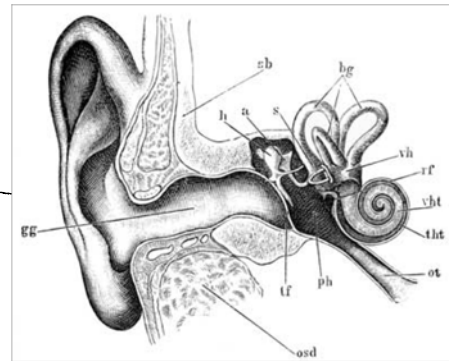
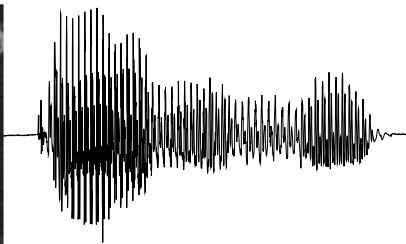
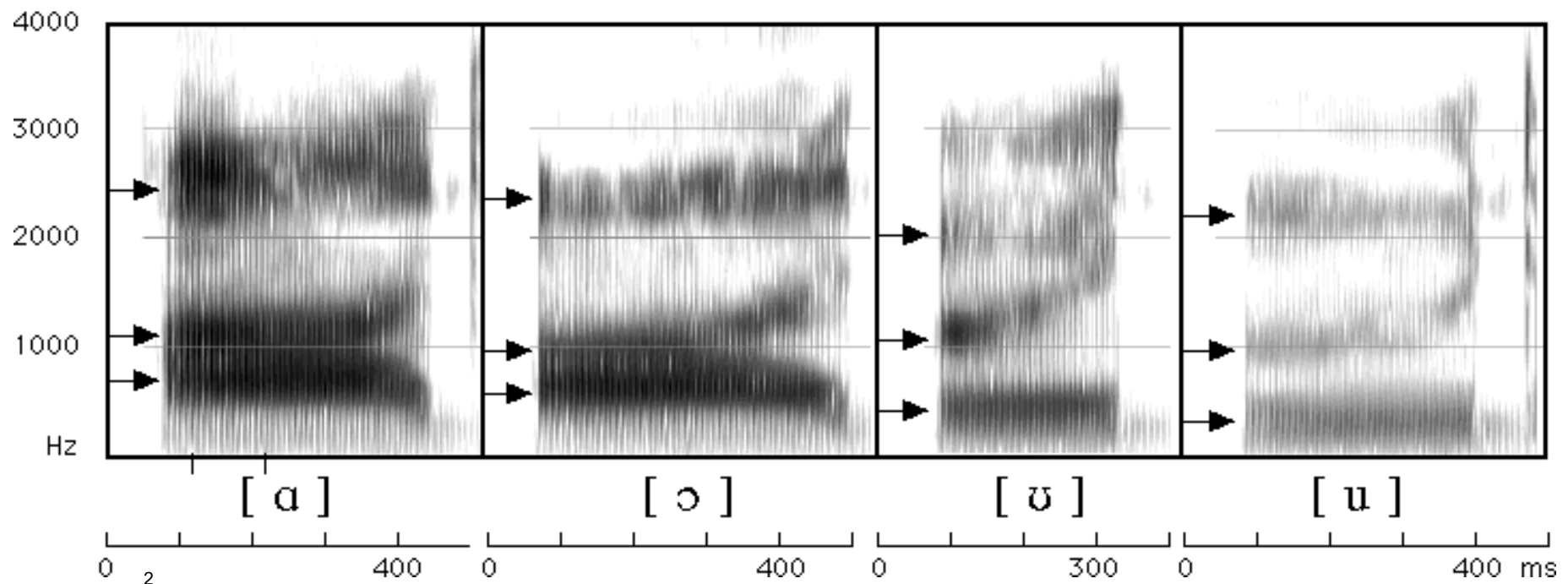
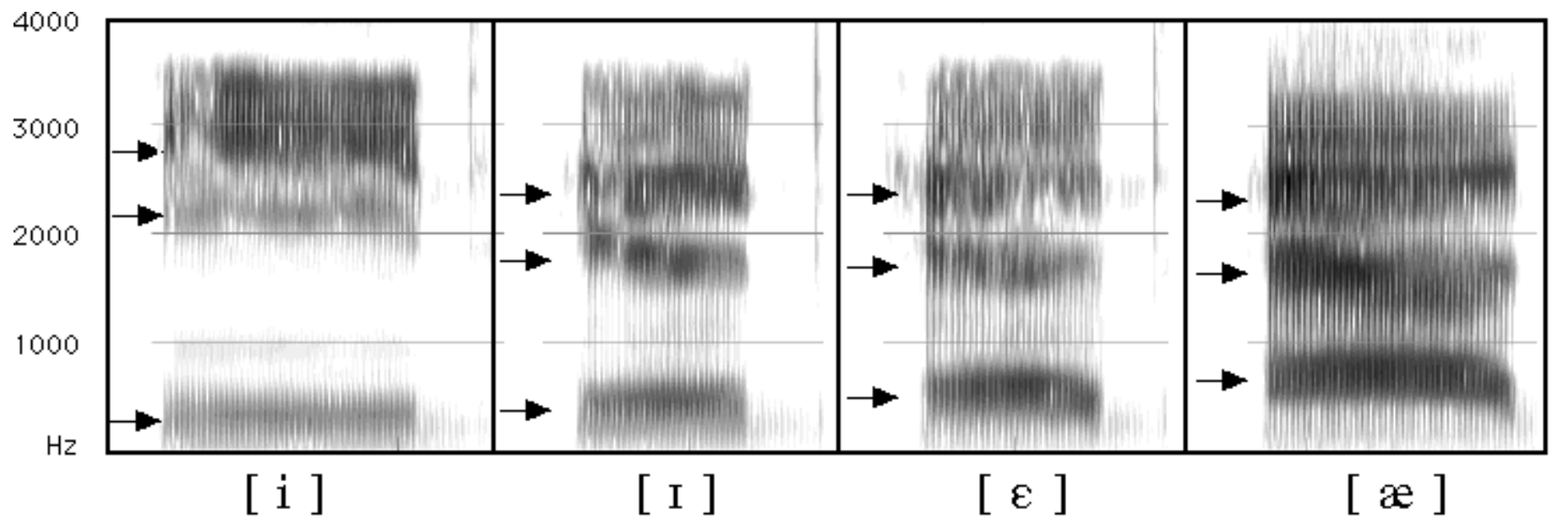


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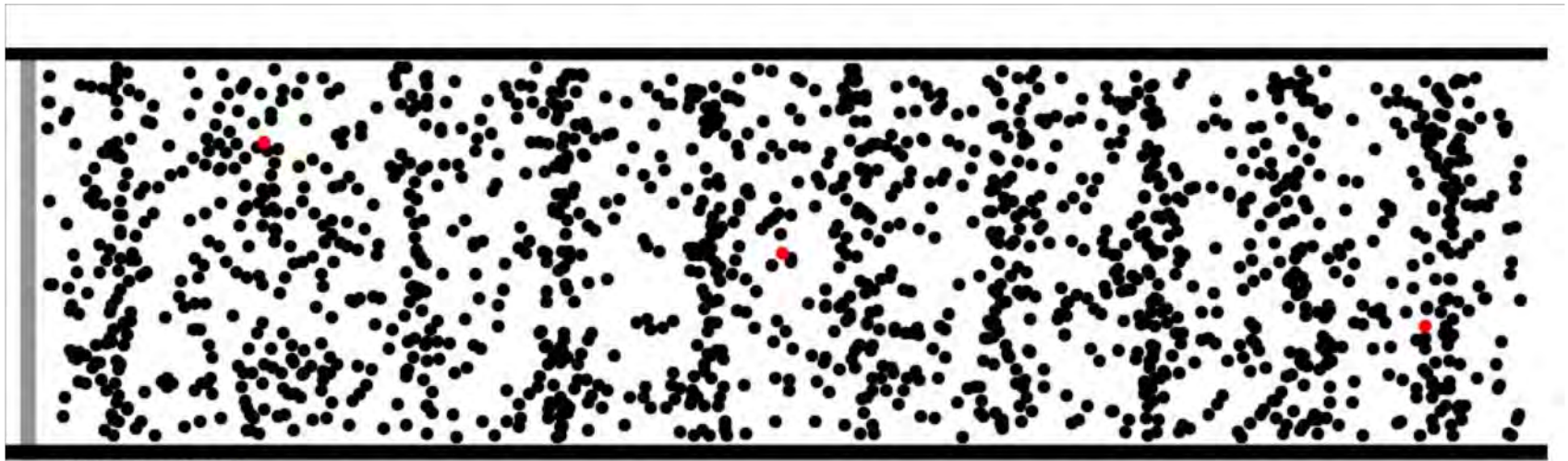
Speech acoustics





Introduction to acoustics

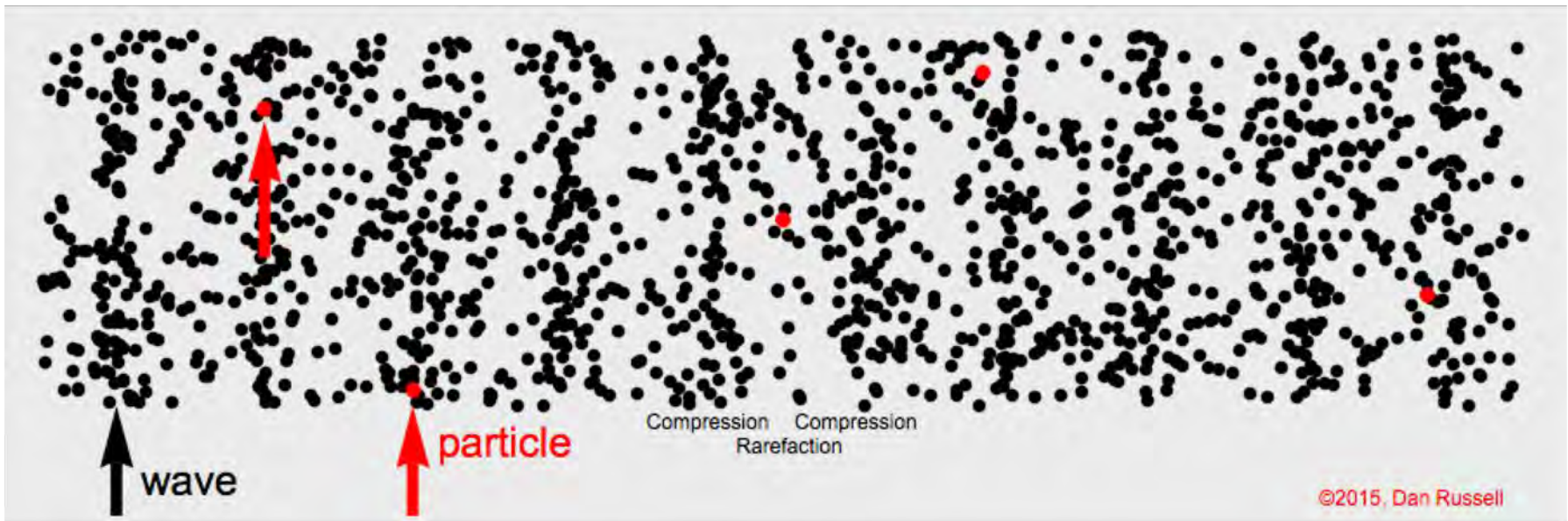
- Sound consists of pressure fluctuations in a medium (usually air).
- Movements at a source produce a sound wave in the medium which carries energy to the perceiver.



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Speech acoustics

- Pressure fluctuations move through space, but each air particle moves only a small distance.



