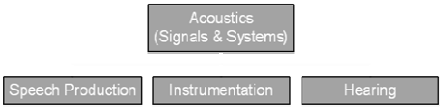
Acoustics of Speech and Hearing

Lecture 3
Periodic Sounds and Vibrations

Overview

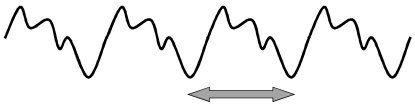


- What is pitch?
- Pitch scales
- Simplest periodic waveforms
- Combining two simple sounds
- Beats

What is pitch?

- Subjective properties of sounds
  - Loudness: "quantity" of sound
    - logarithmically related to physical intensity
  - Pitch: "musical tone" of sound
  - Timbre: "quality" of sound
- Only some sounds have clear pitch:
  - from vibrating systems
  - periodic sounds

Periodic sounds



- have a waveform shape that repeats
- **repetition period** = time taken between repetitions = duration of one cycle
- **repetition frequency** = number of repetitions in one second =

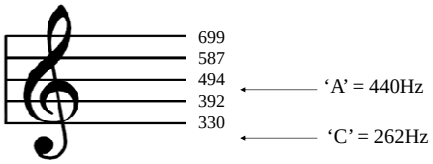
$$\frac{1}{\textit{repetition period}}$$

- frequency measured in hertz (Hz)

Intervals of pitch

- Subjective changes in pitch
  - are they equal steps of Hz
  - or logarithmic steps of Hz?
- Demonstration
  - 8 linear-spaced tones
    - 250, 500, 750, 1000, 1250, 1500, 1750, 2000
  - 8 logarithmic-spaced tones
    - 250, 336, 452, 609, 820, 1104, 1486, 2000

Musical scale



- Concert pitch 'A' = 440Hz
- Middle 'C' = 262Hz
- One octave = 2 × frequency
- One semitone = 1.06 × frequency

Limits to pitch

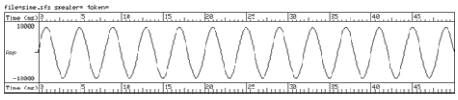
- Low frequency limit ~ 20Hz
  - Below a certain repetition frequency, hear individual pulses
- Clear pitch limit ~ 5kHz
  - Pitch sensation merges with timbre?
- High frequency limit ~ 20kHz
  - Highest sinusoidal frequency detected by ear

Simplest periodic waveform

- Simplest vibrating systems
  - pendulum
  - mass on a spring
  - tuning fork

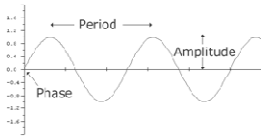
} Ideal, Undamped

- Sinusoidal waveform shape



Simplest periodic waveform

- Sinusoidal Waveform ("sinewave")
  - described completely by Period (s) or Frequency (Hz), Amplitude (Pa or V), and Phase (°)

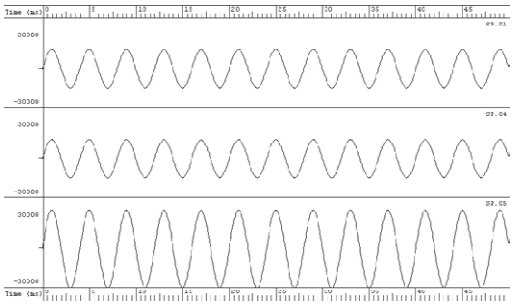


  - construction of a sinewave from rotating disk
  - relation to 'wavelength' (period × speed)

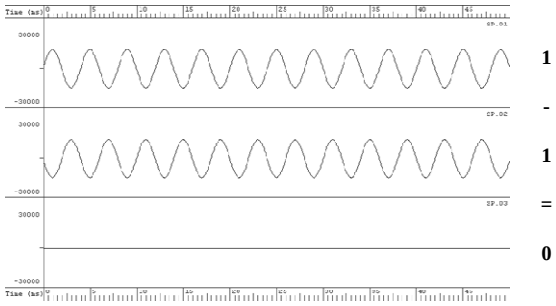
Adding two sinewaves

- What happens when two sources of sound combine together?
- Let's look at the simplest case: two sinewaves
- To begin with, assume they have the same amplitude, frequency and phase ...

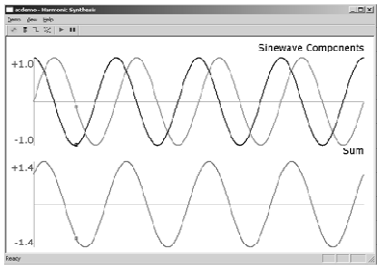
Adding two identical sinewaves



Adding two opposite sinewaves

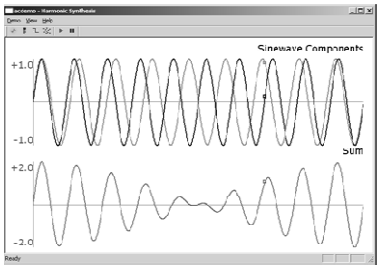


Adding two sinewaves with different phases



- in phase
  - largest output
- opposite phase
  - smallest output
- intermediate phase
  - intermediate output

Adding two sinewaves with different frequencies



- in phase
  - largest output
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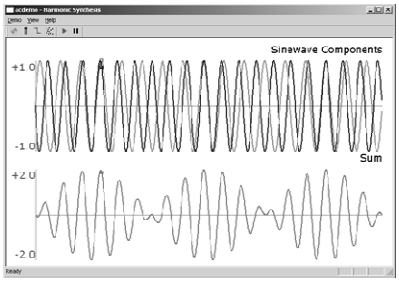
  - intermediate output

Beats

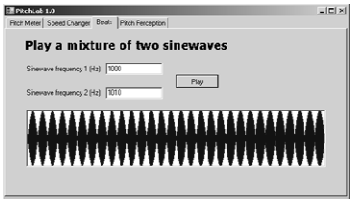


Adding two sinewaves of slightly different frequencies generates a new periodic waveform

Summary

- Periodic sounds
  - repetition period, repetition frequency
- Sinewaves
  - amplitude, frequency, phase
- Combining two sinewaves
  - importance of phase
  - beats

Lab experiment



- Pitch lab
  - Measuring the repetition frequency of sounds
  - Changing the pitch of sounds
  - Beats
  - Pitch perception