$$SPL = 10 \log \left(\frac{\bar{p}^2}{P_{ref}^2} \right)$$?

$$= 10 \log \left(\frac{4\left(\frac{A^2}{2}\right)}{\left(\frac{A^2}{2}\right)} \right)$$

$$= 10 \log 4$$

$$\simeq +6\ dB$$

2nd CASE

$A = A_1 \qquad \omega_1 \neq \omega_2 \qquad \phi = 0$

$$P(t) = A \sin(\omega_1 t) + A \sin(\omega_2 t)$$

$$\bar{P}^2(t) = \frac{1}{T}\int_0^T A^2 \left[\sin(\omega_1 t) + \sin(\omega_2 t)\right]^2 dt$$

$$= \frac{1}{T}\int_0^T A^2 \left[\sin^2(\omega_1 t) + \sin^2(\omega_2 t) + \underbrace{2 \sin(\omega_1 t)\sin(\omega_2 t)}_{\approx 0 \text{ when } \omega_1 \neq \omega_2}\right]$$

$$\bar{P}^2(t) = \frac{1}{T}\int_0^T A^2\left(\sin^2(\omega_1 t) + \sin^2(\omega_2 t)\right) dt$$ (using the average value theorem ?)

$$\bar{P}^2(t) = \frac{A^2}{2} + \frac{A^2}{2}$$

$$\bar{P}^2(t) = A^2$$

$$SPL = 10 \log \left(\frac{A^2}{A^2/2} \right)$$

$$= 10 \log 2$$

$SPL \simeq +3\ dB \quad \rightarrow$ Double A signal what about halved signal?

$10 \log\left(\frac{1}{2}\right)$

$10 \log(2^{-1})$

$-10 \log 2$

$SPL = -3\,db$

MORE WORK (OPTIONAL)

$A = B, \quad \omega_1 = \omega_2 \quad \phi = \frac{\pi}{2}$

$A = B \quad \omega_1 = \omega_2 \quad \phi = \pi$

$A = 3B \quad \omega_1 = \omega_2 \quad \phi = 0$

$A = 3B \quad \omega_1 \neq \omega_2 \quad \phi = 0$

How Does this Relate to Real World?

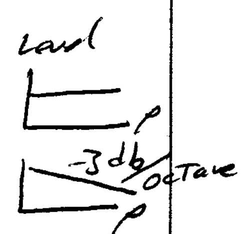
Pg 249
From Fundamentals of Acoustics - Kinsler
(Pass out handout)

Tones do not exist by themselves (Fig 11.1)

TONE: single frequency

BROADBAND: multiples frequencies

WHITE NOISE: equal strength at all frequencies

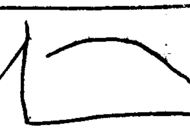


OCTAVE: doubling of frequency

BANDWIDTH: frequency Range

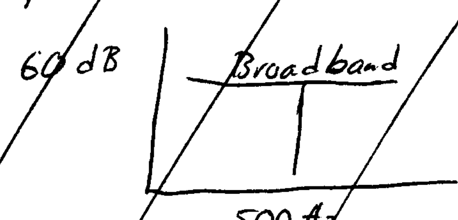
Tuning Fork - single freq
To broad band - range of freq

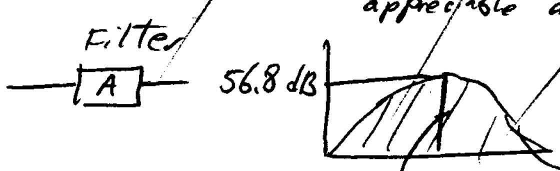
Human Ear (20 Hz → 10 kHz) Fig 12.1



Transmission Bandwidth refers to an acoustical filter - range of freq that will pass without appreciable attenuation

