King Saud University

College of Engineering

IE – 341: "Human Factors"

Fall – 2014 (1st Sem. 1435-6H)

Human Capabilities
Part – I. Hearing (Chapter 6*)

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Lesson Overview

- Hearing
  - Nature and Measurement of Sounds
    - Frequency of Sound Waves
    - Intensity of Sound
    - Complex Sounds
  - Masking
- Auditory Displays
  - Detection of Signals
  - Relative Discrimination of Auditory Signals
  - Absolute Identification of Auditory Signals
  - Sound Localization
- Noise

Hearing

- Direct vs. Indirect hearing:
  - Direct hearing: e.g. baby's natural cry
  - Indirect hearing: e.g. doorbell ⇒ someone at door
  - Indirect stimulus can be more effective than direct
    - e.g. fire alarm (100% detectable) vs. heat/smoke (75%)

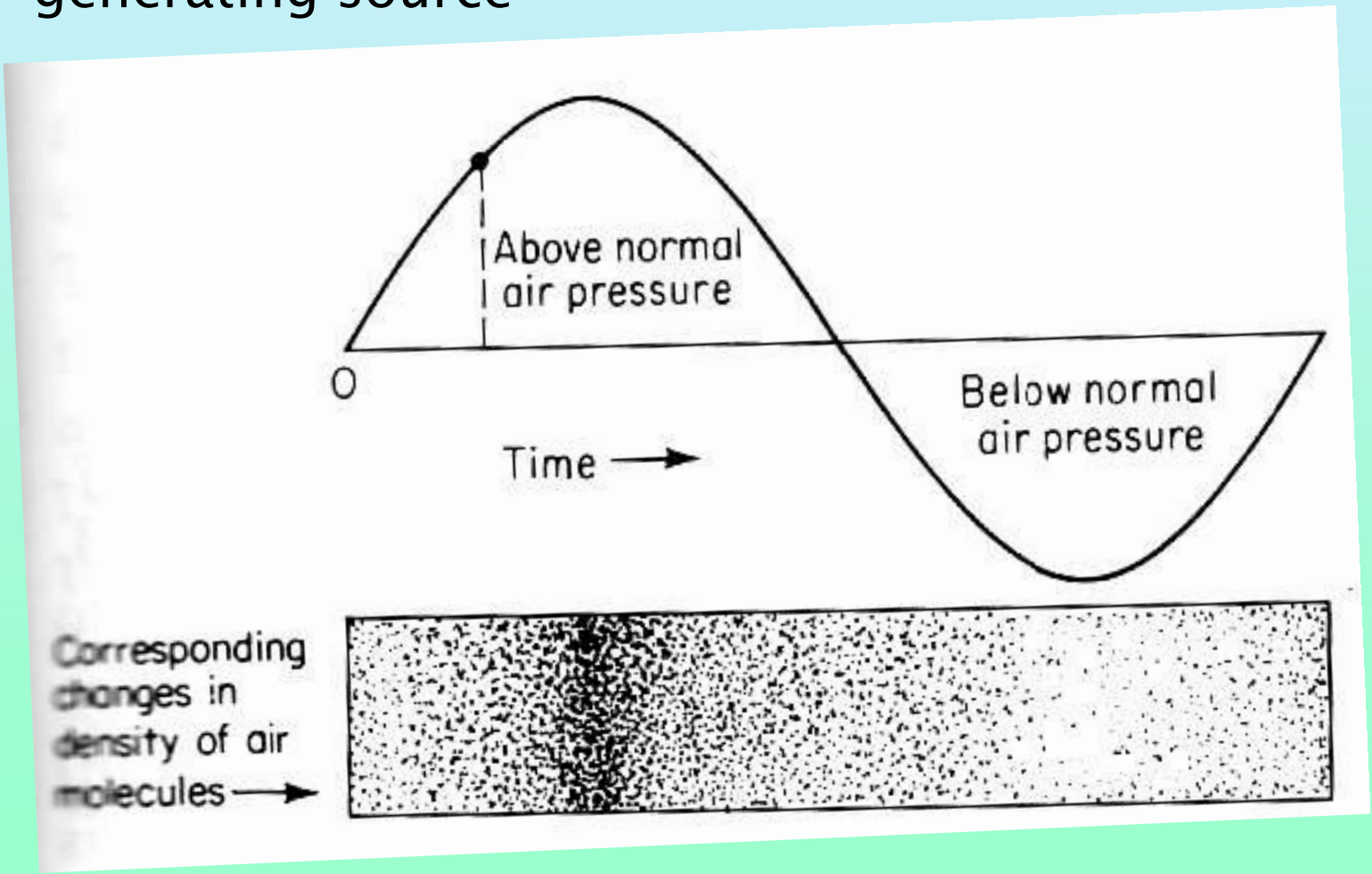
- Nature and Measurement of Sounds
  - **Sound** is created by vibrations from a source and is transmitted through a medium (such as atmosphere) to the ear
  - Two primary attributes of sound:
    - **Frequency**
    - **Intensity** (or **amplitude**)

