Multimedia Systems

II. Introduction to Sound

2.1. Audio Signal Fundamentals

António Sá Pinto

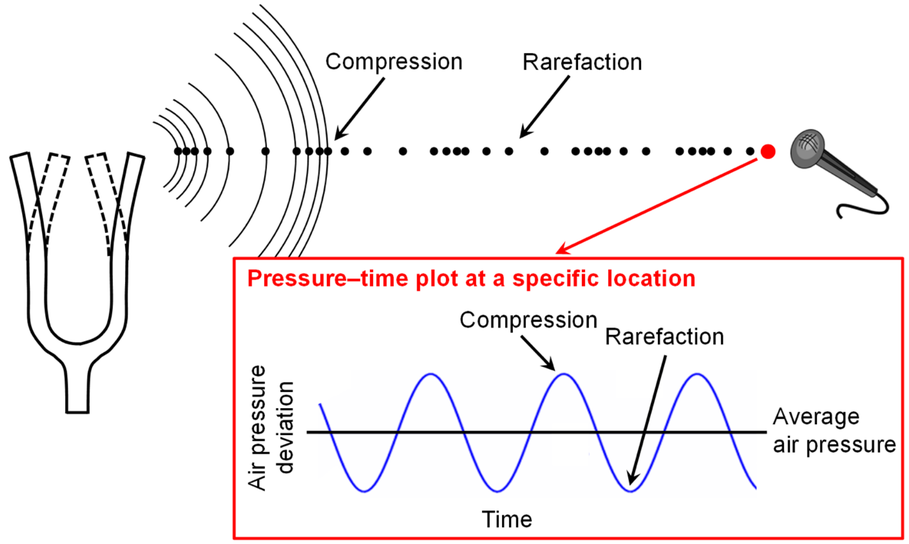
FEUP

Agenda

- Physics of Sound
- Pure Tones *vs* Complex Sounds
- Harmonic vs Inharmonic Sounds
- Basic Characteristics of Sound

Physics of sound

Sound is produced by a vibrating source around which the carrying media (e.g. air) is caused to move. From the vibrating source, a sound wave radiates omnidirectionally away from itself, and the sound energy is transferred to the carrying media through compressions and rarefactions (similar to waves moving on the surface of the sea).



from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Displaying a Sound Wave

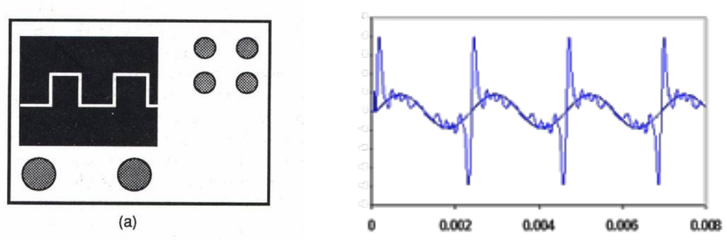
Time domain FFT / IFFT **Frequency domain**