Response is like a weighting





500 · -3.2

H4D20AC

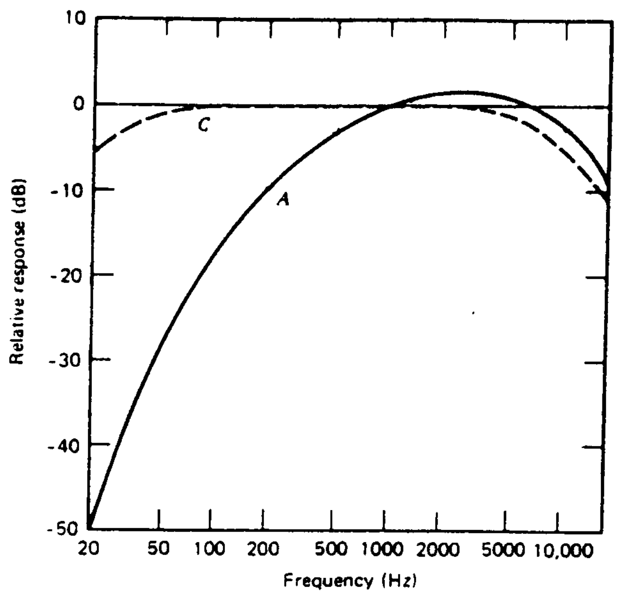


Fig. 12.1. Filter characteristics for A- and C-weighted sound levels.

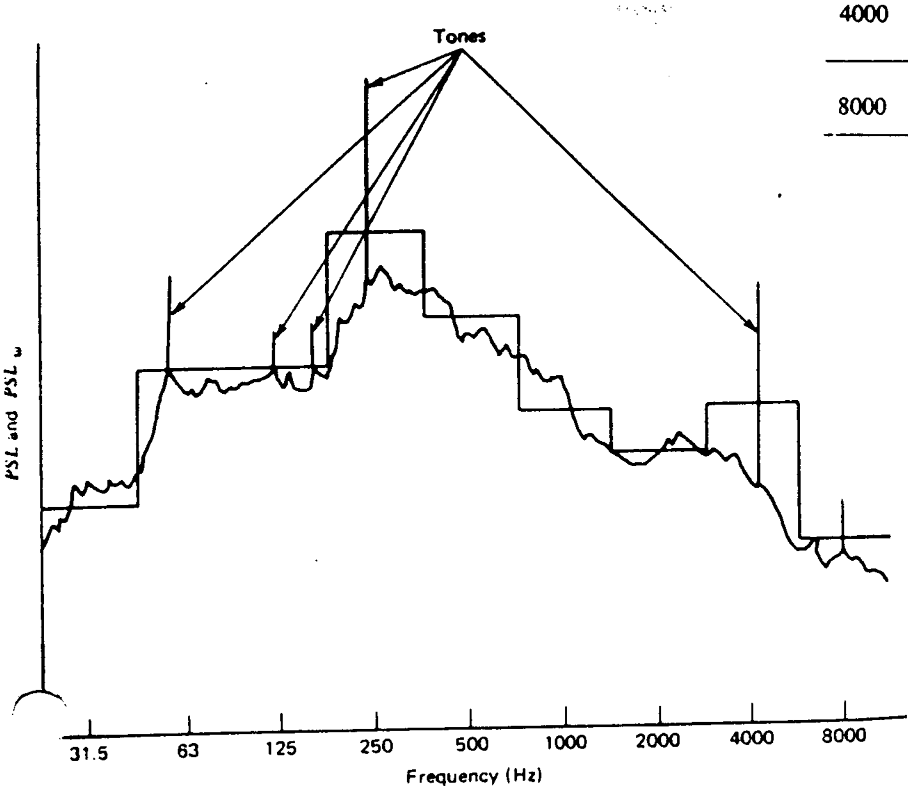


***Fig. 11.1.** Representative spectrum for noise with the PSL determined over octave bands.*

Table 11.1. Preferred octave-band and 1/3-octave-band center frequencies

Center Frequency (Hz)		10 log(*Bandwidth*)	
Octave	1/3-Octave	Octave	1/3-Octave
	10		3.6
	12.5		4.6
16	16	10.5	5.7
	20		6.6
	25		7.6
31.5	31.5	13.4	8.6
	40		9.7
	50		10.6
63	63	16.5	11.6
	80		12.7
	100		13.6
125	125	19.5	14.6
	160		15.7
	200		16.7
250	250	22.5	17.6
	315		18.6
	400		19.7
500	500	25.5	20.6
	630		21.6
	800		22.7
1000	1000	28.5	23.6
	1250		24.6
	1600		25.7
2000	2000	31.5	26.7
	2500		27.6
	3150		28.6
4000	4000	34.5	29.7
	5000		30.6
	6300		31.6
8000	8000	37.5	32.7

Table 12.1. Correction to be added to octave-band levels to convert them to A-weighted band levels

Center Frequency (Hz)	*Correction (dB)*
31.5	−39.4
63	−26.2
125	−16.1
250	−8.6
500	−3.2
1000	0
2000	+1.2
4000	+1.0
8000	−1.1

of rating procedures that use the statistical behavior of the A-weighted sound level are the *day-night averaged sound level* (L_{Adn}) the *50-percentile exceeded sound level* (L_{A50}), and the *community noise equivalent level* (*CNEL*).

