MUM 2600 – Chapter 2 Notes
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Examination of sound

1. Nature of sound as a brain stimulus
2. The physiology of the ear
3. The psychoacoustics of hearing (how & why brain perceives sound in a specific way.)

Sound-Pressure Waves

Sound arrives at ear as small, periodic variations in atmospheric pressure.
Variations in air pressure created by a wave cannot be measured by a barometer because they are too small.
Sound-pressure waves radiate outwardly in a 3-dimensional spherical pattern.
A sound-pressure wave is generated when a vibrating body comes in contact with air.

Compression – a condition defining an area containing greater than normal atmospheric pressure due to the squeezing of additional air molecules by a sound source (vibrating body) into that area.

Rarefaction – a condition when an area with lower than normal atmospheric pressure is created at the source of a sound-pressure wave as it moves away.

Note: The wave and not the molecules move at the speed of sound.

Wave propagation – when high-pressure compression waves push against areas of lower pressure in the atmosphere. These waves move at the speed of sound.

WAVEFORM CHARACTERISTICS

Amplitude – the distance above or below the centerline of a waveform.

a. peak amplitude – (peak value) the measurement between the maximum positive or negative signal levels.
b. peak-to-peak value – the difference between the positive and negative peak signal levels.

Frequency – The rate at which an acoustic generator, electrical signal or vibrating mass repeats a cycle of positive and negative amplitude.

a. Cycle – one completed excursion of a wave.
b. Hertz (Hz) – unit of measurement used to describe/measure the number of cycles occurring in one second.
c. Period – the time it takes to complete one cycle.

Velocity – Sound travels at 1130 ft/sec. The velocity is temperature-dependent and increases by 1.1 ft/sec with each Fahrenheit increase of 1 degree.

Wavelength – The distance between the beginning and the end of a cycle.
Wavelength = Velocity/Frequency (Hz)
Seconds per cycle (T) is given as T = 1/F

Phase – (measured in degrees) the relative phase degree angle with another wave over 360° or one cycle.

If 2 wave forms are in phase (have same frequency, shape and peak amplitude) and are added together, their amplitude doubles and the resulting wave form will have the same frequency, shape and phase.

If 2 waveforms differ by 180°, they will cancel each other out. They will create a zero amplitude.

If 2 waveforms are partially out of phase, the will constructively interfere (gain) at points were both are positive or both are negative. The waveforms will destructively interfere at points where the signs (+/-) of the two waveforms are opposing.

Phase-shift – describes one waveforms lead or lag time in respect to another. Caused by time delay usually due to distance. In order to avoid hearing the interferences by keeping them above 20k Hz, the path-length difference must be less than 0.34 inches or 0.03 ms.

Harmonic Content
Fundamental – a specific pitch that is being generated or played. A note.

Partials – various frequencies that exist in addition to the fundamental pitch being played.
Overtones – partials higher in pitch than the fundamental.
Harmonics – overtone frequencies that are whole-number multiples of the fundamental.

Simple Waves – Square, Triangle, Sawtooth. Continous and repeating in nature.

Complex Waves – Naturally occurring in sound and speech. Don't repeat.

Timbre = harmonic balance.

Reflection of sound
Sound waves reflect off a surface at an angle equal to and in the exact opposite direction of the initial angle of impact.

Solid, smooth surfaces produce a straight bounce of sound waves.
A convex surface (bubble) radiates outward in a wide dispersion pattern.
Concave surfaces focus sound waves to a single point.

A corner with an angle of 90° reflects the pattern back in it's original incident direction. This is why corners often provide a magnification of sound.

Diffraction - The ability of sound waves to bend around an obstacle and reconstruct.

Frequency response – The charted output of a sound-producing device over a range of frequencies. Usually charted in the range of human hearing from 20 – 20,000 Hz. Flat-frequency response is when a device passes all frequencies (in a range) evenly.

Envelope – Characteristic variations in level over the duration of a note.

1. Attack – level at note start
2. Sustain – volume changes during duration
3. Decay – fade or reduction over time once note has stopped sounding.

DECIBEL

Unit of measurement used for measuring sound pressure level.
DB is a logarithmic value that expresses differences in intensities between two levels.
It stands for $1/10^{th}$ of one bell after Alexander Graham Bell (telephone).
Measured in logarithmic numbers.

Logarithm is a mathematical function that reduces large number values into smaller more manageable ones.
Log numbers increase exponentially instead of linearly. We hear exponentially.
Log basics:
Log 2 = 0.3
Log 10 = 1
Log 100 = 2
If number is a power of 10, log is equal to number of zeros.
Numbers > 1 have a positive (+) log value.
Numbers < 1 have a negative (-) log value.

SOUND-PRESSURE LEVEL

SPL is the acoustic pressure built up within a defined atmospheric area.
Usually a square centimeter or cm2.

VOLTAGE

You can measure acoustic energy by comparing one voltage level to another.
Voltage is defined as: A unit of measure of the "push" of electric current. The higher the voltage, the more force there is to push the current through the wire.
www.eeexchange.org/solar/glossary.html

POWER

A measure of wattage or current associated with signals carried through the audio signal path.
Power units are called watts. Watts are defined as:
A measure of electrical power that is determined by multiplying the voltage by the

amperage.
www.smartroofsolar.com/glossary.html

Ohms are the units representing load impedance. Lower impedances are harder for amplifiers to drive. For example, 2 8 ohm rated speakers connected in parallel will result in a 4 ohm amplifier load.

