EDG100 Spring 2000 Alcatel Project

Acoustics and Noise – Background Information

Acoustics is the generation, transmission, and reception of vibrational energy waves. Sound is how we detect vibrations of air molecules, using our sense of hearing.

The average person under 30 years old can sense sounds between the frequencies of 20 Hertz (Hz) and 20,000 Hz.

The simplest sound is a single tone or frequency, like produced by a tuning fork. A more complex sound is a violin, playing two or more strings at the same time, resulting in the sum of two frequencies.

Sound Intensity

Sound intensity is measured in units of watts/meter^2 (W/m^2). Audible sound intensities (what we can hear) range from as low as 10^{-12} W/m^2 to as high as 10 W/m^2. In general, sound intensity is measured in terms of decibels (dB) of sound level. If a signal has sound intensity of I (W/m^2), it has *intensity level* (IL) of:

$$IL\ (dB) = 10 \log (I / I_{ref}) \qquad (1)$$

where I_{ref} is generally chosen to be $I_{ref}=10^{-12}$ W/m^2. Equation (1) applies to narrowband sound, such as single tone sounds.

A measurement called A-weighted sound levels (L_A) are used to quantify effects of sound and noise over time, especially for industrial and recreational sound environments, and is expressed in dBA. The A-weighting assigns a "weight" to each frequency that is related to the sensitivity of the human ear at that frequency. Humans have maximum hearing sensitivity at 4 KHz, and minimum sensitivity at low frequencies. Table 1 shows the A-weighted sound levels for different noise environments.

Table 1: A-Weighted sound levels for some commonly encountered noises

A-Weighted Sound Level (dBA)	Source of noise
110-120	Disco, dance hall, live concert
100-110	Jet flyby at 300 meters (1000 feet)
90-100	Power mower [a], cockpit of light aircraft
80-90	Heavy truck at 40 mph at distance of 50 feet, blender [a]
70-80	Car at 65 mph at a distance of 25 feet; clothes washer [a]
60-70	Vacuum cleaner [a]
50-60	Light traffic at distance of 100 feet
40-50	Quiet residential - daytime
30-50	Quiet residential - nighttime
20-30	Wilderness area

[a] Measured at position of the operator

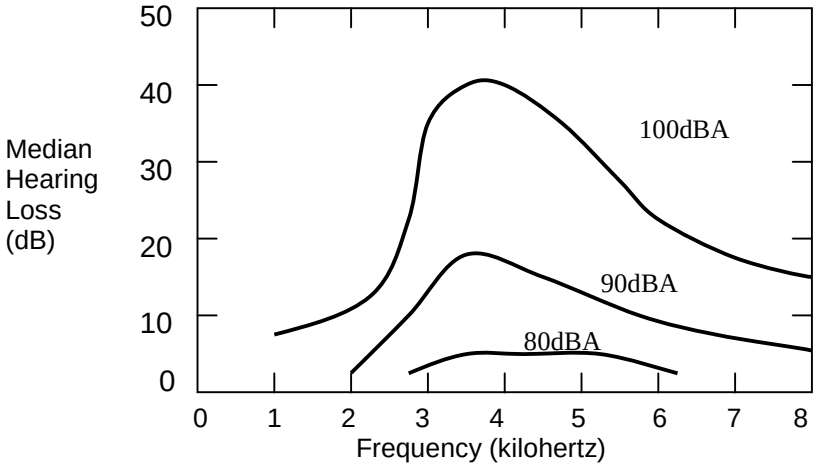
Noise-Induced Hearing Loss

Hearing loss and impairment are quantified by specifying the permanent threshold shift (PTS) as the ability to hear and understanding speech. Noise induced hearing loss occurs in two ways:

- Trauma: due to high intensity transient sound, such as an explosion or jet engine sound
- Chronic: due to lower intensity sound that occurs over a long period of time.

For industrial workers, hearing loss first occurs in frequencies $\geq$ 4KHz – the region of highest acuity. As the exposure time increases, severity of hearing loss > 4KHz increases, and hearing loss begins for frequencies < 4KHz. Figure 1 shows the frequency dependent hearing loss for noise at 80 dBA, 90 dBA and 100 dBA over a period of 10 years.

Figure 1: Median hearing loss after a 10 year exposure to industrial noise.



[*Figure 1 based on Fundamentals of Acoustics, Figure 12.11, page 300.]*

Figure 1 can be summarized as follows:

- At 80 dB of noise exposure for 10 years, permanent hearing impairment is beginning between 3KHz and 6KHz.
- At 90dB of noise exposure over 10 years, permanent hearing impairment bandwidth expands to a range of 2 KHz to 8KHz, with as much as 20 dB loss in hearing sensitivity.
- At 100 dB of noise exposure over 10 years, significant loss in hearing extends over the speech bandwidth, making the understanding of speech difficult.

Therefore, hearing loss is dependent on frequency, level of noise, and the duration of the exposure. The general rule for trading off sound level to exposure time is that a 5 dBA increase in sound level corresponds to a doubling of exposure time. Table 2 is the permissible daily noise exposure limits for industrial noise from OSHA (Occupational Safety and Health Administration).

Table 2: Permissible daily noise exposure limits for industrial noise (OSHA)

Limiting Daily Exposure (hours)	A-Weighted Sound Level (dBA)
8	90
6	92
4	95
3	97
2	100
1.5	102
1.0	105
0.5	110
0.25	115

Notes for Table 2 (from OSHA guidelines):

1. These levels provide protection only for frequencies necessary for understanding speech. Hearing loss at frequencies > 4KHz and must be accepted as part of the job.
2. These levels and guidelines assume 8 hour work days, 5 days per week exposure time, and for the rest of the time, no further damage occurs.
3. These guidelines are set to protect 85% of the exposed population, with financial compensation provided for the hearing impairment of the more susceptible 15% of the population.

Reference: L. Kinser, A. Frey, A. Coppens, J. Sanders; Fundamentals of Acoustics, Third Edition. *John Wiley and Sons, New York; 1982.*