SOUND PRESSURE LEVELS IN VARIOUS SOUND FIELDS   Revision A

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Introduction

Free Field

The surface area of a sphere is proportional to the square of the radius. Sound energy propagating in spherical pattern in a free field thus follows the "inverse square law." The sound power remains constant, but the energy spreads out over the surface area of the sphere. As a result, the sound pressure level decreases 6 dB for a double of the distance from the source.

Near Field

The sound pressure level near a sound source may vary significantly with position. The phase relations of the various radiating portions of the source may vary.

One empirical rule assumes that the near field ends at a distance of about twice the largest dimension of the source. The distance is increased to four times the largest dimension if the source rests on a hard floor.

Far Field

In the far field, the sound pressure level decreases 6 dB for a double of the distance from the source.

Reverberant Field

In a reverberant field, the sound pressure level is uniform throughout the room. A reverberant room must have hard surface areas. The sound at any location is the sum of the direct sound from the source and the reflected sound waves. The sound field is diffuse if a large number of sound waves cross a given point from all directions.

Semireverberant Field

A semireverberant field is an intermediate field between the free field and reverberant field ideals. Sound undergoes distance attenuation in a semireverberant field, but the attenuation value is less than 6 dB per doubling of distance. Reflected sound waves make some contribution to the sound level.

Attenuation formulas for a semireverberant field are given later in this report.

Very Large Room

Three sound fields may be present in a very large room excited by a sound source.

The space near the source is a near field.

The space located some distance away from the source and the walls is free field.

The space near the walls is semireverberant due to the presence of reflected sound waves.

Room Constant

The room constant R in square feet is

$$R = \frac{S_t \,\overline{\alpha}}{1 - \overline{\alpha}} \tag{1}$$

where

S_t is the total area of the room in square feet

$\overline{\alpha}$ is the average absorption coefficient

The room constant is infinity in a free field because there is no reflection whatsoever. The room constant is zero if there is no absorption. Real rooms fall somewhere in between these two extremes.

The room constant can also be calculated from the reverberation time as follows

$$R = \frac{S}{\left[\dfrac{T S}{\left[0.049 \dfrac{\text{sec}}{\text{ft}} \right] [V]} \right] - 1} \tag{2}$$

where

T = reverberation time, seconds

S = total surface area, square feet

V = volume, cubic feet

Absorption Coefficients

Typical absorption coefficients are shown in Table 1, as taken from Reference 1.

Table 1. Sabine Absorption Coefficients for Materials						
Material	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07
Carpet, 1/8 inch pile height	0.05	0.05	0.10	0.20	0.30	0.40
Wood Floor	0.15	0.11	0.10	0.07	0.06	0.07

Note that audiences seated on upholstered seats yield much higher absorption coefficients as shown in Table 2. Ranges are given due to the variability in upholstery type, spacing of seats, etc.

Table 2. Sabine Absorption Coefficients for Audience						
Audience	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Audience seated in Upholstered Seats	2.5 - 4.0	3.5 - 5.0	4.0 - 5.5	4.5 - 6.5	5.0 - 7.0	4.5 - 7.0

The average absorption coefficient $\overline{\alpha}$ is

$$\overline{\alpha} = \frac{\alpha_1 S_1 + \alpha_2 S_2 + \cdots + \alpha_n S_n}{S_1 + S_2 + \cdots + S_n} \tag{3}$$

where

α_i is the absorption coefficient of material i

S_i is the area of material i

Spherical Radiation in a Semireverberant Field

Let SPL be the sound pressure level in dB, referenced to 2.0 (10^{-5}) N/m^2.

Let PWL be the sound power level in dB, referenced to (10^{-12}) W.

The difference in dB between the pressure level and power level for spherical radiation is

$$\mathrm{SPL} - \mathrm{PWL} = 10\log\left[\frac{1}{4\pi r^2} + \frac{4}{R}\right] + 10.5 \tag{3}$$

where r is the distance from the source.

Equation (3) is taken from Reference 2. Equation (3) is plotted for a family of room constant values in Figure 1.