Load impedance is defined as:
The impedance seen by one channel of a power amplifier; it is determined by the number of speakers wired to the channel, the impedance characteristics of each channel, and how they are wired to one another.
http://home.earthlink.net/~cyberses/glossary/glossary.html

The opposition to output current flow caused by the input that it feeds.
recordingeq.com/glossary/glosko.htm

THE EAR
A sound produces waves that compress and rarefy (thin out) the air between the source and listener.

Waves are captured by the ear canal and then directed to the eardrum.

The eardrum transforms the wave into mechanical vibrations which are transferred into the inner ear by three bones: hammer, anvil and stirrup. These bones act as an amplifier and a limiter.

The vibrations are then applied to the cochlea or inner-ear. Snail-like, tubular organ with two fluid filled chambers. In the chamber are small hair recept
ors lined in a row along the length of the inner-ear. The hairs respond to different frequencies. Permanent hearing loss occurs when these are damaged or due to aging.

THRESHOLD OF HEARING IN DIFFERENT MEASUREMENTS
SPL = 0.0002 microbar
One microbar is = one-millionth normal atmospheric pressure.
Usually denoted as 0 dB SPL or the level the average person hears a specific frequency only 50% of the time.

THREHOLD OF FEELING
Level causing discomfort 50% of the time.
118 dB SPL between 200Hz and 10kHz.

THRESHOLD OF PAIN
Level causing pain 50% of the time.
140 dB SPL between 200Hz and 10kHz.

Harmonic distortion occurs naturally in the ear whenever it picks up waves above a certain level.
Harmonic distortion is not part of original signal.

Linear device – input and output amplitude have the same input/output ratio at all signal levels.

The ear is non-linear. Because of this, tones often interact with each other as opposed to being heard separately. Three types of interaction occur:

1. Beats – 2 tones differing slightly in frequency and having approximately the same amplitude will produce beats. Occurs when two instruments play the same note. Beats slow down and stop as two tones reach the same pitch. The beat is a third tone that is the sum of the two tones when they are in phase and the difference when they are out of phase.

2. Combination tones – produced when 2 loud tones differ by more than 50Hz. The ear produces an additional set of tones that's equal to both the sum and difference between the 2 original tones and is also equal to the sum and difference in their harmonics. Sum tone = Freq1 + Freq2, Difference tone = Freq1 – Freq2. Difference tones can easily be heard when they're below the frequency of both tone's fundamentals.
3. Masking – a phenomenon where by loud signals prevent the ear from hearing softer signals. This is exaggerated when the frequencies of the sounds are close to each other. Important in mixing because similar frequencies will mask softer similar frequencies. Example a fluglelhorn will mask another flugelhorn easier than it will mask a soprano saxophone.

DIRECTION
One ear cannot perceive direction of a sound. Two ears can. Called spatial or binaural localization.
Ear receives 3 cues:
1. Interaural intensity differences – middle to high frequencies originating on a particular side, will reach that same side at a higher intensity level.
2. Interaural arrival time differences – used by ear for lower, slower frequencies.
3. The effects of the outer ear (pinnae) – the two ridges of the ear tell us if sound originates from the front, rear or below.

1 &2 give direction or panning. Changing direction or intensity of frequency from left to right.

SPATIAL PERCEPTION
Ears and brain give us distance as well as a sense of the space in which sound occurs.

% of sound reaches ear directly. A larger % reflects off of surfaces or is absorbed by surfaces creating more or less signal respectively.

Sound travels through air at 1130 feet pre second. Direct waves travel shortest path. Early reflections are the ones that reach after bouncing off surfaces. Sometimes these waves are heard after the original source stops and are called reverberation.

Direct sound determines perception of source location. Size conveys true timbre of sound source.

Early reflections (result of bounce off of the largest, most prominent boundaries in room), arrive less than 50msc after the brain perceives original source. The farther the boundaries from the source and listener, the longer the delay.

Temporal fusion – early reflections arriving earlier than 30msc of direct sound are suppressed and fused with the source sound. The 30msc limit is not fixed and depends on the sounds envelope. Fusion breaks down a 4 msc for transient clicks and as long as 80 msc for slowly evolving sounds such as an organ note or long notes on a violin.

REVERB - sounds reaching after more than 50msc reflect off of so many surfaces that they reach listener as a continuous stream from all directions. Characterized by a gradual decrease in amplitude and a sense of warmth and body added to the sound. Timbre is very different from original sound due to the number of bounces.

Decay time or reverb time = time for persisting sound to decrease to 60 dB below it's original level.

As one gets closer to source, the source sound gets louder while the reverb stays the same.

The ratio between the source sound loudness and the reverb allows listener to judge distance from the sound source,

Repeating a signal with a short delay of 4-20 msc, makes part seem doubled.
Cheap way of doubling tracks.

Slap echo or slap back – longer delays of more than 35 msc cause a discreet echo. This is used to thicken up the sound.