LIN228H1F Phonetics
Lecture 4: Intro to Acoustics

Wednesday, May 12th, 2021 Instructor: Emily Blamire

Today’s Plan

1. Instrumental Methodologies
2. Introduction to Acoustics
3. Spectrograms
4. Transcription & Line Drawings

Instrumental Methodologies

Traditional palatography

X-ray

Ultrasound

MRI

Instrumental methodologies

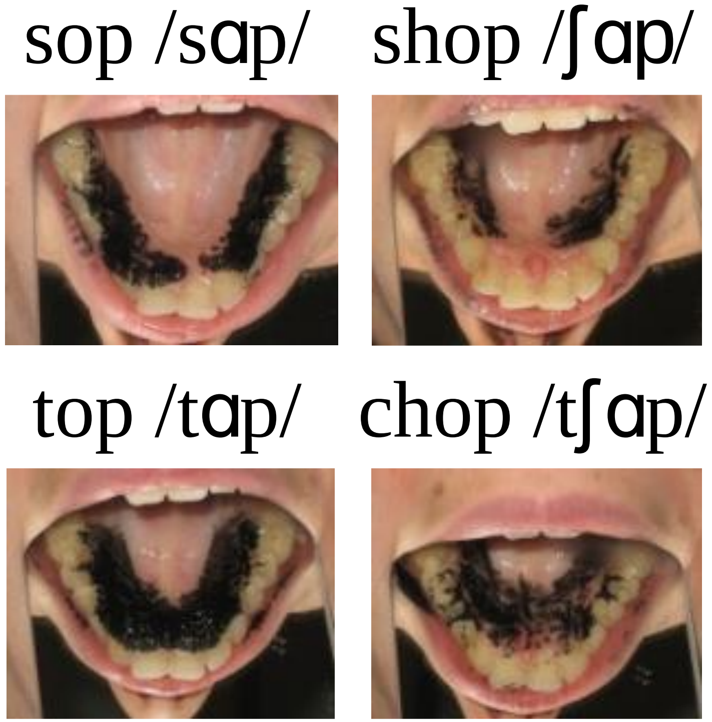
- So far today we have looked at electropalatography to help us visualize what is going on in the mouth, but there are several methods phoneticians can use
    - Traditional palatography
    - X-ray
    - Ultrasound
    - MRI

Traditional palatography

- Need:
  - powdered charcoal
  - olive oil
  - a new paintbrush
  - a small narrow mirror

- Inexpensive and very “low tech”

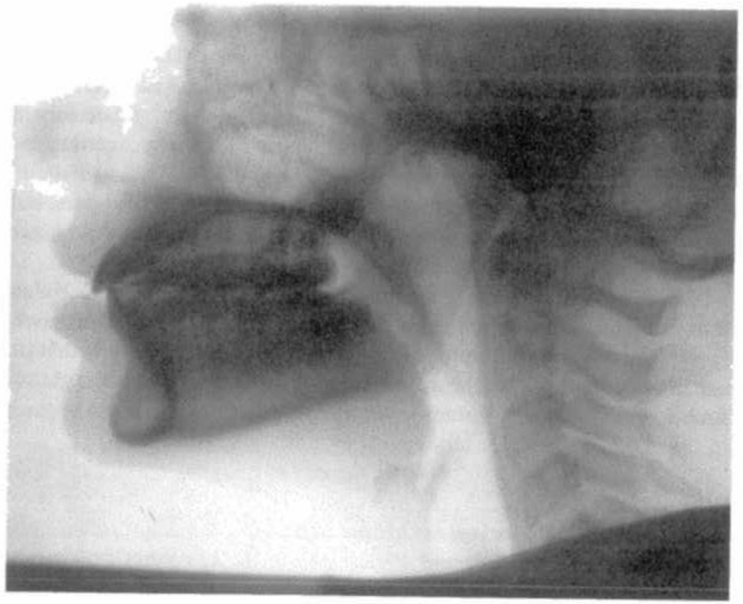
- Drawbacks
  - Very slow
  - Can only look at one sound at a time



Data from a student project in *LIN423 Phonetic Analysis*, Spring 2011

X-ray photography

- 1 = the centre of the tongue
- 2 = the nasal cavity just above the hard palate
- 3 = the end of the velum



See video

X-ray photography

- Results of x-ray investigations are usually presented as trace drawings:
  - (a) = dental
  - (b) = velar

- Drawbacks:
  - It takes a lot of experience to interpret x-ray photographs and see the details.
  - Radiation risk to the speaker.

X-ray

Ultrasound

- <u>Ultrasound</u> has been more recently used to image the tongue during the production of speech sounds.
- The method uses a property of ultra-high speed sound waves to propagate and reflect from surfaces of objects, such as the surface of the tongue.

Ultrasound

See lots of videos on YouTube

- Sagittal (side) and ‘coronal’ (front) ultrasound images of the American English /ɹ/ (from Adler-Bock et al., 2007).

FIGURE 1. A midsagittal view of a retroflexed North American English /r/, with the tongue tip on right near the top of the image, and the tongue root on the left, near the bottom of the image. Note that the bright white lines furthest to the right of the image are extraneous to the /r/ production.

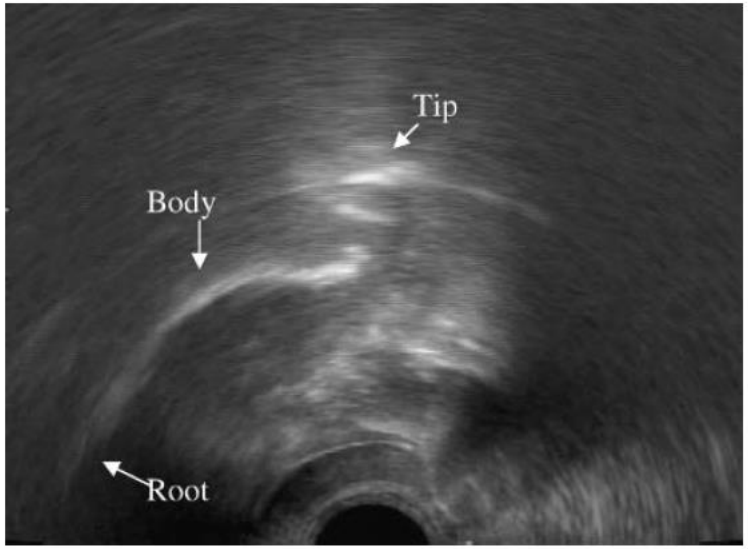
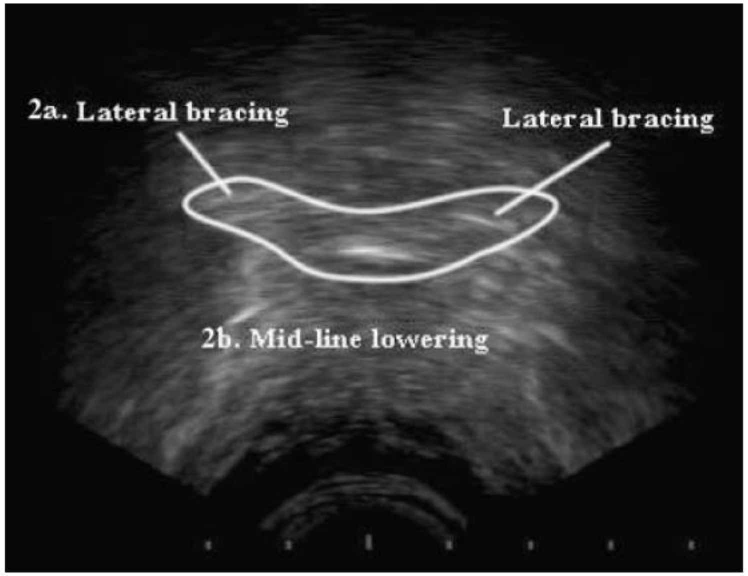


FIGURE 2. A coronal view of an adult North American English /r/ with lateral tongue bracing. Lateral bracing occurs in /r/ when the posterior margins of the tongue press against the back upper molars (2a). Midline lowering occurs behind the palatal constriction (2b).

