Engineering News

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1515 S. Manchester Avenue, Anaheim, California

TECHNICAL LETTER NO. 218

ACOUSTIC ATTENUATION WITH INCREASING DISTANCE

by
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The occurrence of a 6 dB decrease in SPL for each doubling of distance is easily demonstrated in outdoor 'free field' conditions. This relationship is expressed mathematically in Equation 1.

$$(1) \qquad \Delta D_x = 20\log_{10} \frac{dn}{df}$$

Where: ΔD_x = relative attenuation from an assumed arbitrary source

dn = the near distance in meters or feet

df = the far distance in meters or feet

Calculation of ΔD_x for outdoor 'free field' conditions does not work in an enclosed space. There are several useful and accurate formulas available for indoor calculations.

INDOOR CALCULATIONS

Calculating ΔD_x in an enclosed space depends on the reverberation time (in seconds) of the space and the regularity of the space dimensions.

Reverberant Rooms of Regular Dimensions

Equation 2 provides accuracy within ±1 dB under the following conditions:

(a) The space has a reverberation time exceeding 1.6 seconds ($RT_{60} > 1.6$).

(b) No major room dimension exceeds any other major room dimension by a ratio of more than 4 to 1.

$$(2) \qquad \Delta D_x = 10\log_{10} \left[\left(\frac{Q}{4 \pi r^2} \right) + \left(\frac{4}{R} \right) \right]$$

Where: ΔD_x = relative attenuation in dB from an assumed arbitrary source

r = distance in meters or feet from some reference point

Q = the directivity factor (dimensionless) of the source

R = the room constant in meters^2 or feet^2 derived from $\frac{S\bar{a}}{1-\bar{a}}$

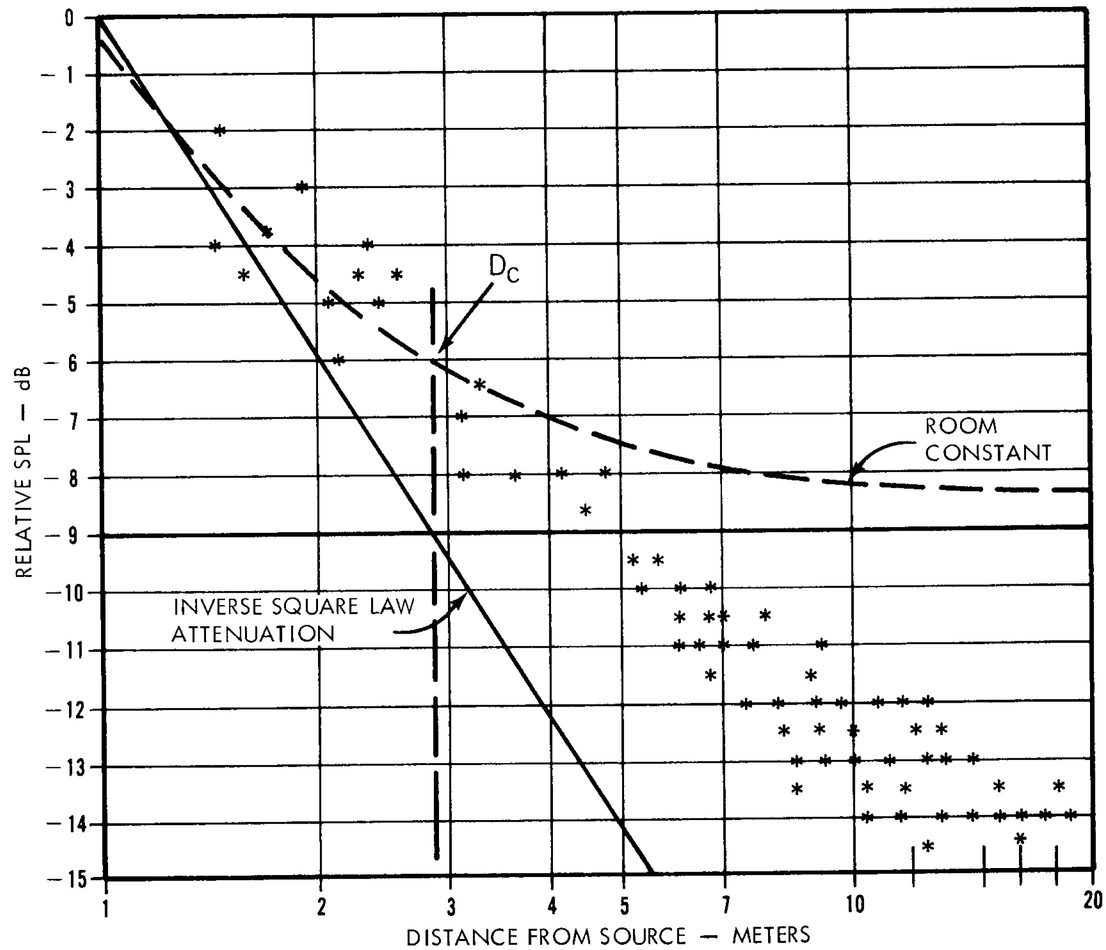

Figure 1. Results of Ogawa Experiment

Less Reverberant Rooms of Irregular Dimensions

More acoustic absorption may be present in smaller spaces and many small spaces have great length or width combined with a low ceiling height. Equation 2 will not yield an accurate value for ΔD_x if applied to such spaces.

Figure 1 shows the results of an experiment by Ogawa in 1965 within a space having the following parameters:

Length = 24 meters

Width = 13.5 meters

Height = 4.2 meters

V = 1360.8 $meters^3$

S = 963 $meters^2$

$\bar{a}$ = 0.25 at 500 Hz

$$RT_{60} = \frac{0.16V}{-S\ln(1-\bar{a})} = 0.791 \text{ second}$$

Because 24 meters divided by 4.2 meters is 5.7, this space qualified as having an irregular shape. This space also qualified as a less reverberant room because $RT_{60} < 1.6$ seconds.

The asterisks in Figure 1 are actual measurements obtained in the room described. The straight line INVERSE SQUARE LAW ATTENUATION was plotted by using Equation 1. The ROOM CONSTANT curve was plotted by using Equation 2. When D_x is greater than D_c, an excellent approximation of the measured data in spaces having such low reverberation time and irregular shape can be calculated with Equation 3.

$$(3) \qquad \Delta D_x = 10\log_{10}\left[\left(\frac{Q}{4\pi r^2}\right) + \left(\frac{4}{R}\right)\right] + 10\log_{10}\left(\frac{D_c}{D_x}\right)$$

SUMMARY

We believe this additional knowledge of the limits affecting the basic Hopkins-Stryker equation (Equation 2) will prove beneficial in designing sound systems for small conference rooms, long corridor-type spaces, etc. As always, we encourage you to write us about your experiences in using these equations because our knowing your problems will aid us in further refining their application to your design needs.