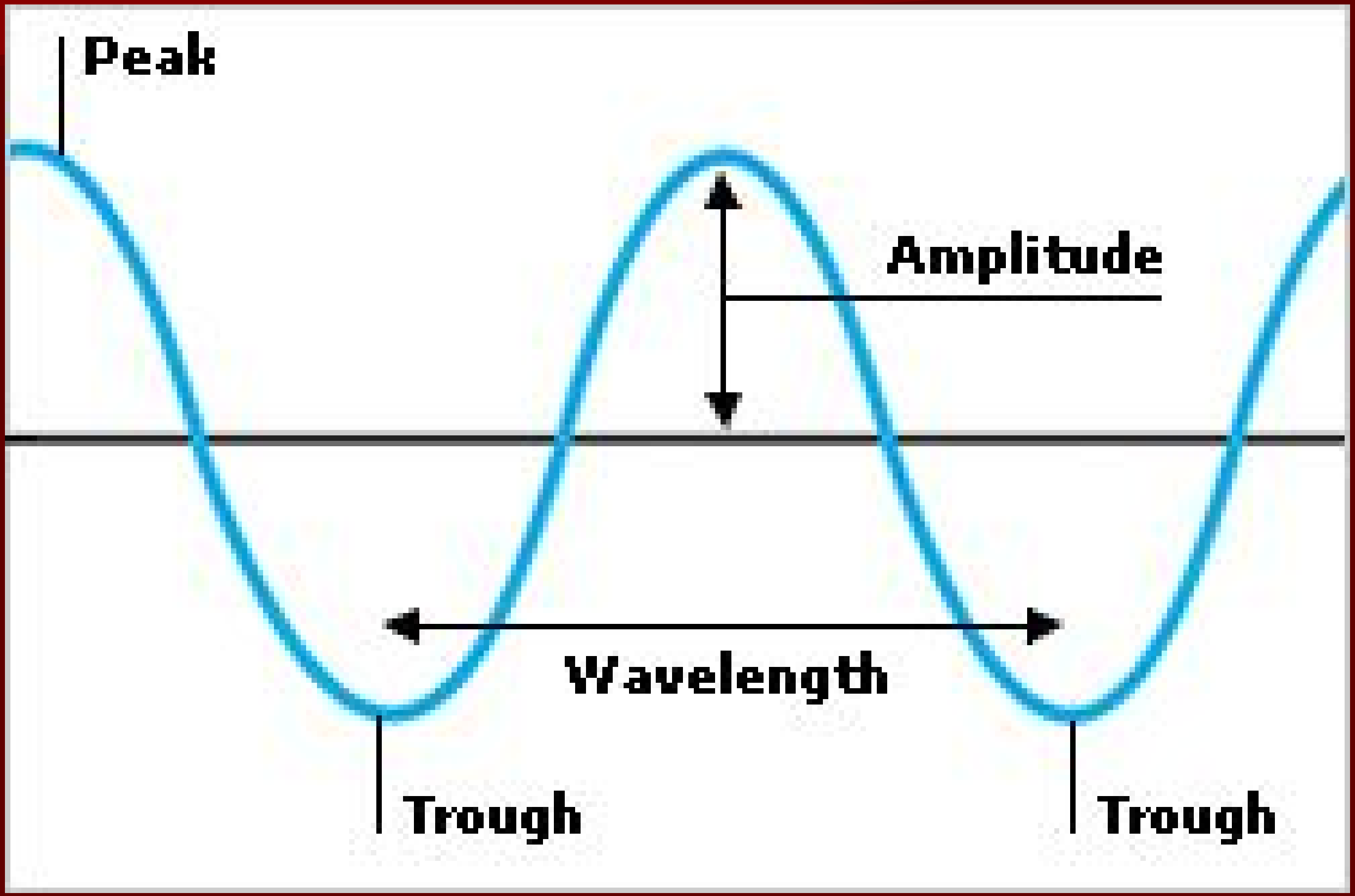
Chapter 3

Sounds, Signals, and Studio Acoustics

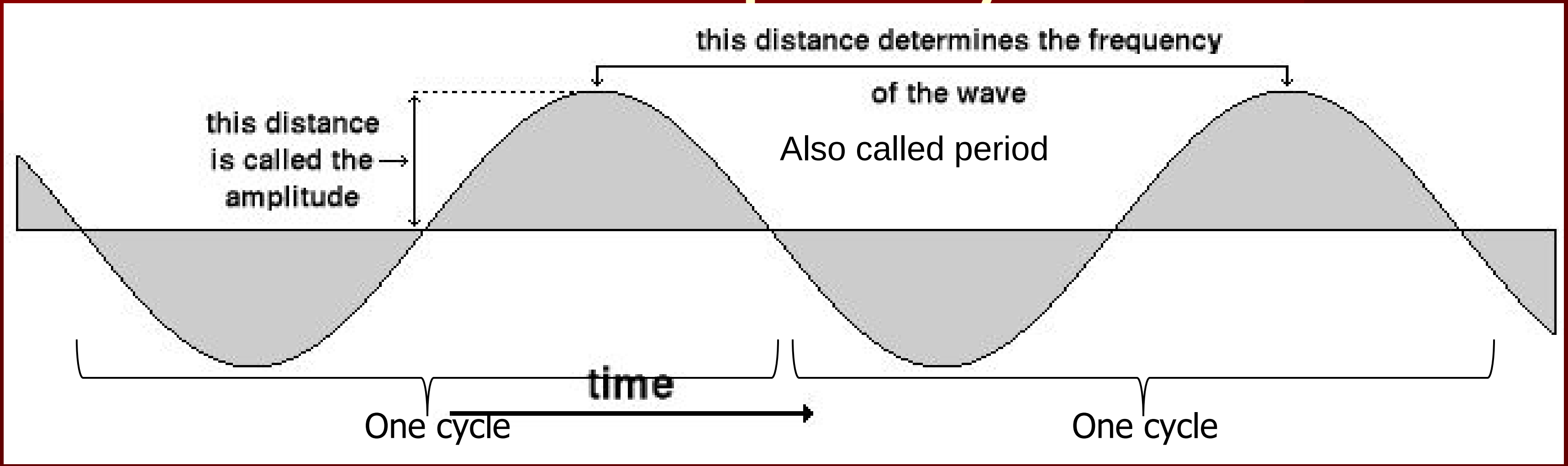
Sound Waves

- 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

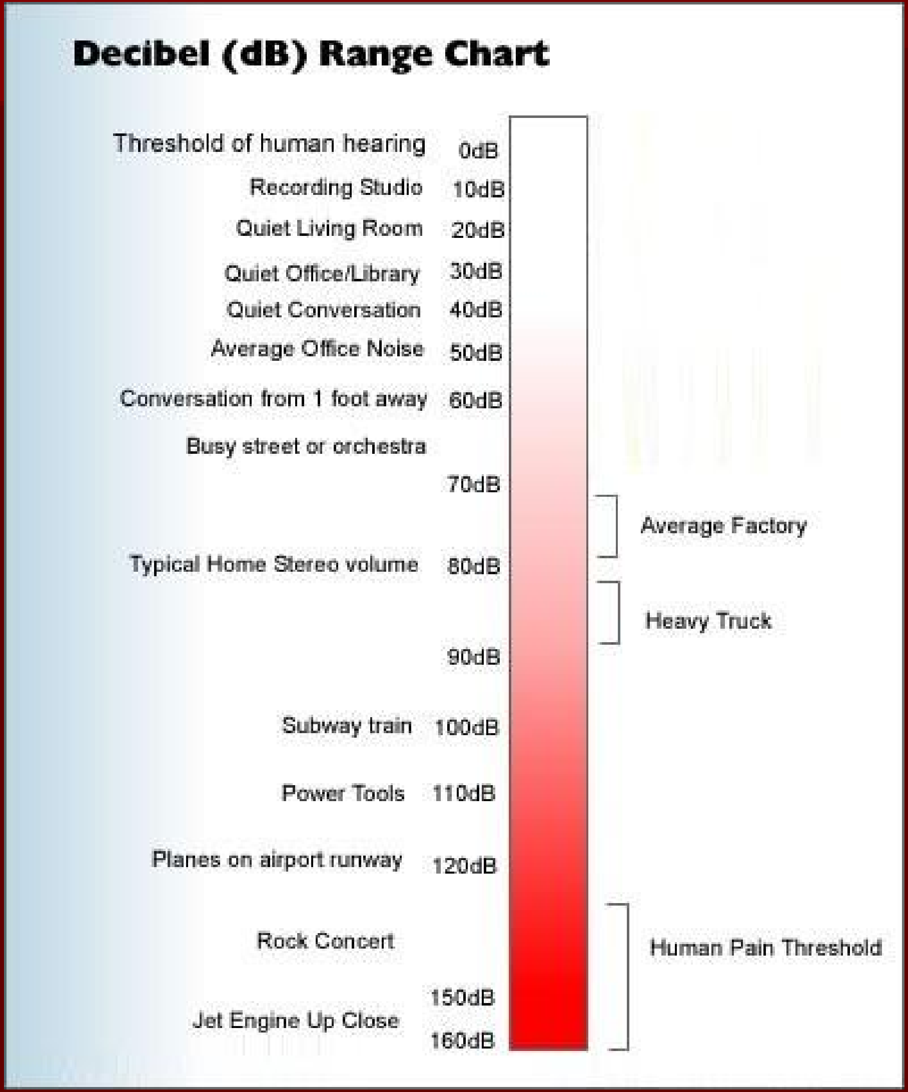


Sound Waves: Amplitude and Frequency

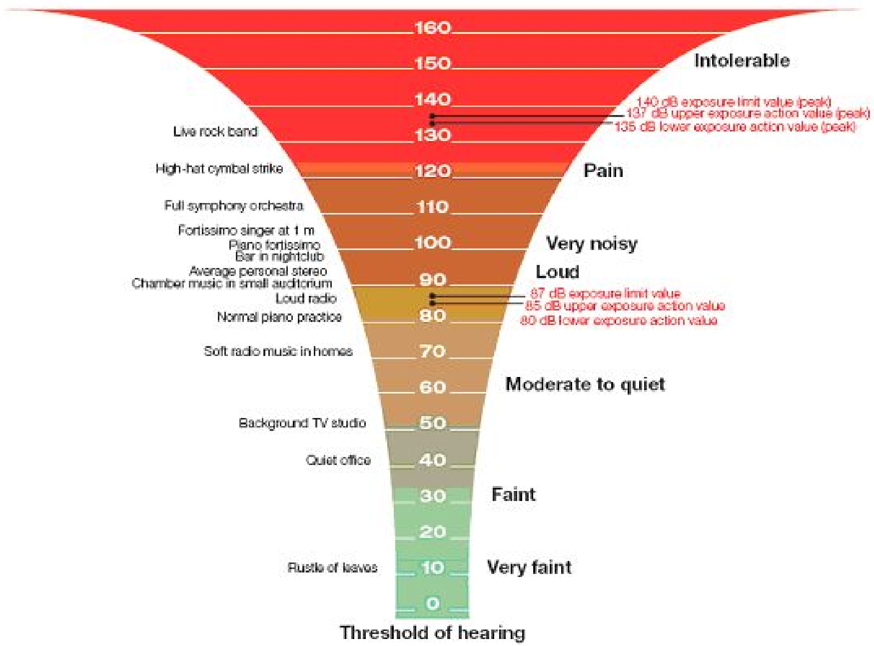


