timara.net/dsp

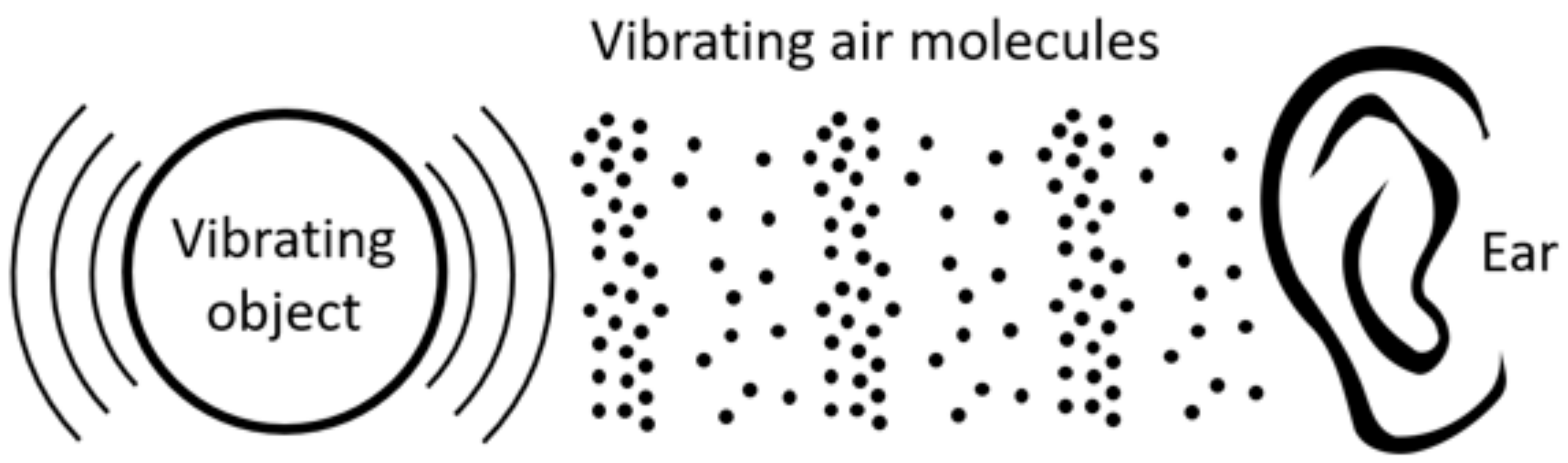
1. What aspects of this DSP course are you most excited about?
2. What aspects of this course do you feel most comfortable with?
3. What aspects of this course do you feel less comfortable with?
4. Are there any topics related to DSP that you’re interested in that aren’t currently on the schedule?

TECH 350: DSP

Class I: Digital Electronic Music Concepts Overview (Part I)

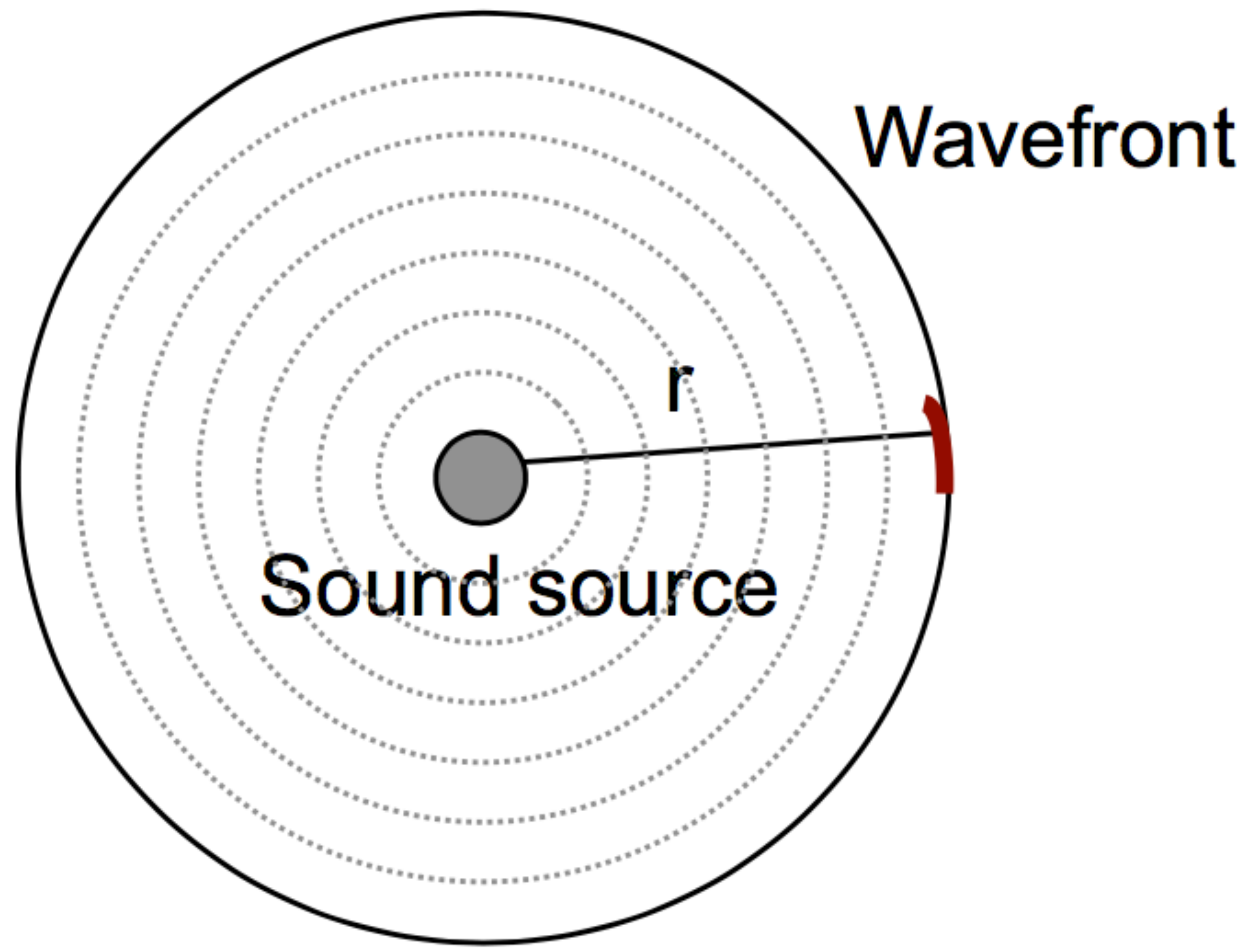
Sound

- Sound is produced by a vibrating source that causes the matter around it to move.
- Matter (e.g. air, water, earth) must be present; no sound is produced in a vacuum (e.g. space)
- The vibration of the source causes it to push/pull its neighboring particles, which in turn push/pull its neighbors and so on
- Pushes increase the air pressure (compression) while pulls decrease the air pressure (rarefaction)
- The vibration sends a wave of pressure fluctuation through the matter
- The composition of the matter affects the speed of sound propagation: At 68 °F, the speed of sound in air is about 1,125 feet per second (or 767 miles per hour). Temperature, humidity, and other properties of the matter affect sound speed.