Representing sound waves

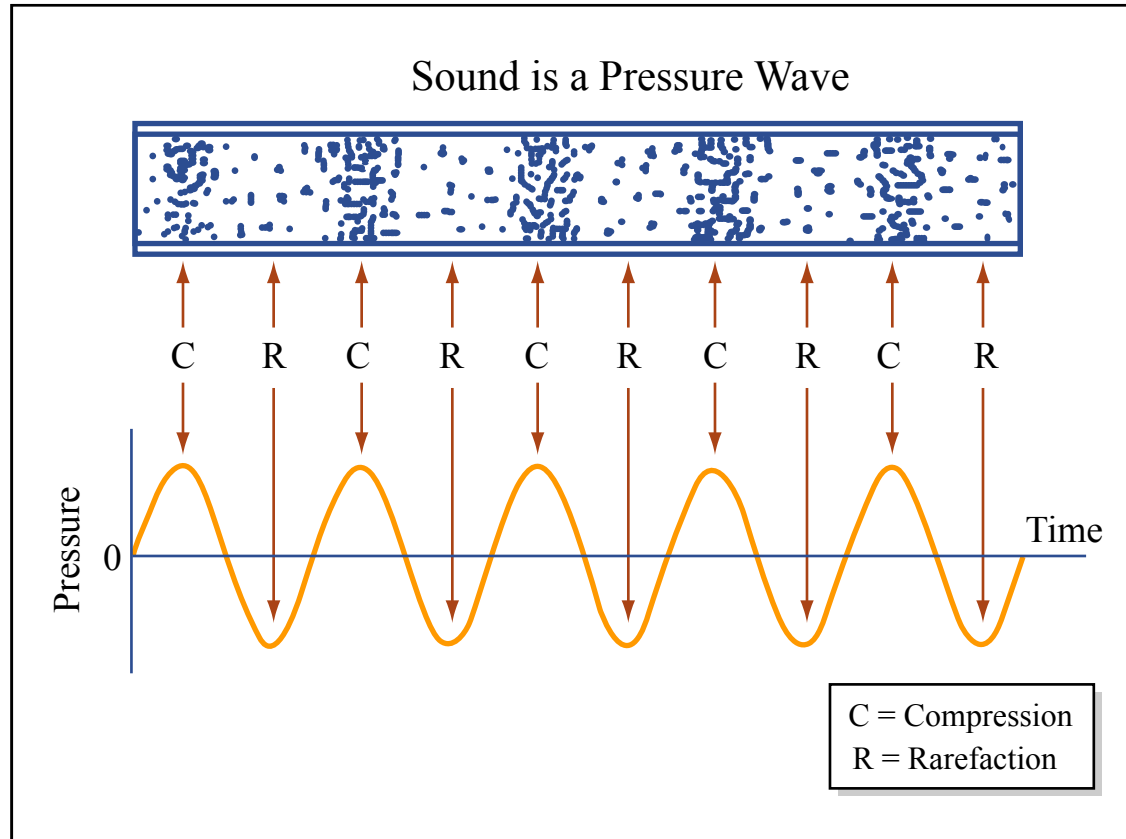
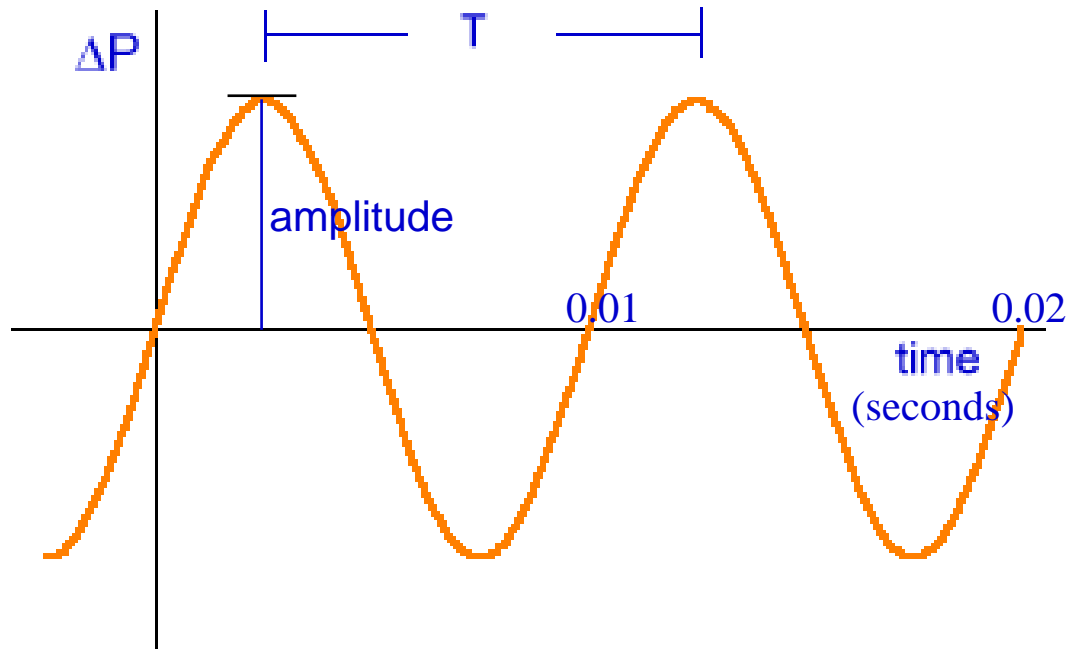


Image by MIT OCW.
Adapted from The Physics Classroom Tutorial.

Periodic sounds

- A waveform is periodic if it repeats at regular intervals.
- Frequency of a wave is the number of cycles occurring per unit of time.
 - Units: 1 Hertz (Hz) is 1 cycle/second



Periodic sounds

- Voiced sounds have complex (quasi-)periodic wave forms.
- The perceived pitch of a sound depends on its frequency.

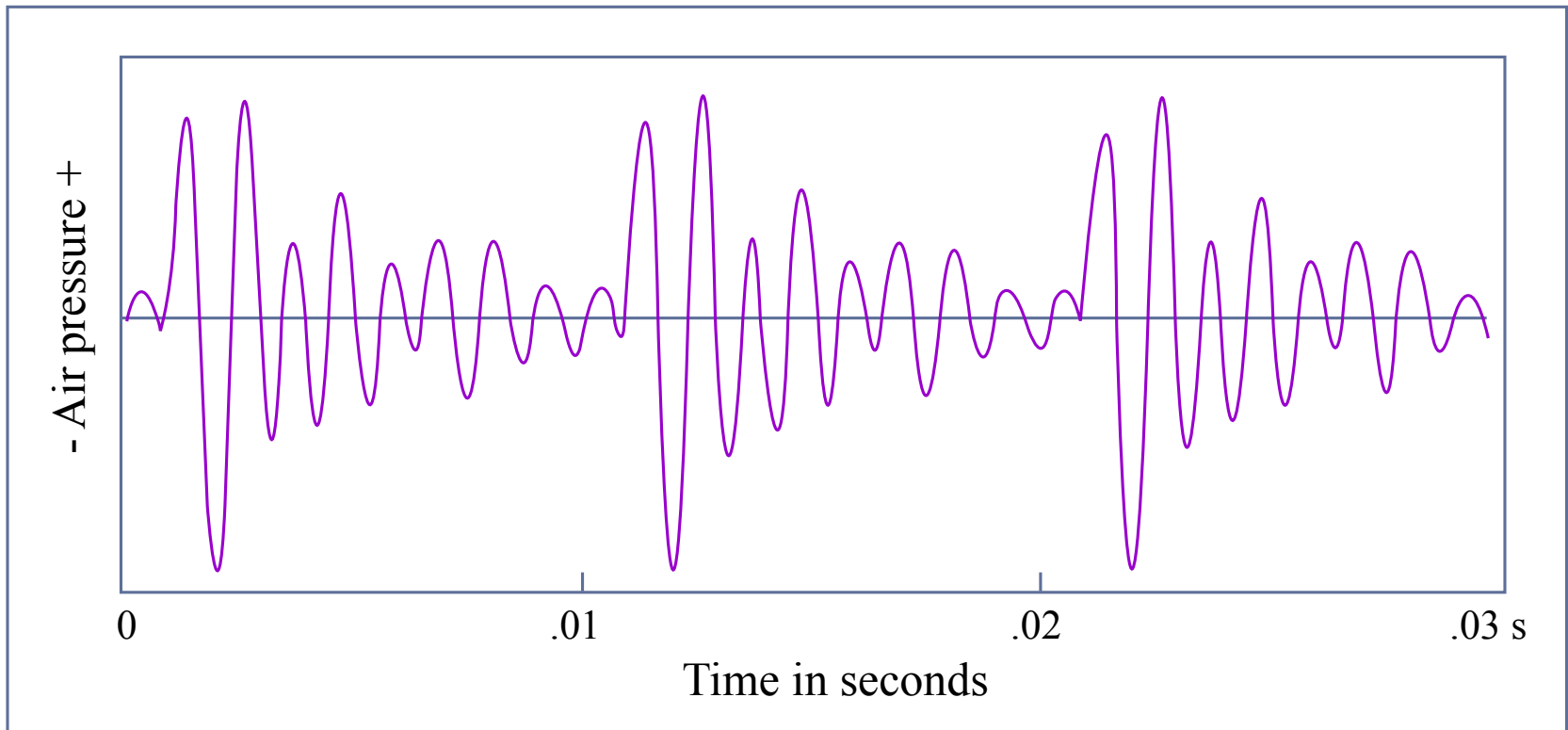
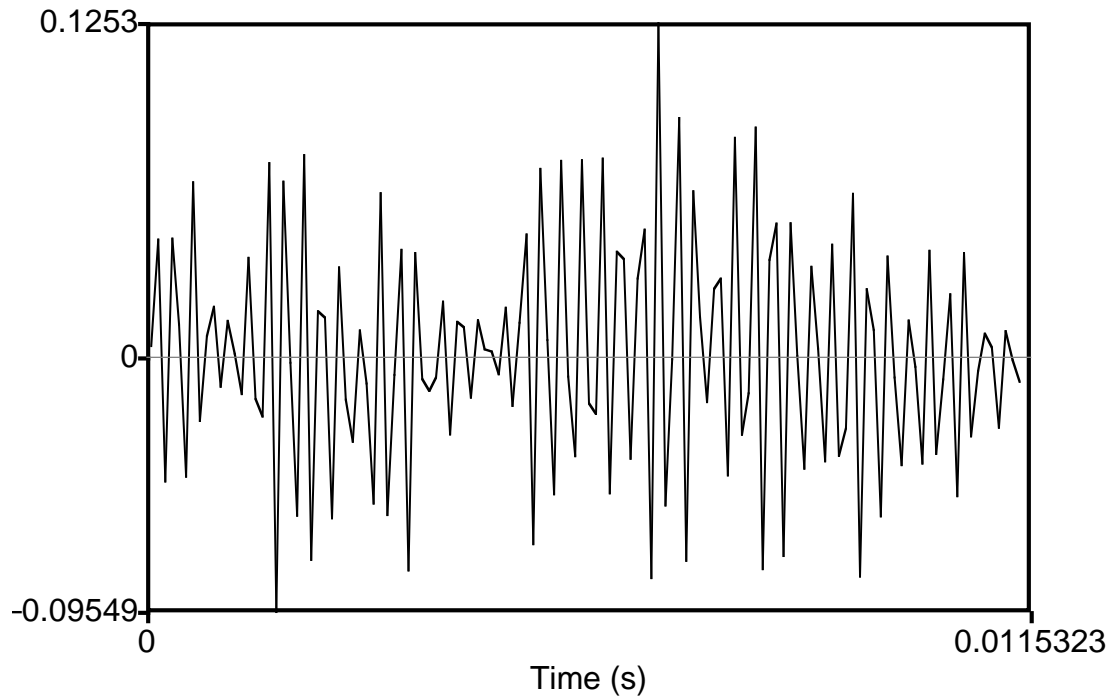


Image by MIT OCW.

Aperiodic sounds

- Aperiodic sounds have waveforms that do not repeat.
- Fricative noise is aperiodic.