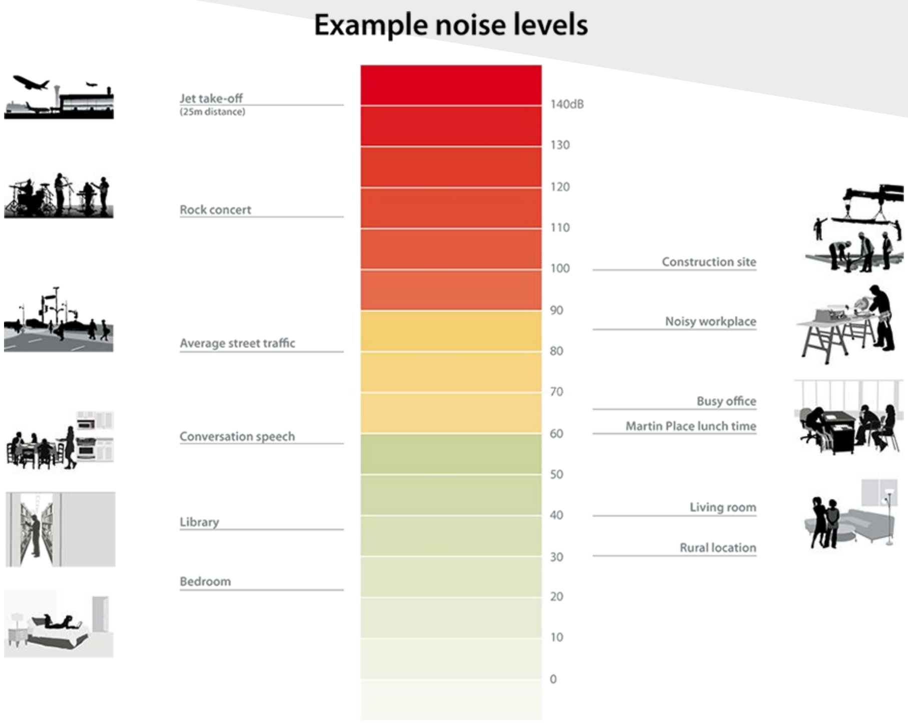
- Amplitude: height of the wave (loudness) measured in decibels (dB)
- Frequency (Hz or kHz) number of cycles per second
- Frequency: highness or lowness of sound
- Human hearing range: 20 Hz – 20kHz (20,000 Hz)
- Doubling Frequency raises the pitch one octave
- Instrument Frequency Chart

