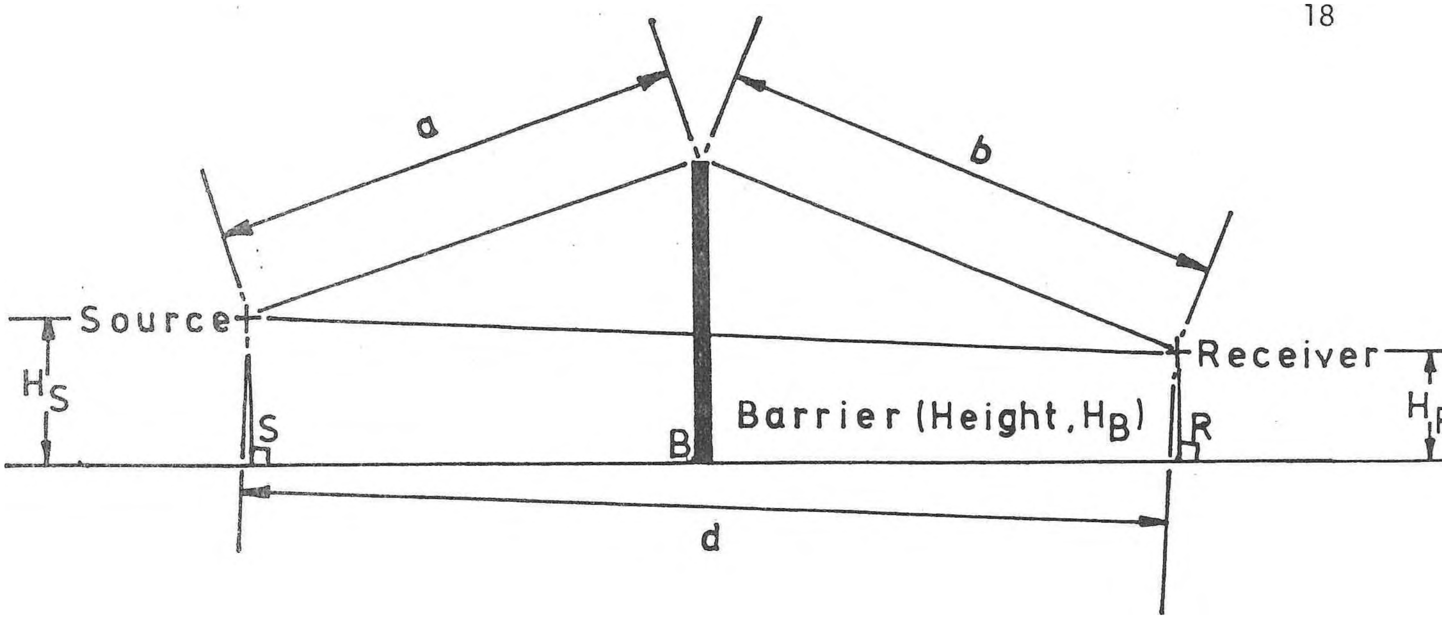

a
b
Source
Receiver
H_S
S
B
Barrier (Height, H_B)
R
H_R
d

FIG 1

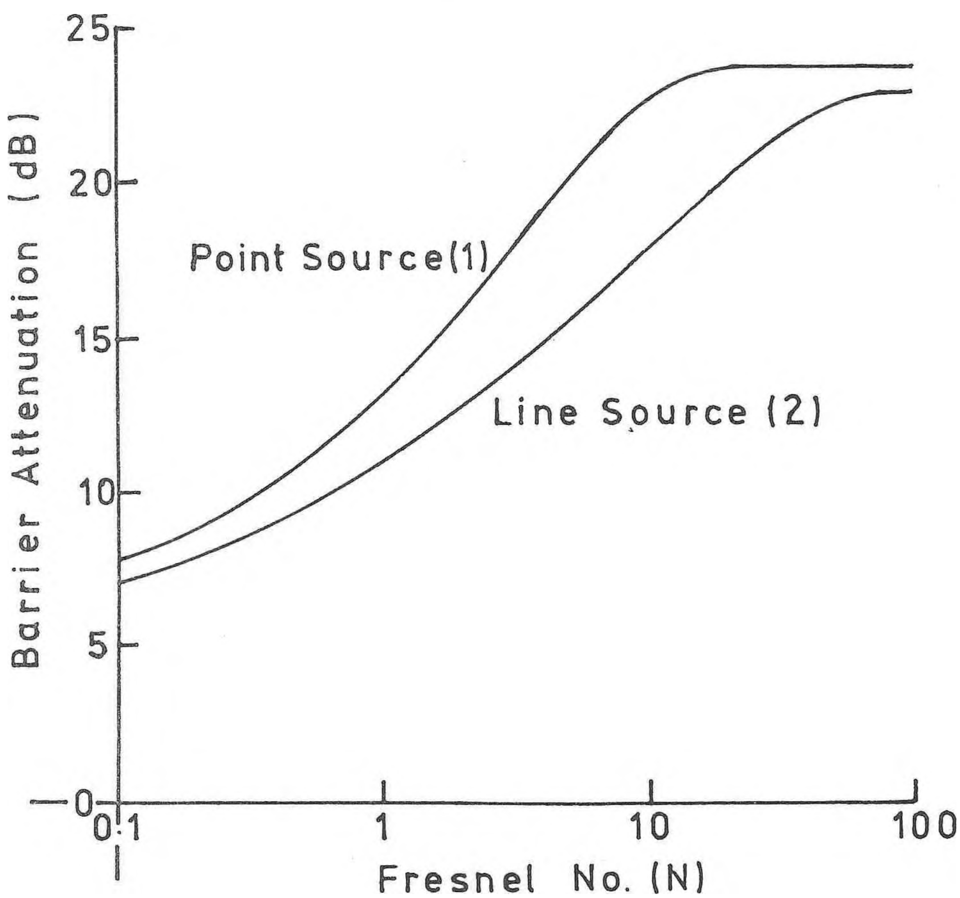

25
20
15
10
5
0
Barrier Attenuation (dB)
Point Source(1)
Line Source (2)
0.1
1
10
100
Fresnel No. (N)

