

Section 13 Acoustics

- 13.1 Abbreviations and Terminology
- 13.2 Velocities, Spectrum and Reference Levels
- 13.3 Pressure, Intensity
- 13.4 Weighting Curves
- 13.5 1/3 Octave Center Frequencies
- 13.6 References

13.1 Abbreviations and Terminology

Abbreviations

<i>ANSI</i>	Acoustic National Science Institute
<i>dB</i>	decibels
<i>f</i>	frequency, cycles/sec
<i>Hz</i>	Hertz
<i>nm</i>	10^{-9} meters
<i>P</i>	sound power
<i>p</i>	pressure
<i>pW</i>	10^{-12} Watts
<i>x</i>	RMS value of quantity
<i>x_o</i>	reference value of quantity
<i>μPa</i>	10^{-6} Pascals

Terminology

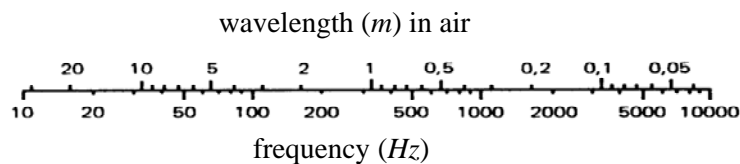
decade	band with the upper frequency x10 that of the lower.
decibels	measure of a magnitude, $dB = 10 \log_{10}(\text{mag})$.
far field	beyond the near field (region where sound level drops -6 <i>dB</i> as distance from the source doubles).
Hertz	frequency in cycles/second.
narrow band	band whose width is less than one-third octave but less than 1% of the center frequency near field range within a distance equal to the wavelength of the lowest frequency emitted or twice the greatest dimension of the subject.
octave	a band with the upper freq exactly twice the lower freq. (common octaves include .0375-.075, .075-.15, .15-.3, .3-.6, .6-1.2, 1.2-2.4, 2.4-4.8, 4.8-9.6 kHz).
pink noise	has equal energy in each octave from 20 to 20,000 Hz, or with an energy content inversely proportional to frequency.
random noise	does not have a uniform frequency spectrum and has an amplitude, as a function of time, consistent with a Gaussian distribution curve.
third-octave	highest frequency = 1.26 x lower frequency (ratio = $2^{1/3}$)
white noise	has a constant spectrum level over the entire band of audible frequencies (need not be random).

13.2 Acoustic Velocities, Spectrum, and Reference Levels

Acoustic Velocity (speed of sound)

<u>Medium</u>	<u>Approximate Velocity</u>
Air (20° C)	343 m/s
Fresh water	1,480 m/s
Aluminum	5,150 m/s
Concrete	3,600 m/s
Glass	5,300 m/s
Steel	6,000 m/s

$$\text{Wavelength } (\lambda) = \frac{\text{acoustic velocity}}{\text{frequency}}$$



Human hearing range is approximately 20 to 20,000 Hz

- Ultrasound lies above 20,000 Hz
- Infrasound lies below 20 Hz

Acoustic Reference Levels

<u>Quantity</u>	<u>Formula</u>	
Velocity (L_v)	$20\log(v/v_0)$	$v_0 = 10 \text{ nm/s}^2$
Intensity (L_I)	$10\log(I/I_0)$	$I_0 = 1 \text{ pW/m}^2$
Sound Power Level (L_W)	$10\log(P/P_0)$	$P_0 = 1 \text{ pW}$
Sound Pressure Level "SPL" (L_p)	$20\log(p/p_0)$	$20 \mu\text{Pa}$ (air)
Pressure Spectrum Level (PSL)*	$\text{SPL} - 10\log\Delta f$	(dB)
Pressure Band Level (PBL)	$\text{PSL} + 10\log\Delta f$	(dB)
Overall SPL (OASPL)	$10\log_{10} \Sigma 10^{\text{SPL}/10}$	$20 \mu\text{Pa}$ (air)

* the SPL contained within a band 1 Hz wide

13.3 Acoustic Pressure and Intensity

Sound Pressure from Sound Power

Transmission Environment	L_p
Free Field	$L_W + \log Q - 20 \log r - 10.8 \text{ dB}$
Reflecting Plane	$L_W + \log Q - 20 \log r - 7.8 \text{ dB}$
Reverberant Room	$L_W + \log Q - 20 \log R - 6.2 \text{ dB}$

where r = distance from source

Q = directivity index of source

R = room constant

Acoustic Intensity

$$I = \frac{\text{Imaginary}[G_{yx}(f)]}{4\pi\rho_0\Delta rf} = \frac{\text{Im}[G_{yx}(f)]}{16.25 \Delta rf} \text{ (for air)}$$

where ρ_0 = fluid density = 1.293 kg/m³ for air

Δr = microphone spacing (meters)

f = frequency

Intensity Spectrum Level (ISL)