Decible Range Chart

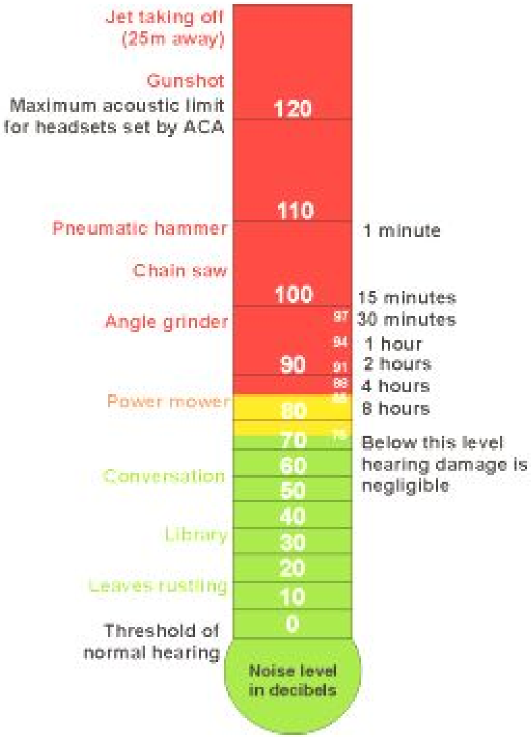


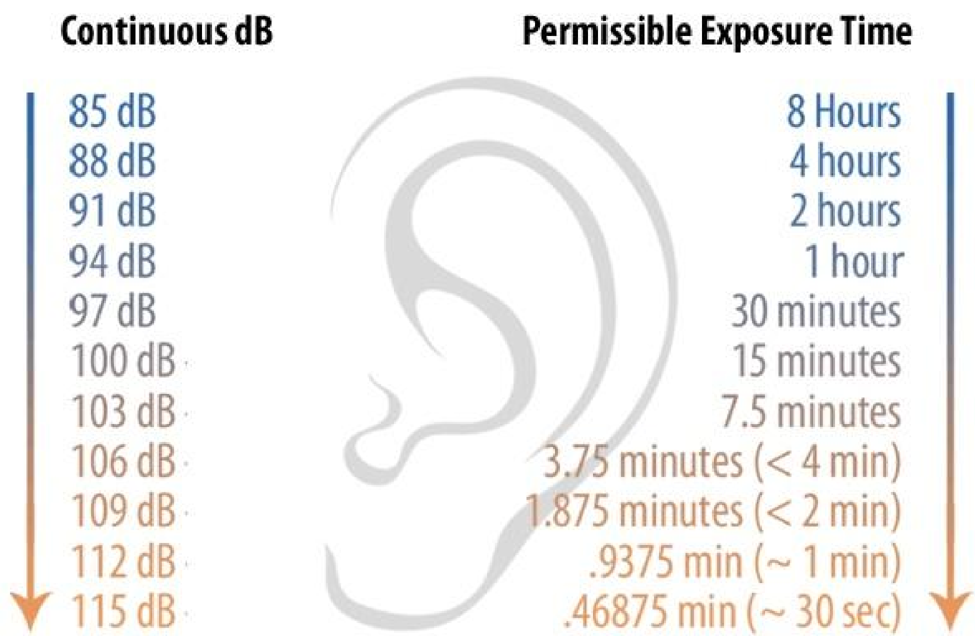
Hearing Damage





Hearing Damage

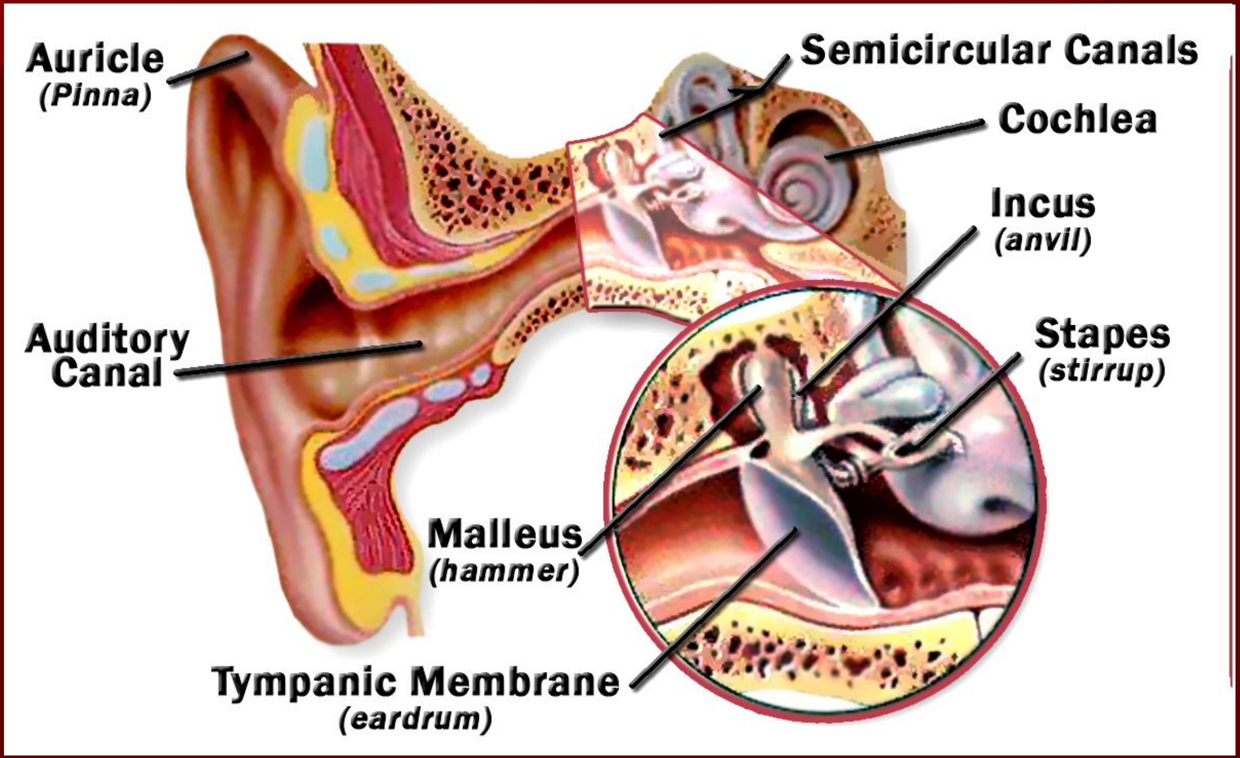




How does sound damage our ears?

- 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



https://www.youtube.com/watch?v=p3Oy4lodZU4