Segment of [s]

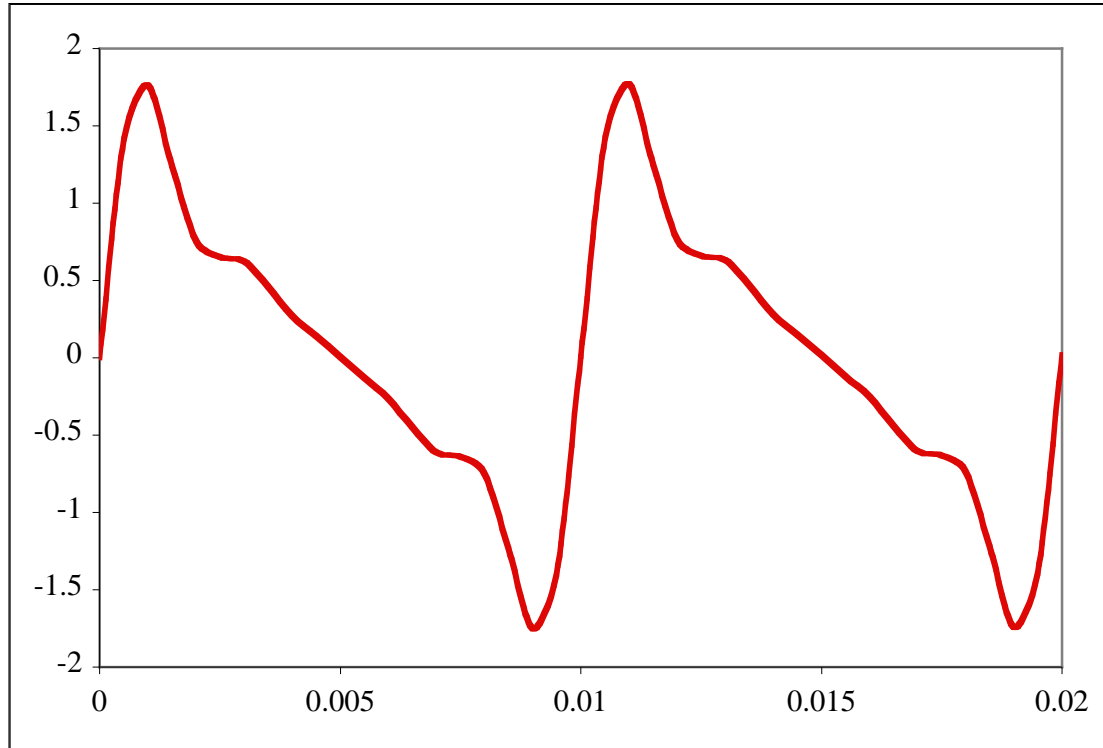
Spectrums and spectrograms

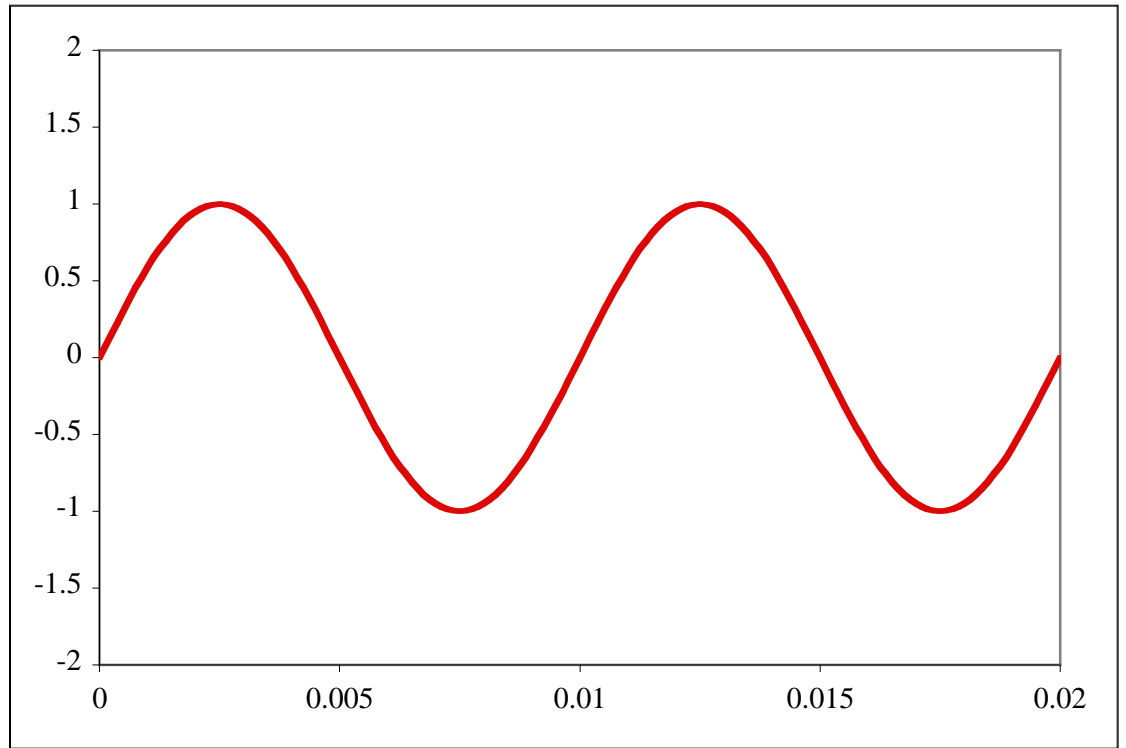
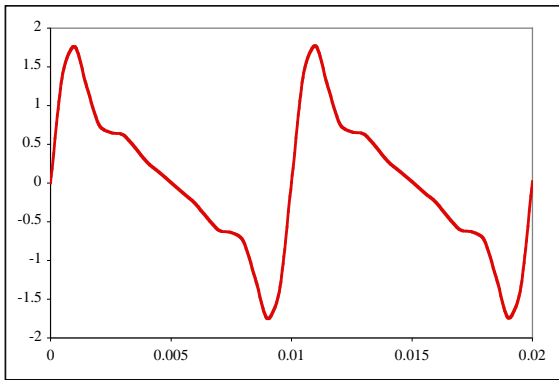
- The spectrum of a sound plays a central role in determining its quality or timbre.

Spectral representation

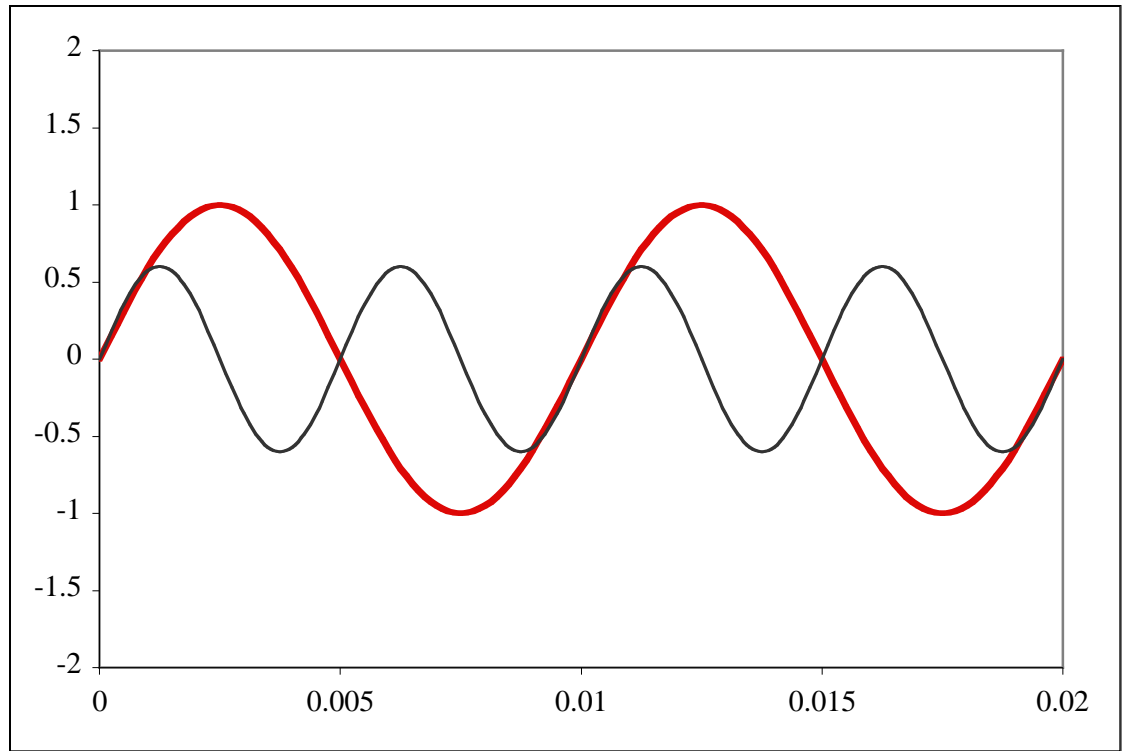
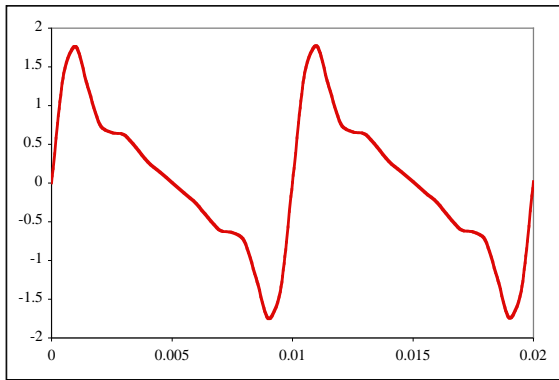
- Any complex wave can be analyzed as the combination of a number of sinusoidal waves of different frequencies and intensities (Fourier theorem).
- In the case of a periodic sound like a vowel these will be
 - the fundamental frequency
 - multiples of the fundamental frequency (harmonics)
- The quality of a periodic sound depends on the relative amplitude of its harmonics.

Spectral representation

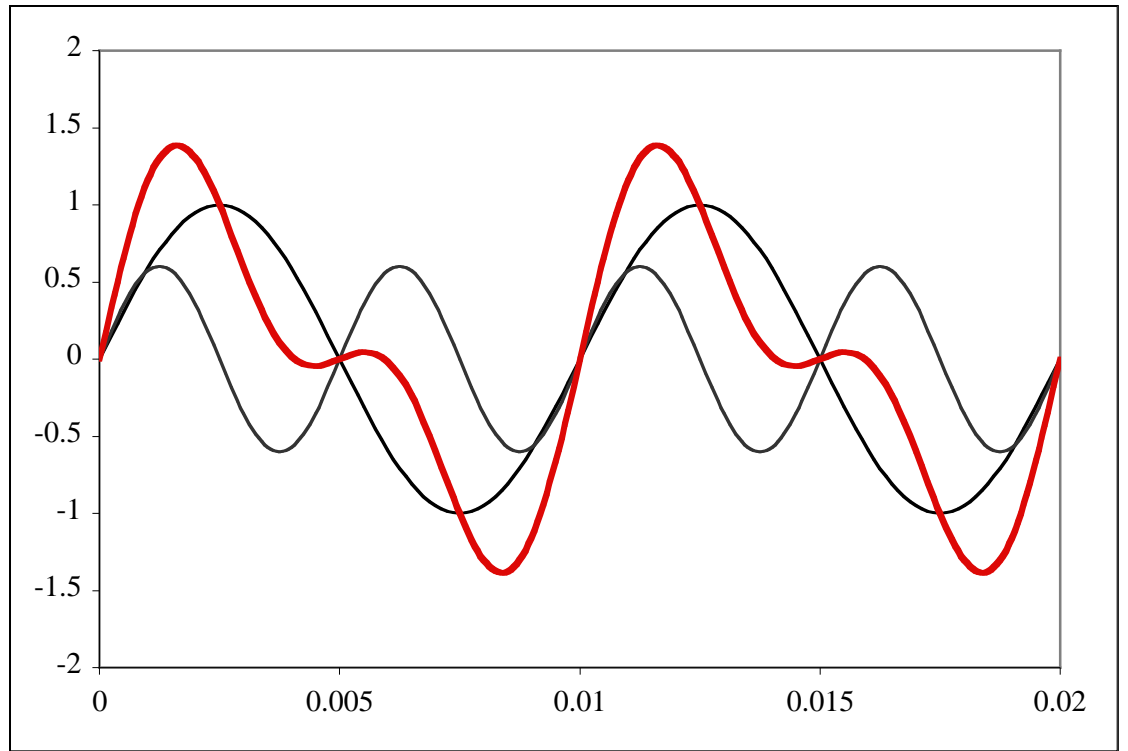
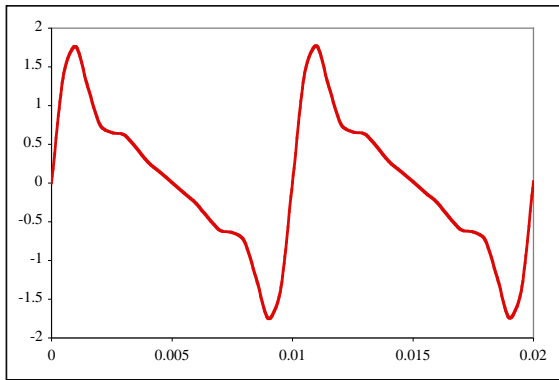