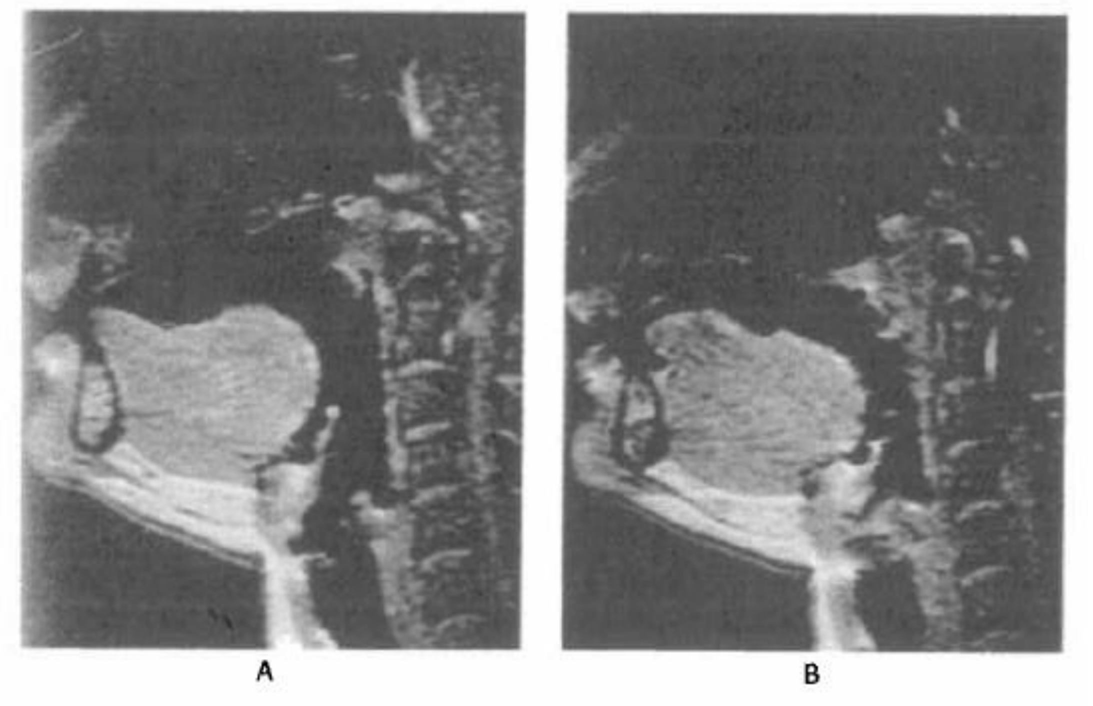


Ultrasound

MRI

- Magnetic Resonance Imaging
  - Pros: Resulting images are much clearer than other options
  - Cons: Slower and more difficult to get moving pictures. Expensive.

  - (a) = [s]
  - (b) = [ʃ]



Introduction to Acoustics

Acoustic Phonetics
Sound Waves
Simple Periodic Waves
Complex Repetitive Waves
Noise

Acoustic Phonetics

- The way we have described speech sounds so far was in terms of
  - how they are produced by manipulating the vocal apparatus and
  - how they can be transcribed with phonetic symbols on paper.

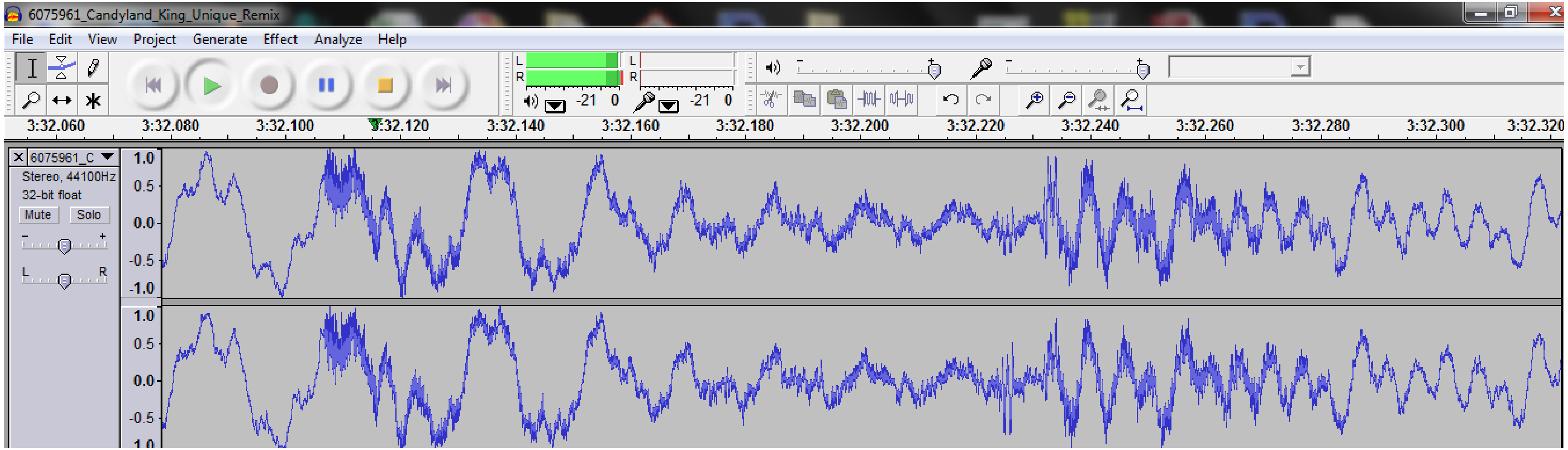
- However, we can also describe sounds in terms of how we can hear them. How we can hear a sound depends on its **acoustic structure**.
  - **Acoustics**: the science of the physical properties of sounds.
  - **Acoustic Phonetics**: the science of the physical properties of speech sounds.

Acoustic Phonetics

- We want to be able to describe the acoustics of speech for many reasons:
  - explanation for why certain sounds are confused with other sounds
  - certain details of speech are not explainable if only articulation is considered
  - vowels are better described in acoustic terms than in articulatory terms
  - vital information for designing automatic speech recognition devices (speech synthesis by computers)
  - insight into sound recognition by humans (perception)
  - audio data of speech is the easiest to obtain.

Sound Waves

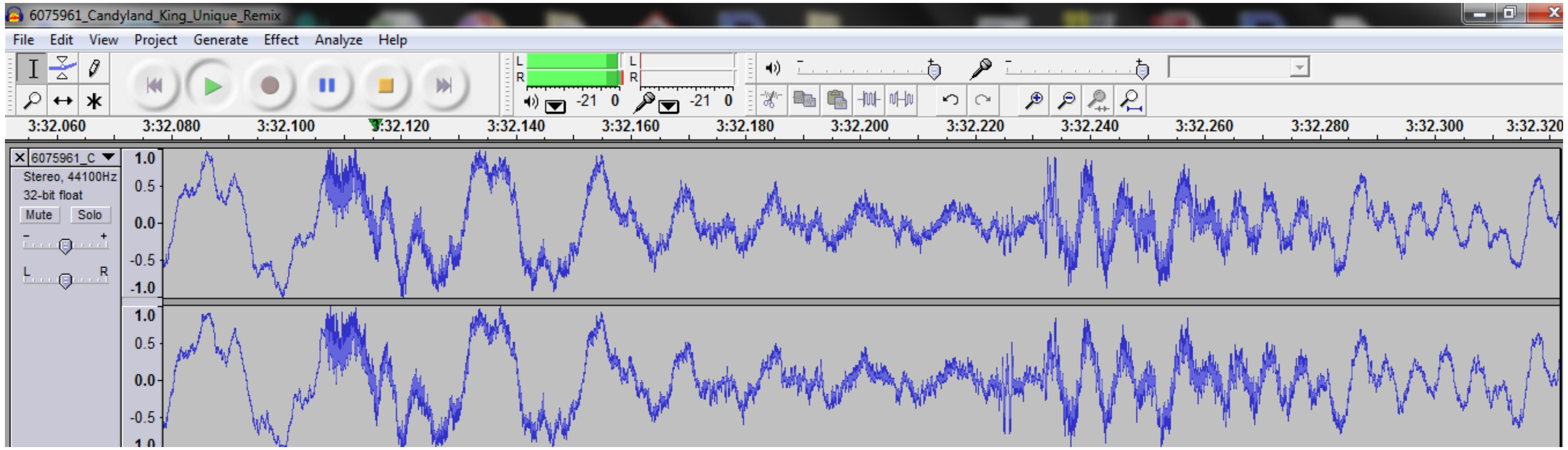
- A **waveform**: a display of a sound wave – fluctuations in:
  - amplitude
  - over time



Sound Waves

- A sound wave is a traveling <u>pressure fluctuation</u> that <u>propagates</u> through a medium (i.e. air)
  - The pressure fluctuation is caused by the pulling and pushing of air molecules.
  - The wave fluctuates with time, having peaks of <u>rarefaction</u> and <u>compression</u>.