FIG 2

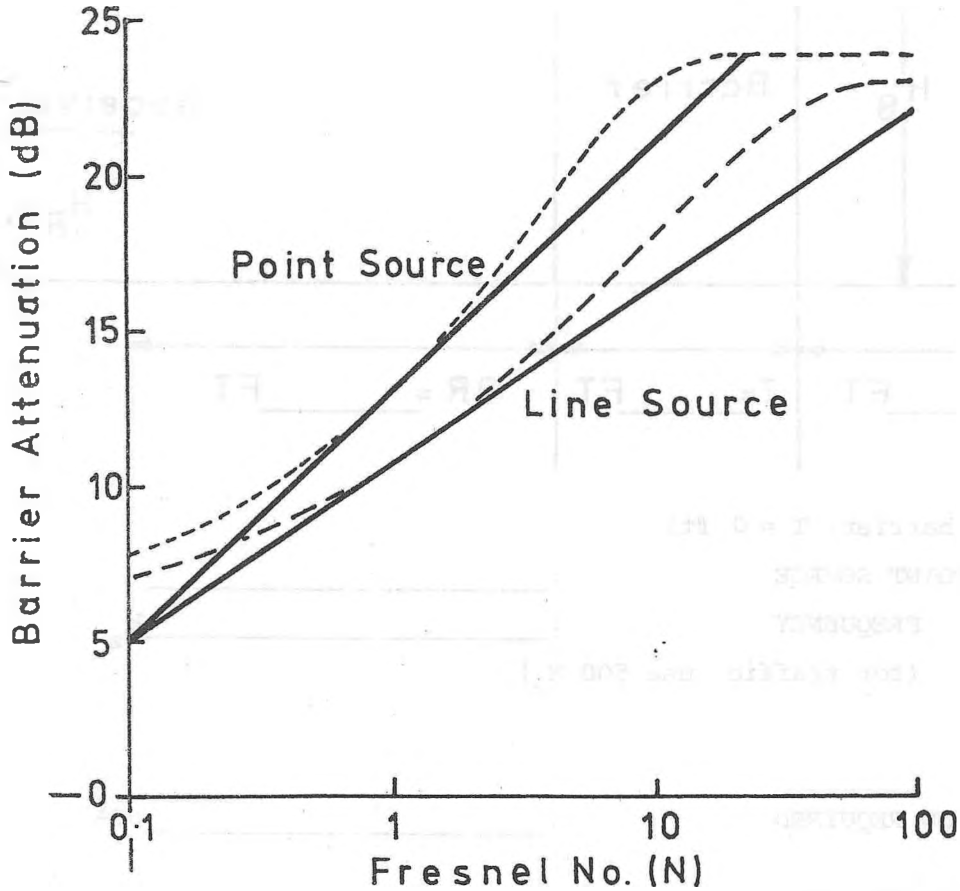
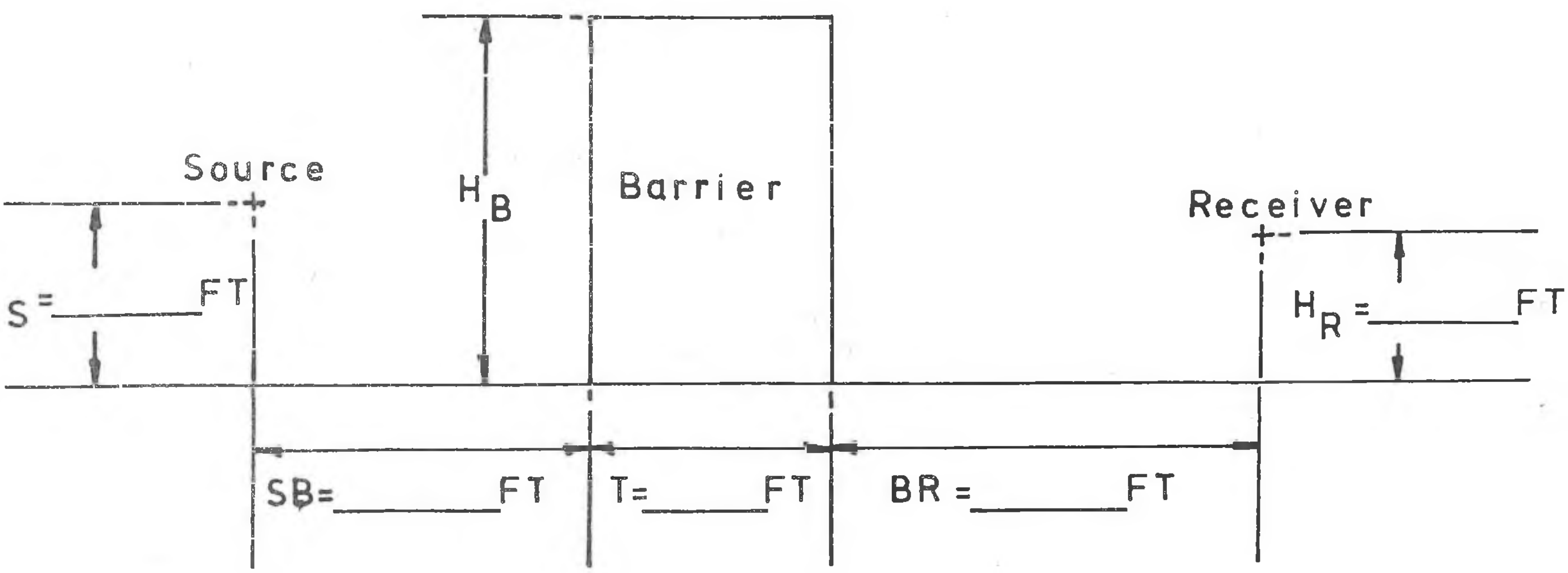

25
20
15
10
5
0
Barrier Attenuation (dB)
Point Source
Line Source
0·1
1
10
100
Fresnel No. (N)

FIG 3

BARRIER HEIGHT CALCULATION WORKSHEET



(for a thin barrier, T = 0 ft)

LINE OR POINT SOURCE : ______________________________

FREQUENCY : ______________________________ H_z

(for traffic use 500 H_z)

ATTENUATION REQUIRED : ______________________________ dBA

1. Calculate A $= \dfrac{SB + BR}{2.\ SB.\ BR} =$

2. Calculate B $= -\left[\dfrac{H_S}{SB} + \dfrac{H_R}{BR}\right] =$

3. Calculate C $= \frac{1}{2}\left[\dfrac{H_S^{\,2}}{SB} + \dfrac{H_R^{\,2}}{BR} - \dfrac{(H_S - H_R)^2}{SB+T+BR}\right] =$

