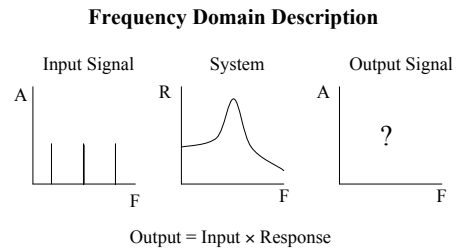


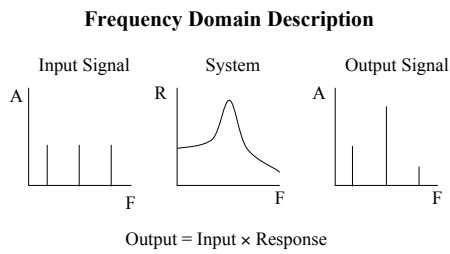
Introduction to Speech and Science

Lecture 5
Fricatives and Spectrograms

Review: Frequency Response Graph

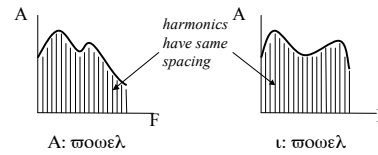


Review: Frequency Response Graph

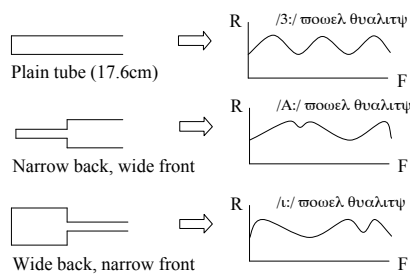


Review: Vowels

Although formant frequencies depend on the **length** of the vocal tract, they can also be changed by the **shape** of the vocal tract.

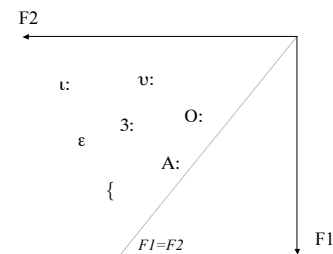


Review: Acoustic tube models



fMRI example

Review: F1-F2 Plane for Vowels



This week

- Dynamic aspects of speech
- Spectrograms
- Fricatives

Part I: Spectrography

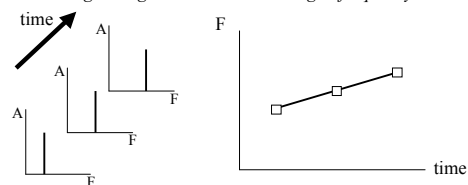
Static vs. Dynamic Sound

- So far we have focused on *static* vowels (i.e., those that do not change over time)
- Spectra show no change over time
- However, real speech is highly dynamic (i.e., changes over time)....

Spectrography

- Adds a "time" dimension to a spectrum analysis

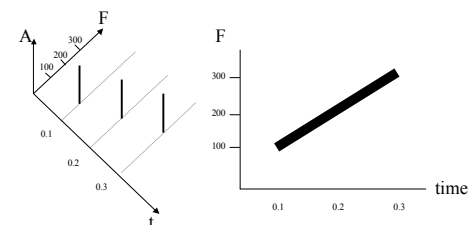
e.g. a single sinewave increasing in frequency



Spectrogram

- Is a graph of the frequency content of a signal plotted as a function of time
- The horizontal axis is time
- The vertical axis is frequency
- The amplitude of any component present in the signal at any given time and frequency is displayed on a grey-scale (white=little, black=lots)

Spectrography

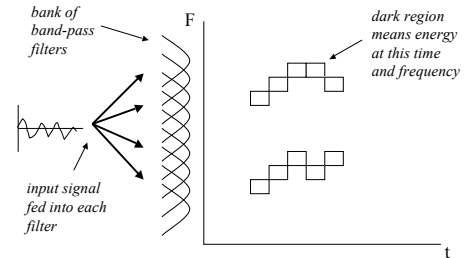


Spectrography

■ Band-pass filter analogy:

- imagine a bank of bandpass filters, each with the same bandwidth but different centre frequencies, covering the speech frequency range.
- Each filter passes energy falling within narrow region of frequency.
- Measure this energy at each time instant, convert to a grey scale: get a **spectrogram**!

Bank of Filters Analogy



What to see on a spectrogram

■ Voicing

- periodic pulses from larynx vibration
- appear as vertical striations

■ Vowel formant resonances

- appear as dark regions between pulses

■ Fricatives

- appear as "speckled" regions typically in high frequency

Part I: Fricatives

Sources

- **Frication**
 - Aperiodic (Noise or Transient)
 - Created by turbulence due to blowing air through a small constriction
 - Present in fricatives like /s/ and /z/
 - Present at the start of plosives like /b/ and /p/
- **Aspiration**
 - Aperiodic (Noise)
 - Created by turbulence due to blowing air through vocal folds
 - Present in voiceless consonants like /p/ and /k/
 - Used for whispered speech
- **Voicing**
 - Periodic (i.e., harmonic)
 - Created by vibration of the vocal folds
 - Present in all vowels and voiced consonants like /b/, /n/, and /z/