Cont. Hearing

- Frequency of Sound Waves :
  - When sound is generated,
    - vibration ⇒ air molecules to move back and forth
    - this alternation ⇒ ↑ and ↓ in air pressure
  - Vibration forms sinusoidal (sine) waves
    - height of wave above and below the midline represents the amount of above-normal and below-normal air pressure respectively
    - The waveform above the midline is the image of the waveform below the midline in a sine wave.
    - The waveform repeats itself again and again in a sine wave
    - **frequency** of sound:
      - "number of cycles per second"
      - expressed in: hertz (Hz) ; 1 Hz ≡ 1cycle / 1 second

Cont. Hearing

- Cont. Frequency of Sound Waves :
  - Sinusoidal wave created by a simple sound-generating source



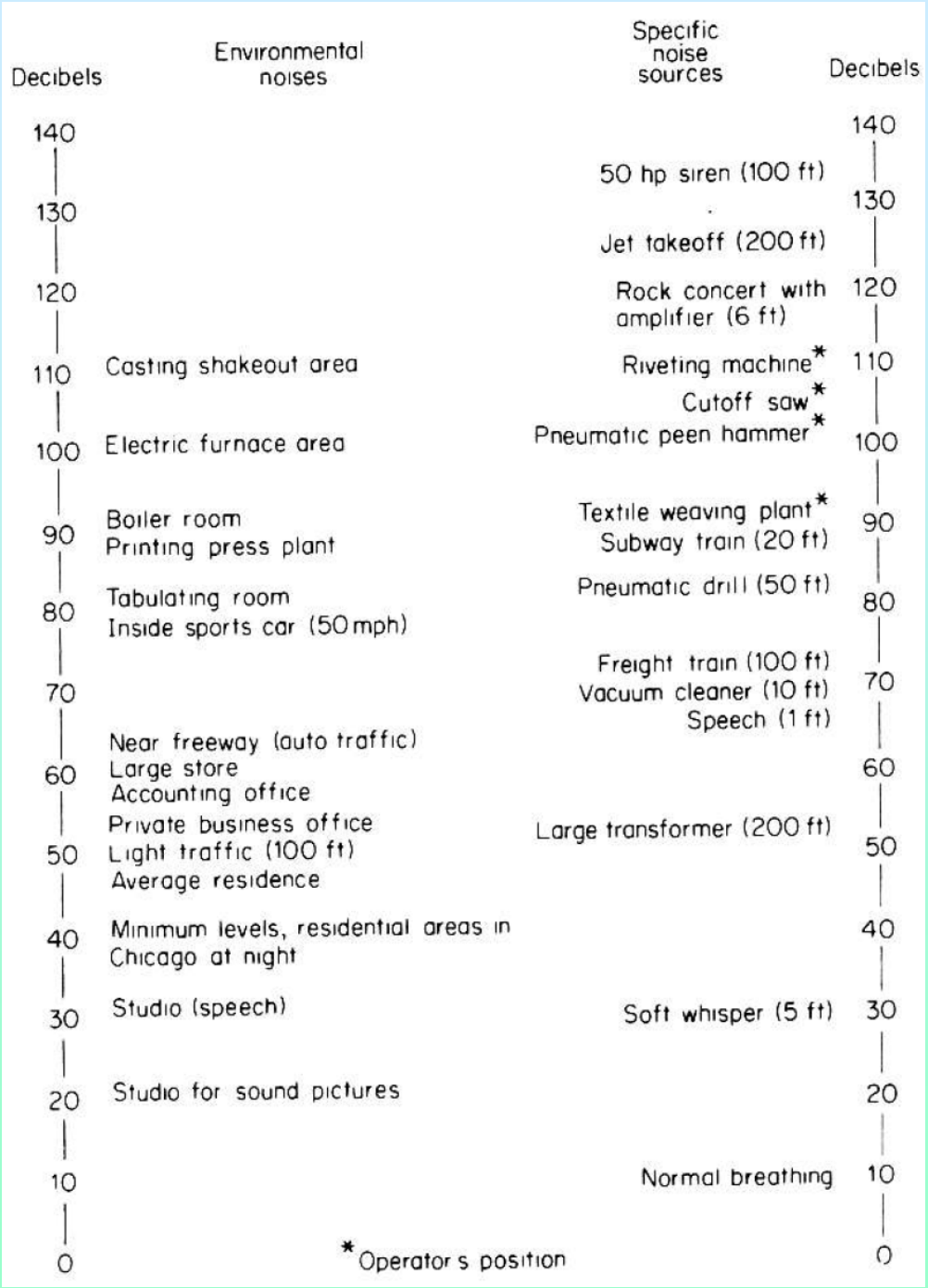
Cont. Hearing

- Cont. Frequency of Sound Waves :
  - The human ear is sensitive to frequencies
    - 20 to 20,000 Hz
    - highest sensitivity: between 1,000 to 3,000 Hz
  - Ear is not equally sensitive to all frequencies
  - People differ in their relative sensitivities to various frequencies