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.
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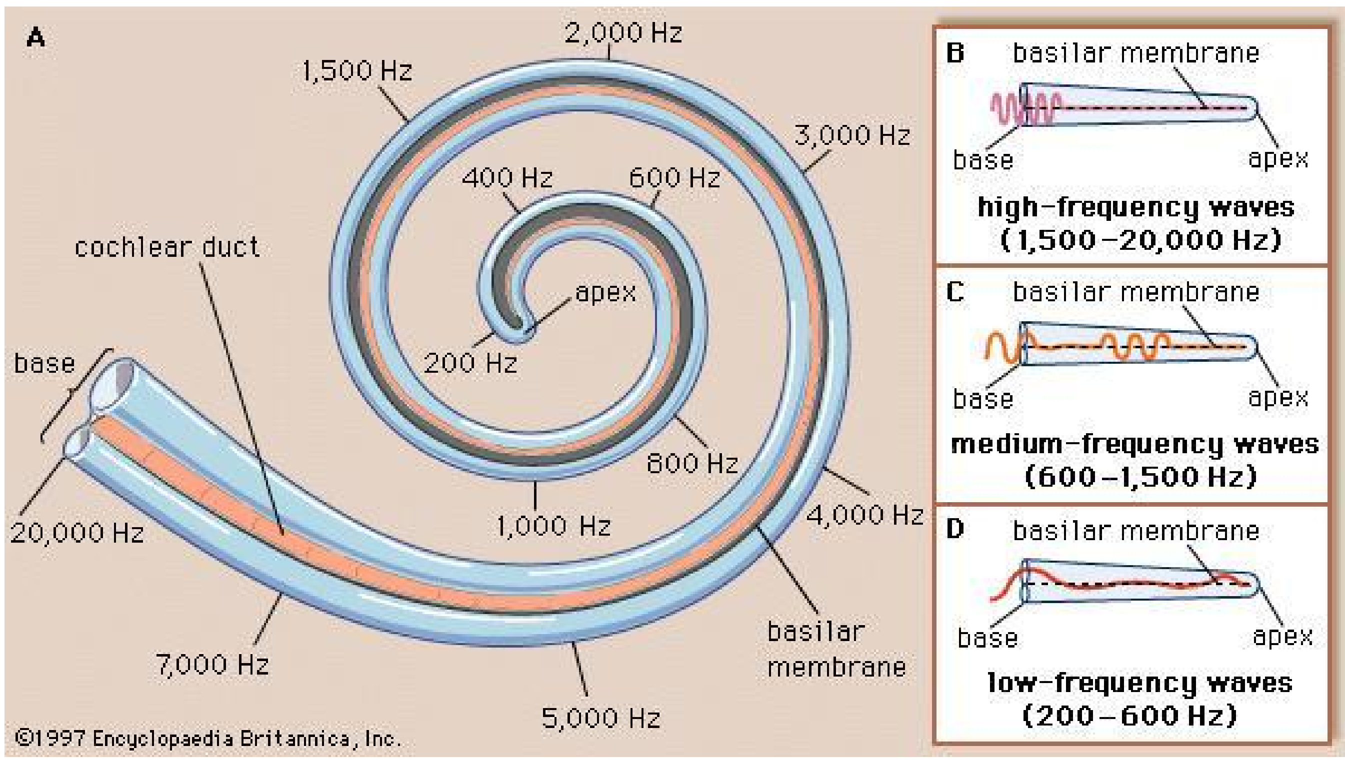
How does sound damage our ears?

- 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



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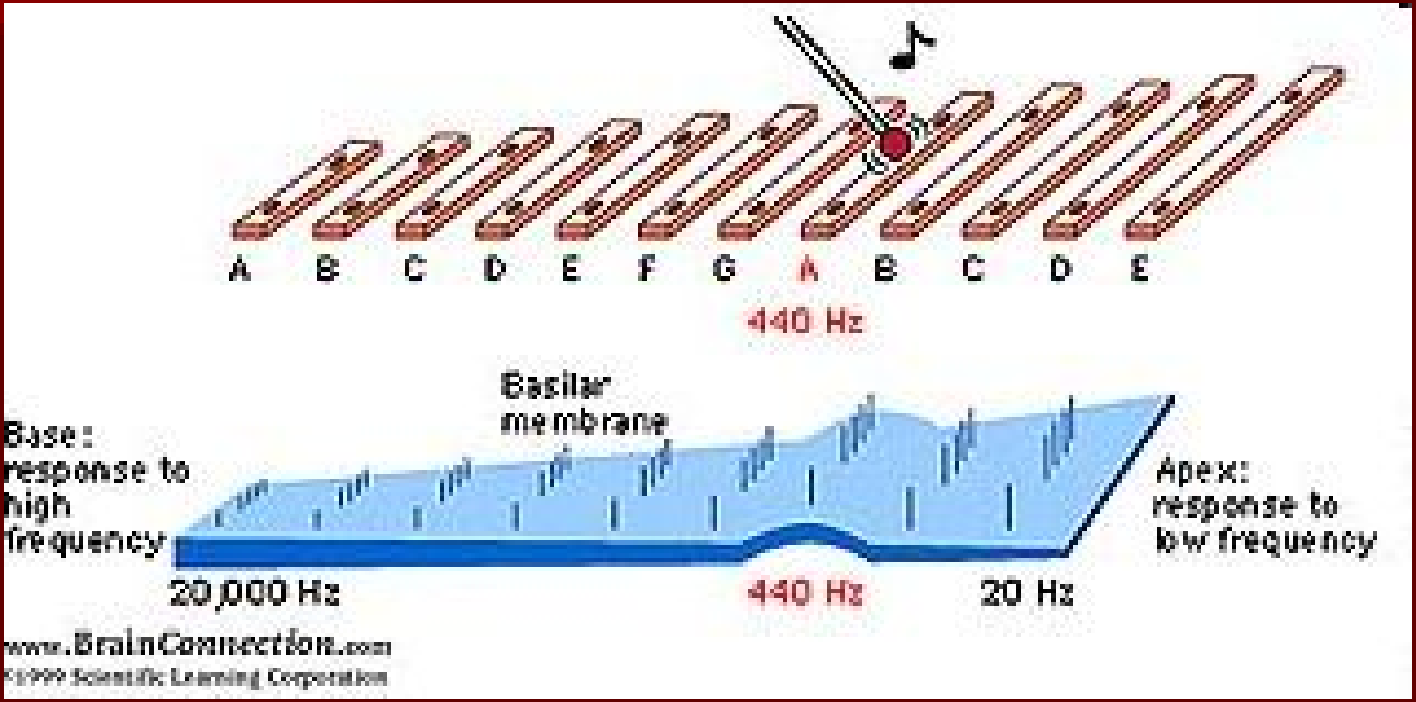
Basilar Membrane