Power + Intensity

- A source (e.g. bell) vibrates when a force (e.g. striking hammer) is applied to it.
- The force applied and the resulting movement characterize the work performed by the source ($W = F \times \Delta s$) (work = force * displacement distance)
- Power ($P = W/t$) (power = work over time) is the rate at which work is performed and is measured in watts.
- An omnidirectional sound source produces a 3-D longitudinal wave. The resulting wavefront is defined by the surface of a sphere ($S = 4\pi r^2$), where r is the distance from the source.



The original power is distributed on the surface of the wavefront.

As r increases, the power per unit area (intensity) decreases: $I = P/S$

Intensity + SPL

- The effect of sound power on its surroundings can be measured in sound pressure levels (SPL) - much as temperature in a room relates to the energy produced by a heater.
- Both intensity (Watts/area) and sound pressure (Newtons/area) are usually represented using decibels (dB)
- dB are based on the logarithm of the ratio between two powers, thus describing how they compare (dB = $10\log_{10}(P1/P2)$). (Is not an absolute!!)
- This can be applied to other measures (amplitude, SPL, voltage), as long as their relationship to power is taken into account.
- In the case of intensity and SPL, the denominator of the ratio is a reference value, defined according to the quietest sound perceivable by the average person.
- Thus by convention, 0 dB corresponds to SPL = 2×10^{-5} N/m^2 or I = 10^{-12} watt/m^2
- Jumping the gun, but we also have dBFS (decibels relative to full scale) and LUFS (loudness units relative to full scale)

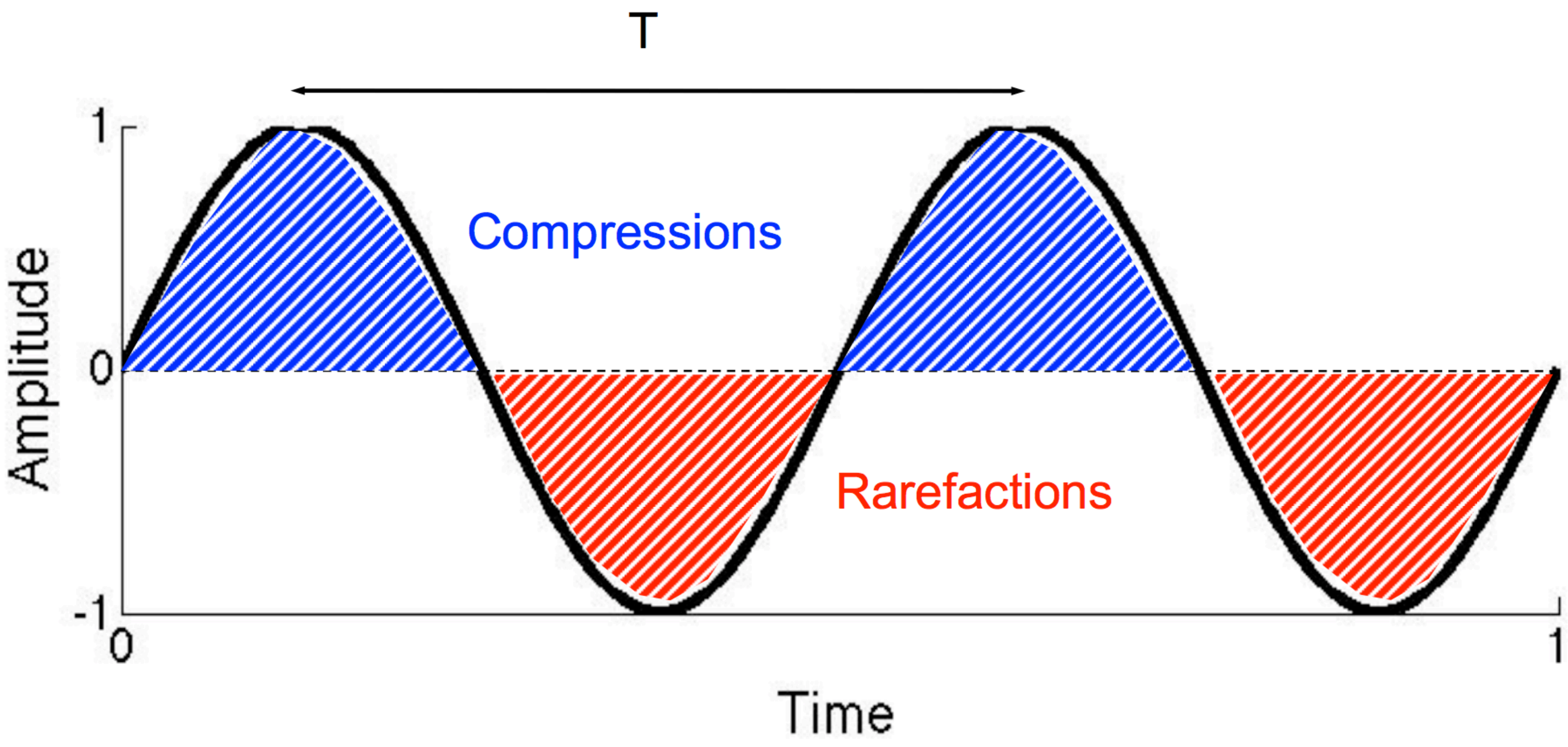
Describing Sound Waves (1)