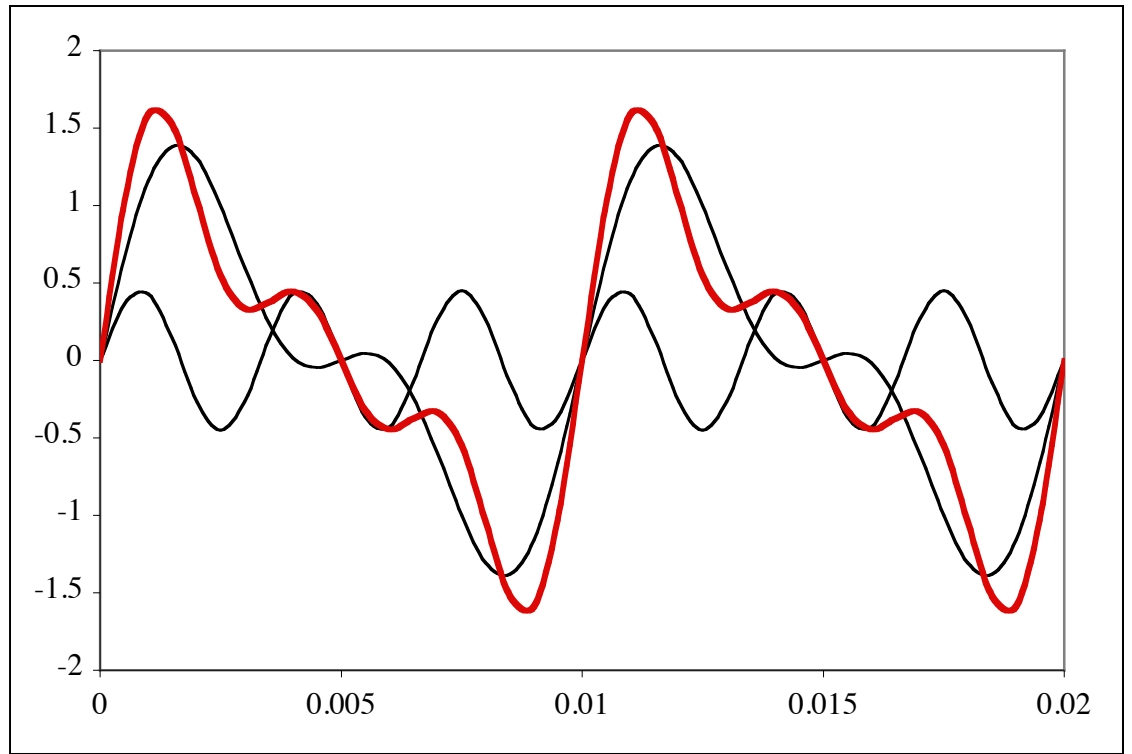
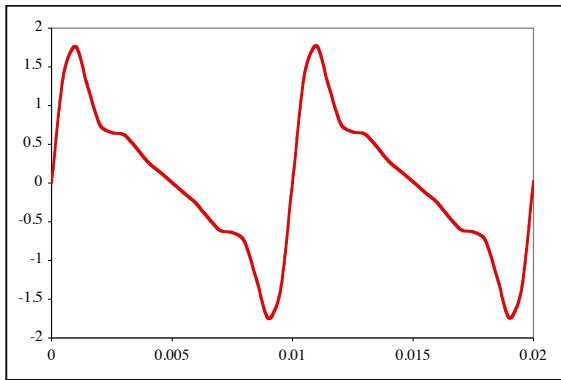


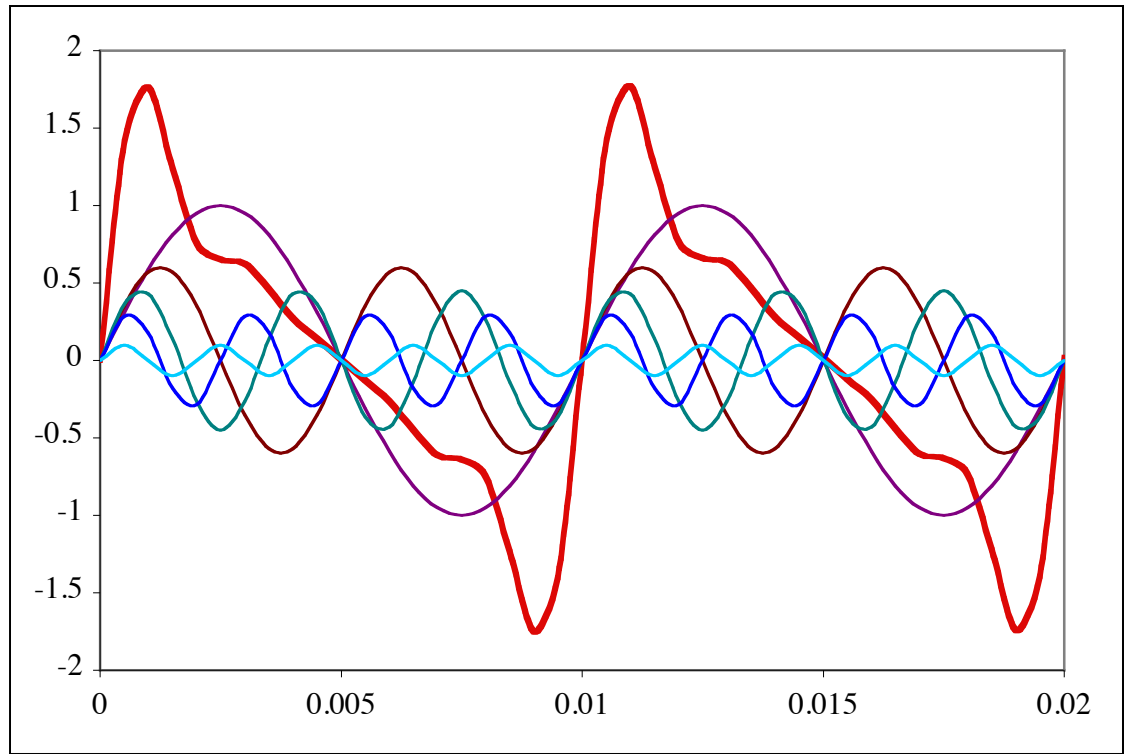
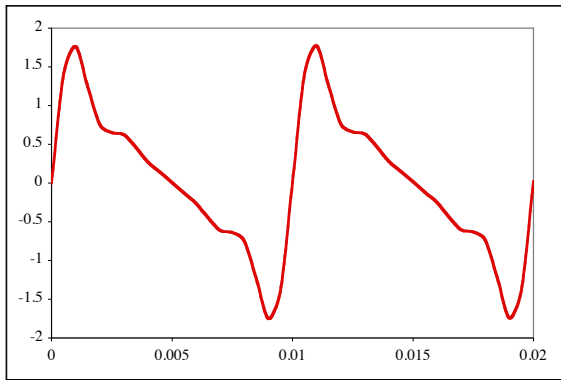
Fundamental frequency



2nd harmonic



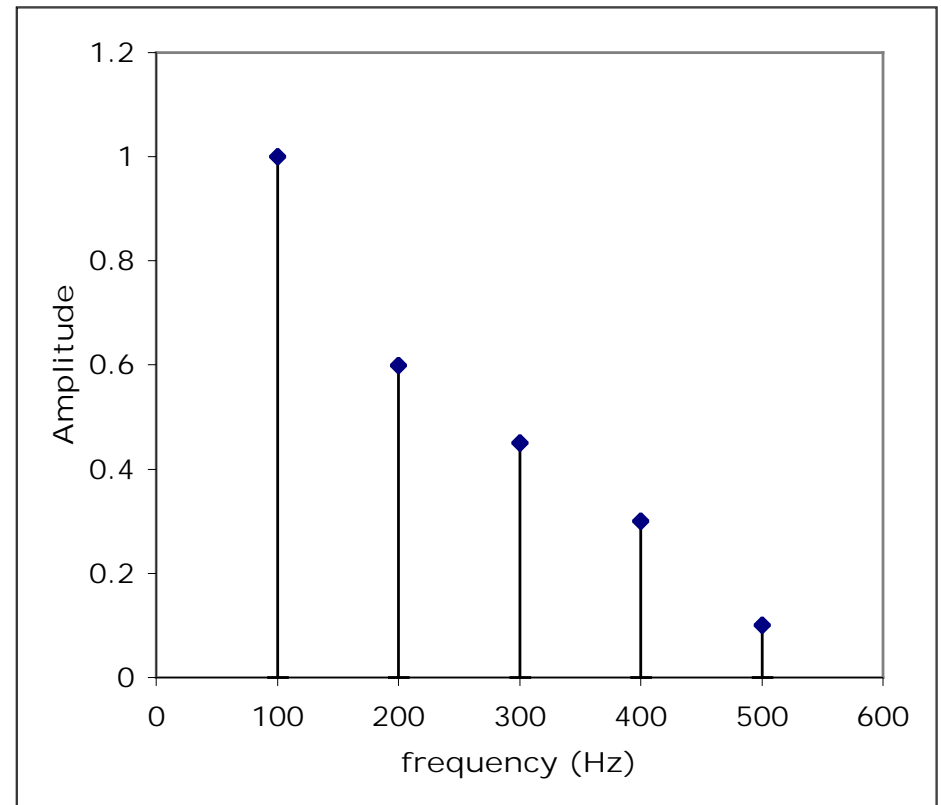




Spectral representation

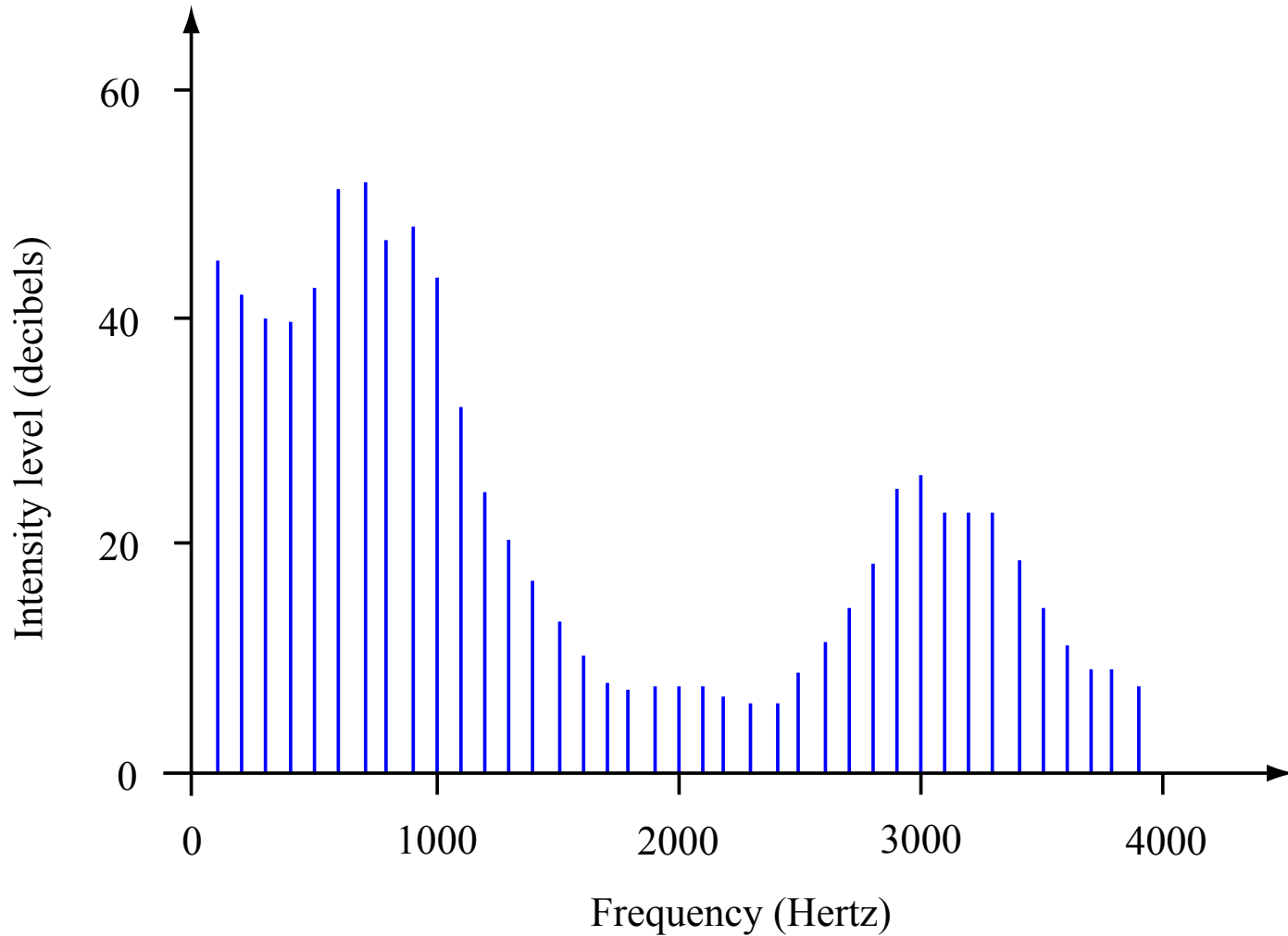
- Phase differences are relatively unimportant to sound quality, so key properties of a complex wave can be specified in terms of the frequencies and amplitudes of its sinusoidal components.