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

Soundwaves: Overtones

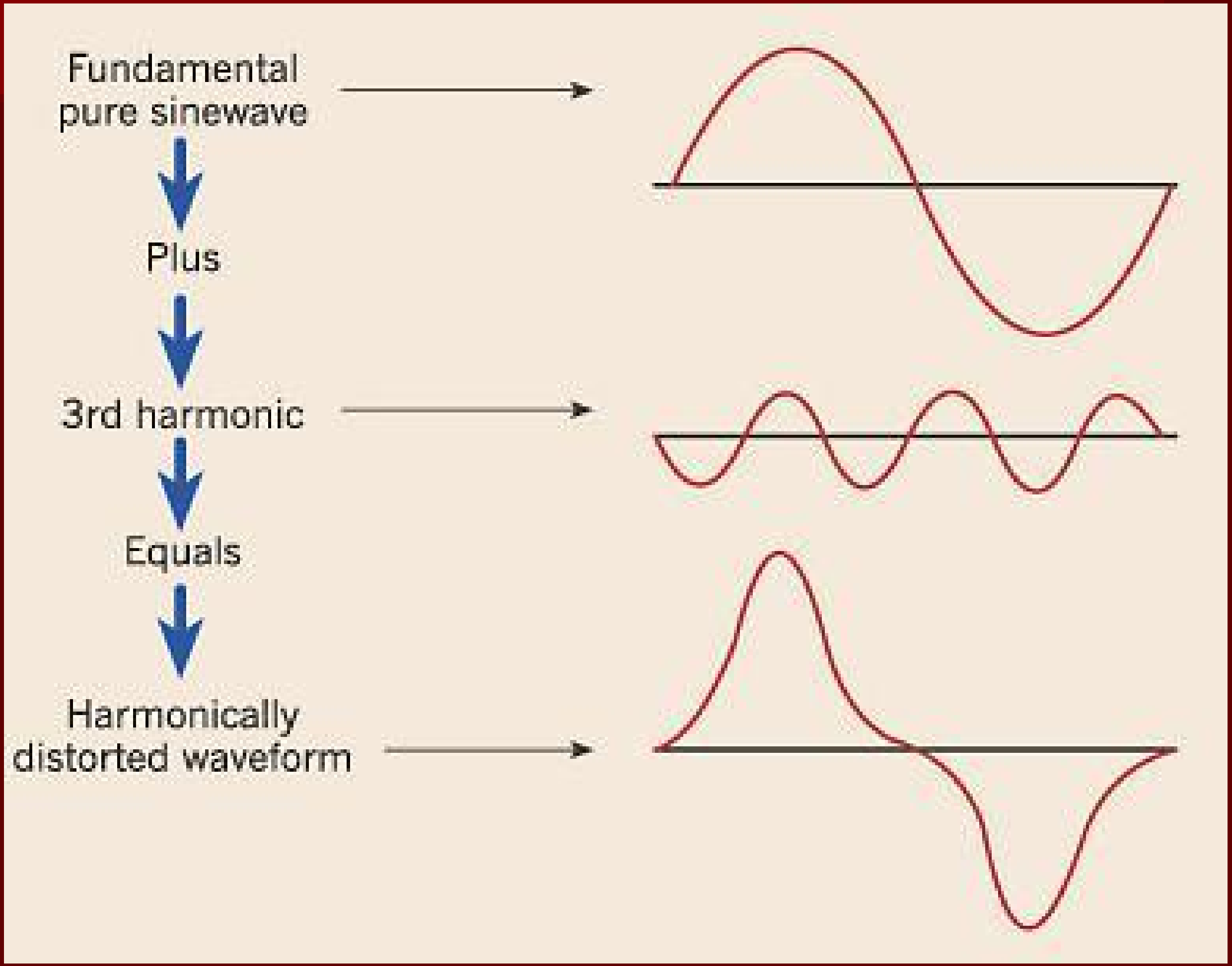
- Most sound waves have more than one frequency component: complex wave
- Single frequency wave: pure tone
- Lowest wave frequency: fundamental. Determines pitch
- Higher frequencies called overtones or upper partials
- If the overtones are a multiple of fundamental, they are called harmonics