- Pressure fluctuations impinging on the eardrum produce the sensation of sound.
- Pressure fluctuations are often **cyclic**, repetitive.

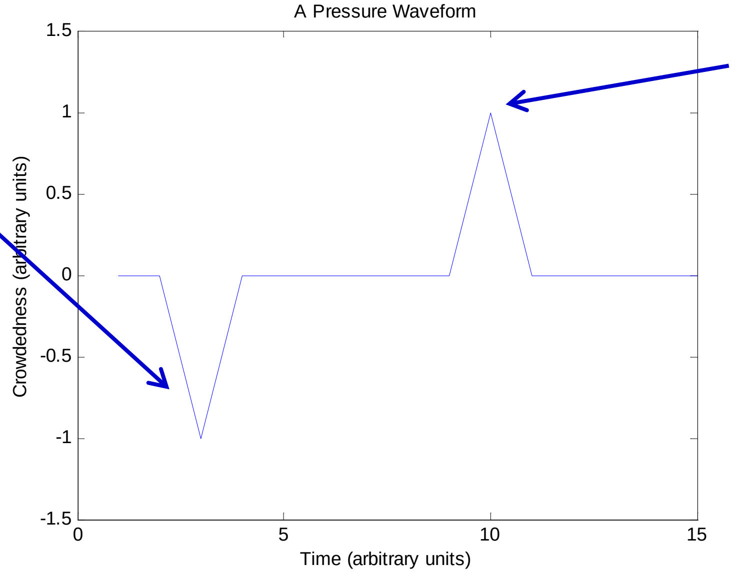


Propagation of sound

- A useful analogy for a sound wave
  - a line of people to buy tickets to a concert.

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		1	1	1	1	1	1	1							
	1		2	2	2	2	2	2	**X**	1	1	1	1	1	1
*	2	2		3	3	3	3	3	3	**X**	2	2	2	2	2
	3	3	3		4	4	4	4	4	4	**X**	3	3	3	3
	4	4	4	4		5	5	5	5	5	5	**X**	4	4	4
	5	5	5	5	5		6	6	6	6	6	6	**X**	5	5
	6	6	6	6	6	6		7	7	7	7	7	7	**X**	6
	7	7	7	7	7	7	7								7

rarefaction

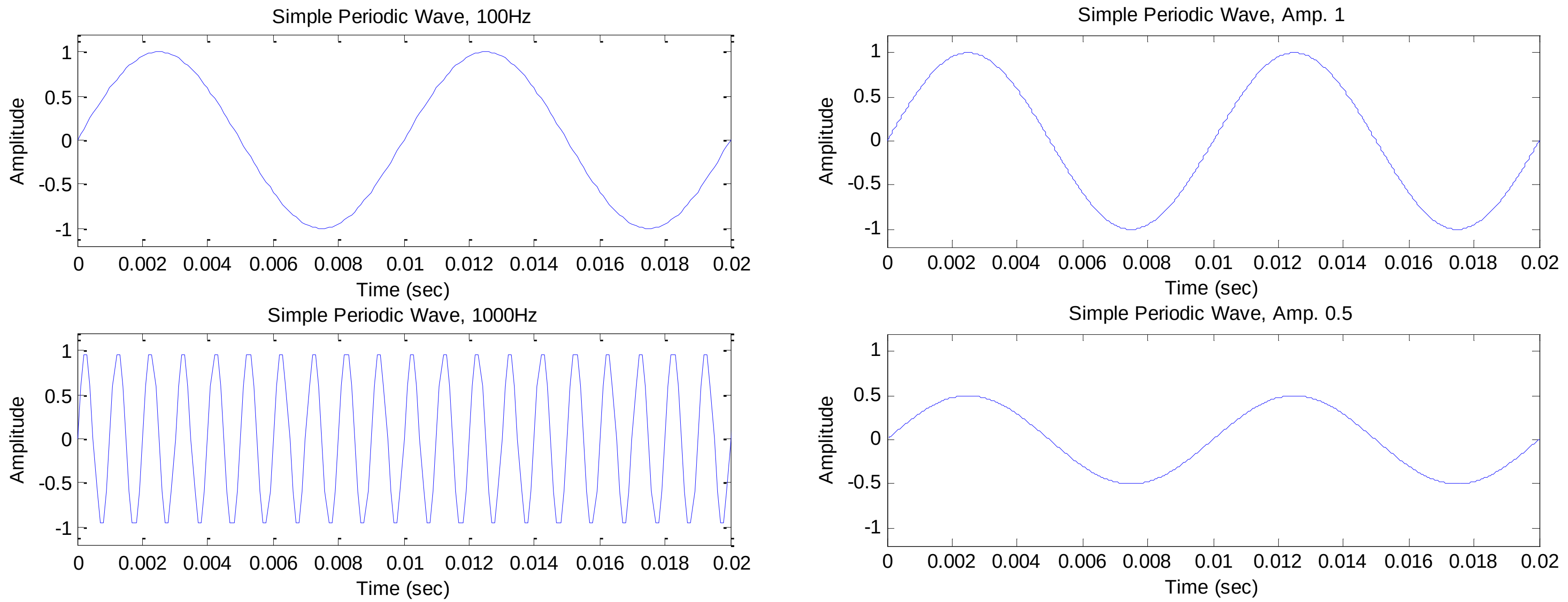


compression

A wave -
has the time and amplitude dimensions

Simple Periodic Waves

- The **waveform** of the pressure variation has the same shape as that of the movement of an air molecule.
  - Pure tones, when represented on a waveform, will appear as **sine waves –** simple periodic waves. Sine waves are smooth and symmetrical s-shaped waves.



Amplitude and Intensity

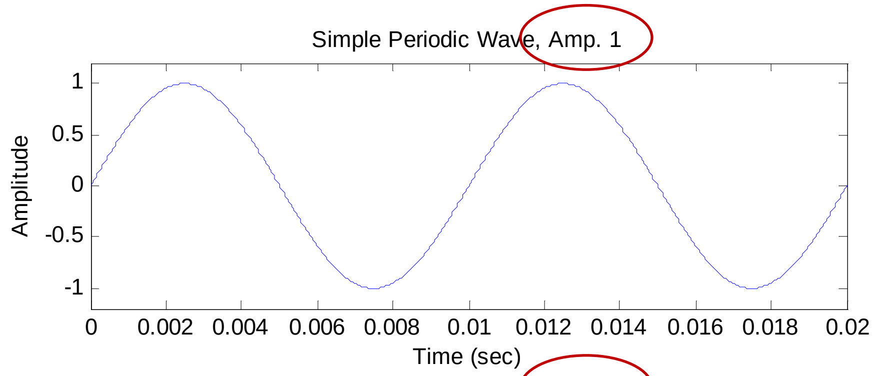
Amplitude and **intensity** are physical properties of sound waves that correlate with the psychological property of **loudness**.

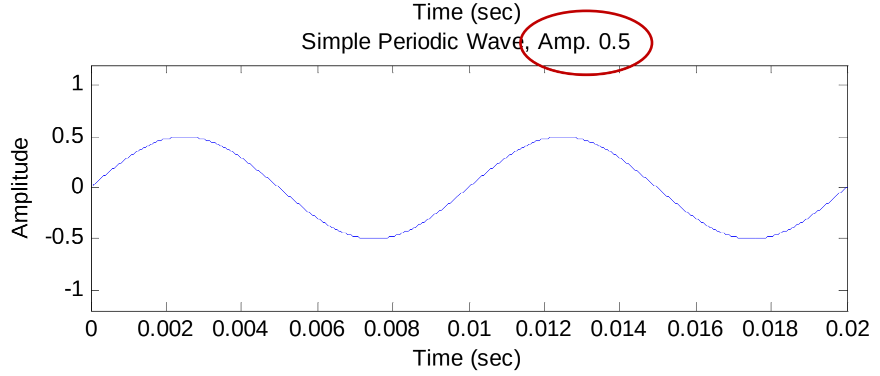
- The greater the amplitude of a sound wave, the louder the sound.
- The greater the intensity of a sound wave, the louder the sound.