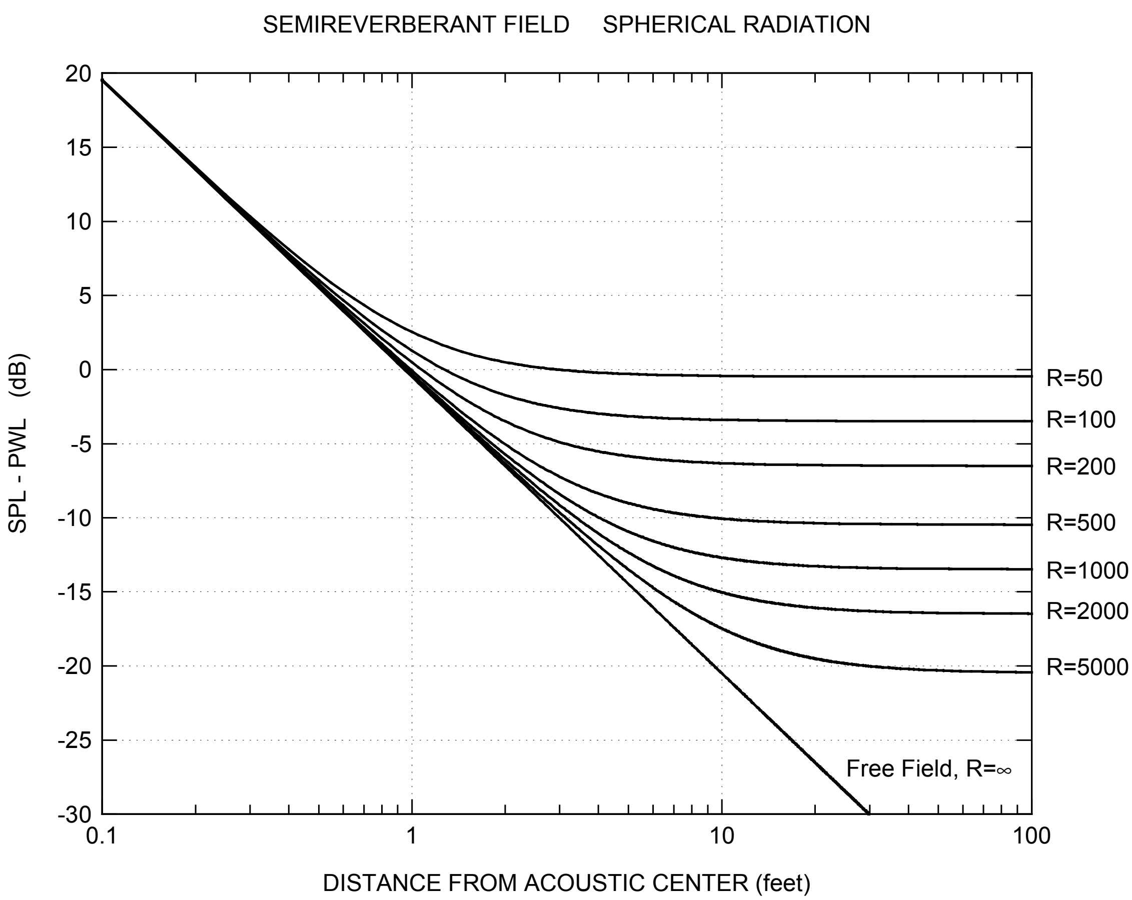

Figure 1. Spherical Radiation

Hemispherical Radiation in a Semireverberant Field

The difference in dB between the pressure level and power level for hemispherical radiation is

$$\mathrm{SPL} - \mathrm{PWL} = 10\log\left[\frac{1}{2\pi r^2} + \frac{4}{R}\right] + 10.5 \tag{4}$$

Equation (4) is taken from Reference 2. Equation (4) is plotted for a family of room constant values in Figure 2.