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

Harmonics

Overtone series

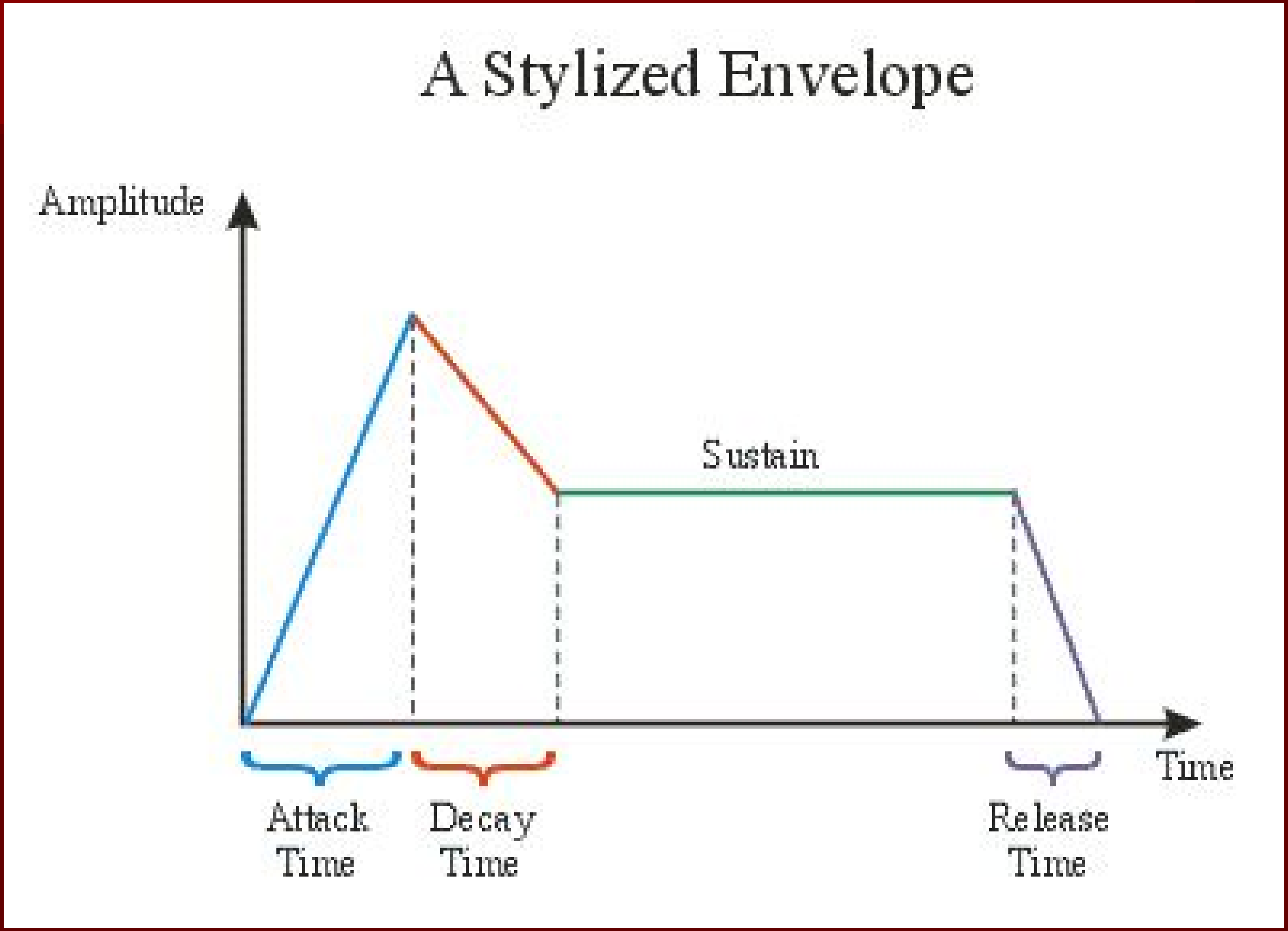


Overtones

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



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 Delay: Hello hello hello hello
- Reverberation time: dead vs live