Frequency (Hz)	Amplitude
100	1
200	0.6
300	0.45
400	0.3
500	0.1

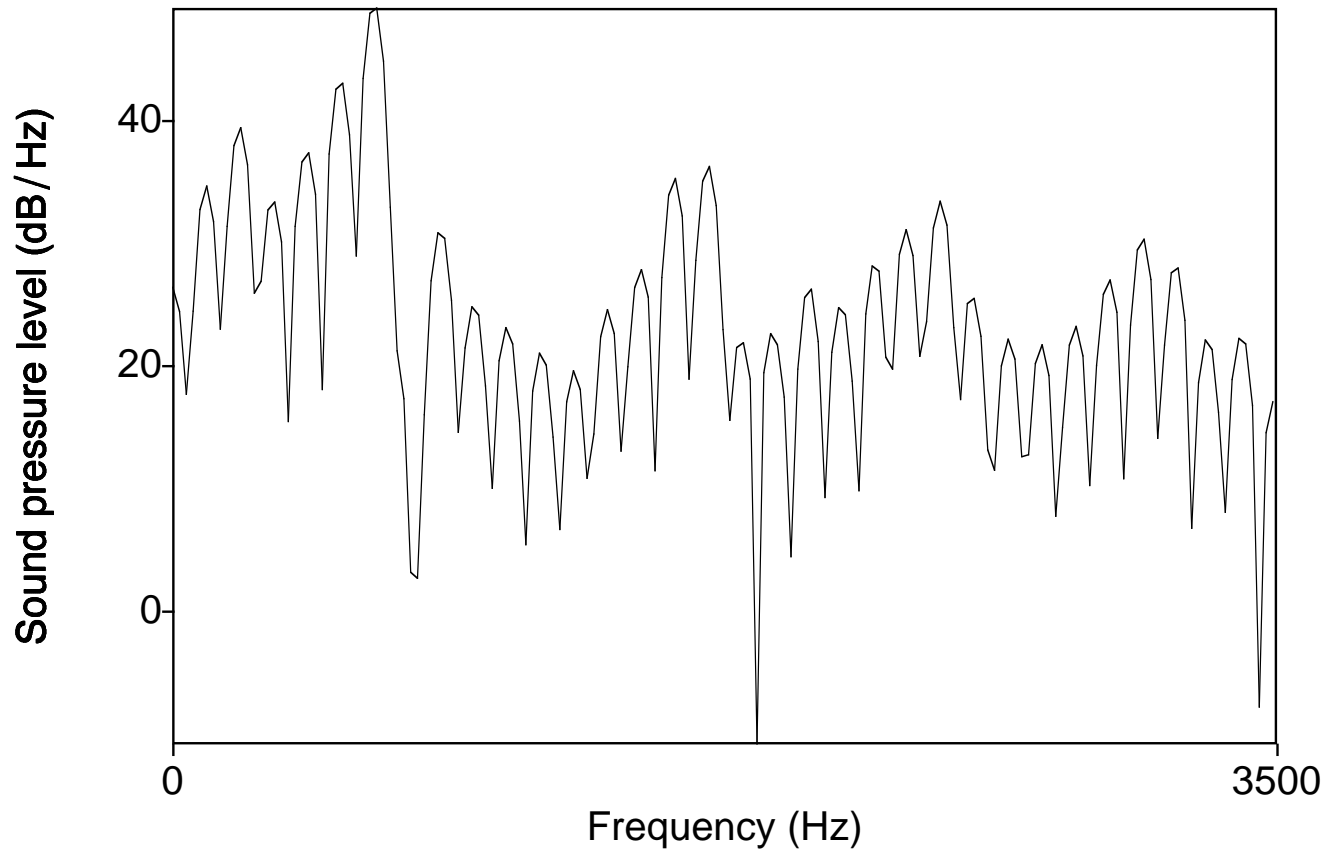


Power spectrum

Idealized vowel spectrum



vowel spectrum

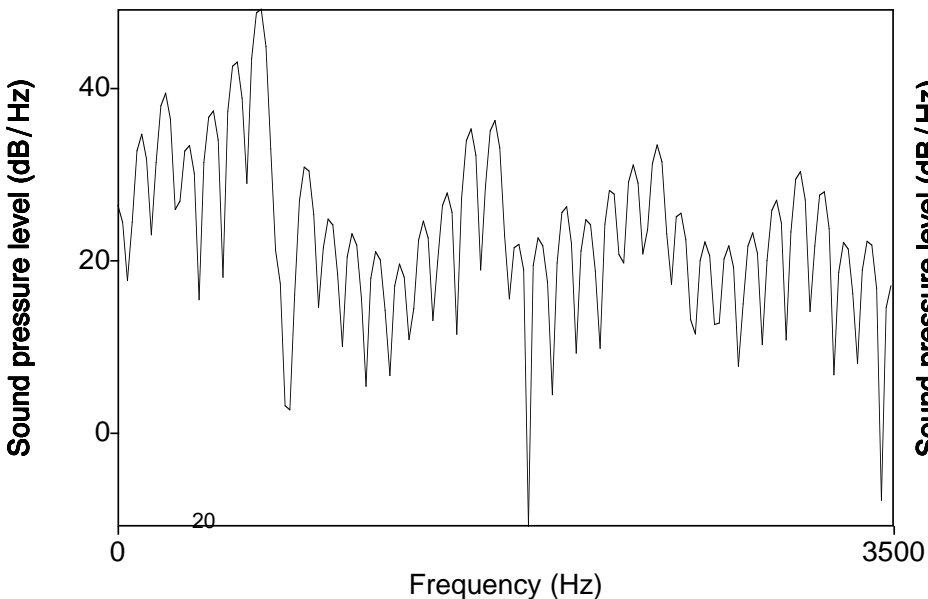


[æ]

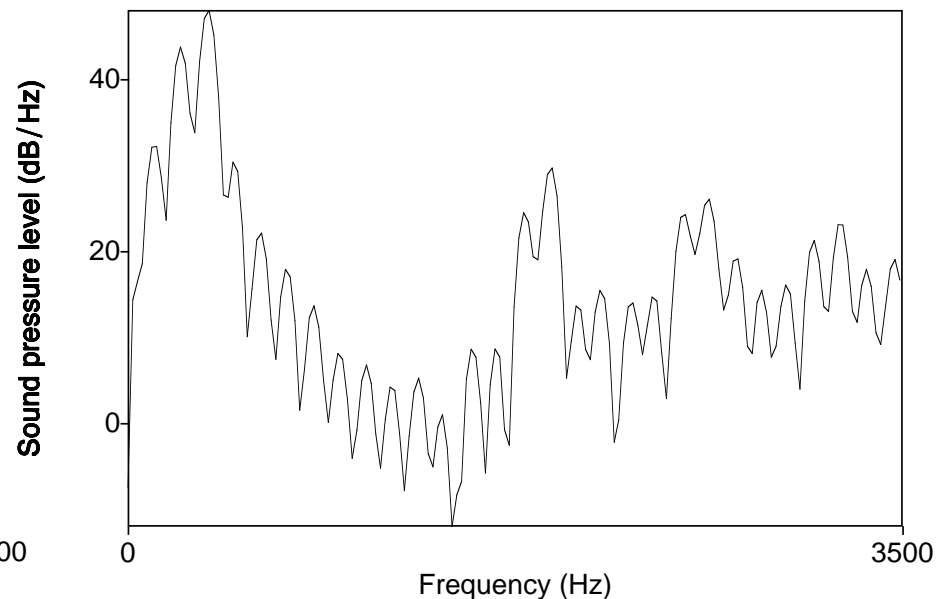
Vowel quality

- The quality of a vowel depends on the shape of its spectrum.
- The shape of the spectrum depends on the shape of the vocal tract.

[æ]



[ɪ]



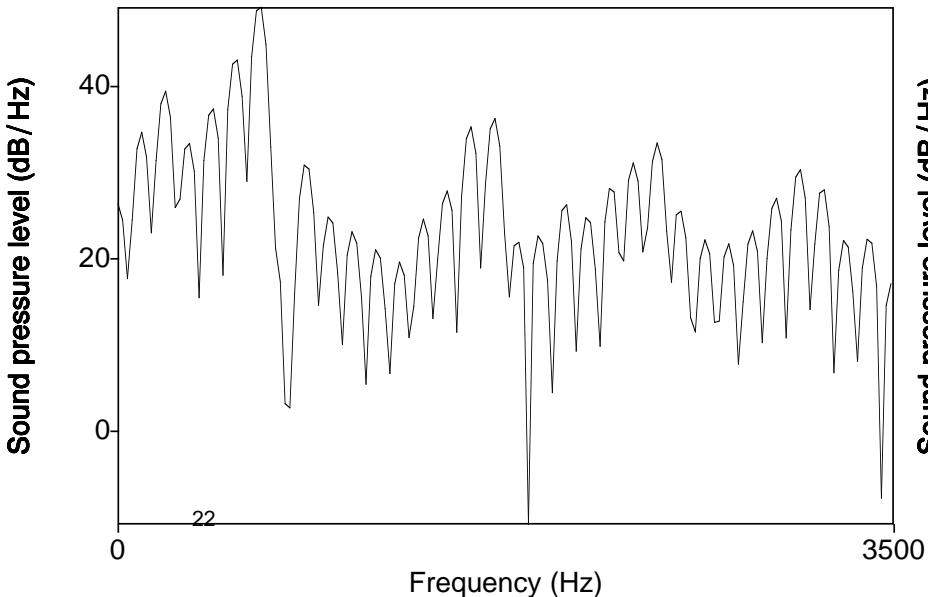
Source-Filter Model of Speech Production

Image deleted due to copyright restrictions. Original image visible at [https://sail.usc.edu/~lgoldste/General Phonetics/Source Filter/Source-filter-schwa.gif](https://sail.usc.edu/~lgoldste/General_Phonetics/Source_Filter/Source-filter-schwa.gif).

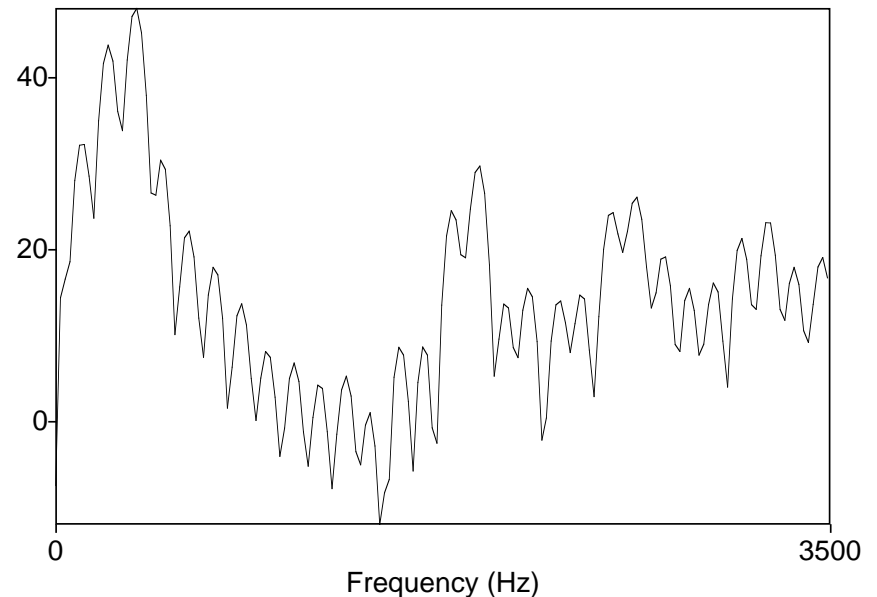
Vowel quality

- The peaks in the spectrum of a vowel are called **formants**.
- Perceived vowel quality depends primarily on the frequencies of the first three formants.

