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Chapter 6
Outdoor Sound Propagation and Reception

Outdoor noise, if loud enough, can be radiated to neighborhood locations and be disturbing to the neighbors. Outdoor noise can originate from either indoor or outdoor sources, such as transformers, cooling towers, diesel-operated equipment, large fans, almost all forms of transportation, and any number of kinds of industrial processes and machinery. Outdoor sound transmission is influenced by three broad types of natural effects: distance effects, atmospheric effects, and terrain and vegetation effects. These effects are covered in this chapter. Radiation of indoor noise to the out-of-doors is discussed briefly, and indoor reception of outdoor noise is covered. A special study of rain and wind noise is also summarized.

6-1. DISTANCE EFFECTS

As a general rule, sound from a localized source spreads out as it travels away from the source, and the sound pressure levels drops off with distance according to fundamental relationships. Most specific individual sound sources may be treated as "point sources" when the distance from the source is large compared to the dimensions of the source. For point sources, sound levels drop off with distance in accordance with the "inverse square law," which yields a 6 dB sound level reduction for each doubling of the distance from the source. This effect is common to all types of energy propagation originating from an essentially point source and free of any special focusing or beam-controlling device. If a sound source is quite long in one dimension, such as a highway filled with autos and trucks or the clatter of the wheels of a long freight train passing over rail joints, the source is considered a "line source" and the drop off of sound level with distance follows a different rate — ideally 3 dB per doubling of distance from the source, but, in most practical geometries, more nearly 4.5 dB per doubling of distance. In addition, the air absorbs a certain amount of sound energy by "molecular absorption," and small amounts of ever-present air movement and inhomogeneities give rise to "anomalous excess attenuation." All these distance effects are summarized briefly in the following paragraphs.

A. SPHERICAL RADIATION. If a point source of sound were suspended in free space high above the earth's surface (with no nearby reflecting surfaces), the sound pressure level, L_p, at a distance d from the source, of sound power L_w, is given by

$$L_w = L_p + 10 \log 4\pi d^2 - 10 \qquad (6\text{-}1)$$

where $4\pi d^2$ is recognized as the surface area of a sphere of radius d. Here, the sound power radiates uniformly in all directions from the source, and the SPL would be the same at all points around the surface of the imagined sphere at a distance d from the source. Figure 6-1 illustrates a small element of a solid angle of sound radiation from a point source at "x." At the distance "d" from the source, the sound energy is uniformly spread over the small area "A" (which is the product of the two lengths "a" and "b"). At twice the distance, 2d, the lengths a and b are expanded to 2a and 2b, and the resulting area over which the sound is now spread has become 4A, four times the area back at distance d. Sound pressure is related to the "energy per unit area" in the sound wave; so, in traveling twice the original distance from the source, the energy per unit area has decreased by a factor of 4. (A factor of 4 corresponds to 6 dB, from 10 log 4 = 10 x 0.602 = 6 dB.) Simply illustrated, this is the "inverse square law"; that is, the SPL decreases at the rate of 6 dB for each doubling of distance from the source.

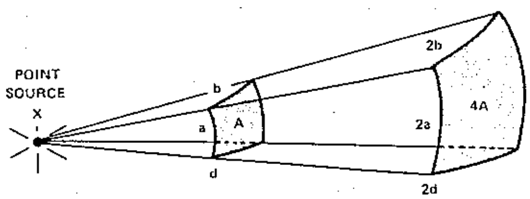

Figure 6-1. Spreading of sound as it travels away from a point source accounts for the "inverse square law" of sound propagation.

6 dB loss in L_p per doubling of distance
1/4 of sound pressure.

B. HEMISPHERICAL RADIATION FROM A POINT SOURCE. If the point source of sound is located on or near a large flat plane (such as the earth's surface, or a parking lot or the large-area roof of a building), sound radiates hemispherically from the source, and

$$L_w = L_p + 10 \log 2\pi d^2 - 10 \qquad (6\text{-}2)$$

where $2\pi d^2$ is the surface area of a hemisphere of radius d, and L_p is the SPL at any point on the hemispherical shell. Conceptually, Figure 6-1 would apply here also. If the power level L_w is the same and if d is the same in both Equation 6-1 and 6-2, the sound pressure level L_p in Equation 6-2 will be 3 dB higher than in Equation 6-1 because the sound that would have radiated into the lower hemisphere (below the earth's surface) is instead reflected into the upper hemisphere, and the SPL is 3 dB higher. The "inverse square law" applies to both spherical and hemispherical radiation, because in both cases, SPL drops off at the rate of 6 dB per doubling of distance or sound pressure is inversely proportional to the square of the distance.

C. CYLINDRICAL RADIATION FROM A LINE SOURCE. Figure 6-2 shows conceptually a short element of an infinitely long line source of sound. The line is so long that there is assumed no energy radiation from the remote ends of the line. For a doubling of the distance from d to 2d, the area through which the radiated energy passes increases from A to 2A (not 4A as in Figure 6-1). Thus, at the doubled distance, the energy per unit area is halved, and the sound pressure level is only 3 dB lower than at the reference distance d. The total area of the cylindrical surface (without end caps) is L x $2\pi d$, where L is the length of the long line and d is the distance from the line to the cylindrical shell (i.e., the radius of the cylinder). Here, then, the sound pressure is inversely proportional to the distance (as compared with the square of the distance for a point source).

For an infinitely long straight line of highway traffic, all the sound is radiated into half a cylinder (the half above the earth's surface), and Equation 6-3 applies:

$$L_w = L_p + 10 \log \pi d L - 10 \qquad (6\text{-}3)$$

and in theory the sound level drops off at the rate of 3 dB per doubling of distance from the source.

In practice, a typical line of traffic is not infinitely long, as observed from a representative community position, and the

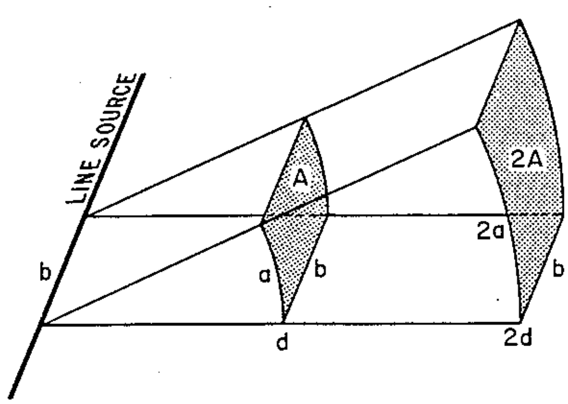

Figure 6-2. Cylindrical spreading of sound from a short element of a long line source.