- In sound wave motion air particles do not travel, they oscillate around a point in space.
- The rate of this oscillation is known as the frequency (f) of the sound wave and is denoted in cycles per second (cps) or hertz (Hz).
- The amount of compression/rarefaction of the air is the amplitude (A) of the sound wave.
- The distance between consecutive peaks of compression or rarefaction is the wavelength of the sound wave (λ, or lambda)

In review: f = frequency, A = amplitude, λ = wavelength

Describing Sound Waves (2)

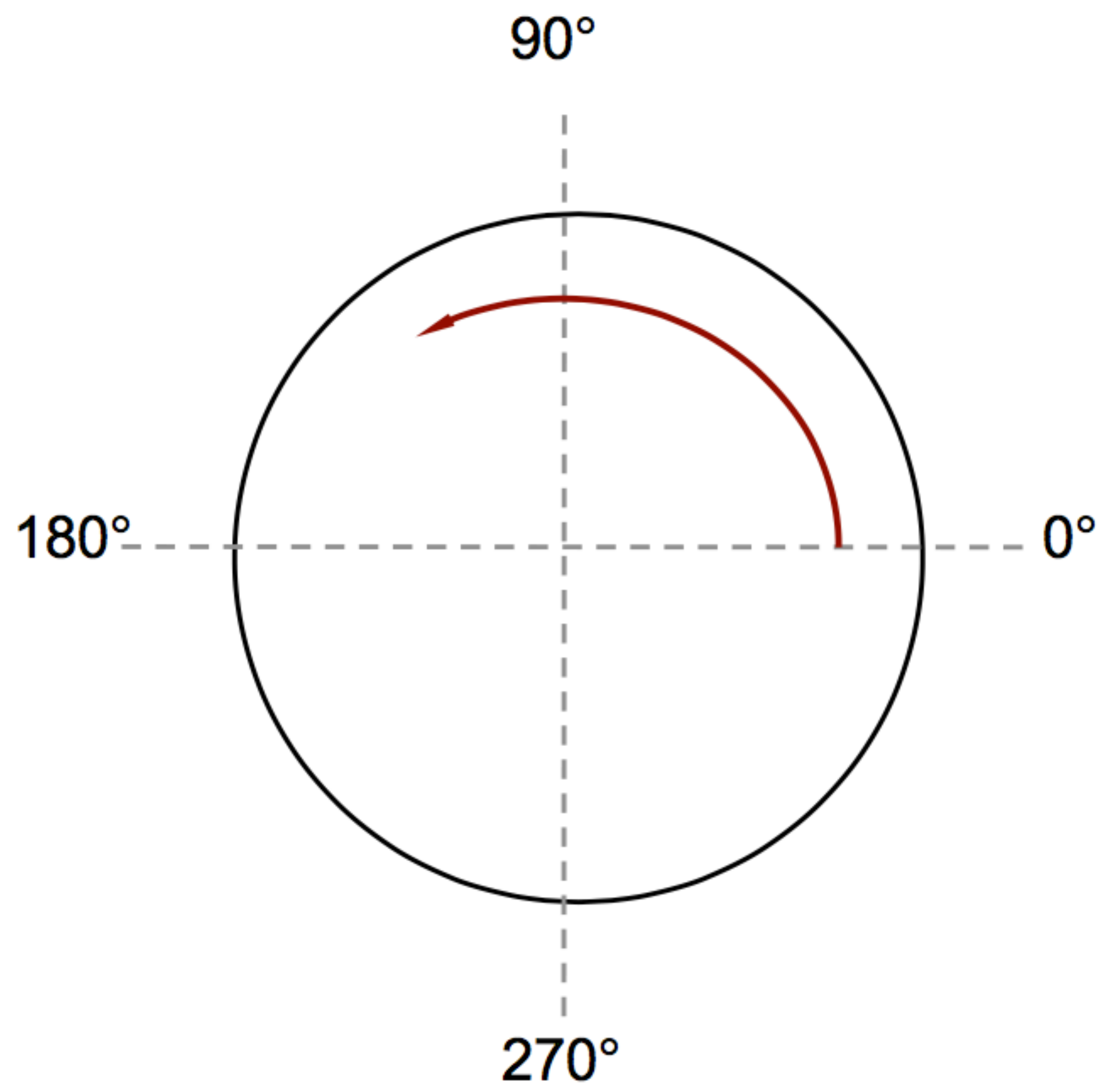
- If the frequency of the oscillation is stable, then the sound wave is periodic (with period T, and frequency $f = 1/T$)
- The simplest periodic wave is a sinusoid: $x(t) = A \cdot \sin(2\pi f t + \theta)$