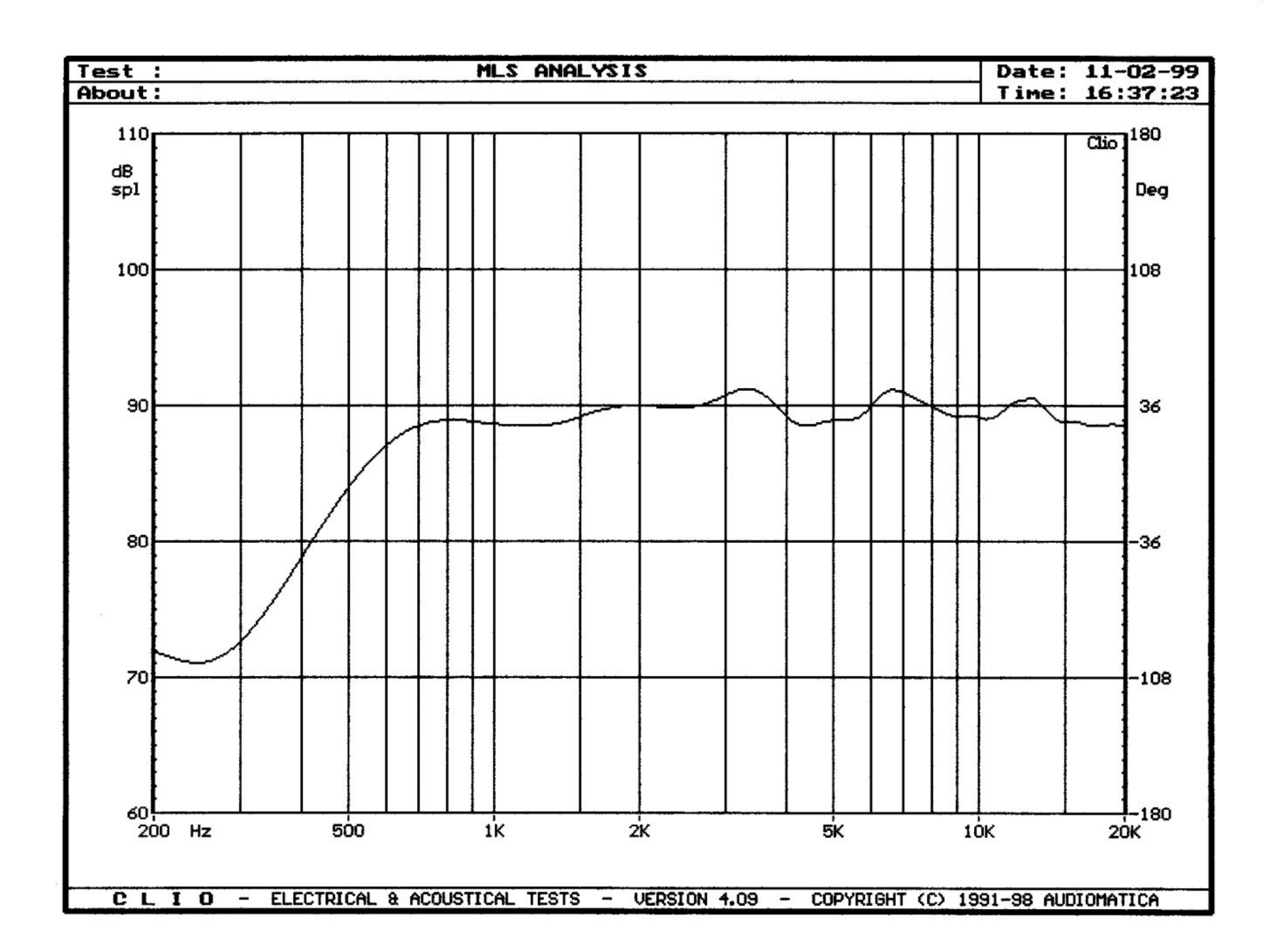
Reverb and Echo

Signal Characteristics: Frequency Response

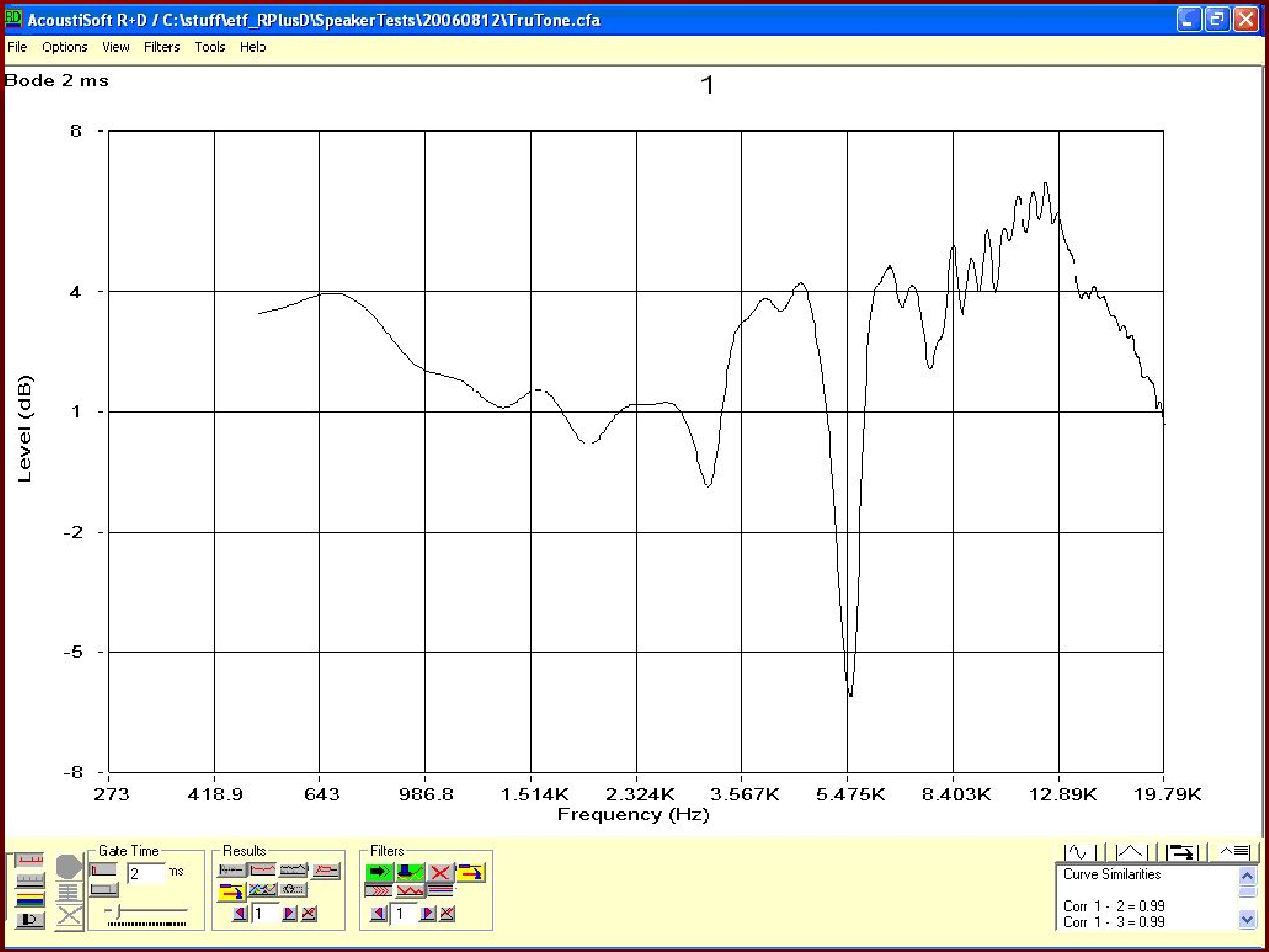
- Range of frequencies that an audio device (mic, mixer, speaker, etc…) will REPRODUCE at an equal level (within a tolerance, such as ±3dB)
- Range of frequencies that a device (mic, human ear, etc..) can DETECT
- Devices respond differently to different frequencies.
- Flatter the frequency response, 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