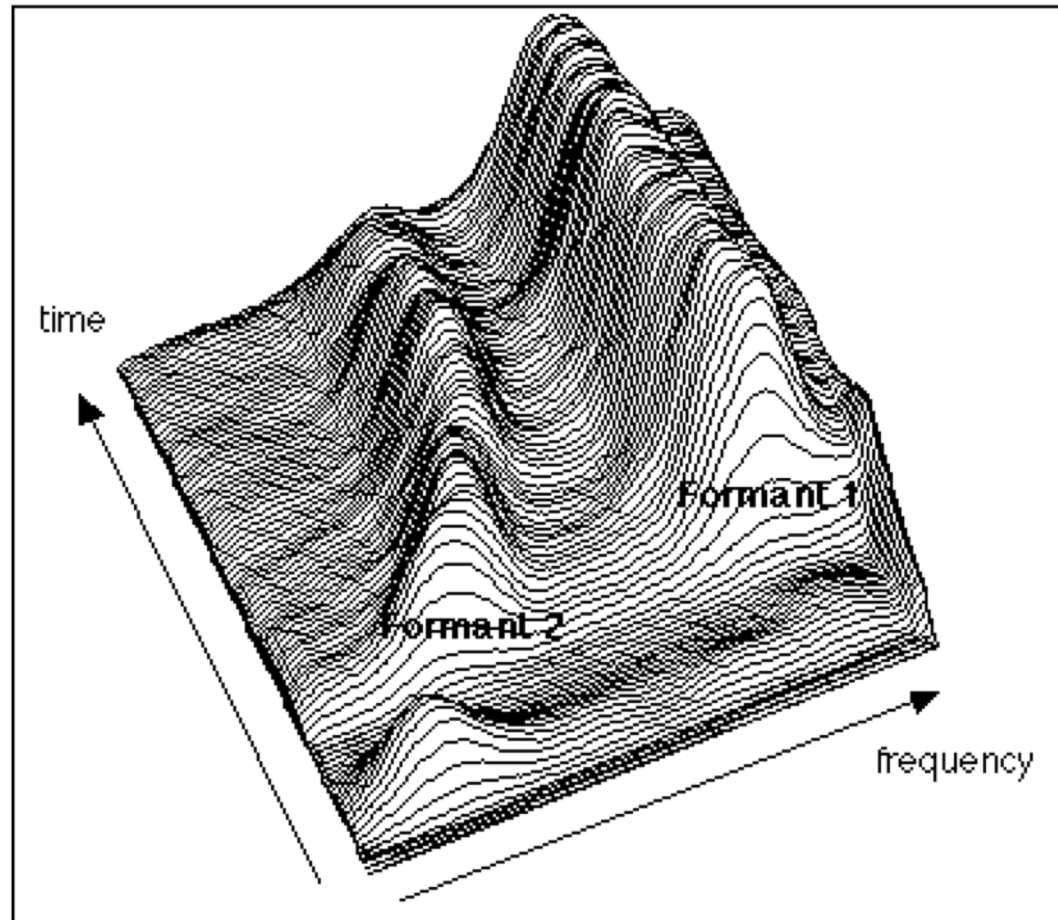
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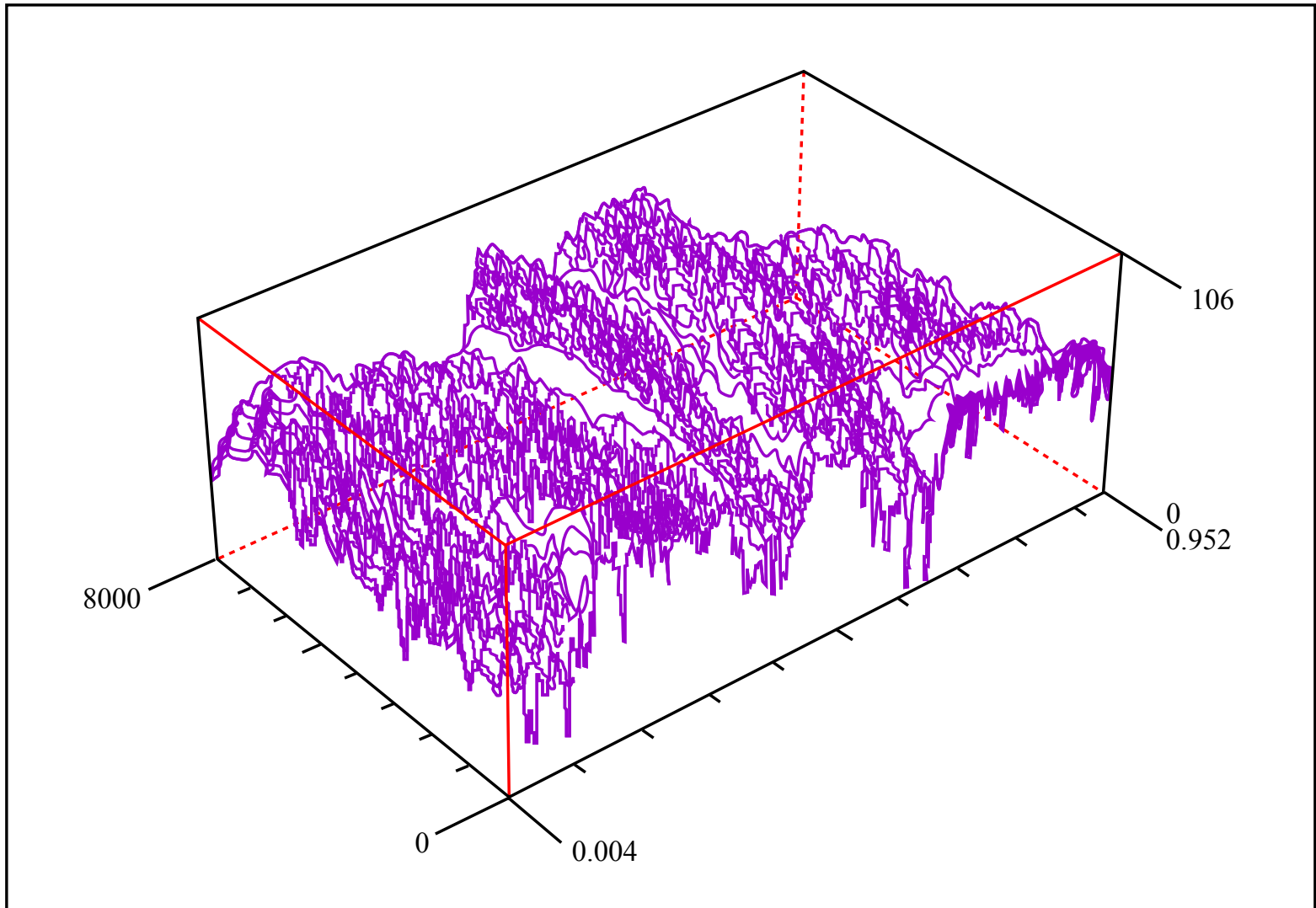
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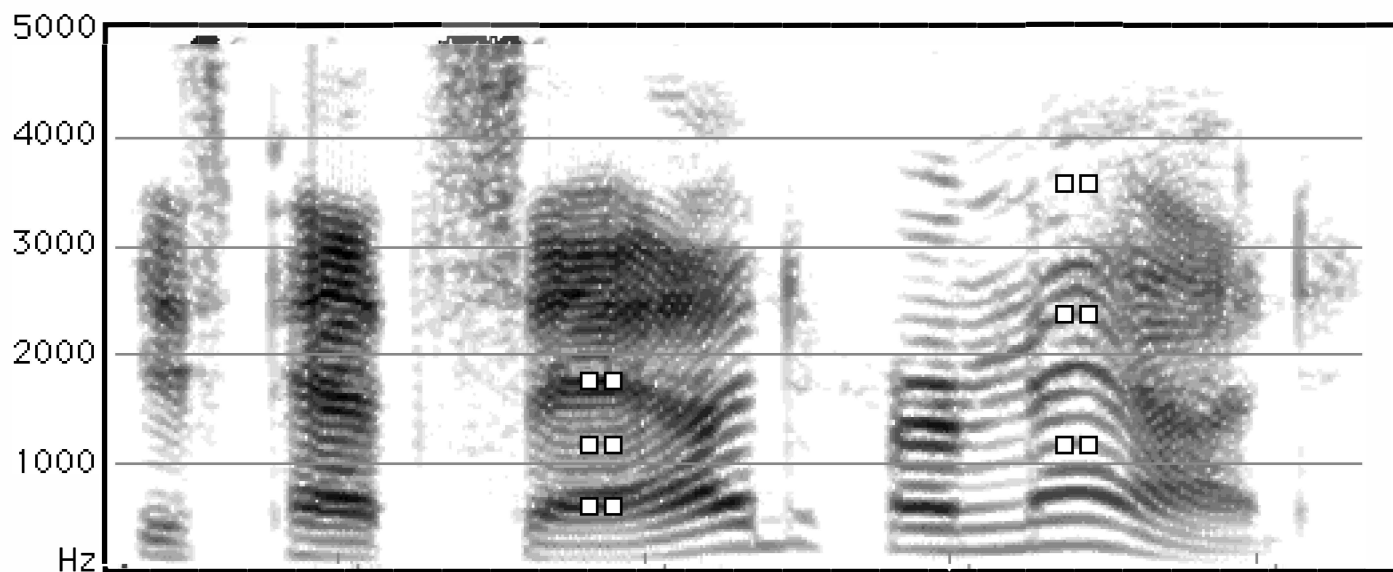
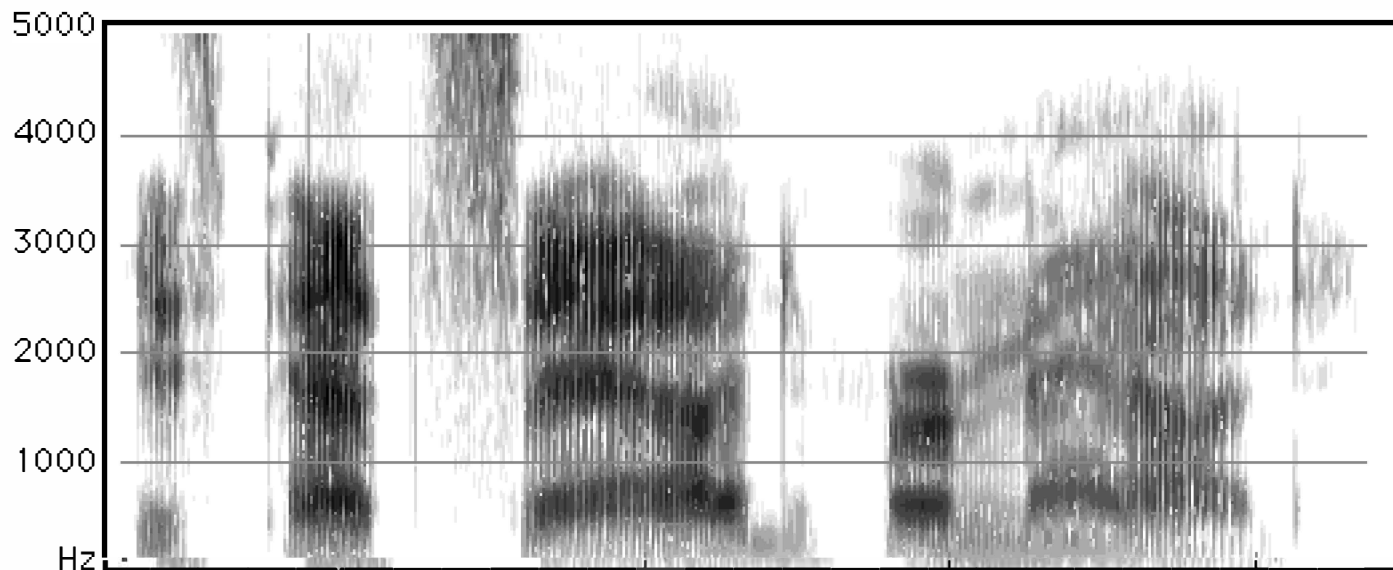


