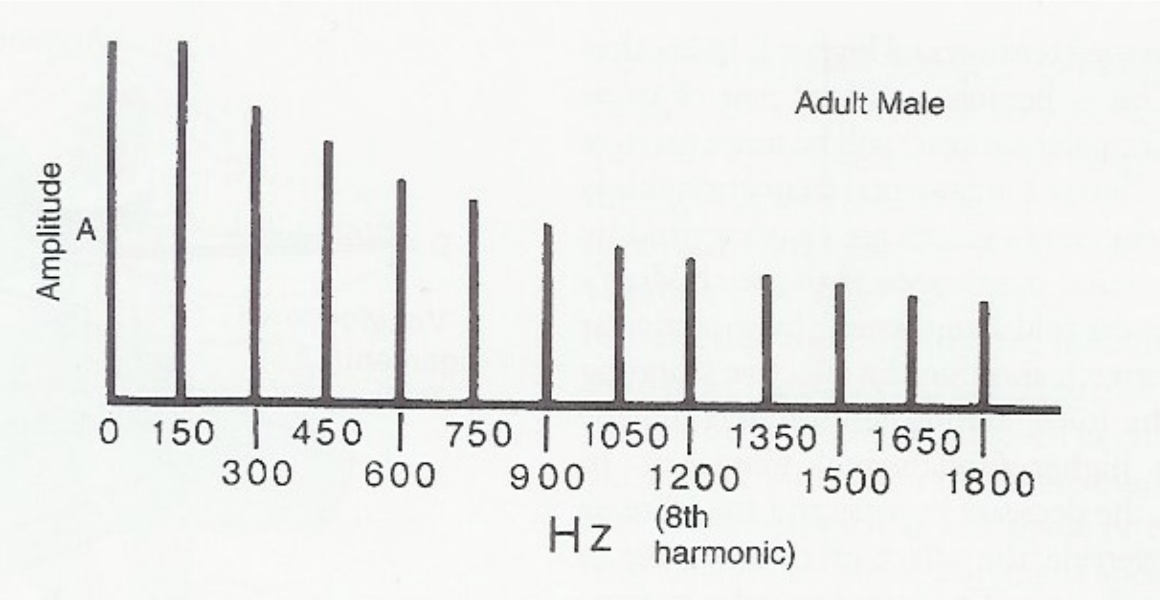
Vowels: Source/Filter Theory

Source/Filter Theory: The Source

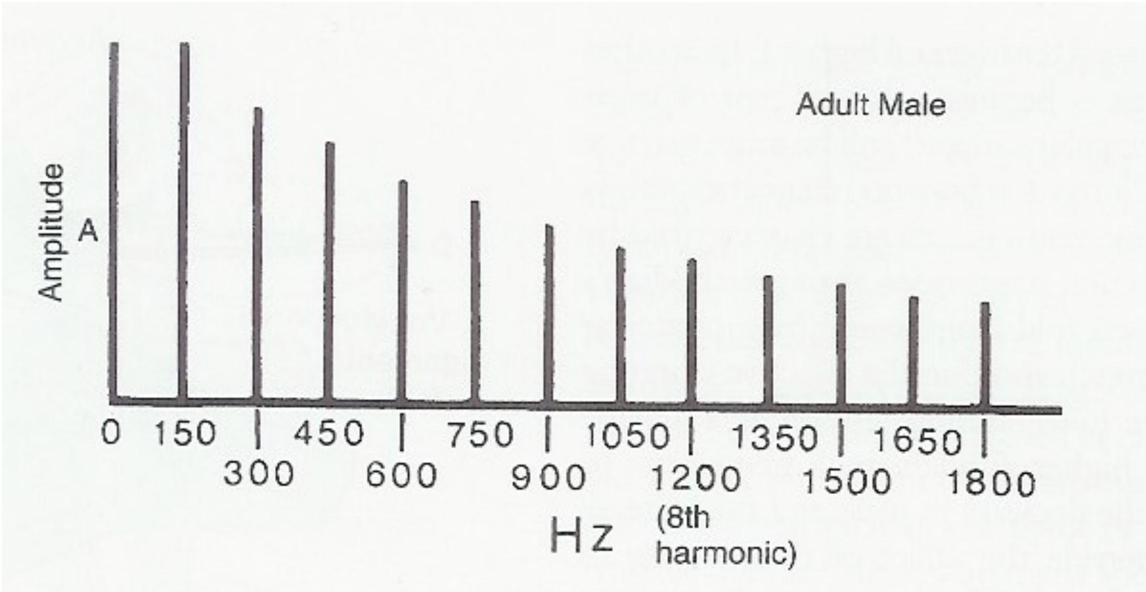
- Developed by Gunnar Fant (1960)
- For speech, the **source** of sound = complex waves created by periodic opening and closing of the vocal folds