Amplitude: degree of variation in air pressure from neutral to higher and lower (hPa [hecto-Pascal] or mb [millibar])

Intensity: power transmitted by the wave (dB [decibels])

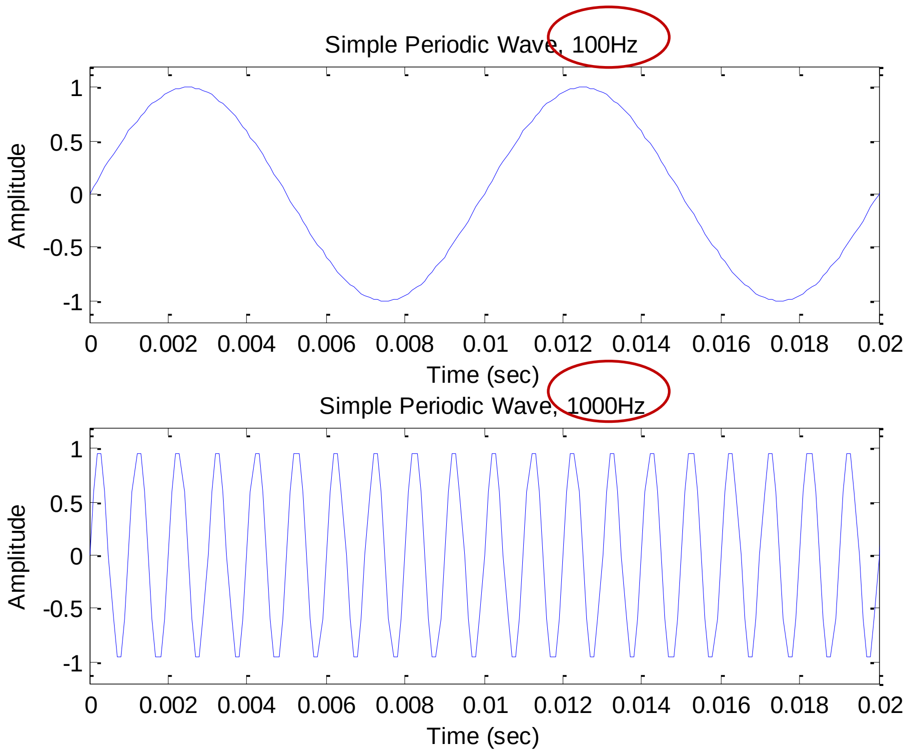
- *Some Intensities*
  - 0 dB threshold of audibility
  - 30 dB whispered conversation
  - 60 dB normal conversation
  - 110 dB rock concert
  - 120 dB threshold of pain





Frequency

- **Frequency:** a number of cycles per second (Hz [Hertz]).
  - a physical property
  - correlates with pitch (a psychological property).
  - greater the frequency - the higher the perceived **pitch** of a sound.



- *Some Frequencies*
  - 20,000 Hz highest perceptible
  - 265 Hz average child's speech
  - 225 Hz average woman's speech
  - 120 Hz average man's speech
  - 20 Hz lowest perceptible

Frequency

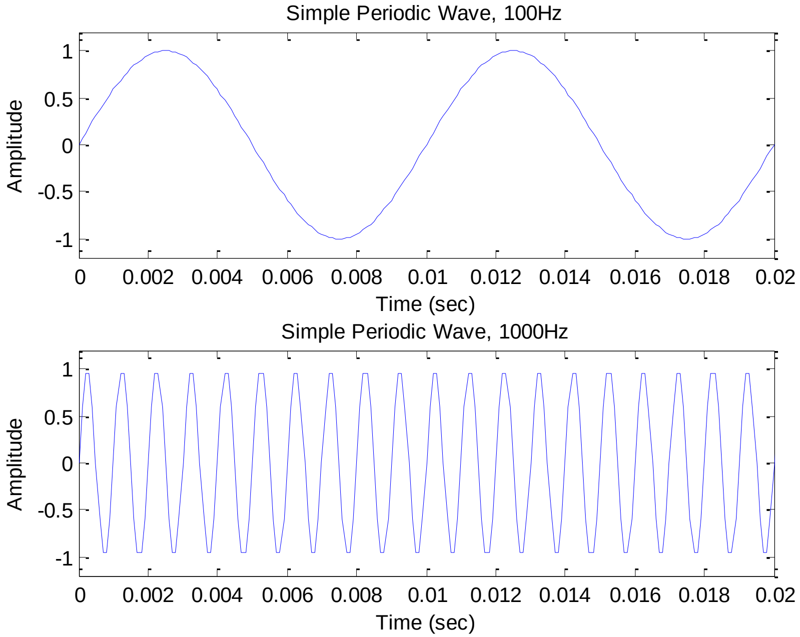
- **Frequency:** a number of cycles per second (Hz [Hertz]).
  - a physical property
  - correlates with pitch (a psychological property).
  - greater the frequency - the higher the **pitch** of a sound.

$$\text{Frequency in Hz} = \frac{\text{number of cycles}}{\text{time in seconds}}$$