Spectrograms



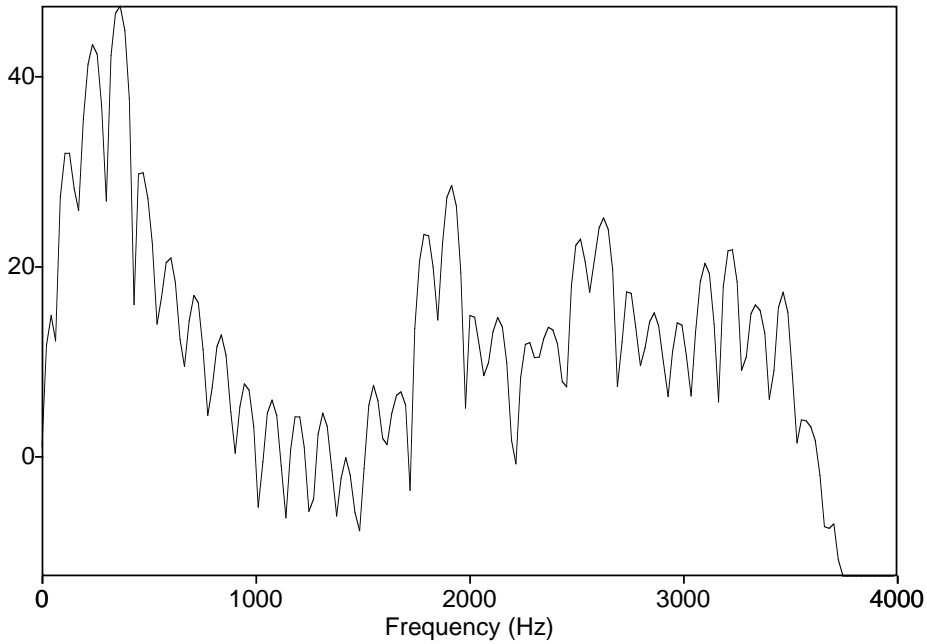
Spectrograms





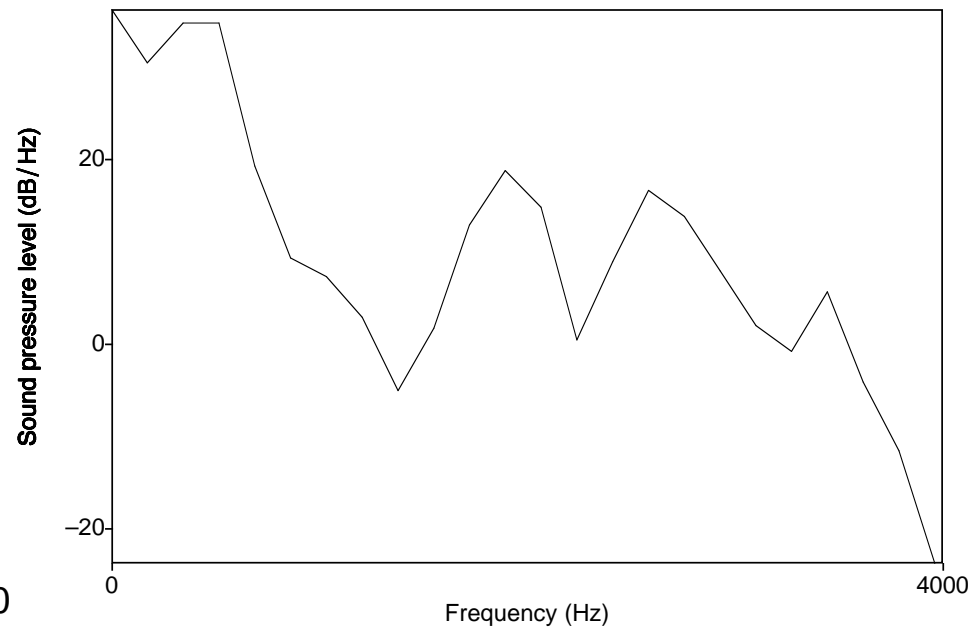
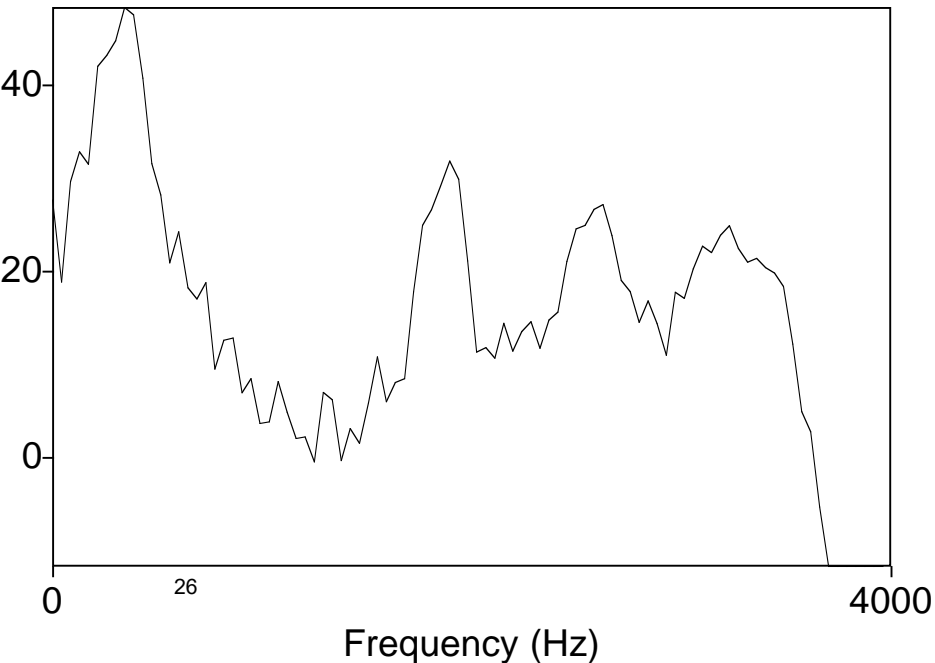
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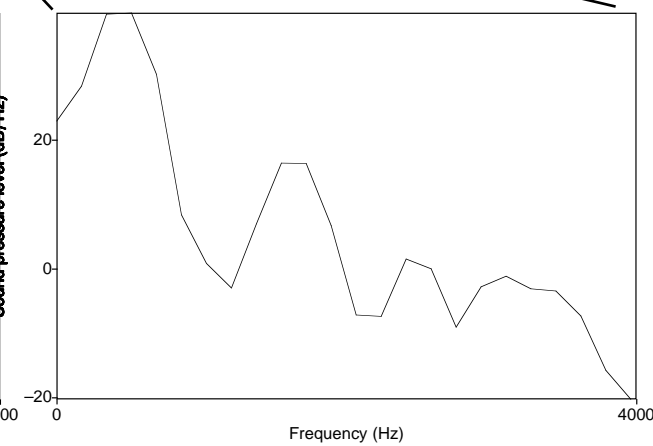
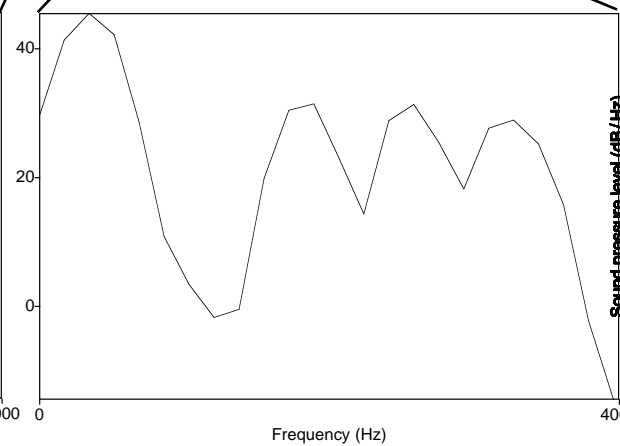
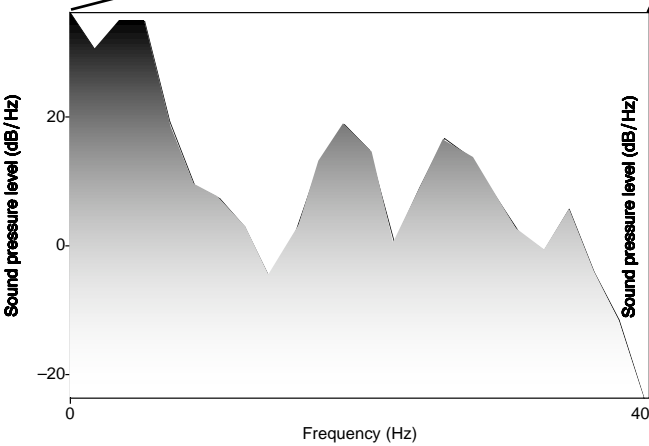
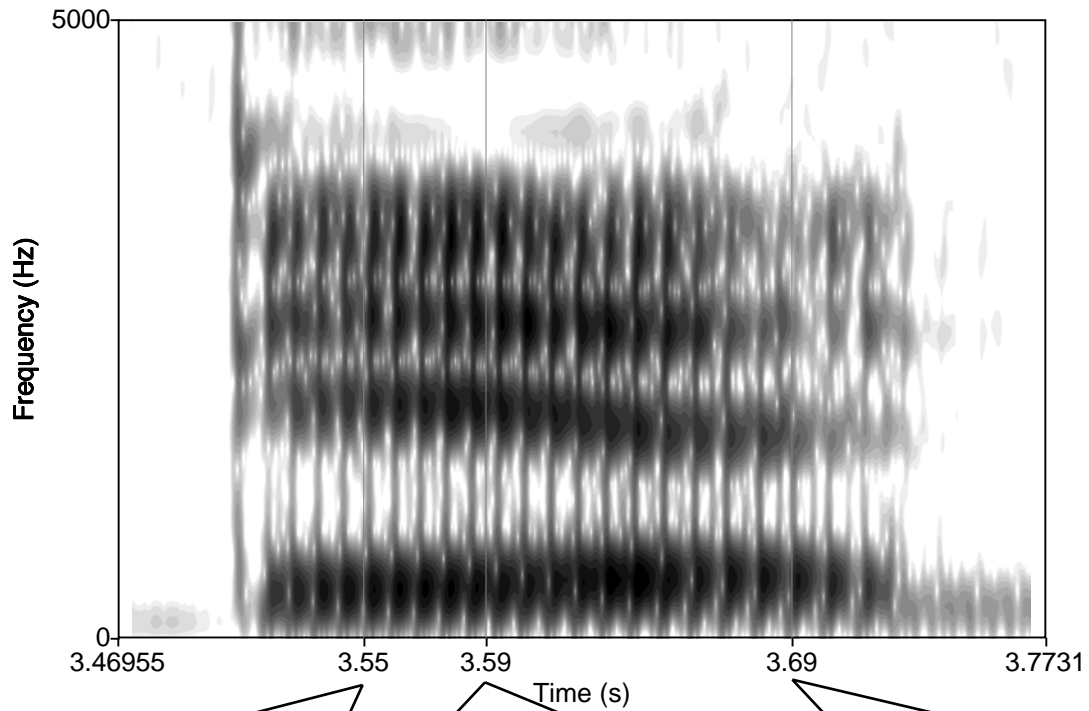
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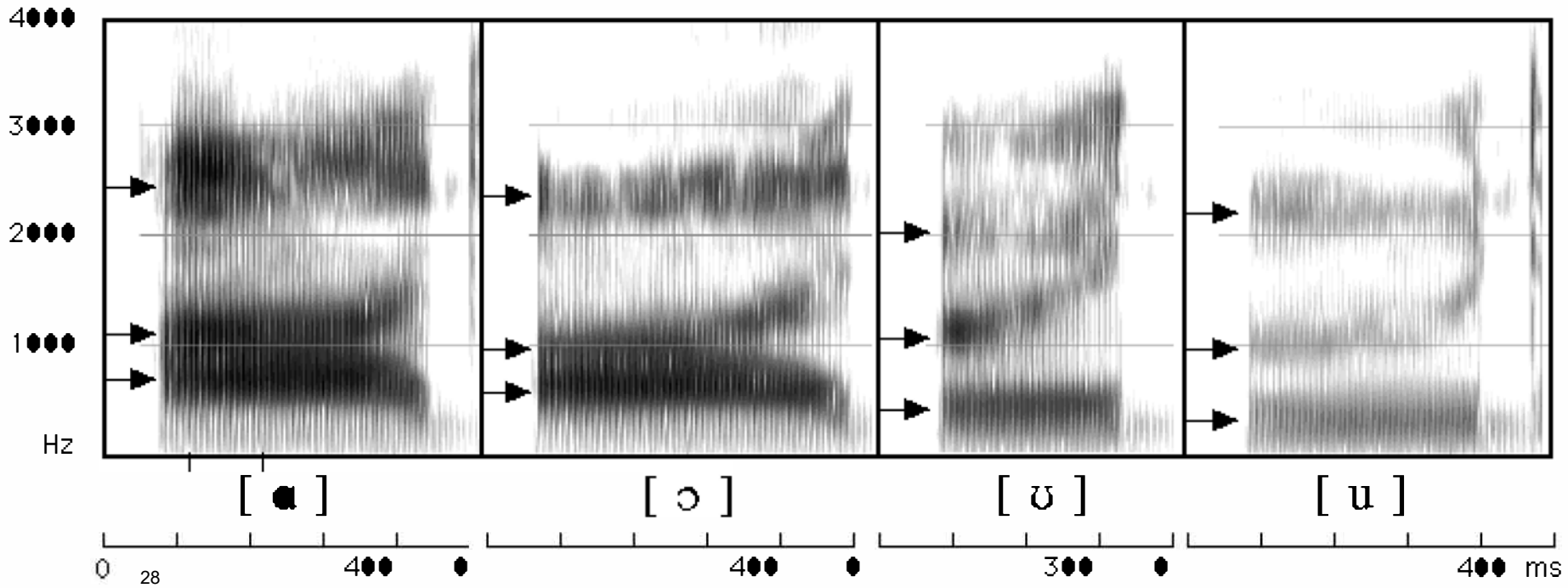
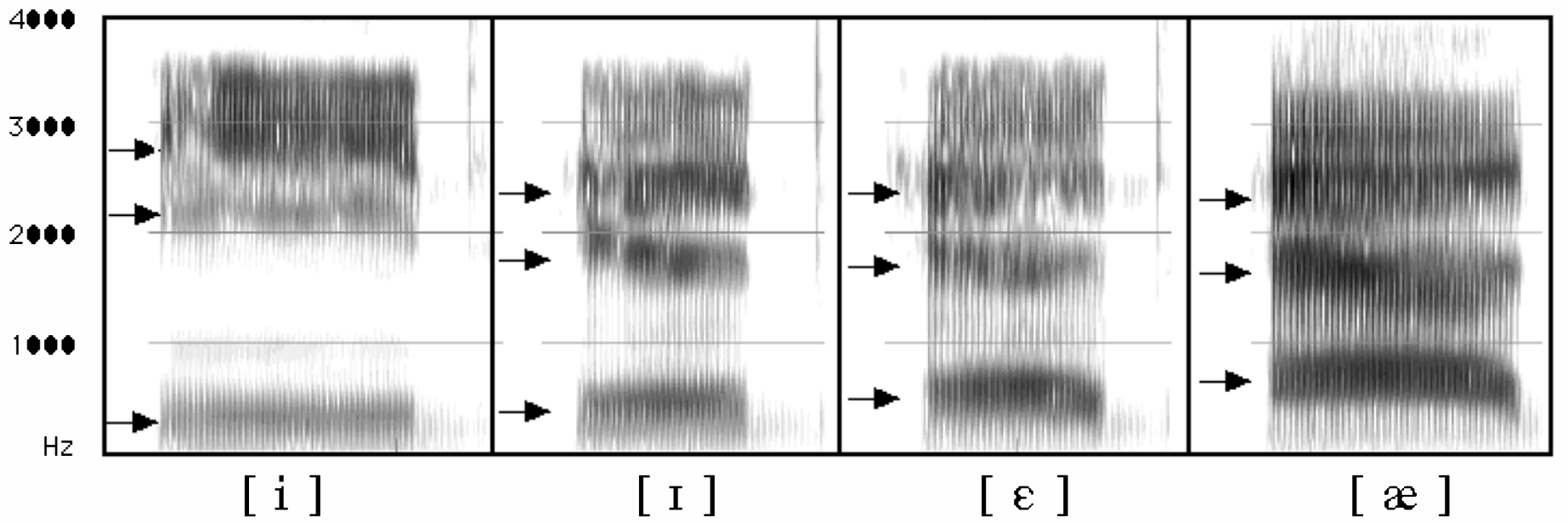