Source Differences

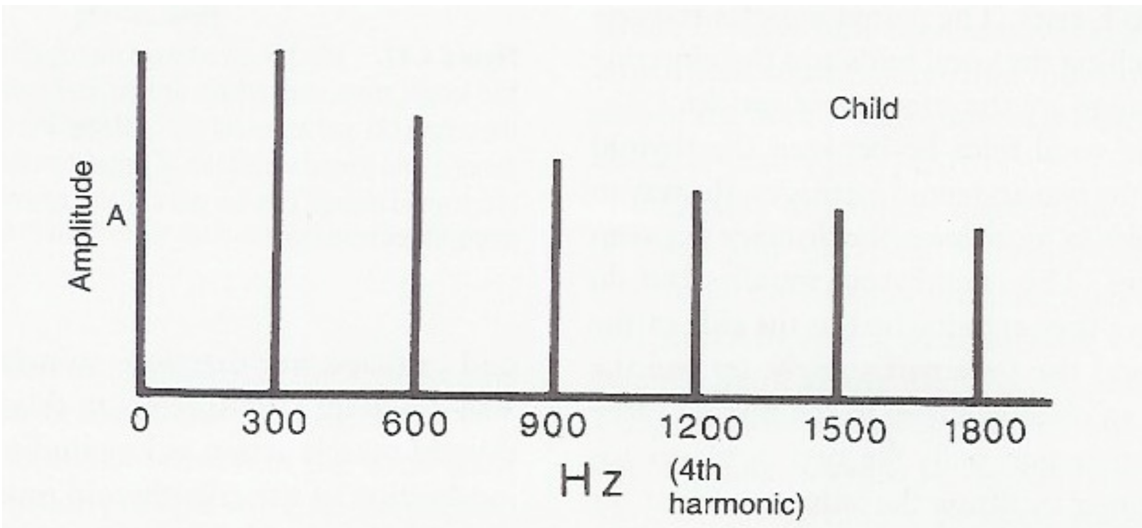
adult male voice

(F0 = 150 Hz)



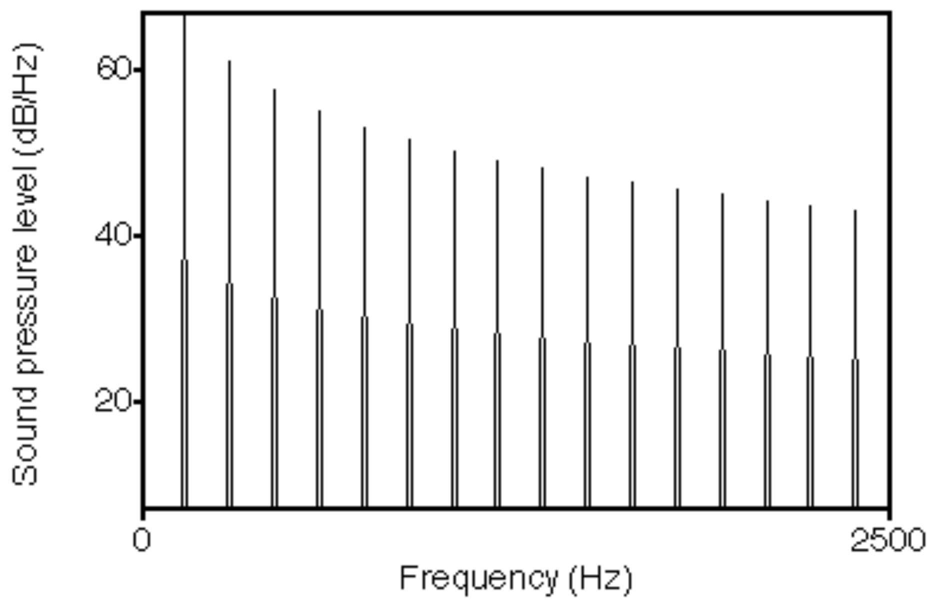
child voice

(F0 = 300 Hz)