1/.01 =
100 Hz

or 2/.02 =
100 Hz

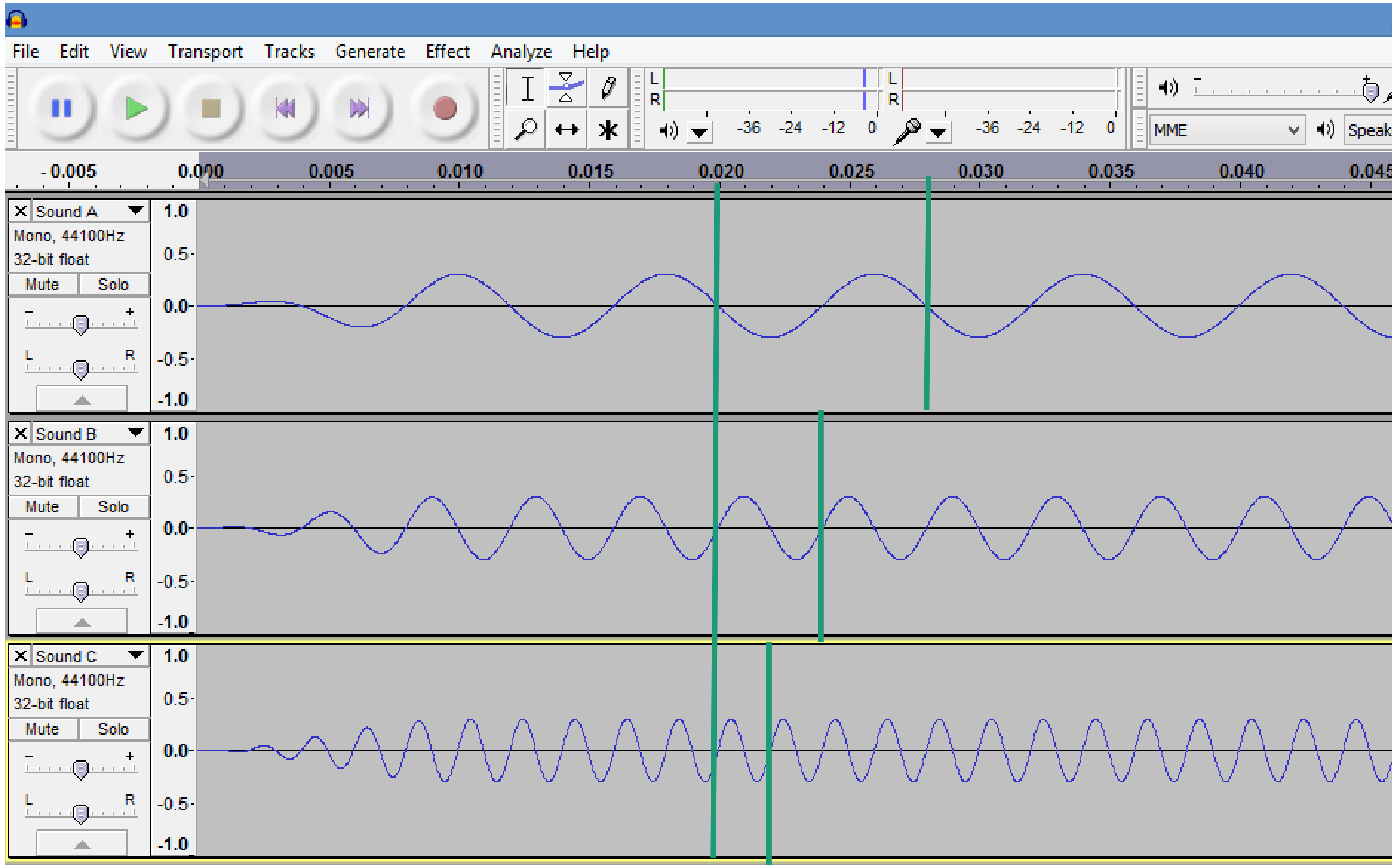
2/.002 =
1000 Hz



Questions:

- 1 cycle = 6.25 milliseconds; what's the frequency?
  - 1/0.00625 s = 160 Hz.
- A wave frequency = 250 Hz; how long is 1 cycle?
  - 1/250 Hz = 0.004 s (or 4 ms)
  - (i.e. # of cycles / frequency)

Frequency

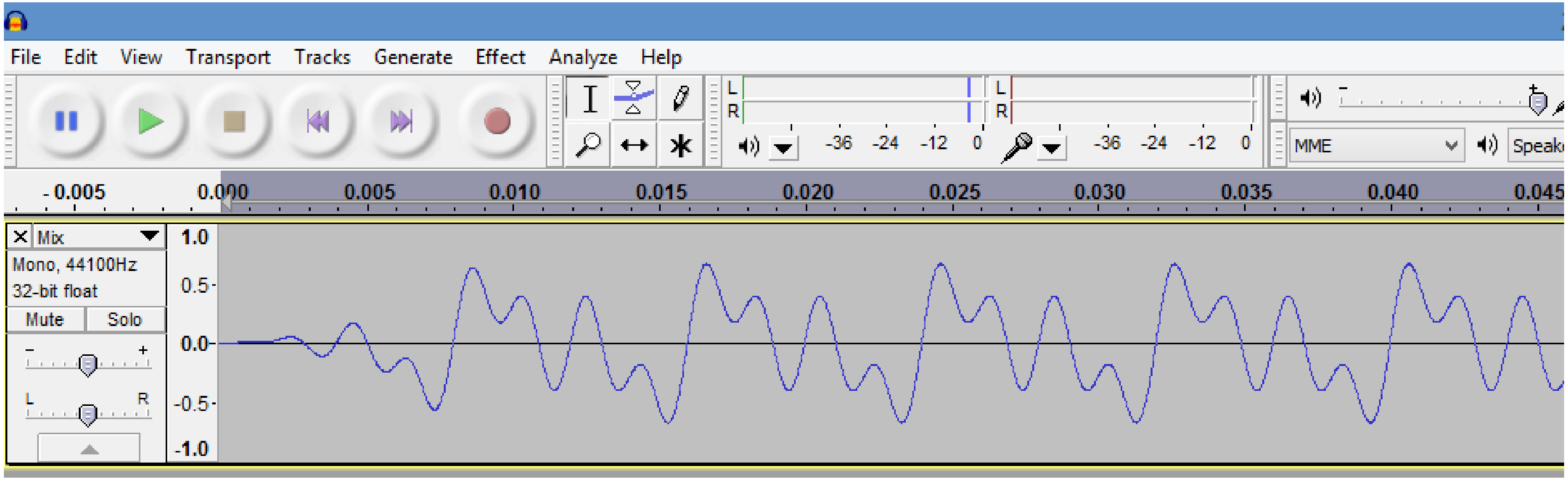


Start: 0.020
End: 0.028
Dur: 0.008 sec
1/0.008 = **125 hz**

Start: 0.020
End: 0.024
Dur: 0.004 sec
1/0.004 = **250 hz**

Start: 0.020
End: 0.022
Dur: 0.002 sec
1/0.002 = **500 hz**

Complex Repetitive Waves



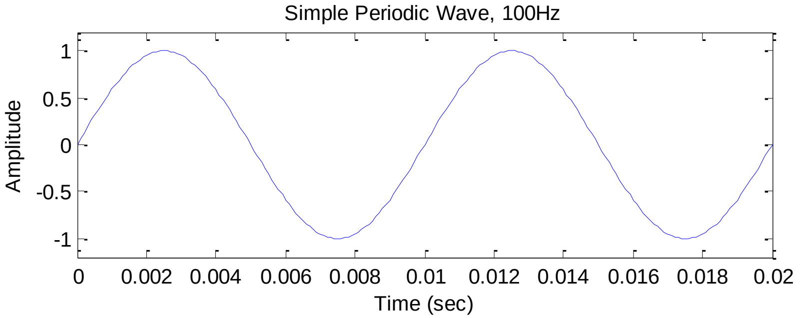
Complex Repetitive Waves

- Speech sounds are more complex.
  - **Complex repetitive** (periodic) **waves**.

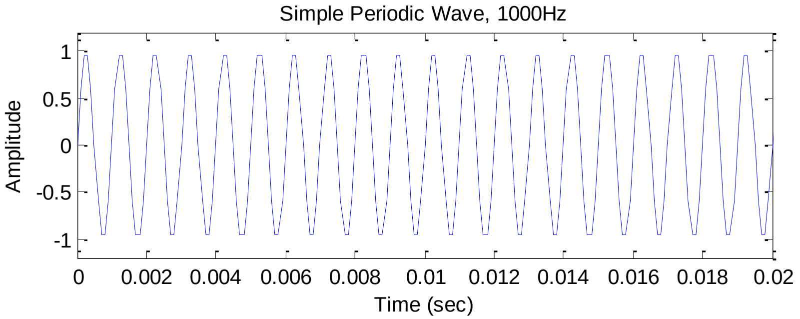
  - E.g. wave 1 (100 Hz) + wave 2 (1000 Hz).