- Intensity of Sound (amplitude/loudness):
  - defined in terms of power per unit area
  - The Bel (B) [after *Alexander Graham Bell*] is the basic unit for measuring sound (log scale)
  - The most convenient measure is:
    - decibel (dB)
    - 1 dB=0.1B

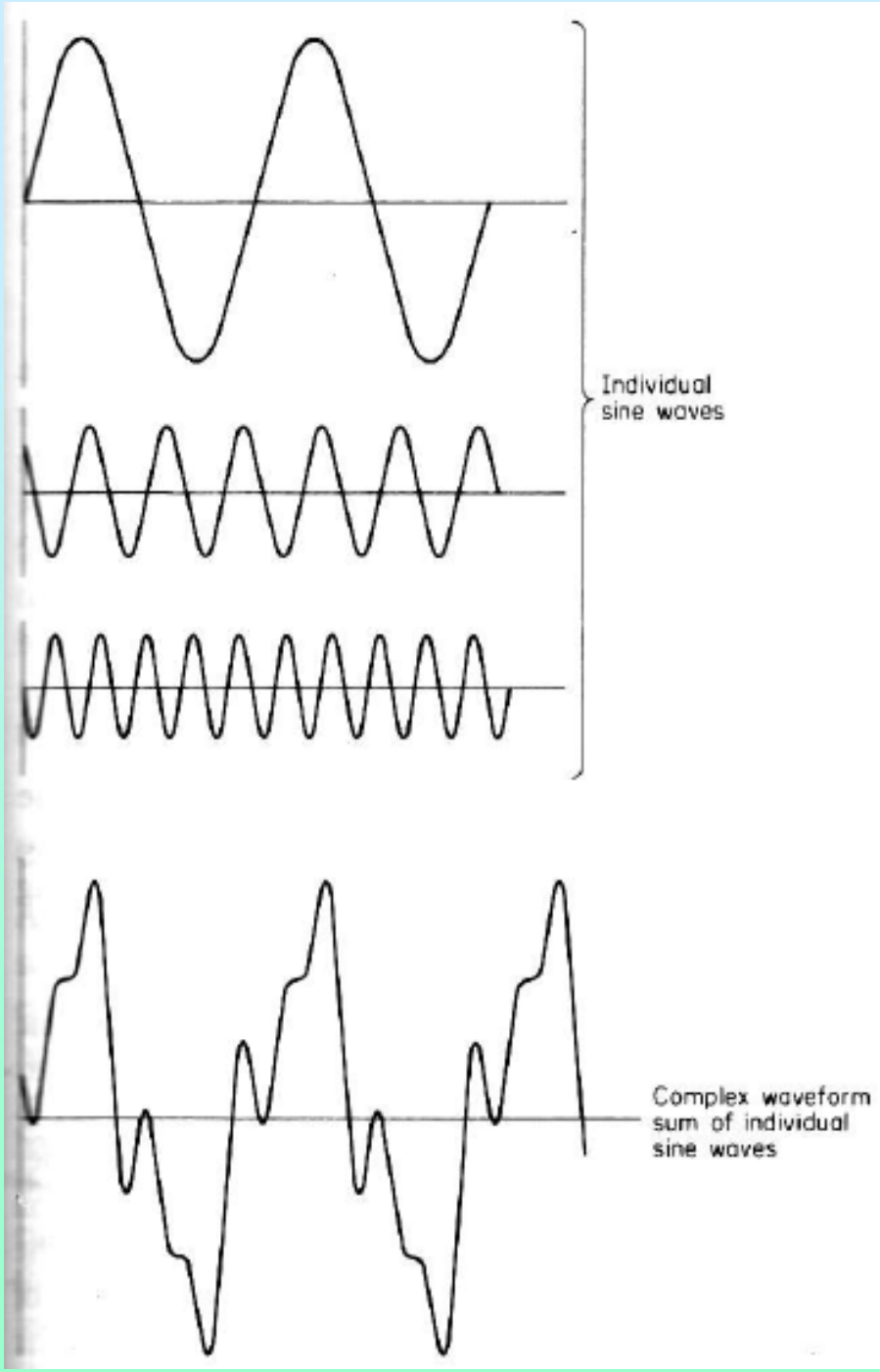
Cont. Hearing

- Cont.
  Intensity of Sound
  - Figure 6-2:
    Decibel levels for various sounds.
  - Note ↑ 10 dB ⇒
    ↑ 100-fold
    sound pressure
  - Signal-to-Noise Ratio (SNR): difference bet. meaningful signal, & background noise
    - e.g. 90 dB signal, 70 dB noise ⇒ SNR = +20 dB