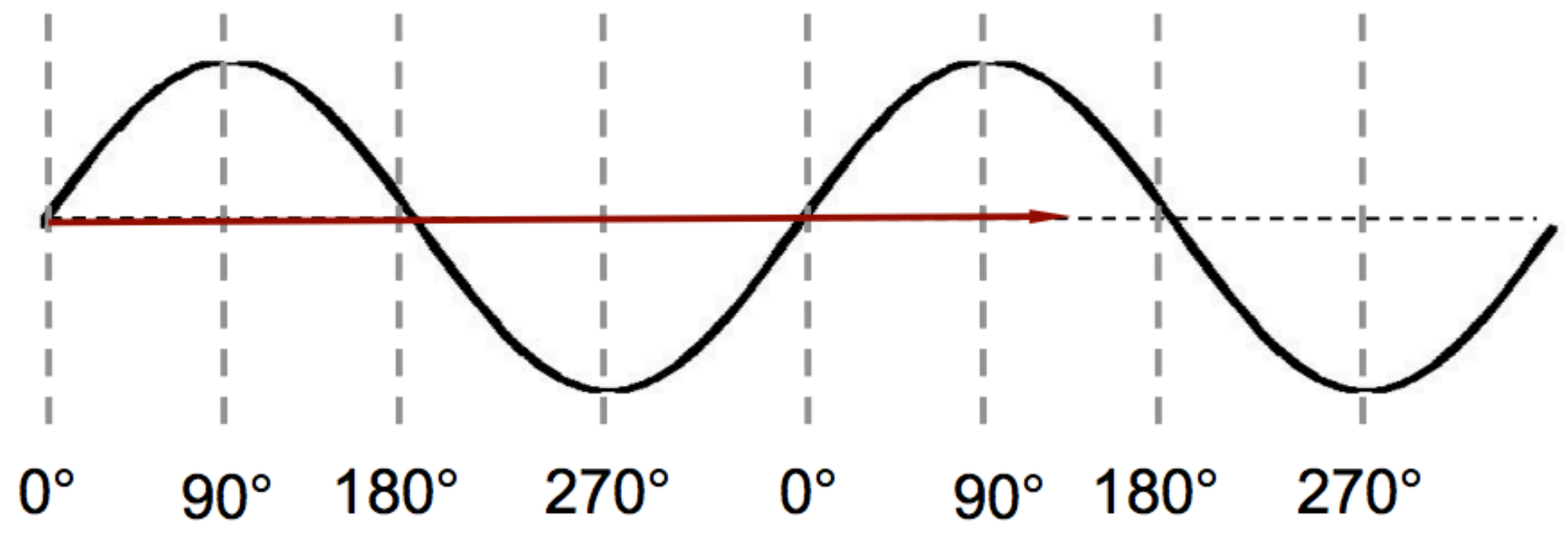


- θ, or theta, is a constant offset that determines phase, and is measured in degrees (0-360°) or radians (0-2π)

Describing Sound Waves (3)

- Phase is a temporal offset, defined in terms of a fraction (degrees) of a complete cycle of the periodic wave.

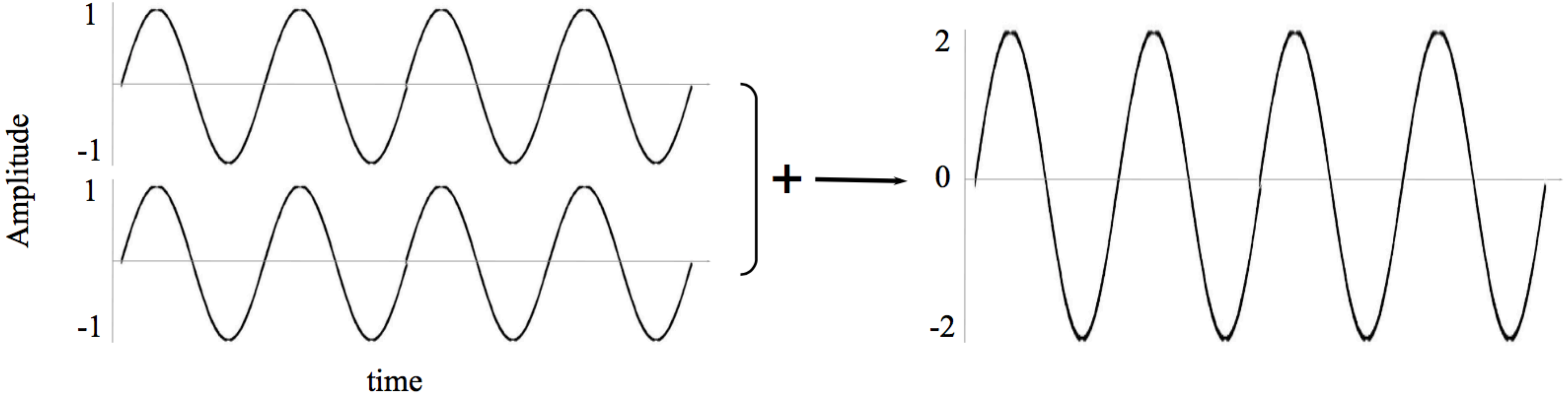




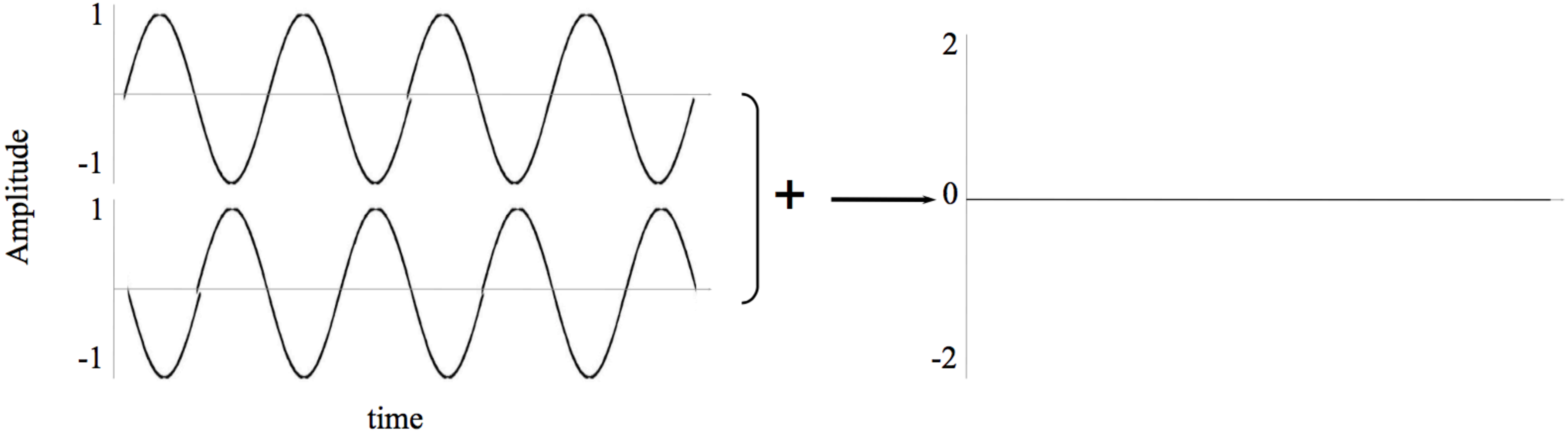
- The frequency defines the number of cycles per second, thus the time x frequency x 360° returns the (unwrapped) angular phase

Phase (1)

- In phase: cycles coincide exactly (sum duplicates amplitude)