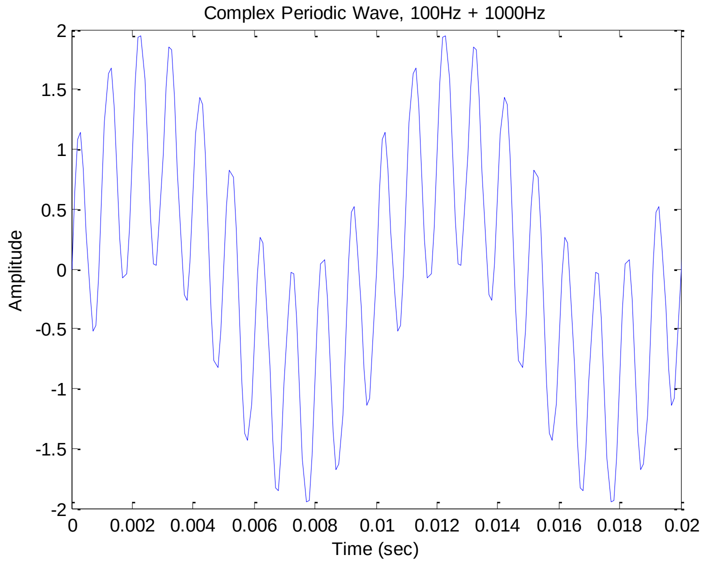
1/.01 =
100 Hz

or 2/.02 =
100 Hz



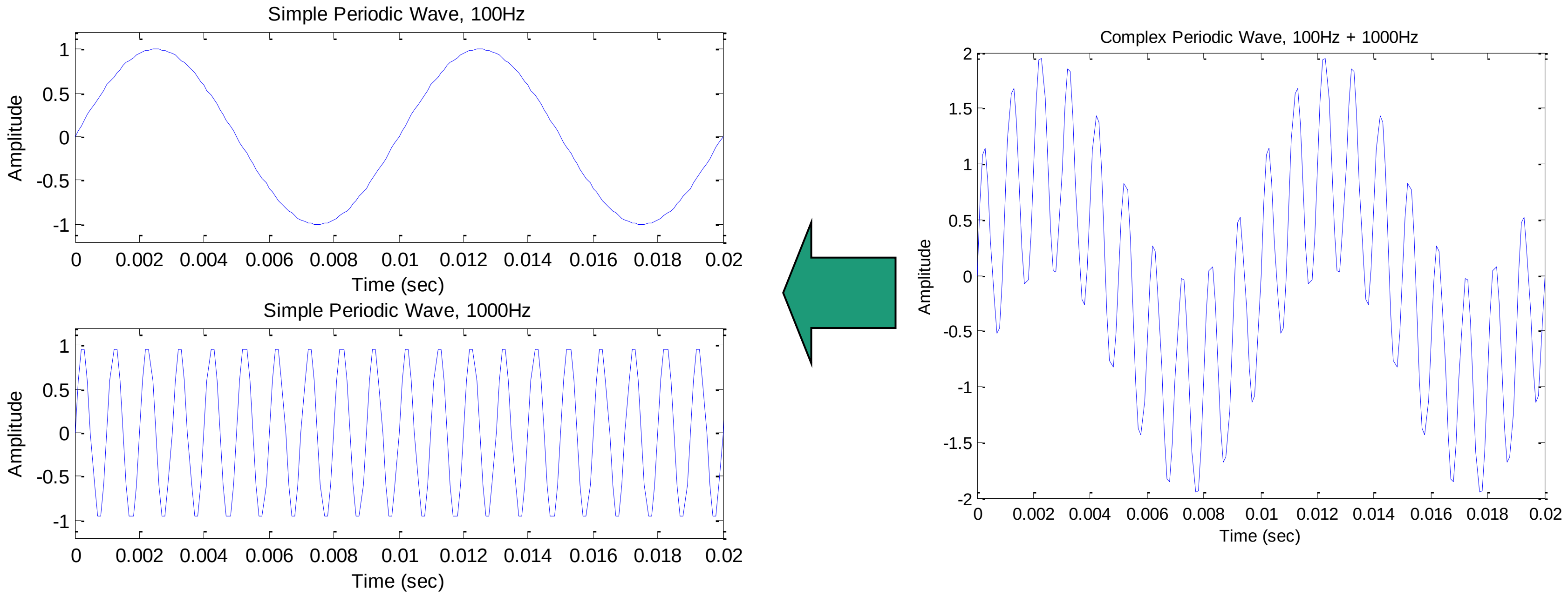
2/.002 =
1000 Hz



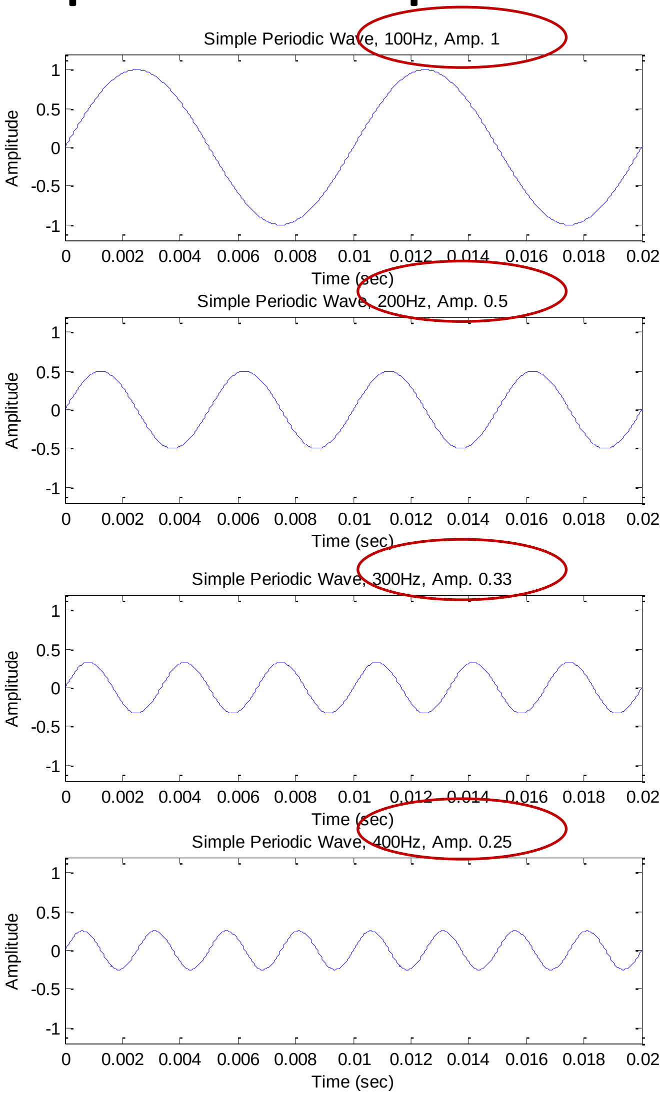


Complex Repetitive Waves

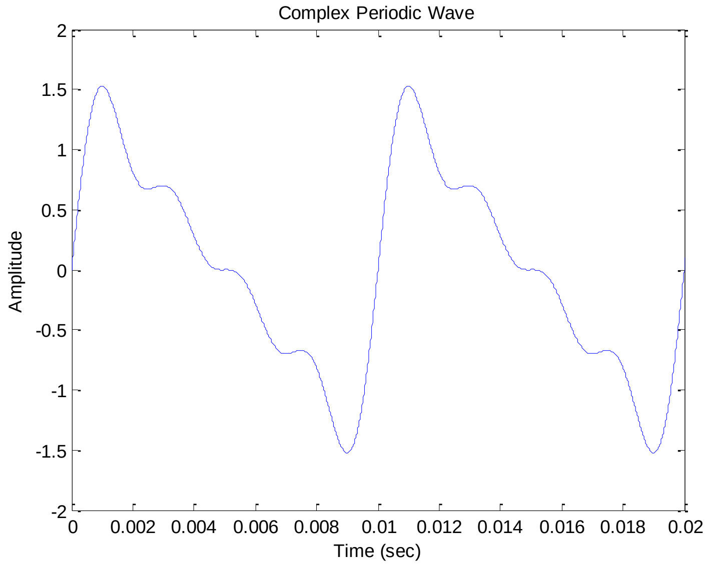
- **Fourier analysis:**
  - a mathematical technique decomposing complex repetitive waves into combinations of simple sine waves.
- A human ear is believed to perform a Fourier-like analysis.



Complex Repetitive Waves



Harmonics: Individual component waves of a complex wave.



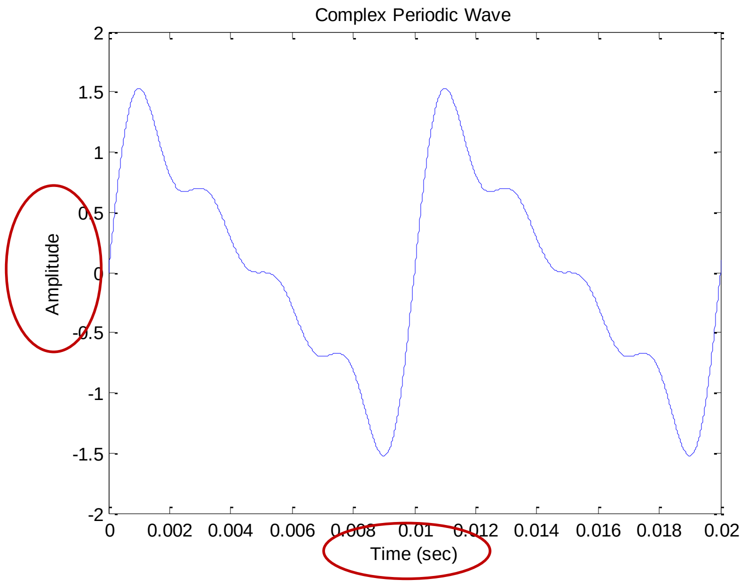
The fundamental frequency (F0) of a complex wave = the harmonic with the lowest frequency

