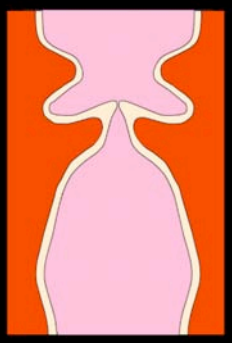
Introduction to Speech Science - Week 3

Acoustics of vocal fold vibration

- Waveform and Spectrum Displays
- Amplitude, Frequency, Phase
- Types of waveforms
- Fourier Analysis & Synthesis

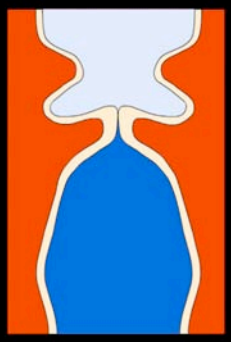
Acoustics of vocal fold vibration



Voicing is a series of opening and closing of the vocal folds

- Vocal folds are placed together
- Vocal folds get blown apart by air from the lungs
- Vocal folds snap back together due to the elasticity of the vocal folds and the Bernoulli effect.

Acoustics of vocal fold vibration



When vocal folds are shut..

- Air pressure above equals atmospheric pressure
- Air pressure in lungs is higher

Acoustics of vocal fold vibration

When vocal folds are open..

- Air pressure above equalizes with pressure below (increases)

Acoustics of vocal fold vibration

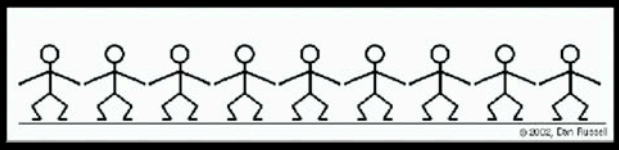
Cycle repeats to cause changes in pressure over time

- In other words, *SOUND*

What is sound?

http://www.gmi.edu/~drussell/Demos.html

What is sound?



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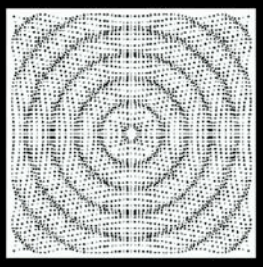
What is sound?

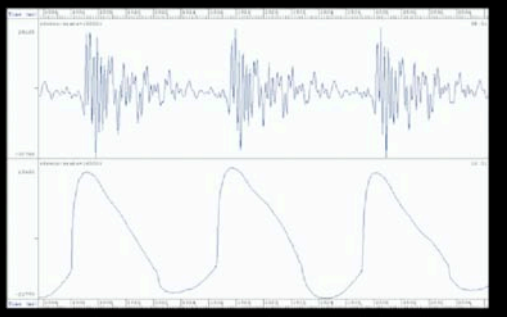


http://www.gmi.edu/~drussell/Demos.html

How do we measure sound?

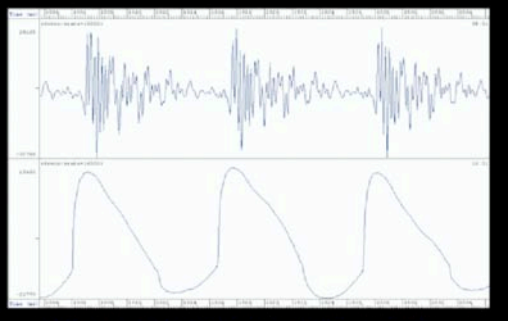
Sound waveform

LX



Sound waveform

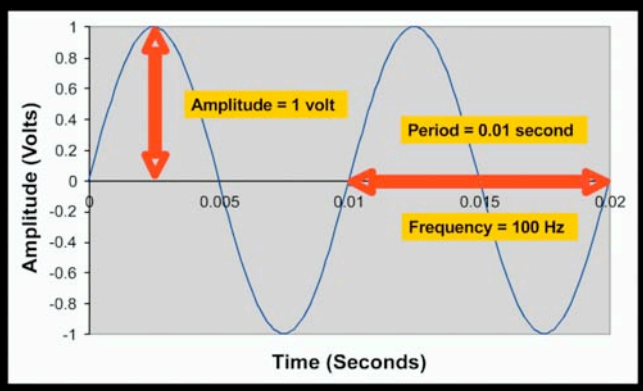
LX



Speech sound waveforms contain *many frequencies.*

It is easier to begin by looking at simpler waveforms...