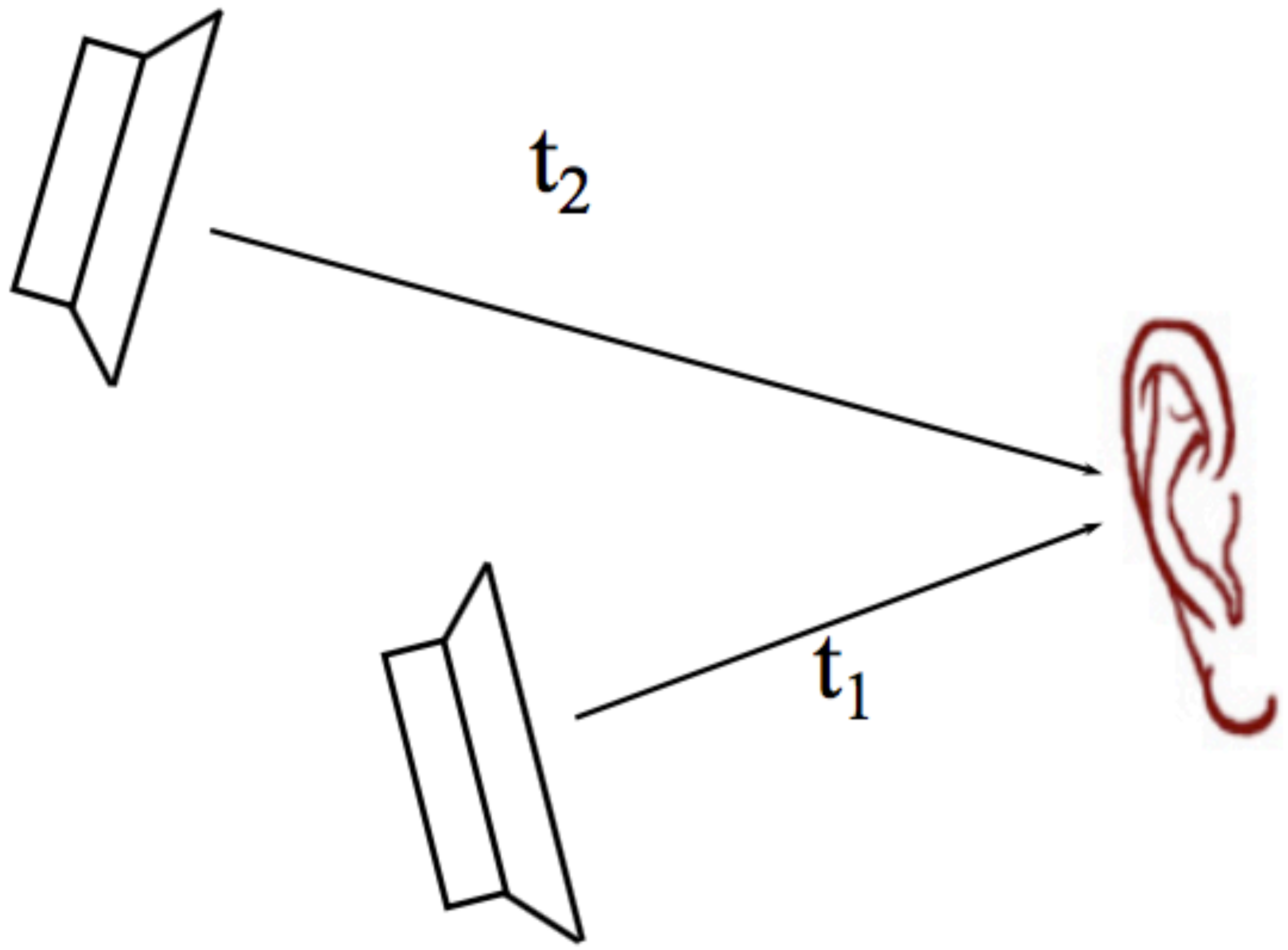


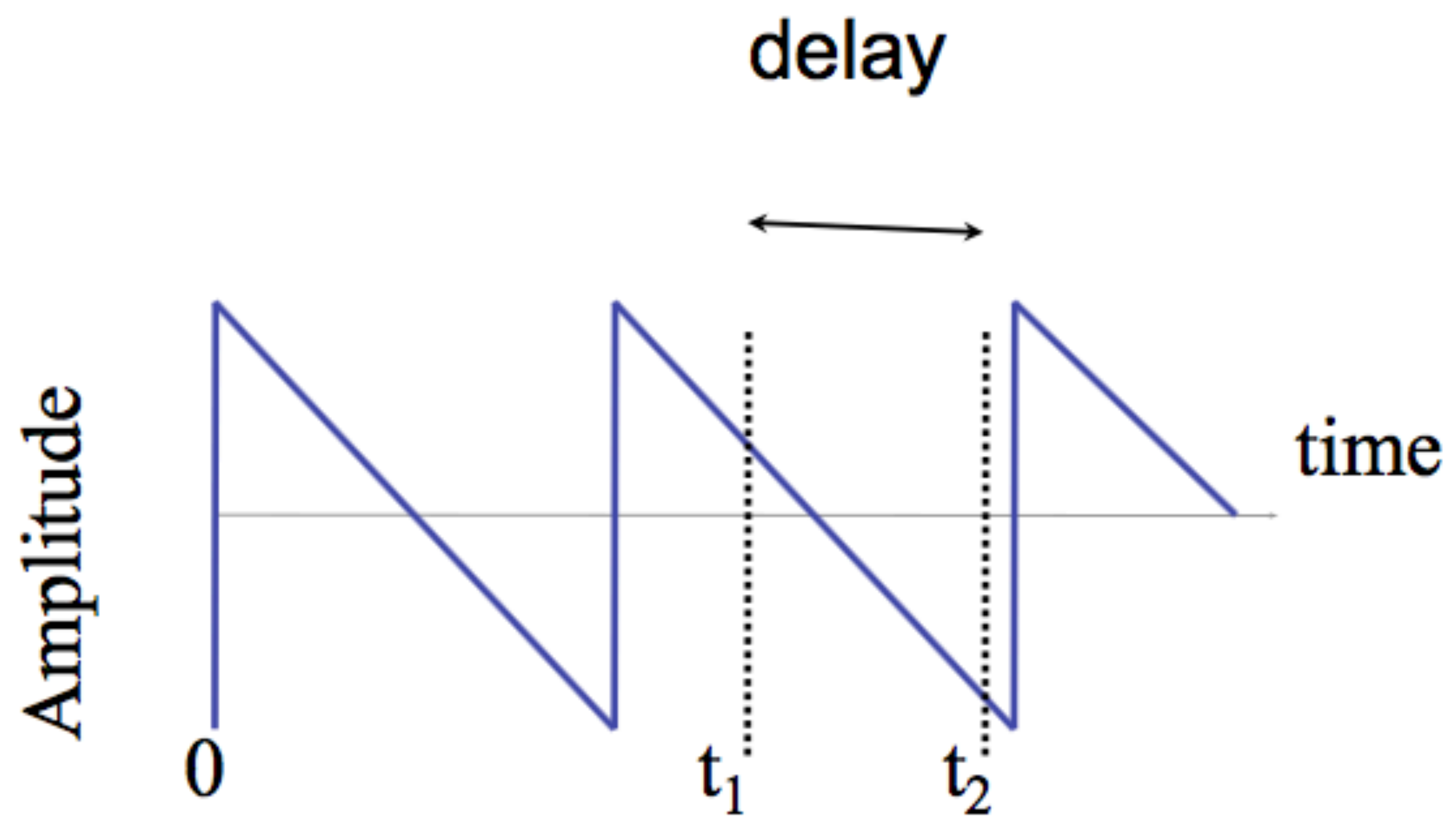
- Out of phase: half cycles are exactly opposed (sum cancels them)