- here 100 Hz

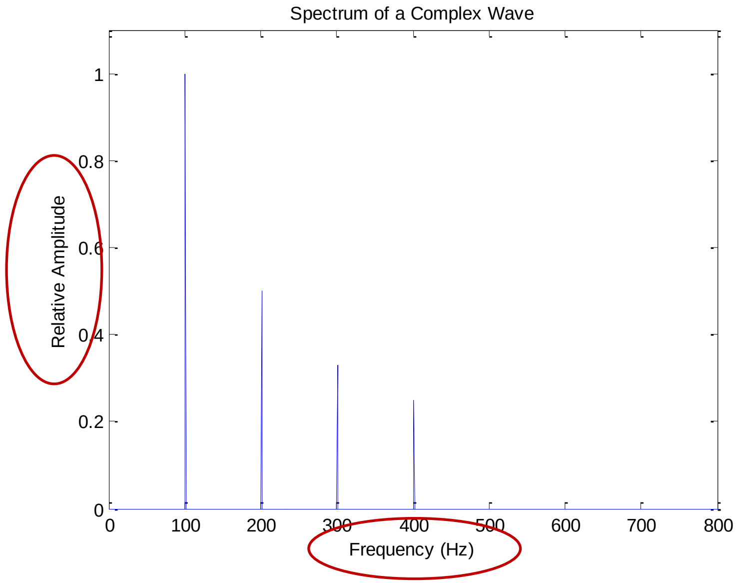
All harmonics above have frequencies that are multiple of the fundamental.

Spectrum

- **Spectrum**:
  - a display that shows the amplitude (or intensity) of each harmonic.



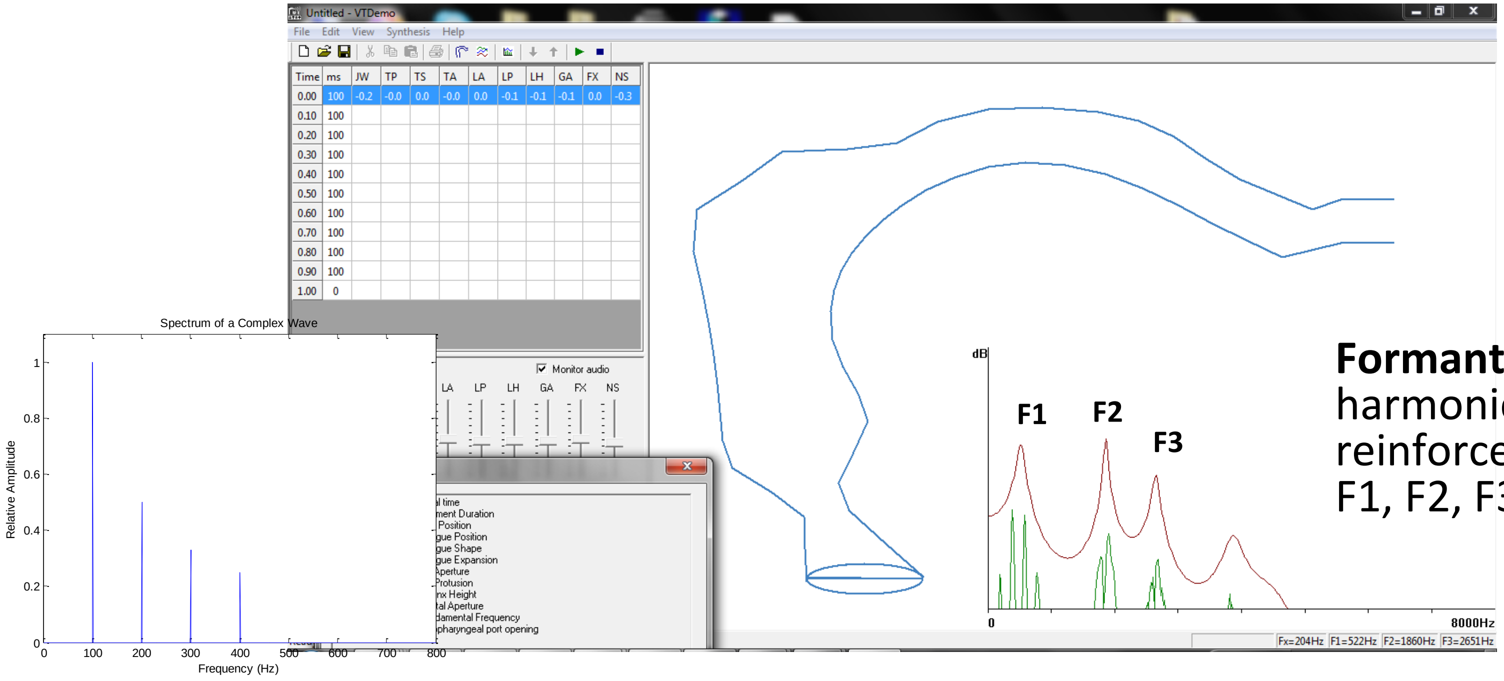
a complex repetitive wave



its spectrum

Resonance

- **Resonance:** a natural tendency of a body to vibrate at certain frequencies.
- Resonating properties of the vocal tract can change as we change the shape of our vocal tract.
  - some frequencies are **reinforced**, others are **filtered out**.