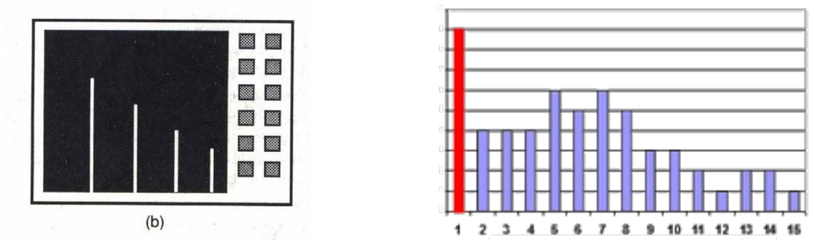
a) Waveform

b) Spectrum

Old days: using oscilloscope

Old days: using spectrum analyser

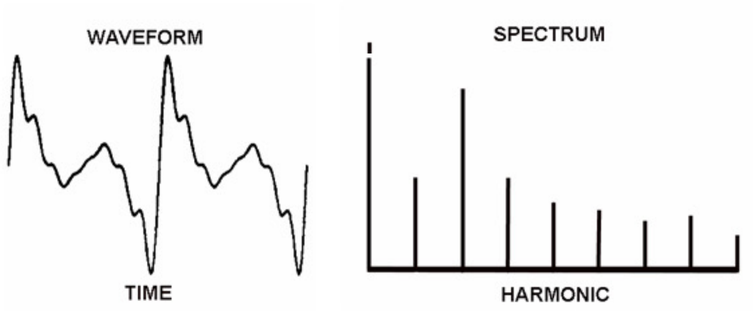




Pure Tone *vs* Complex Sounds

- **Pure Tone** has (almost) all its energy located at 1 frequency (sine wave). *E.g. audiometric tones, forking tune.*

- **Complex sound** is composed of multiple frequencies. Almost all sounds in our day-to-day lives are complex in nature.

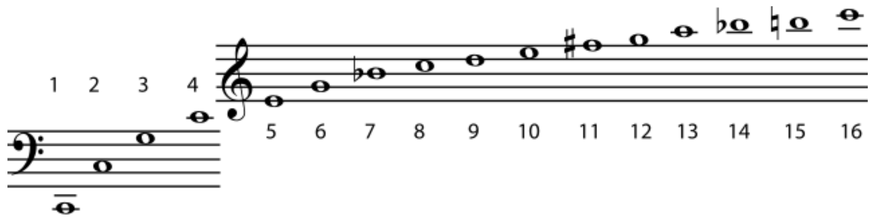


from: (Rumsey and McCormick 1994) *Sound and Recording*

Harmonic (repetitive) Sounds

- Different from the pure tone (single frequency, which is not commonly heard in real life), real music audio is much more complex and is a mixture of harmonic sounds (multiple frequencies).

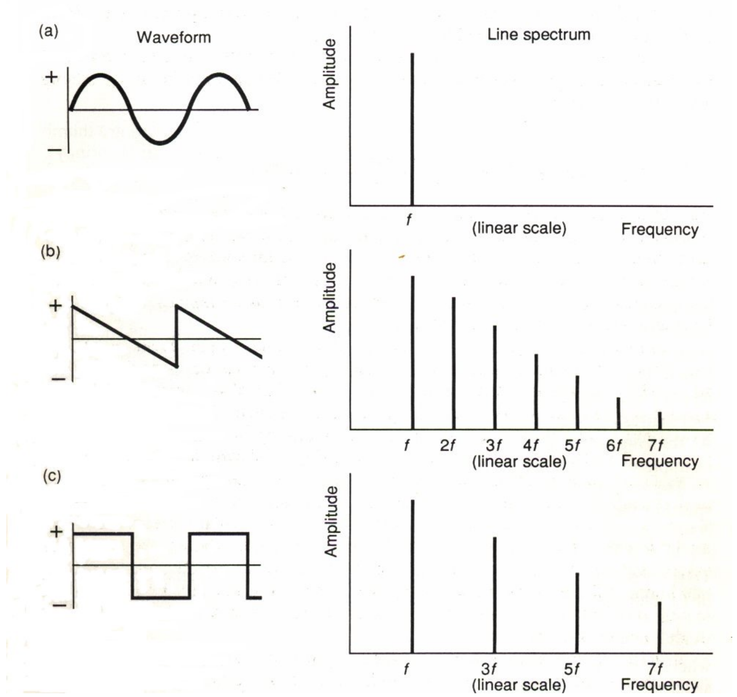
- Harmonic frequencies are the integer multiples of the fundamental frequency. For example, the first harmonic is equal to the fundamental frequency, the second harmonic (also known as the first overtone, or partial) is a doubling of the fundamental frequency, the third harmonic (i.e. the second overtone) is three times of the fundamental frequency, etc.