Phase (2)

- There is a range of partial additions and cancellations in between those extremes • What causes phase difference?

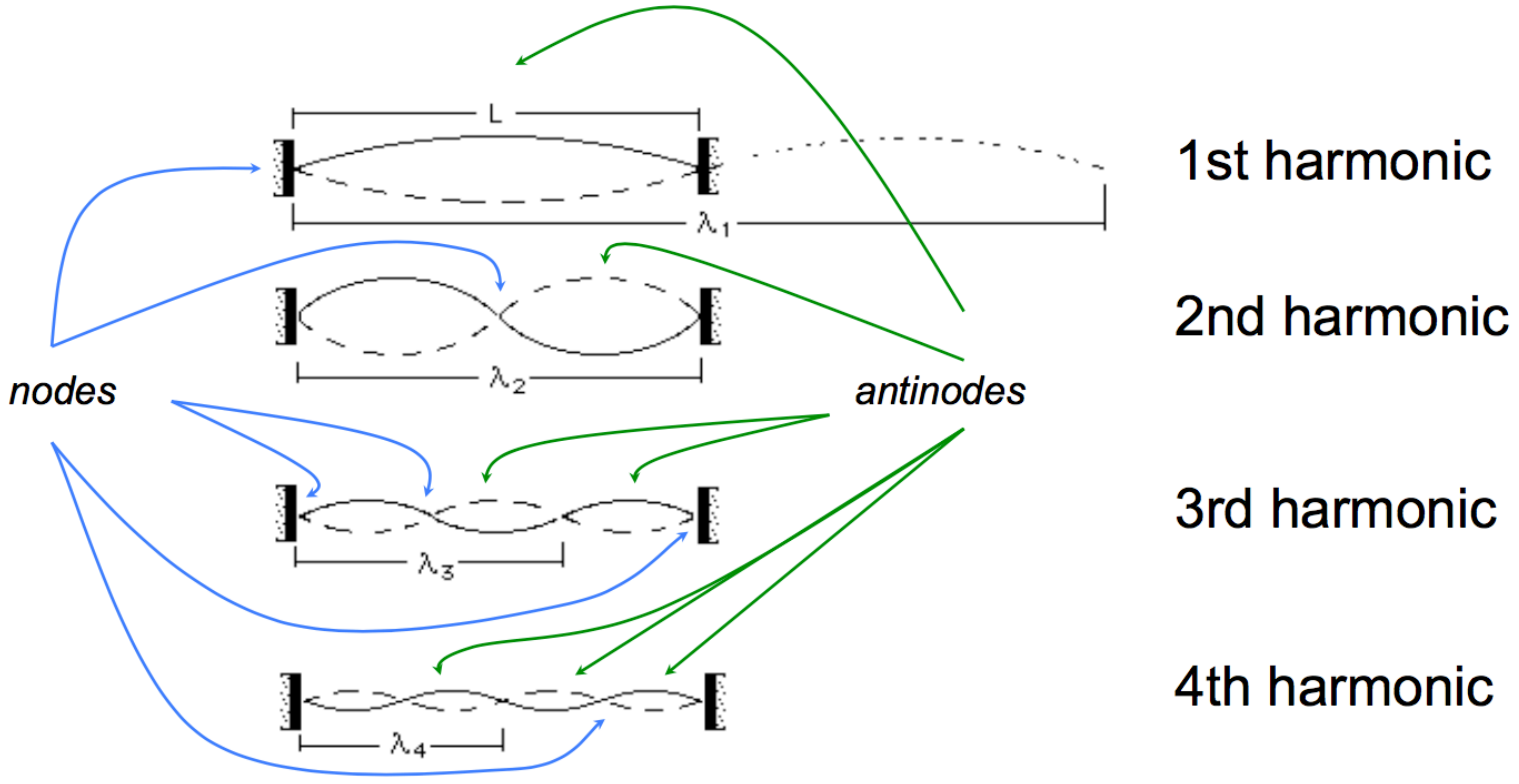




- The phase difference depends on the time deviation and the wave’s frequency

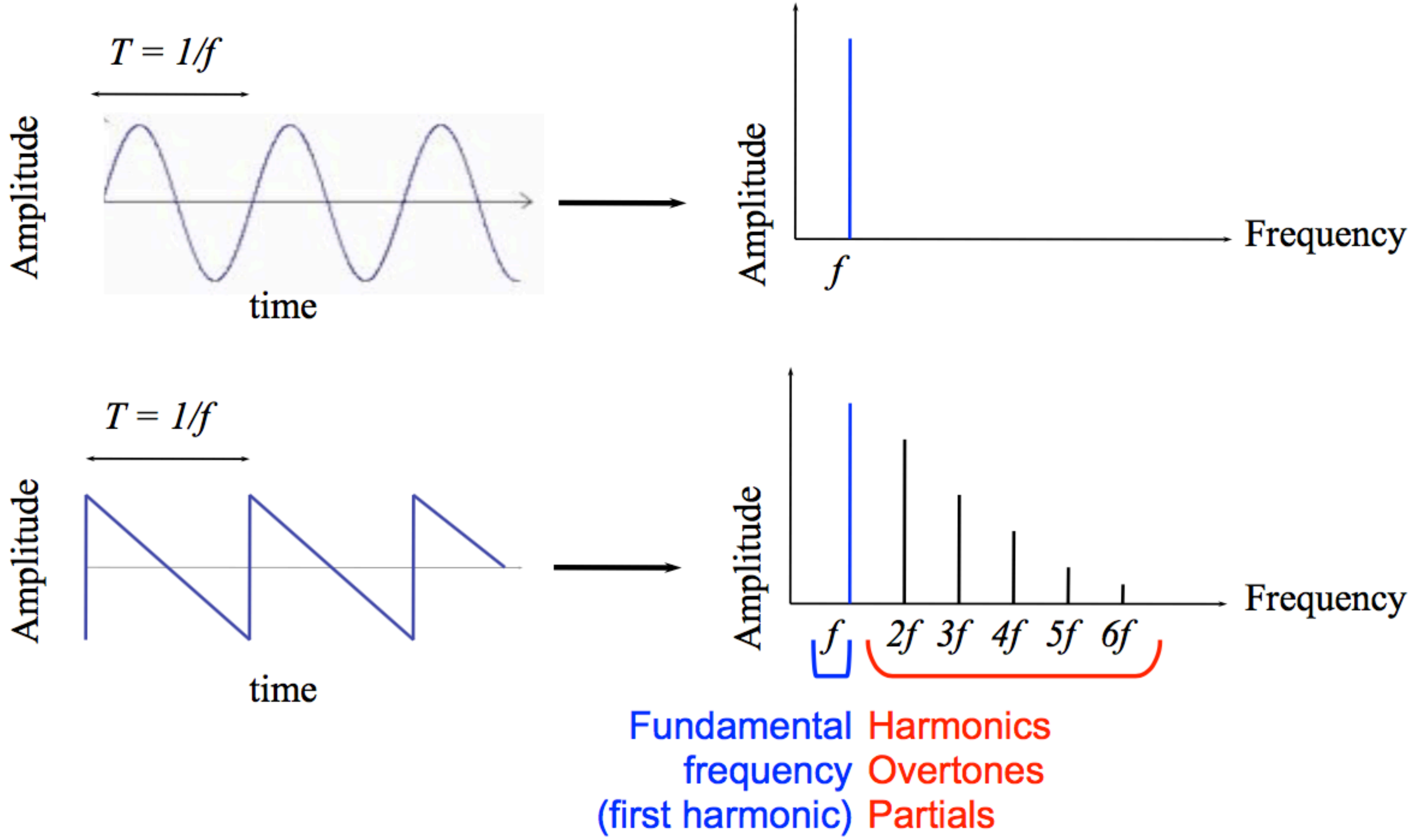
Sound Typology (1)