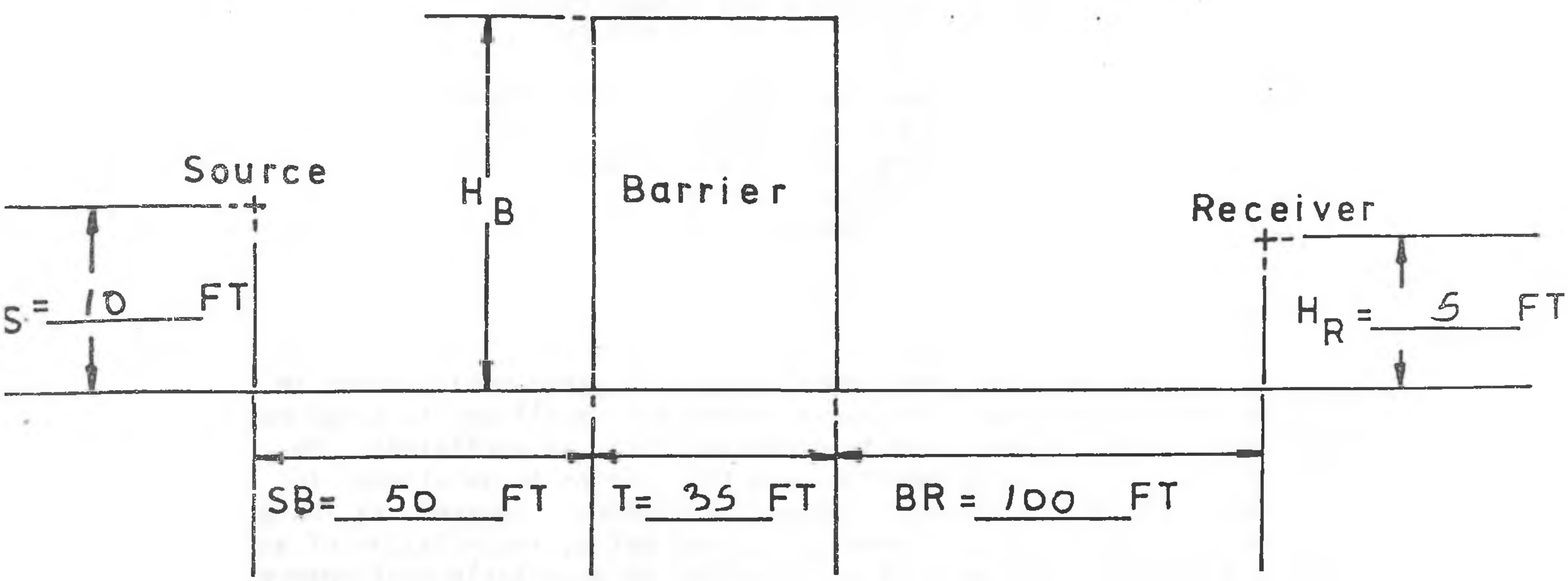
4. Calculate PLD
   a/ Point Source PLD $= \dfrac{565}{\text{frequency}} \cdot 10^{0.118\,(\text{attenuation} - 13.0)} =$

   or b/ Line Source PLD $= \dfrac{565}{\text{frequency}} \cdot 10^{0.175\,(\text{attenuation} - 10.7)} =$

5. Calculate H_B $= \dfrac{-B + \sqrt{B^2 - 4A(C-PLD)}}{2A} =$

FIG 4

BARRIER HEIGHT CALCULATION WORKSHEET



(for a thin barrier, T = 0 ft)

LINE OR POINT SOURCE : LINE

FREQUENCY : 500 H_z

(for traffic use 500 H_z)

ATTENUATION REQUIRED : 15 dBA

1. Calculate A $= \dfrac{SB + BR}{2.\ SB.\ BR} = 0{\cdot}015$

2. Calculate B $= -\left[\dfrac{H_S}{SB} + \dfrac{H_R}{BR}\right] = -0{\cdot}25$

3. Calculate C $= \tfrac{1}{2}\left[\left(\dfrac{H_S}{SB}\right)^2 + \left(\dfrac{H_R}{BR}\right)^2 - \left(\dfrac{H_S - H_R}{SB+T+BR}\right)^2\right] = 2{\cdot}11$

4. Calculate PLD
   a/ Point Source PLD $= \dfrac{565}{\text{frequency}} \cdot 10^{\,0.118\,(\text{attenuation} - 13.0)} =$

   or b/ Line Source PLD $= \dfrac{565}{\text{frequency}} \cdot 10^{\,0.175\,(\text{attenuation} - 10.7)} = 6{\cdot}39$

5. Calculate H_B $= \dfrac{-B + \sqrt{B^2 - 4A(C - PLD)}}{2A} =$ 27 ft

FIG 5