Simple waveform (sinusoid)



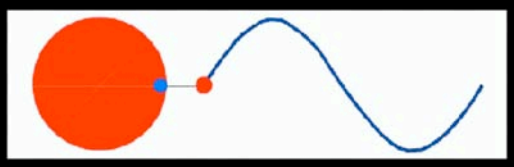
Amplitude

- Measurement
  - Linear (e.g., pressure, voltage)
  - Logarithmic (dB)
- Perception: Loudness
  - Hearing Threshold: 0 dB SPL
  - Conversational Speech: 60 dB SPL
  - Pain Threshold: 140 dB SPL

Repetition Rate

- Measurement
  - Period (e.g., s, ms)
  - Frequency (Hz)
    - Number of cycles per second
- Perception: Pitch or Timbre
  - Range of Hearing: 20 - 20,000 Hz
  - Voice Pitch: 100 - 250 Hz

Sinusoids

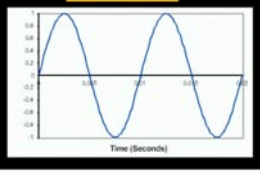


The simplest waveform, created by plotting the height of a rotating circle over time.

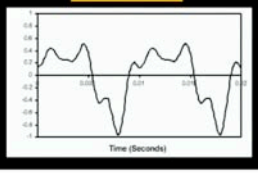
Different Types of Waveforms

Periodic Waveforms
•Repeat in time
•Tones w/ pitch

Simple
Sinusoid



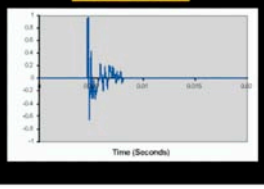
Complex



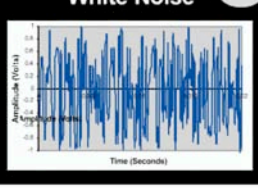
Different Types of Waveforms

Aperiodic Waveforms
•Do not repeat
•Noise

Transient



Random
White Noise



How can we analyze these waveforms?

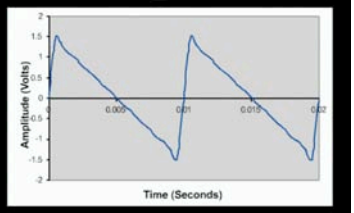
- *Fourier Analysis*
  - All sounds can be analyzed by breaking them down into sinusoids
- *Fourier Synthesis*
  - All sounds can be synthesized by adding sinusoids
  - Also called *Harmonic Synthesis* when making periodic sounds
- *Why is this useful?*
  - Human hearing
  - Acoustic analysis

Fourier Analysis of Periodic Sounds

- Periodic sounds can only have sinusoids that are multiples of its *fundamental frequency*
  - E.g., fundamental frequency: 100 Hz
  - Contains sinusoids of 100, 200, 300, etc. Hz
- Sinusoidal components of periodic sounds are called *harmonics*

Example: Synthesis of a sawtooth waveform

Frequency (Hz)	Amplitude (v)
100	1.00
200	0.50
300	0.33
400	0.25
500	0.20
600	0.17