One exception to the use of A-weighted sound levels is the calculation of the impact of airport noise, where the *effective perceived noise level* (L_{EPN}), calculated from the instantaneous spectra, is used to make a *noise exposure forecast* (*NEF*).

Excellent general and comprehensive treatments of environmental noise and its control are contained in the books edited by Harris[1] and Beranek.[2]

12.2 WEIGHTED SOUND LEVELS. The simplest and probably most widely used measure of environmental noise is the *A-weighted sound level* (L_A), expressed in dBA or dB(A). (The reference pressure is 20 μPa as discussed in Sect. 5.12 and will be left implicit.) A-weighting assigns to each frequency a "weight" that is related to the sensitivity of the ear at that frequency. For example, in a sound level meter the received signal is passed through a filter network with the dBA frequency characteristic, as shown in Fig. 12.1, and the level of the filtered signal is then determined and displayed. The dBA frequency characteristic was originally designed to mirror the 40-phon equal-loudness-level contour of the 1933 Fletcher-Munson data. It is also a good approximation of the 10-phon contour of the more recent Robinson-Dadson data, which is reproduced in Fig. 11.9. Accurate A-weighted levels can be obtained from octave-band levels by applying the corrections shown in Table 12.1 to each band level and then combining the corrected band levels with the nomograph of Fig. 11.2. Table 12.2 displays A-weighted sound levels for some commonly encountered noises.

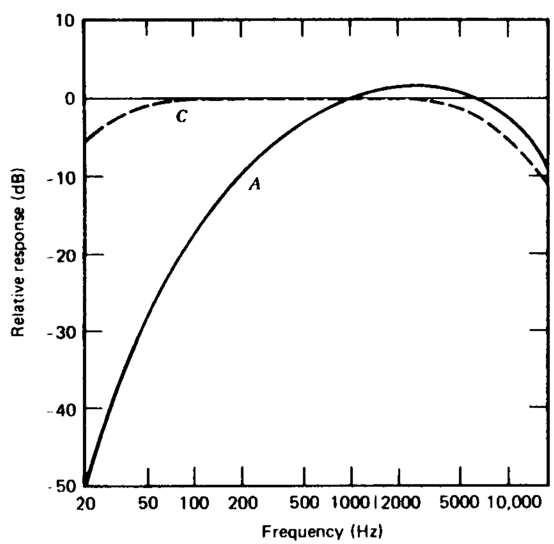


Fig. 12.1. Filter characteristics for A- and C-weighted sound levels.

[1] Harris (editor), *Handbook of Noise Control*, 2nd ed., McGraw-Hill (1979).
[2] Beranek (editor), *Noise and Vibration Control*, McGraw-Hill (1971).

Table 12.1. Correction to be added to octave-band levels to convert them to A-weighted band levels

Center Frequency (*Hz*)	*Correction* (*dB*)
31.5	−39.4
63	−26.2
125	−16.1
250	−8.6
500	−3.2
1000	0
2000	+1.2
4000	+1.0
8000	−1.1

Other weightings have been proposed but few have gained widespread acceptance. Most sound level meters will allow selection of either A-weighting, L_A, or C-weighting, L_C. The frequency characteristic for C-weighting (also shown in Fig. 12.1) is nearly flat, rolling off slightly at high and low frequencies. Although no single overall sound level can give information about the spectrum of a noise, measurement of both L_A and L_C will yield some information about the prominence of noise for frequencies below about 200 Hz. If there is significant energy in these lower frequencies, the L_C will be appreciably greater than the L_A.

The L_A is in widespread use mainly because it is inexpensive to obtain and easier for laypersons to appreciate than are any of the other more accurate, but more complicated, noise rating procedures. In addition, for most environmental noises L_A does correlate fairly well with the other rating procedures. While the A-weighted sound level L_A cannot completely replace more precise rating procedures, it has been shown[3] that for a wide variety of environmental noises measurements of L_A and L_C can be used to predict accurately the results of more complicated procedures. When a loudness level (for example, calculated by the method of Stevens, as mentioned in the previous chapter) is plotted against the A-weighted sound level for the same noise, the data for a given $L_C - L_A$ difference fall nearly on a line (Fig. 12.2).