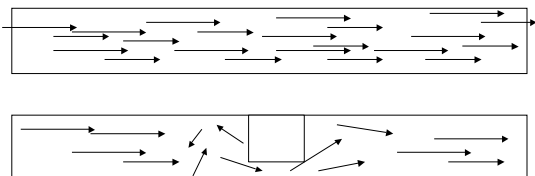
Aperiodic sounds

- **Turbulence created by forcing air through a small constriction**



Aperiodic sounds

- Turbulence created by forcing air through a small constriction



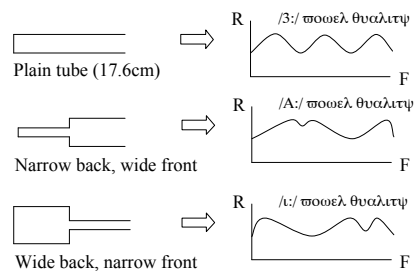
Aperiodic sounds

- Aspiration: Noise caused by turbulence at the vocal folds
- Fricative: Noise caused by turbulence in the oral cavity
- Burst: Transient caused by turbulence at the moment of a closure release

Fricatives (e.g., /s/, /z/, /f/, /v/)

Created by filtering the aperiodic source....

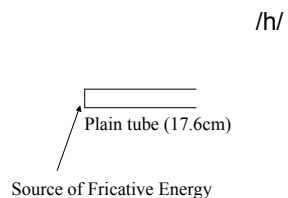
Acoustic tube models of Vowels



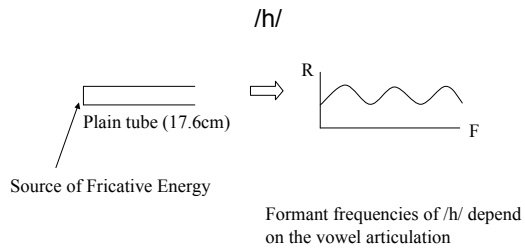
Acoustics of Fricatives

- Same tube models apply
- However, location of fricative source in tubes affects the filter

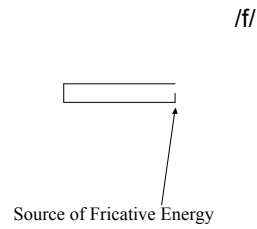
Acoustic tube models of fricatives



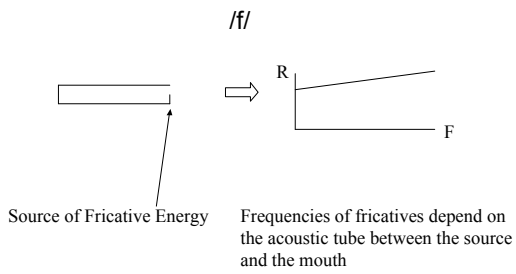
Acoustic tube models of fricatives



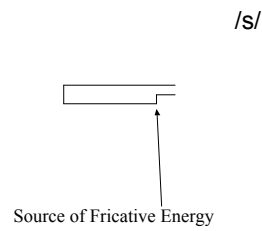
Acoustic tube models of fricatives



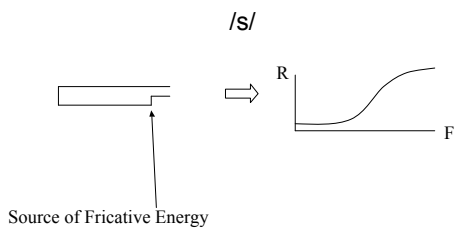
Acoustic tube models of fricatives



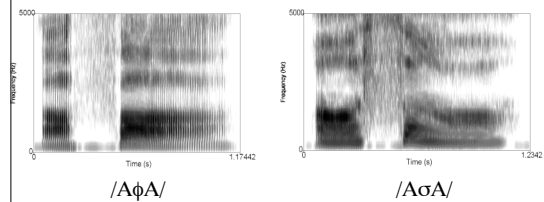
Acoustic tube models of fricatives



Acoustic tube models of fricatives



Fricatives (e.g., /s/, /z/, /f/, /v/)



Voiced Fricatives (e.g., /z/,/v/)

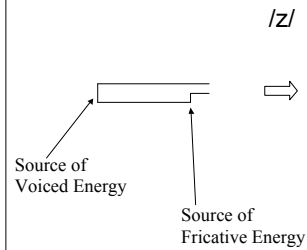
Vocal folds can vibrate at the same time that fricative energy is produced

- Creates a voice bar during the fricative

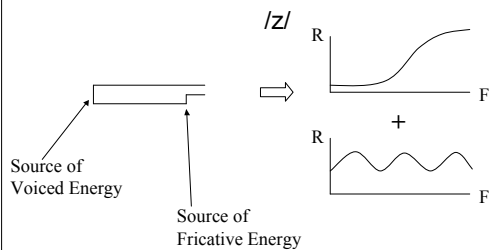
Vocal fold vibration reduces airflow

- Reduces the amplitude of the fricative energy

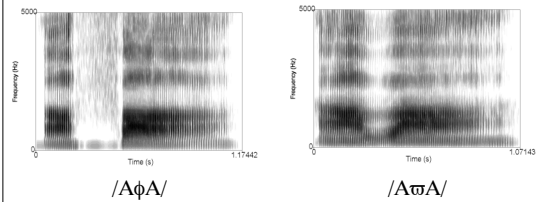
Acoustic tube models of voiced fricatives



Acoustic tube models of voiced fricatives



Voiced Vs. Voiceless Fricatives



Acoustics of Fricatives

■ Frequency

- Front of vocal tract - higher frequencies because of shorter tube
- Back of vocal tract - lower frequencies because of longer tube

■ Bandwidth

- Front of vocal tract - broader bandwidth
- Back of vocal tract - more formant structure

Summary

- Dynamic aspects of speech
- Spectrograms
- Fricatives