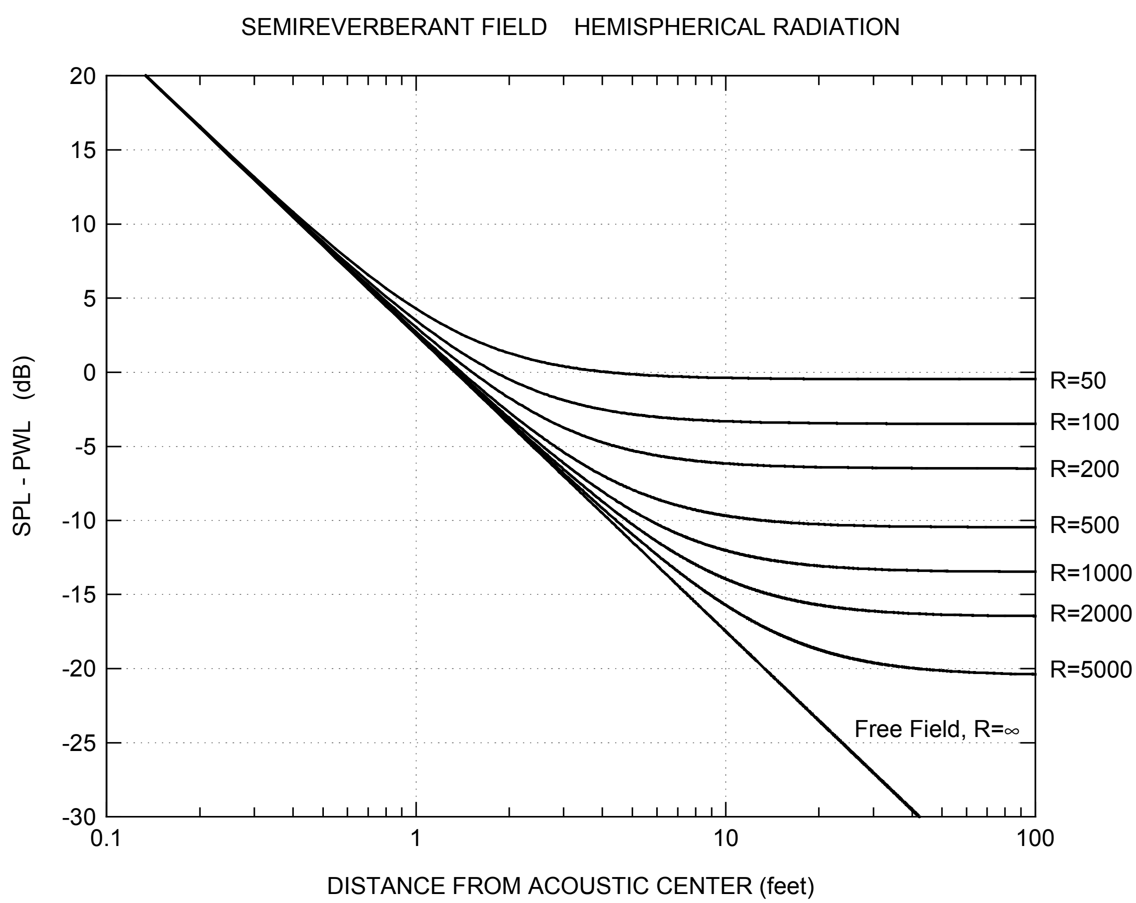

Figure 2. Hemispherical Radiation

Sound Radiation in a Reverberant Field

The sound pressure level in a reverberant room is

$$SPL = PWL - 10 \log V + 10 \log T + 29.5 \tag{5}$$

where

T = reverberation time, seconds

V = volume, cubic feet

Equation (5) is taken from Reference 2.

Spherical Radiation in a Free-Field

A free field is a volume in which there are no reflections. Free field propagation is characterized by a 6 dB drop in the sound pressure level and in the intensity level for each doubling of distance. This is essentially the "inverse-square law."

Consider a point source which radiates sound in spherical manner in a free field. The intensity magnitude I is related to the sound power W by

$$\left| I \right| = \frac{W}{4\pi r^2} \tag{6}$$

where r is the radius.

The magnitude symbol on the left side of equation (6) is necessary because intensity is a actually a vector.

Note that the denominator in equation (6) is the surface area of a sphere.

The sound intensity is related to the root-mean-square pressure P_{rms} by

$$\left| I \right| = \frac{\left(P_{rms}\right)^2}{\rho c} \tag{7}$$

where

ρ = mass density of medium

c = speed of sound in the medium

Example

A small, nondirectional sound source has a sound power level of 100 dB, referenced to (10^{-12}) W. The source is located in a room with a room constant R = 500 ft^2. Calculate the sound pressure level at a distance of 2 feet from the acoustic center assuming spherical radiation in a semireverberant field.

$$\mathrm{SPL} = \mathrm{PWL} + 10\log\left[\frac{1}{4\pi r^2} + \frac{4}{R}\right] + 10.5 \tag{8}$$

$$\mathrm{SPL} = 100\ \mathrm{dB} + 10\log\left[\frac{1}{4\pi\,(2\ \mathrm{ft})^2} + \frac{4}{500\ \mathrm{ft}^2}\right] + 10.5\ \ \mathrm{dB} \tag{9}$$

$$\mathrm{SPL} = 95.0\ \mathrm{dB} \tag{10}$$

References

1. Alton Everest, The Master Handbook of Acoustics, Tab Books, Blue Ridge Summit, PA, 1981.
2. George Diehl, Machinery Acoustics, Wiley-Interscience, New York, 1973.