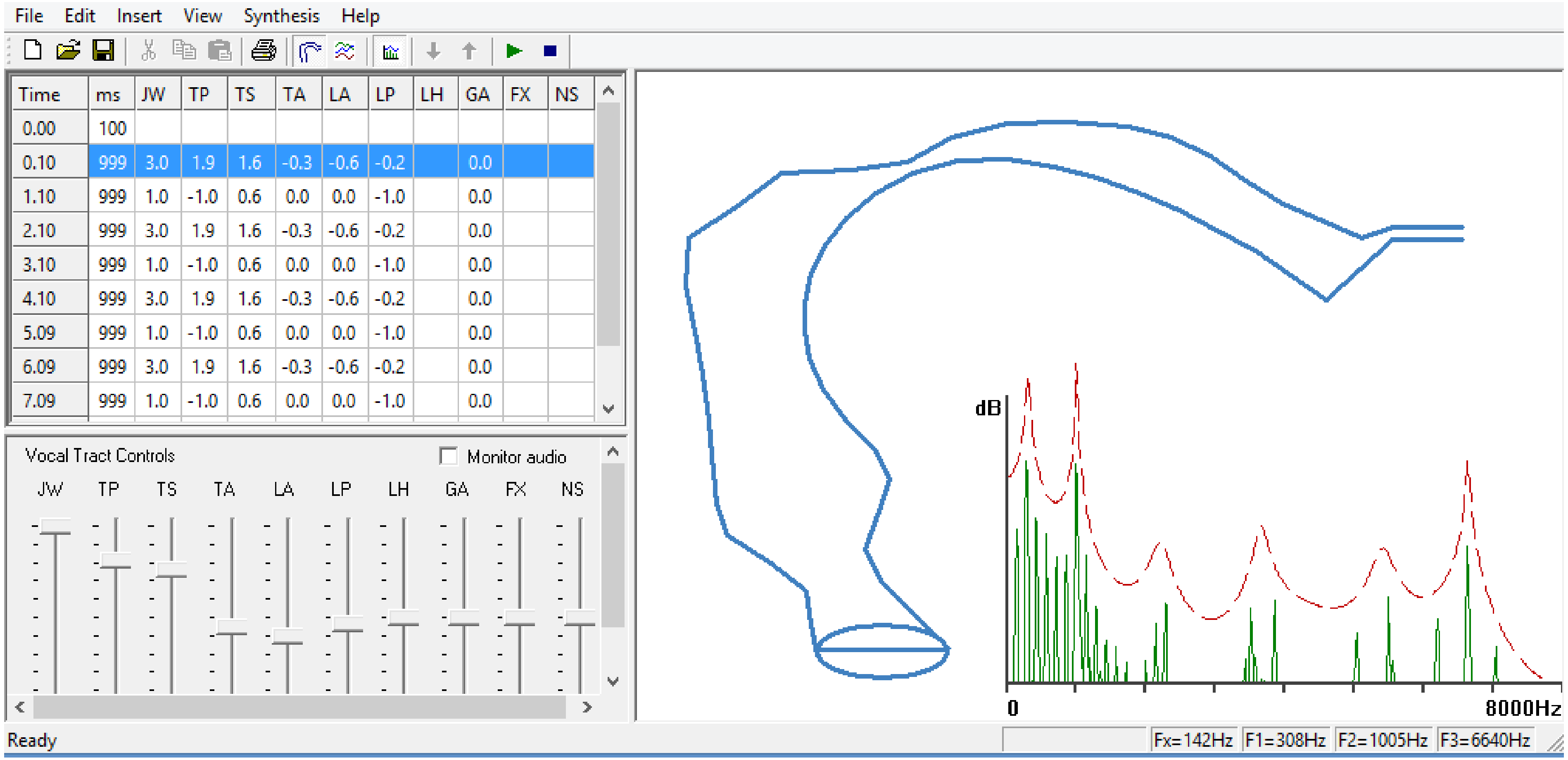


Formants: clusters of harmonics that are reinforced.
F1, F2, F3…

a glottal wave: airflow through the glottis

VTDemo - Vocal Tract Acoustics Demonstrator
http://www.phon.ucl.ac.uk/resource/vtdemo/

Resonance



File Edit Insert View Synthesis Help
Time ms JW TP TS TA LA LP LH GA FX NS
0.00 100
0.10 999 3.0 1.9 1.6 -0.3 -0.6 -0.2 0.0
1.10 999 1.0 -1.0 0.6 0.0 0.0 -1.0 0.0
2.10 999 3.0 1.9 1.6 -0.3 -0.6 -0.2 0.0
3.10 999 1.0 -1.0 0.6 0.0 0.0 -1.0 0.0
4.10 999 3.0 1.9 1.6 -0.3 -0.6 -0.2 0.0
5.09 999 1.0 -1.0 0.6 0.0 0.0 -1.0 0.0
6.09 999 3.0 1.9 1.6 -0.3 -0.6 -0.2 0.0
7.09 999 1.0 -1.0 0.6 0.0 0.0 -1.0 0.0
Vocal Tract Controls
Monitor audio
JW TP TS TA LA LP LH GA FX NS
dB
0
8000Hz
Ready
Fx=142Hz F1=308Hz F2=1005Hz F3=6640Hz

Formants and Vowels

- Acoustically, different vowels are distinguished from one another on the basis of formants.
  - **Formants** are **clusters of harmonics** which are **enhanced** by the **resonating properties** of the **vocal tract**.
  - The configuration of the vocal tract differs for each vowel leading to different formant frequencies for each vowel.
  - The lowest formants, F1 and F2, give us the most information in distinguishing one vowel from another.
    - **F1** is determined by the resonating frequency of the **back cavity**
    - **F2** is determined by the resonating frequency of the **front cavity.**

Formants and Vowels

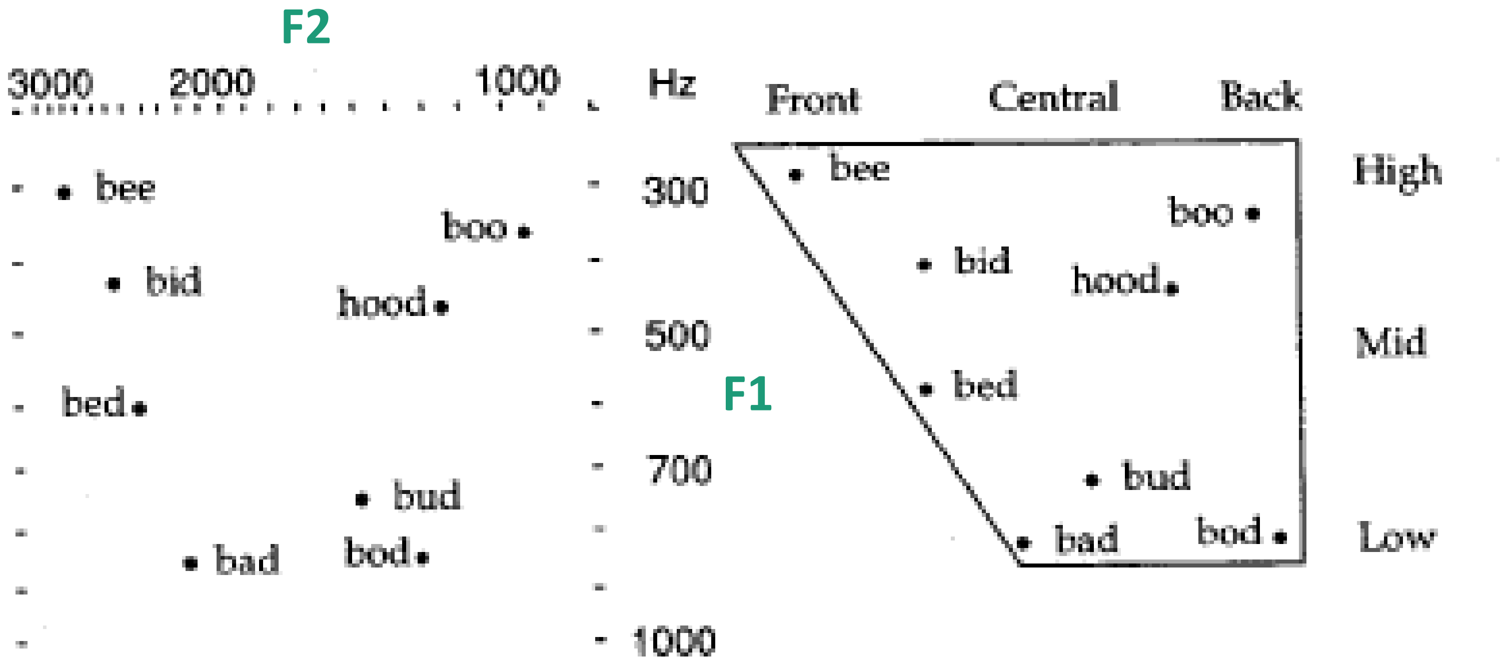


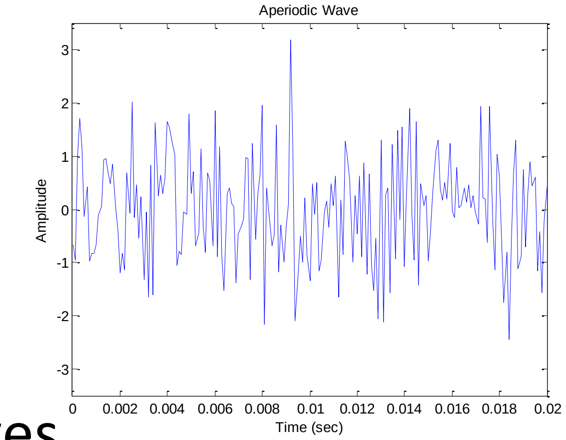
Figure 11.9 The quadrilateral on the right is a traditional representation of what is taken to be the relative position of the highest point of the tongue in some American English vowels. The corresponding acoustic data (taken from figure 6.5) are shown on the left.

From: Ladefoged (2001) *Vowels and Consonants*, pages 115-116

Noise

- Up till now, we have been examining periodic sounds
  - characterized in terms of a repeating waveform (e.g. glottal wave)

- There are, however, waves that are **aperiodic**, involving random fluctuations of amplitude (or intensity)



- Aperiodic waves are also called **noise**
  - Can you think of an example of a speech sound that is aperiodic?

- Many sounds are combinations of periodic and aperiodic waves
  - Can you think of an example of a speech sound that combines periodic and aperiodic waves?

Announcements and Reminders

- I will be holding office hours on **Friday, May 14th** at **1-2 PM**

- On-line assignment 2 is due on **Saturday, May 15th at 11:59 PM**

- For Monday, you should read:
  - All of Chapter 8
  - Download Praat on to your computer, and begin playing around with it
    - http://www.fon.hum.uva.nl/praat/

Handwriting IPA - Consonants

p b t d k g ʔ

f v θ ð s z ʃ ʒ h

tʃ dʒ m n ŋ

w j ɹ l

Handwriting IPA - Vowels