- Sinusoids are only one possible type of sound corresponding to the simplest mode of vibration, producing energy at only one frequency
- Most sources are capable of vibrating in several harmonic modes at the same time, generating energy at different frequencies



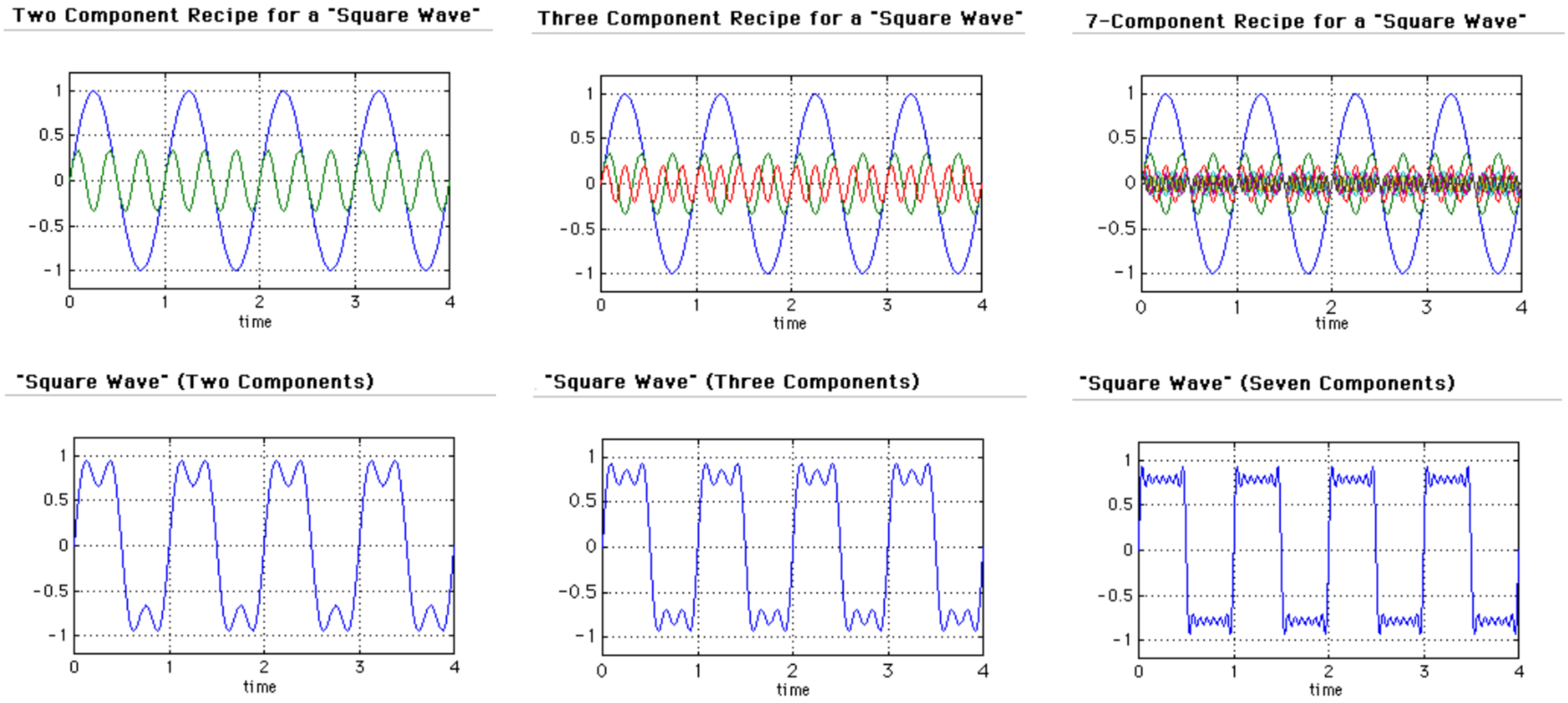
Sound Typology (2)