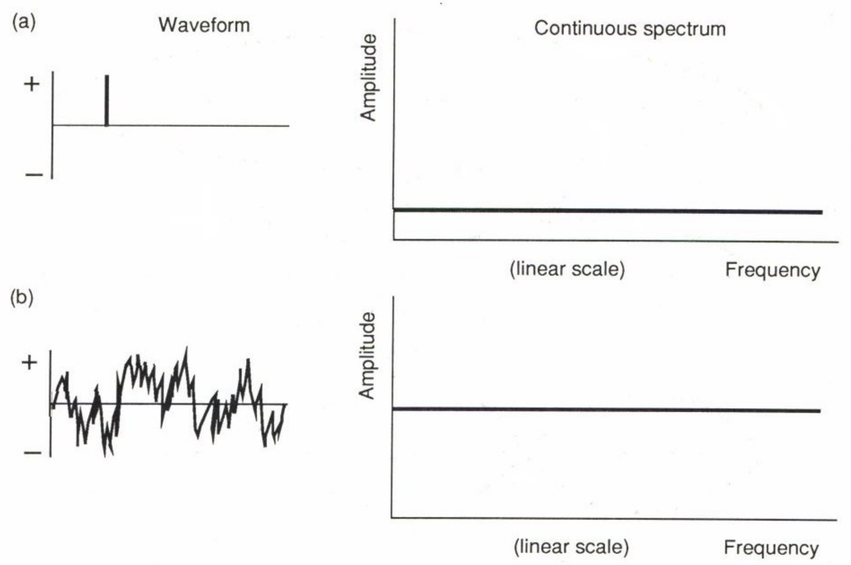
The Harmonic Series

Harmonic *vs* Inharmonic Sound

- **Harmonic** sounds exhibit a pattern (repetition).



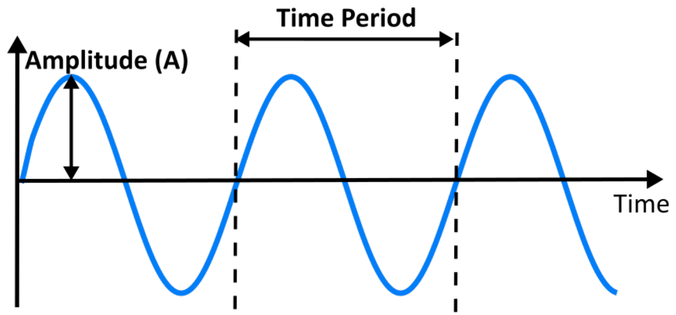
- **Inharmonic** sounds exhibit an absence of pattern or a highly random pattern. (Noise)



from: (Rumsey and McCormick 1994) *Sound and Recording*

Basic characteristics of sound waves (1)

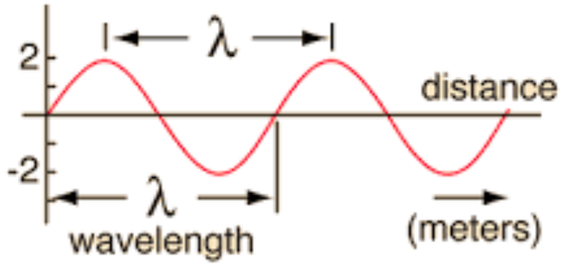
- **Period**: is the time it takes to complete one cycle. The standard unit of a wave period is seconds.
- **Frequency:** the rate at which the vibrating source oscillates, quoted in hertz (Hz) or cycles per second (cps), measured as the number of cycles of a wave that occur in one second. *The human ear is able to perceive sounds with frequencies between approximately 20 Hz and 20 kHz (known as audio frequency range).*
- **Amplitude:** the amount of compression and rarefaction of the carrying media resulting from the motion of the vibrating source, *related to the loudness of the sound when perceived by human ears.*

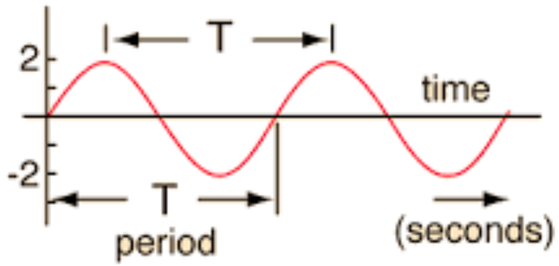


Frequency = 1/Time Period

Basic characteristics of sound waves (2)

