Chapter 3

Sounds, Signals, and Studio Acoustics
Sound Waves

- Compression/Rarefaction: speaker cone
- Sound travels 1130 feet per second
- Sound waves hit receiver
- Sound waves tend to spread out as they travel away from source, getting weaker over distance (halves each time distance doubles: inverse square law)
Sound Waves

- Peak
- Amplitude
- Wavelength
- Trough
- Trough
Sound Waves: Amplitude and Frequency

- **Amplitude**: height of the wave (loudness) measured in decibels (dB)
- **Frequency** (Hz or kHz) number of cycles per second
- **Frequency**: highness or lowness of sound
- **Human hearing range**: 20 Hz – 20kHz (20,000 Hz)
- **Doubling Frequency** raises the pitch one octave
- **Instrument Frequency Chart**
Decible Range Chart

Threshold of human hearing: 0dB
Recording Studio: 10dB
Quiet Living Room: 20dB
Quiet Office/Library: 30dB
Quiet Conversation: 40dB
Average Office Noise: 50dB
Conversation from 1 foot away: 60dB
Busy street or orchestra: 70dB
Typical Home Stereo volume: 80dB
90dB
Subway train: 100dB
Power Tools: 110dB
Planes on airport runway: 120dB
Rock Concert
Jet Engine Up Close: 150dB
Jet Engine Up Close: 160dB

Average Factory: 85dB
Heavy Truck: 92dB
Human Pain Threshold: 140dB
Hearing Damage

Example noise levels

- Jet take-off (close distance)
- Construction site
- Noisy workplace
- Busy office
- Martin Place lunch time
- Living room
- Rural location
- Conversation speech
- Library
- Bedroom
- Average street traffic
- Quiet office
- Background TV studio
- Soft music in homes
- Loud radio
- Chamber music in small auditorium
- Airplane
- Concert
- Rock concert
- Band in night club
- Average personal Steele
- Normal piano practice
- Quiet office
- Background TV studio
- Soft music in homes
- Loud radio
- Chamber music in small auditorium
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- Soft music in homes

Intolerable

Pain

Very noisy

Loud

Moderate to quiet

Faint

Very faint

Threshold of hearing
Hearing Damage

<table>
<thead>
<tr>
<th>Noise level in decibels</th>
<th>Continuous dB</th>
<th>Permissible Exposure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>120 dB</td>
<td>8 Hours</td>
</tr>
<tr>
<td>10</td>
<td>115 dB</td>
<td>4 Hours</td>
</tr>
<tr>
<td>20</td>
<td>112 dB</td>
<td>2 hours</td>
</tr>
<tr>
<td>30</td>
<td>109 dB</td>
<td>1 hour</td>
</tr>
<tr>
<td>40</td>
<td>106 dB</td>
<td>30 minutes</td>
</tr>
<tr>
<td>50</td>
<td>103 dB</td>
<td>15 minutes</td>
</tr>
<tr>
<td>60</td>
<td>100 dB</td>
<td>7.5 minutes</td>
</tr>
<tr>
<td>70</td>
<td>97 dB</td>
<td>3.75 minutes (&lt; 4 min)</td>
</tr>
<tr>
<td>80</td>
<td>94 dB</td>
<td>1.875 minutes (&lt; 2 min)</td>
</tr>
<tr>
<td>90</td>
<td>91 dB</td>
<td>.9375 min (~ 1 min)</td>
</tr>
<tr>
<td>95</td>
<td>88 dB</td>
<td>.46875 min (~ 30 sec)</td>
</tr>
<tr>
<td>100</td>
<td>85 dB</td>
<td></td>
</tr>
</tbody>
</table>

Below this level hearing damage is negligible.
How does sound damage our ears?

- Sound waves enter the outer ear and travel through a narrow passageway called the ear canal, which leads to the eardrum.
- The eardrum vibrates from the incoming sound waves and sends these vibrations to three tiny bones in the middle ear.
- The bones in the middle ear couple the sound vibrations from the air to fluid vibrations in the cochlea of the inner ear, which is shaped like a snail and filled with fluid.
Inner Ear Damage

- Auricle (Pinna)
- Semicircular Canals
- Cochlea
- Incus (anvil)
- Stapes (stirrup)
- Auditory Canal
- Malleus (hammer)
- Tympanic Membrane (eardrum)
How does sound damage our ears?