- Harmonics (or Overtones or Partials) are frequency components that occur at integer multiples of the fundamental frequency
- Their amplitude variations determine the timbre of the sound



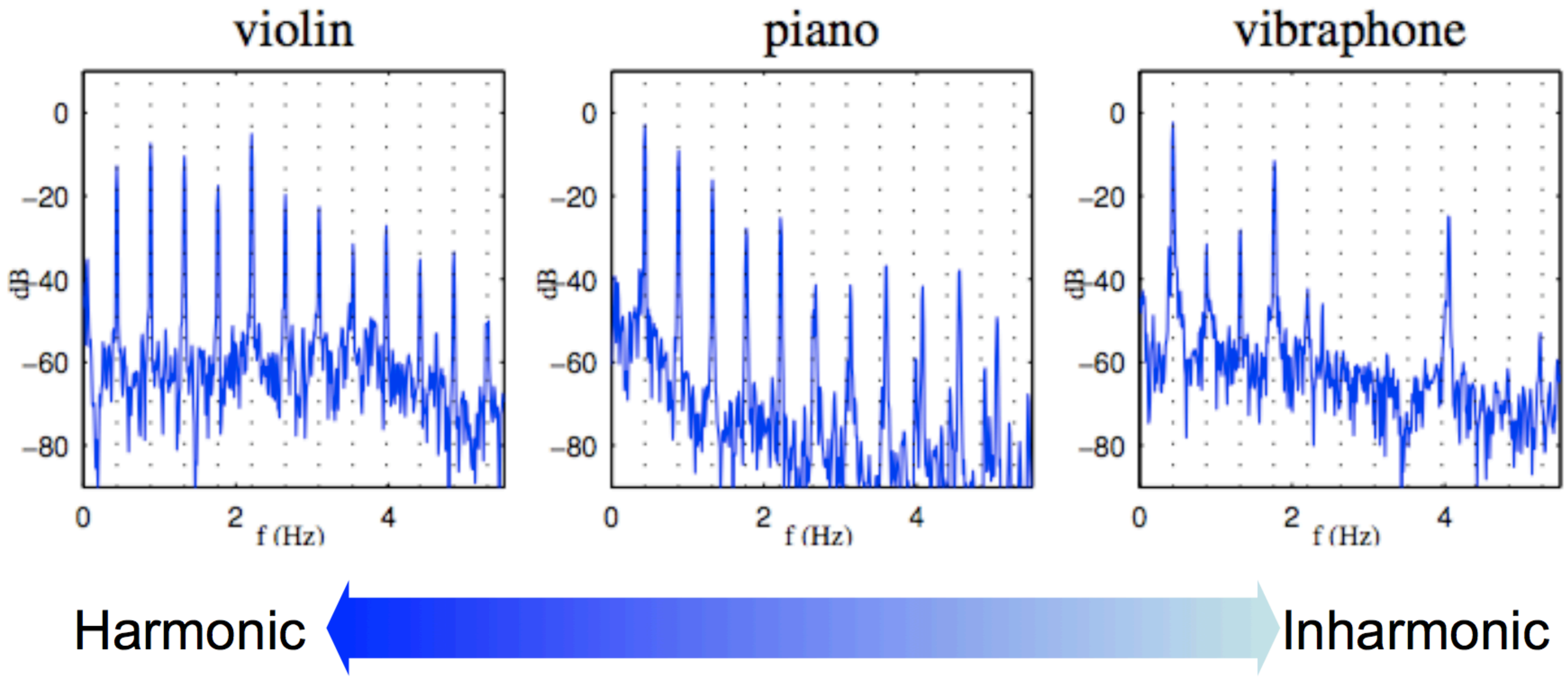
Sound Typology (3)

- Example: Square wave - only odd harmonics (even are missing). Amplitude of the nth harmonic = 1/n



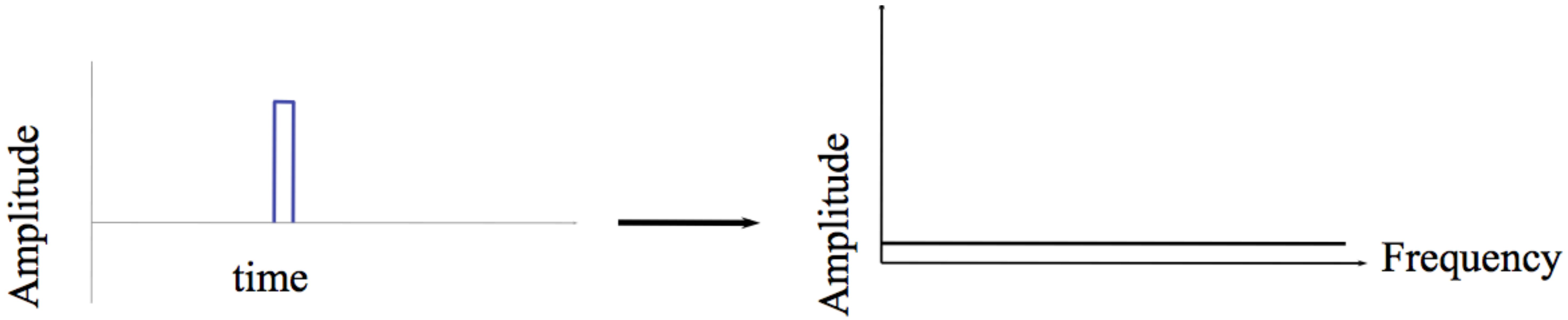
Sound Typology (4)

- Most natural pitched sounds also present overtones which are not integer multiples of the fundamental.
- These are known as inharmonic partials



Sound Typology (5)

- Non-periodic sounds have no pitch and tend to have continuous spectra, e.g. a short pulse (narrow in time, wide in frequency)



- The most complex sound is white noise (completely random)