narrow band
(long window)

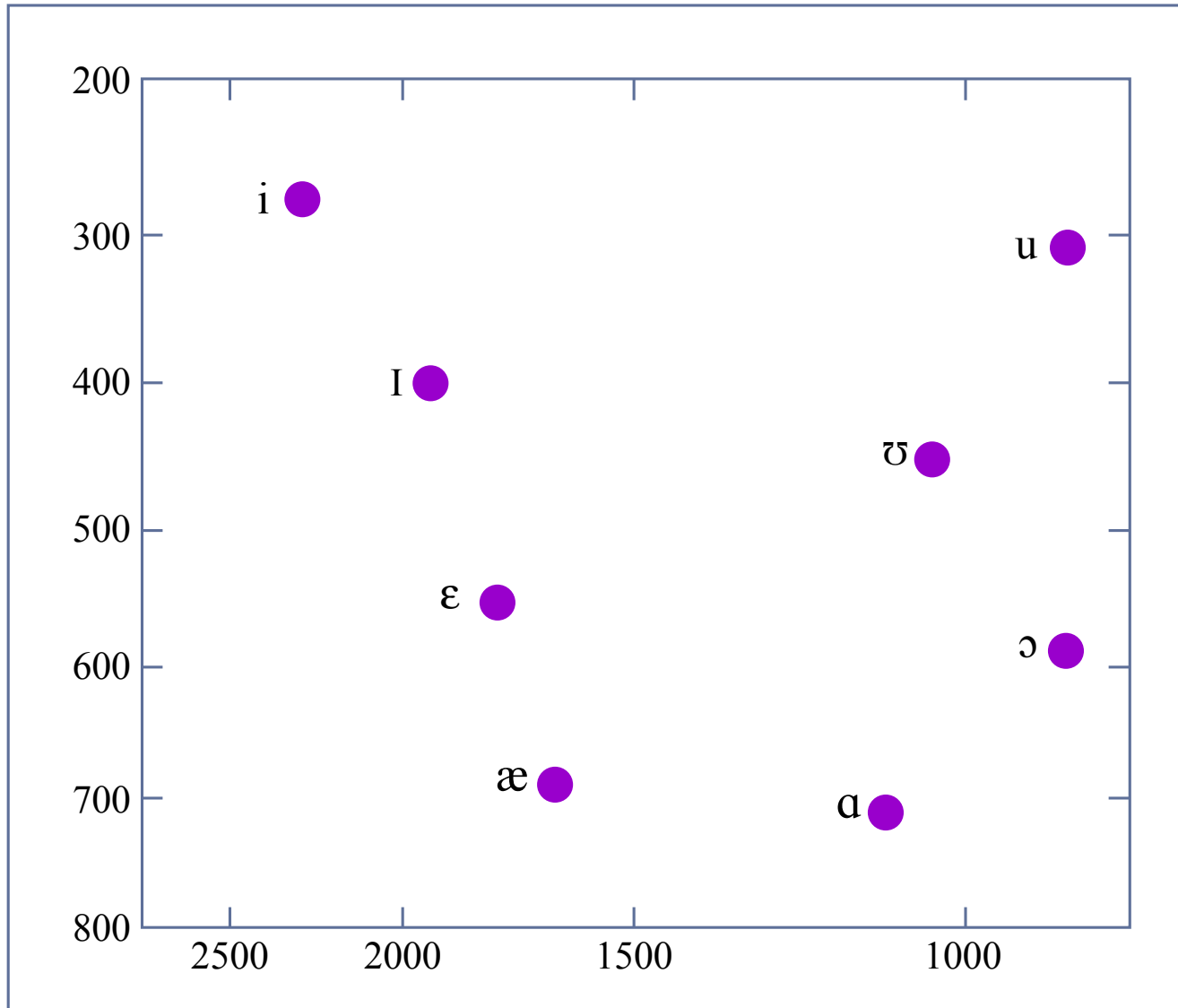
broad band
(short window)





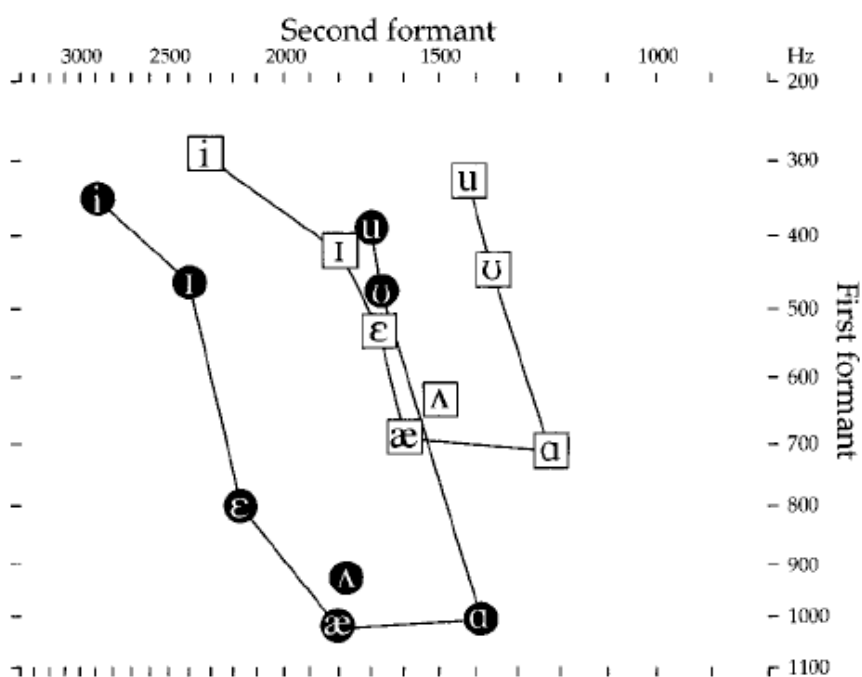


F2 (Hz)

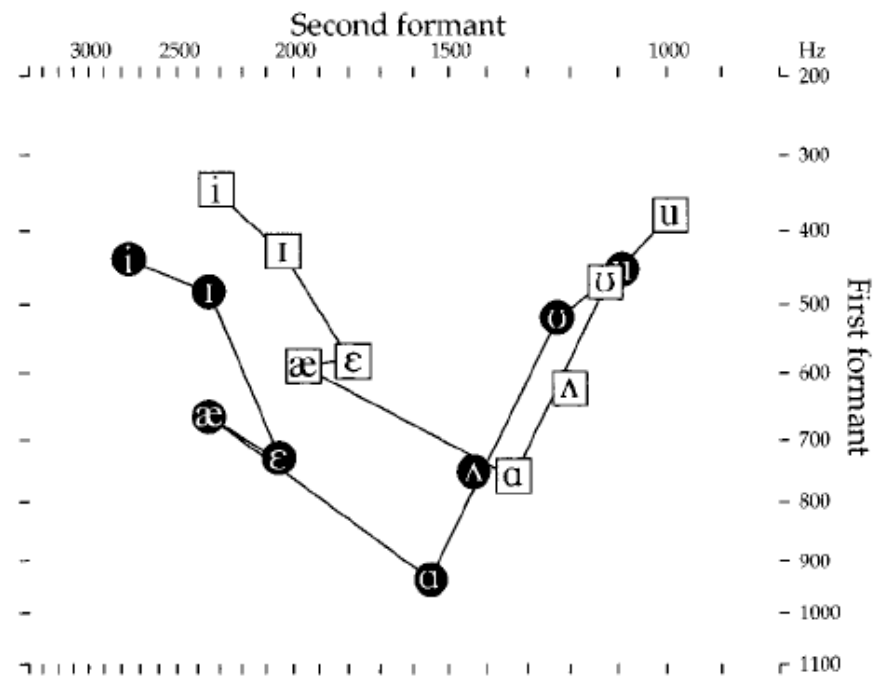


F1 (Hz)

Dialect differences in vowels



- Californian speakers (M open, F closed) (Hagiwara 1997).



- N. Midwest speakers (M open, F closed) (Hillenbrand et al 1995).

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24.914 Language Variation and Change
Spring 2019

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