- **Wavelength:** the distance between two adjacent peaks of compression or rarefaction as the wave travels through the carrying media. (same quantity as **period** but different units)





- **Velocity:** the speed of the sound energy transfer. The velocity of sound in air is about 314 meters per second. The velocity of sound depends on the carrying media and also its density.

$$v = \frac{\lambda}{T}$$

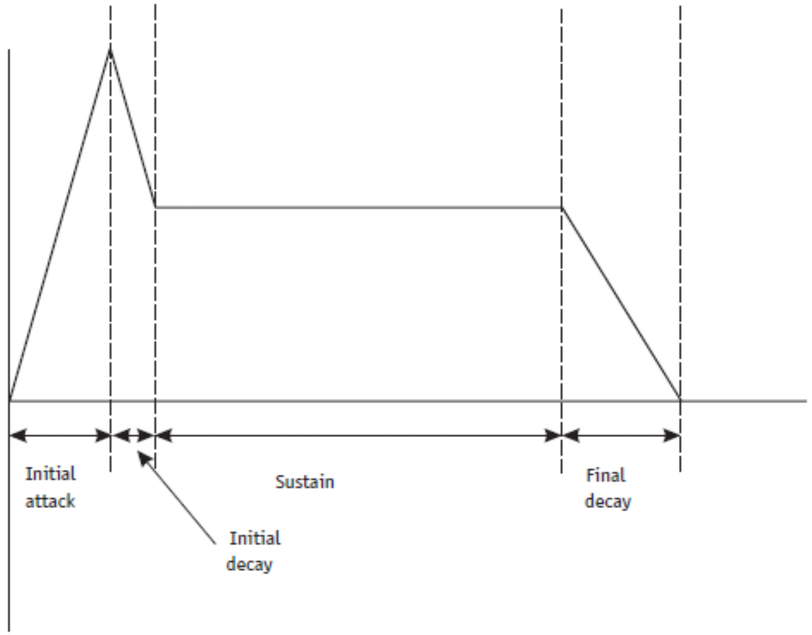
v : speed $(m.s^{-1})$
λ : wavelength (m)
T : period (s)

$$v = f\lambda$$

v : speed $(m.s^{-1})$
λ : wavelength (m)
f : frequency $(Hz$ or $s^{-1})$

Basic characteristics of sound waves (3)

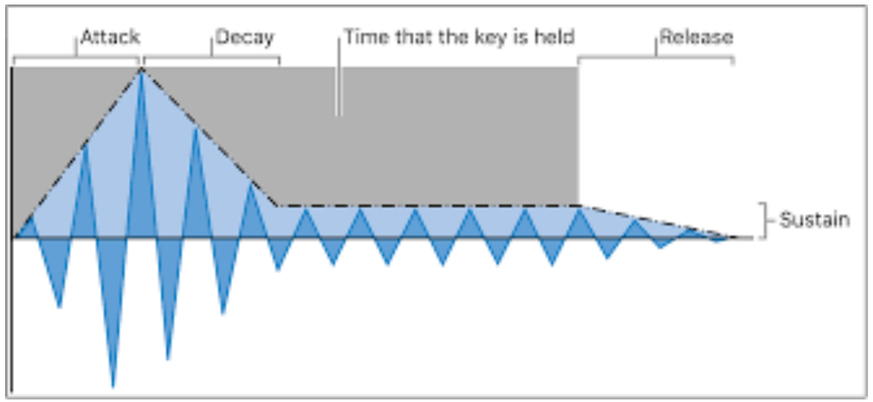
- **Envelope:** the shape of sound wave evolution. Usually, it includes four main parts: the attack, the initial decay, the sustain (i.e. internal dynamic), and the final decay (i.e. release).