Intensity level of a sound contained within a band 1Hz wide

$$ISL = 10 \log \frac{I}{I_o \Delta f} = IL - 10 \log \Delta f \text{ (dB)}$$

where f = center frequency of band

I = sound intensity (watts/m²)

$I_o = 10^{-12}$ watt/m² reference intensity

Δf = bandwidth (Hz)

13.4 Acoustic Weighting Curves (ANSI S1.4 1983)

Weighting for SPL

Nominal <u>Freq (Hz)</u>	Exact <u>Freq (Hz)</u>	A <u>(dB)</u>	B <u>(dB)</u>	C <u>(dB)</u>
10	10.00	-70.4	-38.2	-14.3
12.5	12.59	-63.6	-33.3	-11.3
16	15.85	-56.4	-28.3	-8.4
20	19.95	-50.4	-24.2	-6.2
25	25.12	-44.8	-20.5	-4.4
31.5	31.62	-39.5	-17.1	-3.0
40	39.81	-34.5	-14.1	-2.0
50	50.12	-30.3	-11.6	-1.3
63	63.10	-26.2	-9.4	-0.8
80	79.43	-22.4	-7.3	-0.5
100	100.0	-19.1	-5.6	-0.3
125	126.9	-16.2	-4.2	-0.2
160	158.5	-13.2	-2.9	-0.1
200	199.5	-10.8	-2.0	.0
250	251.2	-8.7	-1.4	.0
315	316.2	-6.6	-0.9	.0
400	398.1	-4.8	-0.5	.0
500	501.2	-3.2	-0.3	.0
630	631.0	-1.9	-0.1	.0
800	794.3	-0.8	.0	.0
1,000	1,000	.0	.0	.0
1,250	1,259	0.6	.0	.0
1,600	1,585	1.0	.0	-0.1
2,000	1,995	1.2	-0.1	-0.2
2,500	2,512	1.3	-0.2	-0.3
3,150	3,162	1.2	-0.4	-0.5
4,000	3,981	1.0	-0.7	-0.8
5,000	5,012	0.6	-1.2	-1.3
6,300	6,310	-0.1	-1.9	-2.0
8,000	7,943	-1.1	-2.9	-3.0
10,000	10,000	-2.5	-4.3	-4.4
12,500	12,589	-4.3	-6.1	-6.2
16,000	15,849	-6.7	-8.5	-8.6
20,000	19,953	-9.3	-11.2	-11.3

13.5 1/3 Octave Center Frequencies

(ANSI S1.6 1984)

Band No.	Nominal Center (Hz)	Exact Center (Hz)	Octave Center (Hz)
1	1.25	1.26	
2	1.60	1.58	
3	2.00	2.00	2.0
4	2.50	2.51	
5	3.15	3.16	
6	4.00	3.98	4.0
7	5.00	5.01	
8	6.30	6.31	
9	8.00	7.94	8.0
10	10.00	10.00	
11	12.5	12.59	
12	16.0	15.58	16.0
13	20.0	19.95	
14	25.0	25.12	
15	31.5	31.62	31.5
16	40.0	39.81	
17	50.0	50.12	
18	63.0	63.10	63.0
19	80.0	79.43	
20	100.0	100.00	
21	125.0	125.89	125.0
22	160.0	158.49	
23	200.0	199.53	
24	250.0	251.19	250.0
25	315.0	316.23	
26	400.0	398.11	
27	500.0	501.19	500.0
28	630.0	630.96	
29	800.0	794.33	
30	1,000	1,000.0	1,000
31	1,250	1,258.9	
32	1,600	1,584.9	
33	2,000	1,995.3	2,000
34	2,500	2,511.9	
35	3,150	3,162.3	
36	4,000	3,981.1	4,000
37	5,000	5,011.9	
38	6,300	6,309.6	
39	8,000	7,943.3	8,000
40	10,000	10,000.0	
41	12,500	12,589.3	
42	16,000	15,848.9	16,000
43	20,000	19,952.6	

13.6 References

- 13.1 Beranek, Leo L., *Acoustic Measurements*, John Wiley & Sons, New York, New York, 1956.
- 13.2 Peterson, Arnold P.G. and Gross, Ervin E., Jr., *Handbook of Noise Measurement*, GenRag Incorporated, Concord, Massachusetts, 1978.
- 13.3 *Measuring Sound*, (Pamphlet), Bruel & Kjaer, Naerum, Denmark, September 1984.
- 13.4 *Pocket Handbook, Noise, Vibration, Light, Thermal Comfort*, Bruel & Kjaer, Naerum, Denmark, 1986.

Additional Reading

Hunter, Joseph L., *Acoustics*, Prentice-Hall Incorporated, Englewood Cliffs, New Jersey, 1957.

NOTES