- An elastic partition runs from the beginning to the end of the cochlea, splitting it into an upper and lower part. This partition is called the basilar membrane because it serves as the base, or ground floor, on which key hearing structures sit.

- Once the vibrations cause the fluid inside the cochlea to ripple, a traveling wave forms along the basilar membrane. Hair cells—sensory cells sitting on top of the basilar membrane—ride the wave.
As the hair cells move up and down, microscopic hair-like projections (known as stereocilia) that perch on top of the hair cells bump against an overlying structure and bend. Bending causes pore-like channels, which are at the tips of the stereocilia, to open up. When that happens, chemicals rush into the cell, creating an electrical signal.

The auditory nerve carries this electrical signal to the brain, which translates it into a sound that we recognize and understand.
Basilar Membrane of the Cochlea

https://www.youtube.com/watch?v=TobHJt1jIHg

https://www.youtube.com/watch?v=oapGVi6tOCU
Basilar Membrane
Human Hearing

- Signal Generator - different frequencies
Soundwaves: Wavelength

- Physical distance from peak to peak
- Low pitches have long wavelengths
- High pitches have short wavelengths
- Speed of sound divided by frequency
Soundwaves: Phase, Phase Shift, and Phase Interference

- **Phase**: degree of progression in the cycle
- Measured in degrees
- **Beginning**: 0°, **peak**: 90°, **end**: 360°
- **Phase shift**: two identical waves, with one delayed
- **Phase interference**: 180° phase shift
- Also called cancellation: hollow, filtered tone quality
Most sound waves have more than one frequency component: complex wave

Single frequency wave: pure tone

Lowest wave frequency: fundamental. Determines pitch

Higher frequencies called overtones or upper partials

If the overtones are a multiple of fundamental, they are called harmonics
Soundwaves: overtones con’t

- Fewer overtones produce pure smooth sounds (flute), while many strong harmonics produce edgy sounds (trumpet, distorted guitar)
- Equalization adjusts amplitude (loudness) of harmonics, and changes tonal balance
- Noise has irregular, nonrepeating waveform
Overtone series

Fundamental pure sinewave

Plus

3rd harmonic

Equals

Harmonically distorted waveform

Overtones
Soundwaves: Envelope

- Rise and fall in volume of a sound with respect to time
- Attack: note rises from silence to max. Volume (TRANSIENT)
- Decay: decrease in volume to mid-range level
- Sustain: middle level (hold of note)
- Release: fall in volume back to silence
Envelope Diagram

A Stylized Envelope

Amplitude

Time

- Attack Time
- Decay Time
- Sustain
- Release Time

Envelope
Sound Environments: Echo

- Surfaces: direct sound, absorption, diffusion, reflection
- Repeated sound (from hard surfaces)
- Speed of sound: 1 foot per millisecond
- Echo: sound must be delayed by 50 milliseconds or more
- Flutter Echo
Sound Environments: Reverb

- Reflections that “sustain” the note
- Reverb: the persistence of sound in a room after the original sound has stopped
- Hundreds of fast echoes that gradually get quieter
- Reverb: Hello-o-o-o-o-o-o Delay: Hello hello hello hello hello
- Reverberation time: dead vs live

Reverb and Echo
Signal Characteristics: Frequency Response

- Range of frequencies that an audio device (mic, mixer, speaker, etc…) will REPRODUCE at an equal level (within a tolerance, such as ±3dB)
- Range of frequencies that a device (mic, human ear, etc..) can DETECT
- Devices respond differently to different frequencies.
- Flatter the frequency response, the higher the fidelity or accuracy
- May be non-flat on purpose: cut low frequency, equalizer, boost high frequencies to add presence/sizzle.

Frequency response example
Frequency Response
Frequency Response
Signal Characteristics: Noise

- All signals produce noise
- Sounds like rushing wind
- Turn up signal level – keep the noise in the background
Signal Characteristics: Distortion

- Signal too hot (loud): gritty, grainy sound; clicks
- Also called clipping: peaks of signal clipped off and flattened
Signal Characteristics: Optimum Signal Level

- Boost signal to cover noise, low enough to avoid distortion
- Optimum signal level: “0”
- Signal level
- Headroom
- Noise Floor
- Signal to noise ratio (S/N)
Signal to Noise Ratio

Diagram showing the dynamic range and undesirable noise levels.
S/N Ration II

- Headroom
- Dynamic Range
- SNR
- Distortion Region
- Noise “Floor”
- Nominal Electronic Line Level
- Peak Level - Clipping Point