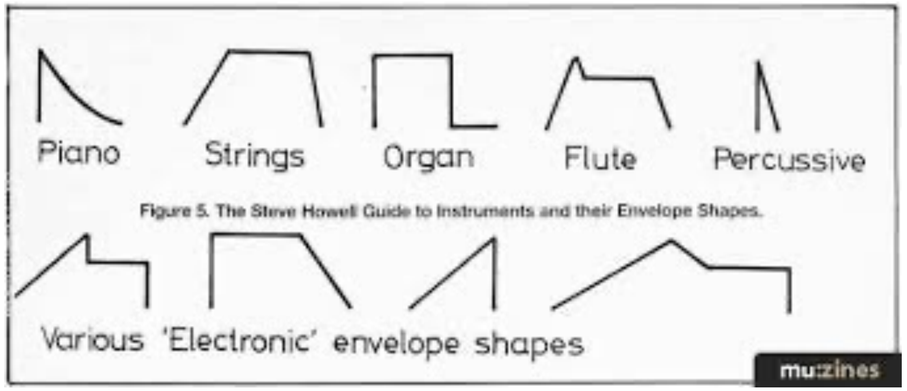


from: (Kefauver and Patschke 2007) Fundamentals of Digital Audio

Basic characteristics of sound waves (3)

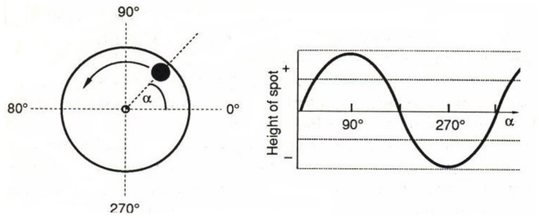
- **Envelope:** the shape of sound wave evolution. Usually, it includes four main parts: the attack, the initial decay, the sustain (i.e. internal dynamic), and the final decay (i.e. release).



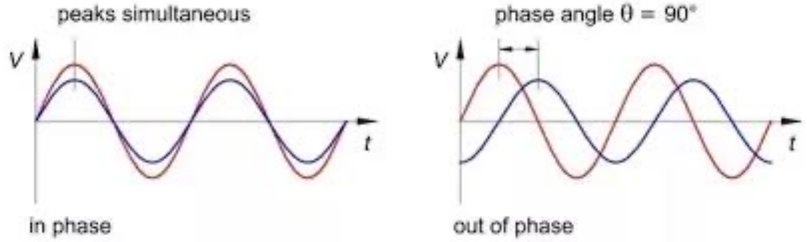


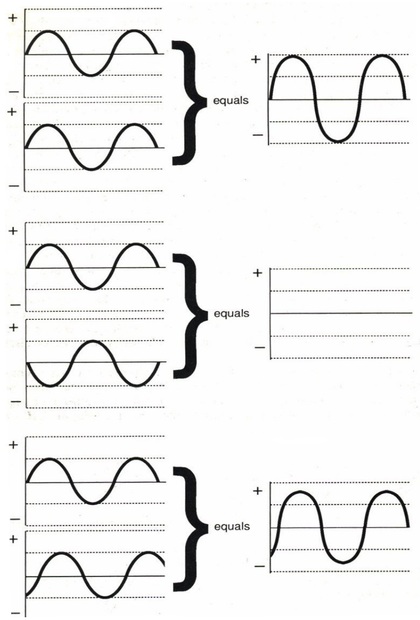
Basic characteristics of sound waves (4)

- **Phase**: the time course of a signal relative to a reference arriving to a receiver (i.e. ear).



from: (Rumsey and McCormick 1994) *Sound and Recording*





In phase: If the compression (positive) and rarefaction (negative) half-cycles of two waves of the same frequency coincide exactly in time and space. If the two signals are added together, they will produce another signal of the same frequency but twice the amplitude.

Out of phase: If the positive half-cycle of one signal coincides with the negative half-cycle of the other. If these two are added together, they will cancel each other.

Partially out of phase: when they are added together, the phase and amplitude will be the point-by-point sum of the two, resulting partial addition or cancellation, and a phase somewhere between those of the original two.

Summary

- Physics of Sound
- Pure Tones *vs* Complex Sounds
- Harmonic vs Inharmonic Sounds
- Basic Characteristics of Sound

End.