[3] Botsford, *Sound and Vibration*, 3, 16 (Oct. 1969).

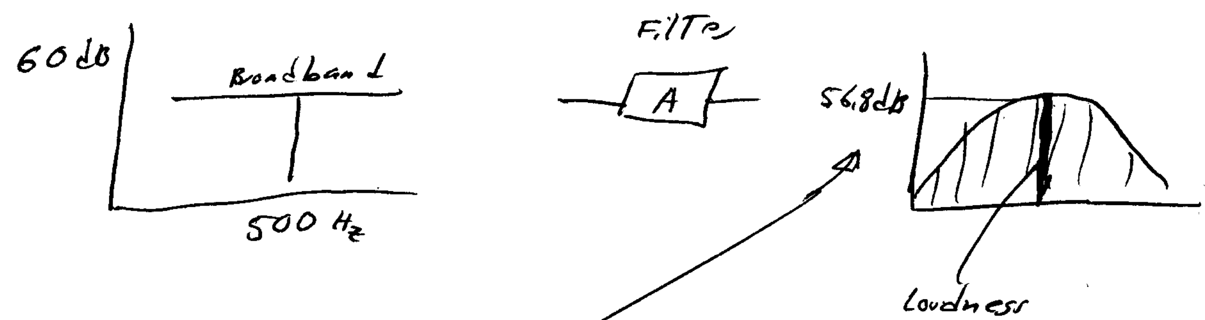
Transmission Bandwidth refers to an acoustical filter – range of frequencies that will pass without appreciable attenuation

The bandwidth of filters can be

- single freq
- narrow band
- octave band
- "weighted" to simulate the freq response of the ear.

Human Ear (20 Hz → 10 kHz) ~~Fig~~ Table 12.1

Response is like a weighting



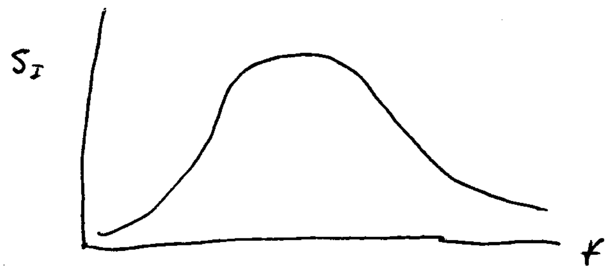
from Table 12.1

freq	correction
500	−3.2

A-weighting assigns to each frequency a "weight" that is related to the sensitivity of the ~~weighting~~ ear at that frequency

~~A weighting~~

~~[illegible]~~



Broad band

Narrowband

S_I = Spectral (Intensity) or spectrum level

BL (Band level) $= 10 \log \frac{I_w}{I_{ref}}$

$I_w = \Delta I$

$BL = SPL + 10 \log W$

$W = \Delta f$ (frequency band)

dB(A)	Location	P_o
20 - 30 db	Wilderness	3.5×10^{-4} Pa
30 - 50 db	Quiet Residential (night)	45×10^{-4} Pa
40 - 50 db	" " (day)	1.2×10^{-3} Pa
60 - 70 db	vacuum cleaner	8×10^{-3} Pa
100 - 110 db	Jet @ 300 m	0.32 Pa
110 - 120 db	Night Club	0.79 Pa
140	Threshold of Pain	

Homework

due Monday 9/11

1) the power output from a loudspeaker is raised from 5 to 50 watts. what is the change in sound power level?

2) Show that the ratio of the acoustic power of two sounds in decibels is equal to the difference of their power levels.

3) Determine the acoustic intensity level at a distance of 10 m from a source which radiates 1 watt of acoustic power. Use reference intensities of a) 100 b) 1 c) 10^{-12} d) 10^{-13} $\frac{watts}{m^2}$

4) An air-conditioning unit operates with a sound intensity level of 73 db. If it is operated in a room with an ambient sound intensity level of 68 db, what will be the resultant intensity level?

(5) Calculate the sound pressure level for a sound wave having an effective pressure of 3.5 nt/m^2. (3.5)
Use reference pressures of a) 10 b) 1 c) 10^{-4} d) $2(10)^{-4}$ microbar
1 microbar $= 0.1\ nt/m^2$

(6) If sound pressure is doubled, find the increase in sound pressure level.

(7) Two sound sources S_1 and S_2 are radiating sound waves of different frequencies. If their sound pressure levels recorded at position S as shown in the figure are 75 and 80 db respectively, find the total sound pressure level at S due to the two sources together.