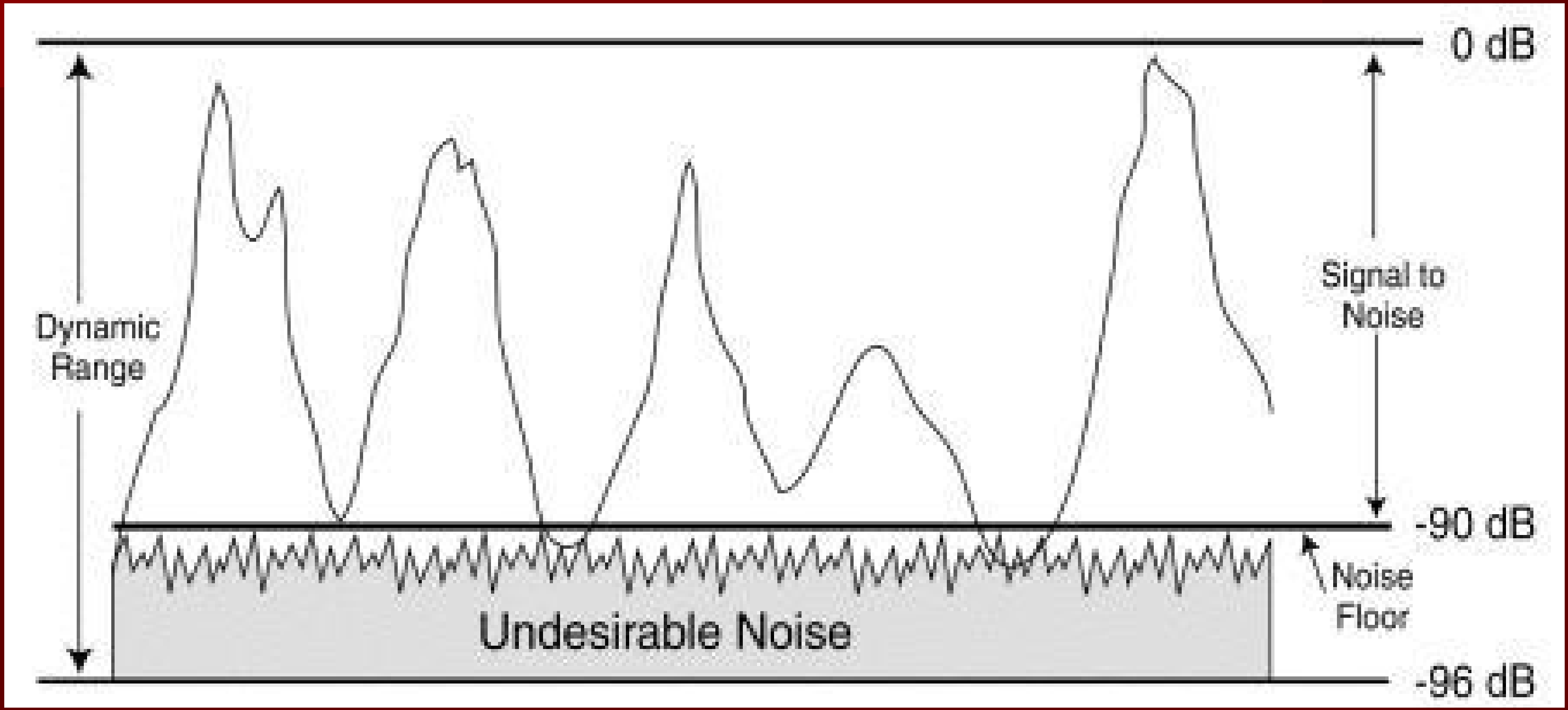
Noise/Distortion

Signal Characteristics: Optimum Signal Level

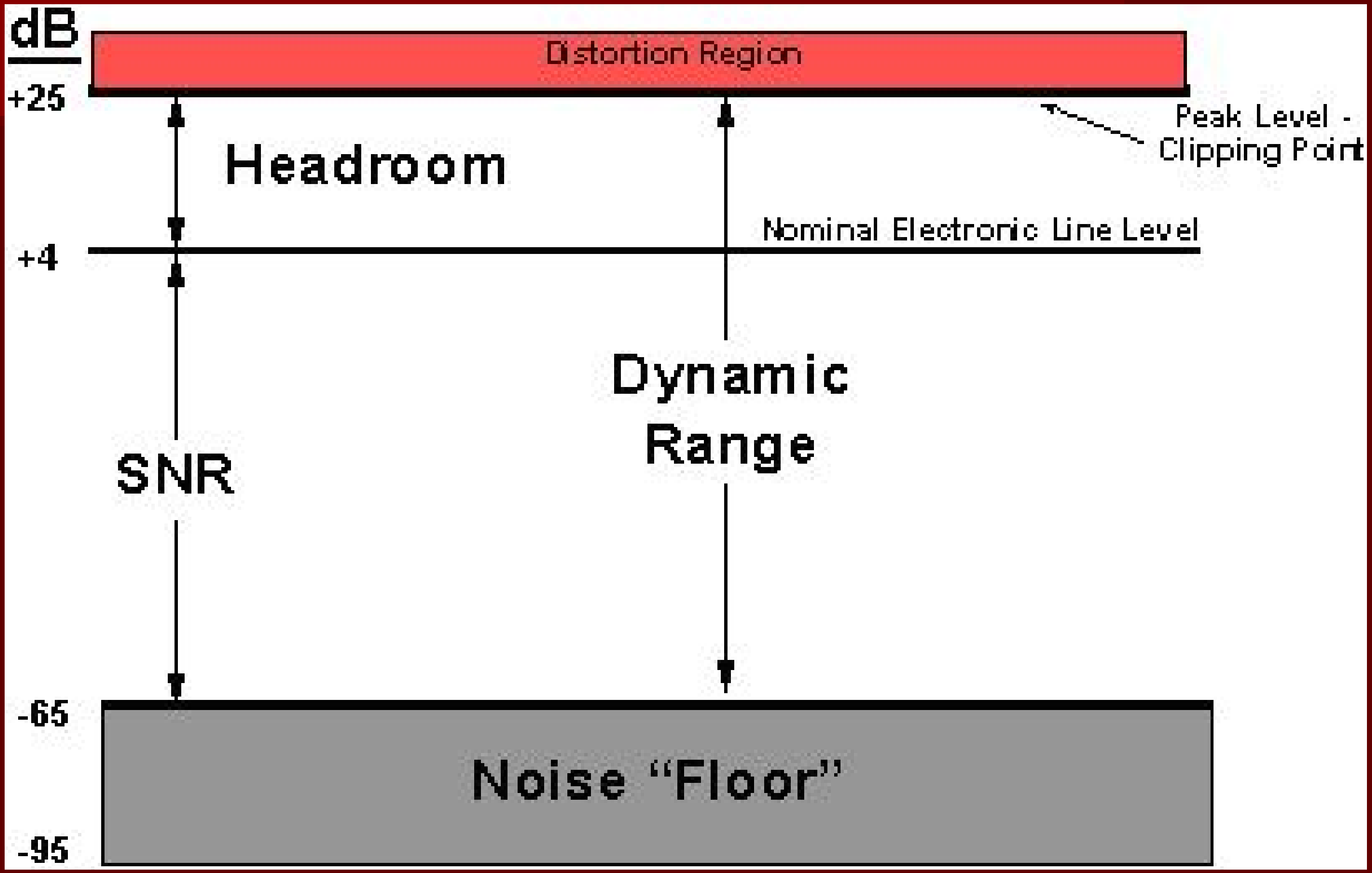
- Boost signal to cover noise, low enough to avoid distortion
- Optimum signal level: “0”
- Signal level
- Headroom
- Noise Floor
- Signal to noise ratio (S/N)

Signal to noise ratio

Signal to Noise Ratio



S/N Ration II


dB
Distortion Region
+25
Peak Level -
Clipping Point
Headroom
Nominal Electronic Line Level
+4
Dynamic
Range
SNR
-65
Noise "Floor"
-95