# Acoustics of Speech and Hearing

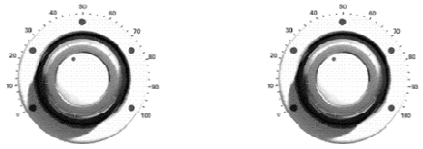
Lecture 7
Source-Filter Model
of Speech Production

## Overview

- Properties of vowel sounds
- Source-Filter model
- Source: Larynx Excitation Signal
- Filter: Vocal Tract System
- Relationship between Acoustic and Phonetic descriptions of vowels.

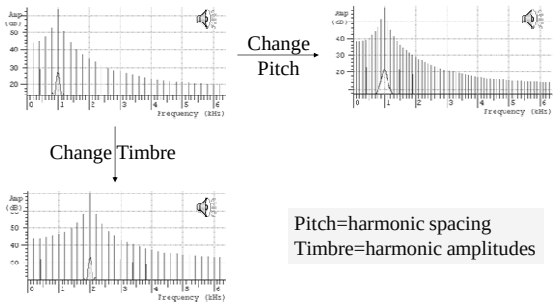
## Properties of Vowel Sounds

**Pitch Dial** **Timbre Dial**



**We can set the pitch and the timbre of vowels INDEPENDENTLY**

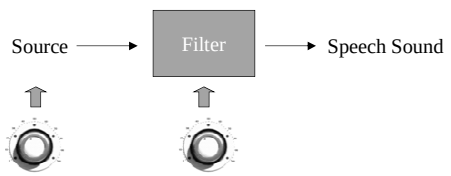
## Independence of Pitch & Timbre




Pitch=harmonic spacing
Timbre=harmonic amplitudes

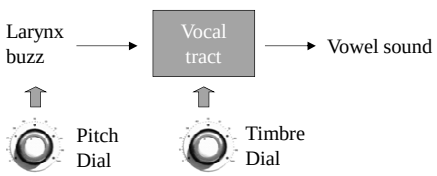
## Source-Filter Model

- Many speech sounds can be understood as arising from two **independent** components:
  - a *source* of sound generated in the vocal tract
  - a *filter* which shapes the sound spectrum




## Source-Filter Model for Vowels

- **Source** is 'buzz' generated by vocal fold vibration in larynx
- **Filter** is resonant cavity comprising the vocal tract tube extending from larynx to lips

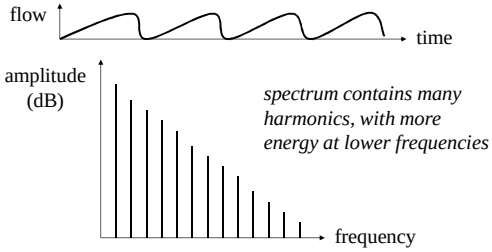


## Vowel Sounds: Source

- Source
  - Vocal fold vibration in larynx
  - Air blown between two elastic membranes
  - Periodic buzz
  - Intensity set by lung pressure
  - Repetition frequency set by vocal fold tension
  - Other qualities of sound affected by degree of approximation of vocal folds (among other things)

## Vowel Sounds: Source

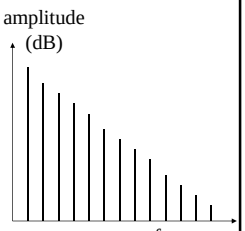
- Source Signal and Spectrum




*spectrum contains many harmonics, with more energy at lower frequencies*

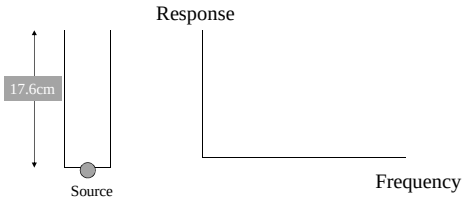
## Vowel Sounds: Source

- Typical character of source
  - Fundamental frequency range for men
    - typically 100-200Hz
  - Fundamental frequency range for women
    - typically 150-300Hz
  - Slope of spectrum
    - typically 6dB fall every doubling in frequency



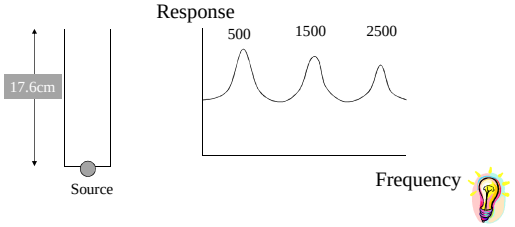

## Vowel Sounds: Filter

- Frequency Response of an open tube of 17.6cm in length




## Vowel Sounds: Filter

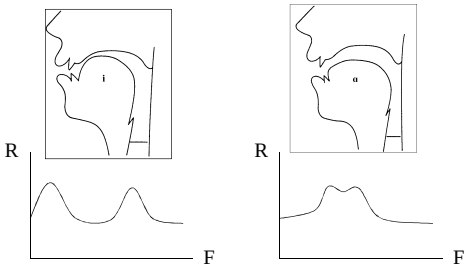
- Frequency Response of an open tube of 17.6cm in length