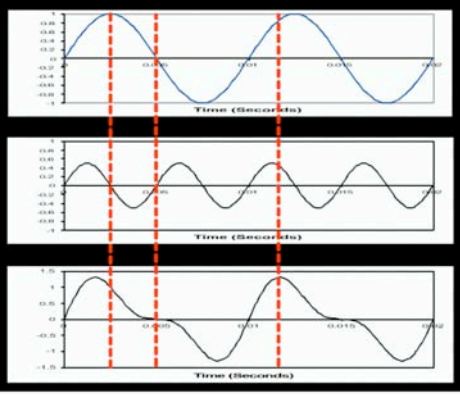


Example: Synthesis of a sawtooth waveform

100 Hz

200 Hz

100 + 200 Hz

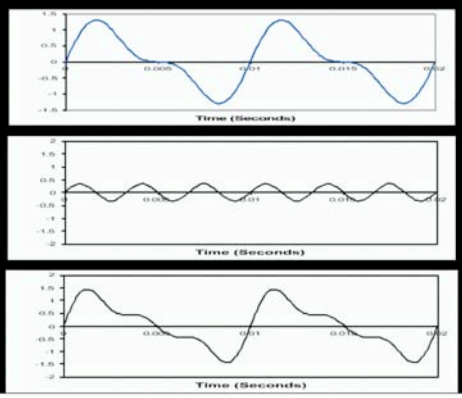


Example: Synthesis of a sawtooth waveform

100 + 200 Hz

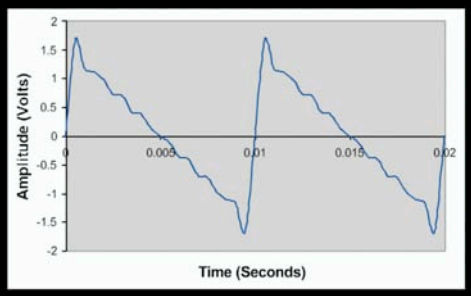
300 Hz

100 + 200 + 300 Hz



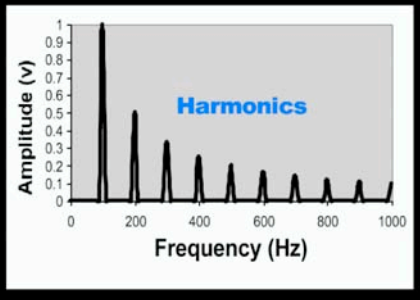
Example: Synthesis of a sawtooth waveform

100 + 200 + 300 + 400 + 500 + 600 + 700 + 800 Hz



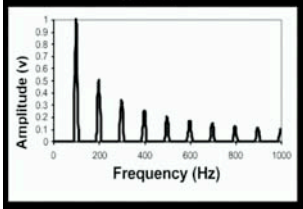
Spectrum: Periodic Sound

Frequency (Hz)	Amplitude (v)
100	1.00
200	0.50
300	0.33
400	0.25
500	0.20
600	0.17

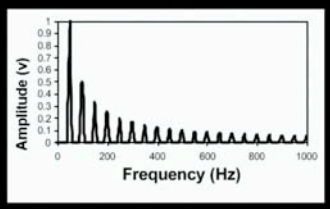


Spectra: Different Pitches

Fundamental frequency: 100 Hz

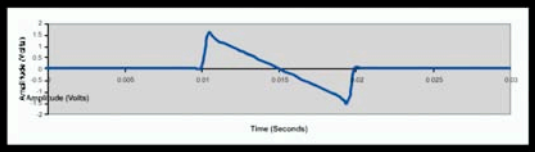


Fundamental frequency: 50 Hz



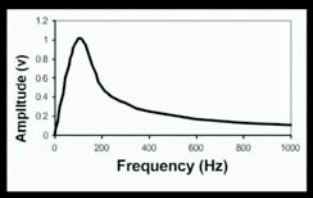
With lower fundamental frequencies, harmonics get closer together in the spectrum and cycles get further apart in the waveform.

What happens to the spectrum if we play only one cycle?

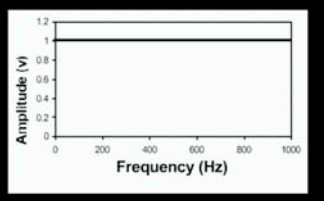


Spectra: Aperiodic Sounds

Same *spectral envelope*



White Noise



Continuous spectrum
- No individual harmonics

Summary: Most Important Points

- Waveform and Spectrum Displays
- Amplitude, Frequency, Phase
- Periodic vs. Aperiodic
- Simple, Complex, Transient, Noise
- Fourier Analysis & Synthesis