Section 13 Acoustics

13.1 Abbreviations and Terminology

Abbreviations

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

Terminology

decade band with the upper frequency x10 that of thelower.
decibels measure of a magnitude, $dB = 10log_{10}$(mag).
far field beyond the near field (region where sound level drops -6 *dB* 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, .6-1.2, 1.2-2.4, 2.4-4.8, 4.8-9.6 k*Hz*).
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, consis tent 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).

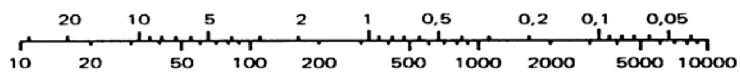
13.2 Acoustic Velocities, Spectrum, and Reference Levels

Acoustic Velocity (speed of sound)

Medium	Approximate Velocity
Air (20^o 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

Wavelength (λ) = $\dfrac{\text{acoustic velocity}}{\text{frequency}}$

wavelength (m) in air



frequency (Hz)

Human hearing range is approximately 20 to 20,000 Hz

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

Acoustic Reference Levels

Quantity	Formula	
Velocity (L_v)	$20\log(v/v_0)$	$v_o = 10\ nm/s^2$
Intensity (L_I)	$10\log(I/I_0)$	$I_o = 1\ pW/m^2$
Sound Power Level (L_W)	$10\log(P/P_0)$	$Po = 1\ pW$
Sound Pressure Level "*SPL*" (L_p)	$20\log(p/p_0)$	$20\mu Pa$ (air)
Pressure Spectrum Level (*PSL*)*	SPL – $10 log\Delta f$	(dB)
Pressure Band Level (*PBL*)	$PSL + 10 log\Delta f$	(dB)
Overall SPL (*OASPL*)	$10log_{10}\ \Sigma 10^{SPL/10}$	$20\ \mu Pa$ (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	$L_W + \log Q - 20 \log r - 10.8\ dB$
Reflecting Plane	$L_W + \log Q - 20 \log r - 7.8\ dB$
Reverberant Room	$L_W + \log Q - 20 \log R - 6.2\ dB$

where r = distance from source
Q = directivity index of source
R = room constant

Acoustic Intensity

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

where ρ_0 = fluid density = 1.293 kg/m^3 for air
Δr = microphone spacing (meters)
f = frequency

Intensity Spectrum Level (ISL)

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

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

where f = center frequency of band
I = sound intensity (watts/m^2)
$I_o = 10^{-12}$ watt/m^2 reference intensity
Δf = bandwidth (Hz)

13.4 Acoustic Weighting Curves (ANSI S1.4 1983)

Weighting for SPL

Nominal Freq (*Hz*)	Exact Freq (*Hz*)	A (*dB*)	B (*dB*)	C (*dB*)
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