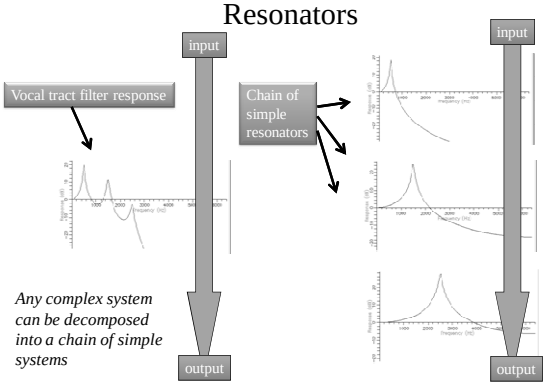



## Vowel Sounds: Filter

- Vocal tract filter frequency response



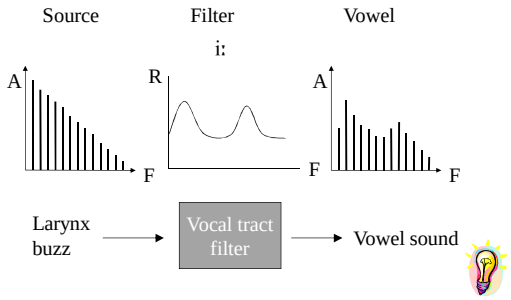
## Describe VT Filter as Chain of Simple Resonators



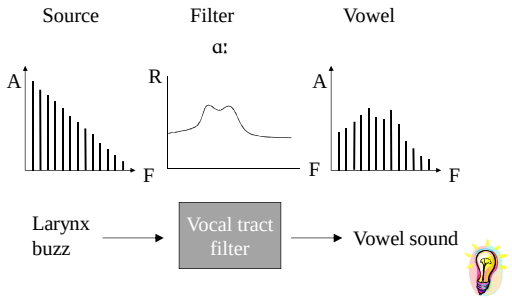

## Vowel Sounds: Filter

- Characteristics of Vocal Tract Filter
  - typically made up of a small number of resonant peaks
  - peaks in response called *formants*
  - formant frequencies depend on position of articulators (affect shape of tube)
  - frequency of first 2 or 3 peaks most important for setting phonetic quality

## Vowel Sounds: Output



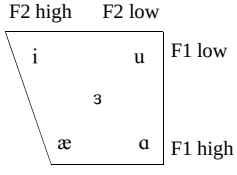

## Vowel Sounds: Output




## Vowel Phonetics

- Can roughly relate formant frequencies to position on Vowel Quadrilateral

| Vowel | F1 | F2 |
|---|---|---|
| i: | low | high |
| æ | high | high |
| ɑ: | high | low |
| u: | low | low |

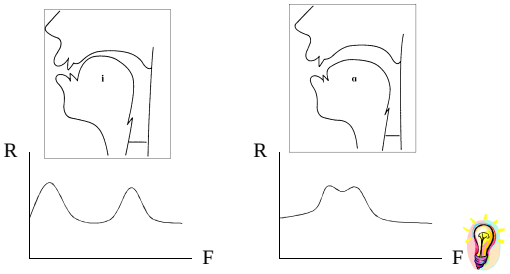



## Formant Frequencies

- First formant frequency: F1
  - frequency roughly related to ‘openness’ of vowel
  - frequency high when pharyngeal cavity small
- Second formant frequency: F2
  - frequency roughly related to ‘frontness’ of vowel
  - frequency high when front cavity small

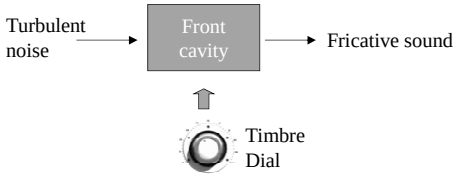
## Vowel Sounds: Filter

- Vocal tract filter frequency response




## Source-Filter Model for Fricatives

- **Source** is 'hiss' generated by turbulence as air forced through constriction
- **Filter** is resonant cavity comprising the vocal tract tube extending from constriction to lips




## Summary

- Source Filter model describes speech sound production in terms of independent source and filter
  - Explains separation of pitch and timbre for vowels
- Vowel filter is characterised by small number of resonances called formants
- Relationship exists between formant frequencies and articulatory phonetic description of vowels

## Lab Experiment

- Look at spectra of some vowels
  - Measure fundamental frequency
  - Measure formant frequencies
- Look at spectra of some fricatives
- Measure frequencies from spectrum
- Match what you see to source-filter model