Cont. Hearing

- Complex Sounds:
  - Very few sounds are pure
  - Most complex sounds are non-harmonic
  - Figure 6-3: waveform of a complex sound formed by 3 individual sine waves



Cont. Hearing

- Masking (defined):
  - Condition when one component of the sound environment reduces the sensitivity of the ear to another component
  - It is amount that the "**threshold of audibility**" of a sound (the masked sound) is raised by the presence of another (masking) sound

  - **Q**: Can you a give an example of "masked" and "masking" sounds from our everyday lives?
  - **Q**: difference between masked and complex sounds?

Auditory Displays

- Chapter 3: auditory vs. visual modality (e.g. auditory preferred: message is short, simple)
- 4 types of human functions/tasks involved in the reception of auditory signals:

1. **Detection** (i.e. whether a signal is present)
2. **Relative discrimination** (differentiating bet. ≥2 signals presented together)
3. **Absolute identification** (only 1 signal is present)
4. **Localization** (knowing the direction that the signal is coming from)

Cont. Auditory Displays

- Detection of signals
  - Signals can occur in “peaceful” surroundings or noisy surroundings
  - The signal plus noise (SN) should be distinct from the noise (N) itself
  - Otherwise, signal cannot always be detected in the presence of noise
    - i.e. signal (masked sound) + noise (masking sound) ⇒ **threshold of detectability** is elevated
    - ⇒ signal must be > threshold to detect signal
  - Using filters ⇒ noise removed ⇒ ↑ detectability, SNR ⇒ more audible sound

Cont. Auditory Displays

- Relative Discrimination of Auditory Signals
  - Relative discrimination of signals on basis of
    - intensity
    - frequency
  - A common measure of discriminability: **just-noticeable difference** (JND):
    - JND: "the smallest difference or change along a stimulus dimension (frequency, intensity) that can just be detected 50% of the time by people."
    - The smaller the JND, the easier it is for people to detect differences on the dimension being changed.
      - Small JND ⇒ subjects could detect small changes
      - Large JND ⇒ large change necessary before noticing change

Cont. Auditory Displays

- Absolute Identification
  - This is used when it is necessary to make an absolute identification of an individual stimulus (by itself)
  - e.g. identify
    - someone's pitch/frequency
    - specific animal/bird
    - certain car siren/honk tone
    - Sound durations
  - Number of levels along a continuum (range or scale) that can identified usually is quiet small
  - It is better to use more dimensions with fewer steps or levels of each dimension, than to use fewer dimensions and more levels of each

Cont. Auditory Displays

- Localization
  - ***Stereophony:*** "the ability to localize (guess/predict) the direction from which the sound is emanating (coming from)"
  - Primary factors/cues used to determine direction
    - intensity of sound
    - phase (lag) of sound
    - e.g. if sound reaches directly one side of head first, sound reaches the nearer ear approx. 0.8 ms before other ear ⇒ localizing sounds below 1500 Hz
    - For frequencies > 3000 Hz, intensity is used to localize sound (e.g. try to gradually increase volume in one speaker and decrease volume in opposite speaker)
    - Sounds between 1500-3000 Hz: hard to localize

Cont. Auditory Displays

- Special purpose auditory displays:
  - Warning and alarm signals
    - Each signal having preferred frequency, intensity
    - Each causing certain “attention-getting” and “noise-penetration” ability
  - Aids for the blind
    - Mobility aids (go-no-go safety signals at certain distance)
    - Environmental sensors (information about surrounding, e.g. surface characteristics, directional information, distance)

Noise

- Noise ≡
  - “Unwanted sound”
  - Information theory: “auditory stimulus of stimuli bearing no informational relationship to the presence or completion of the immediate task”

- Effects of noise
  - Hearing loss (e.g. occupational hearing loss)
  - Temporary loss, permanent loss
  - Physiological effects
  - Psychological effects

References

- **Human Capabilities – Hearing**
  - ***Human Factors in Engineering and Design***. Mark S. Sanders, Ernest J. McCormick. 7th Ed. McGraw: New York, 1993. ISBN: 0-07-112826-3.
  - **Slides by: *Dr. Khaled Al-Saleh*; online at:** http://faculty.ksu.edu.sa/alsaleh/default.aspx