Just So You Know

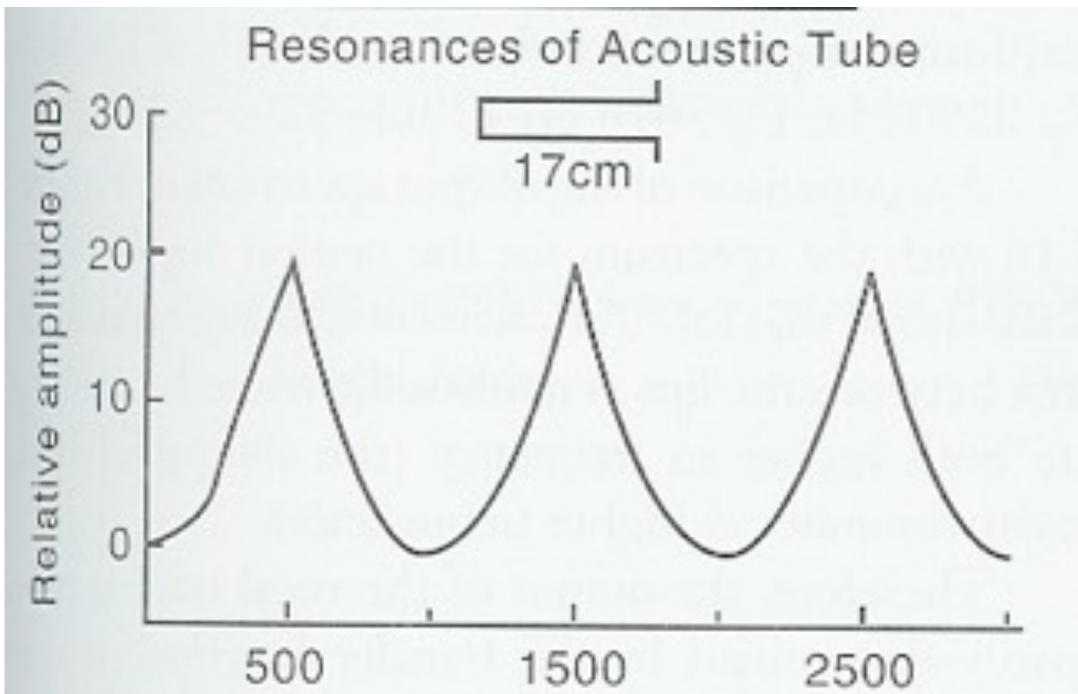
- Voicing, on its own, would sound like a low-pitched buzz.
- Check out the sawtooth wave spectrum:



- Vowels don’t sound like this because the source wave gets “filtered” by the vocal tract.

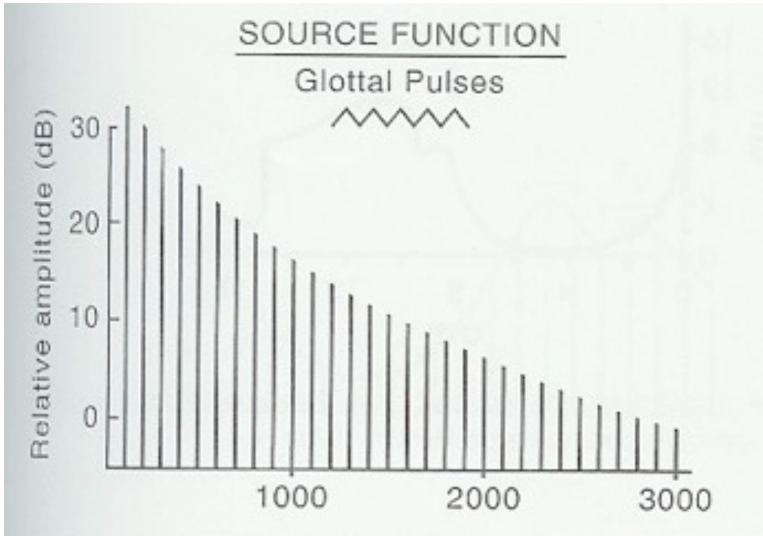
"Filters"

- For any particular vocal tract configuration, certain frequencies will resonate, while others will be damped.
  - analogy: natural variation/environmental selection



- This graph represents how much the vocal tract would resonate for sinewaves at every possible frequency.

Source + Filter = Output



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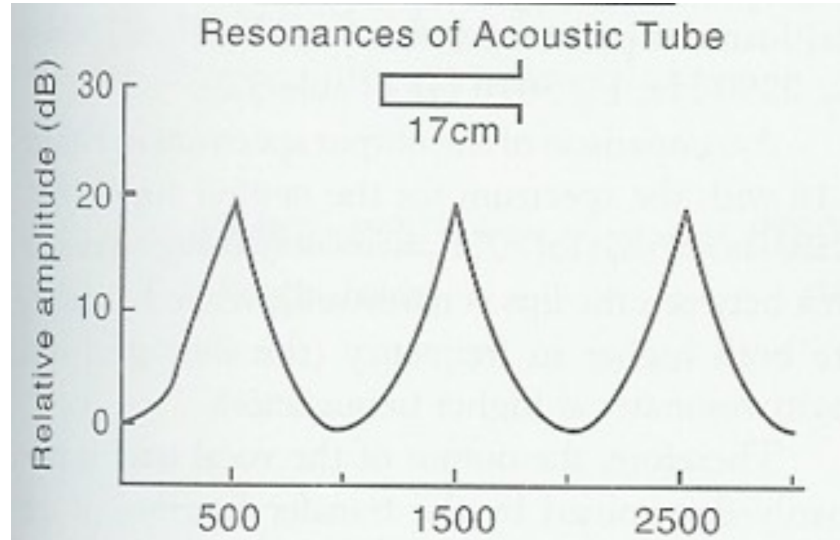

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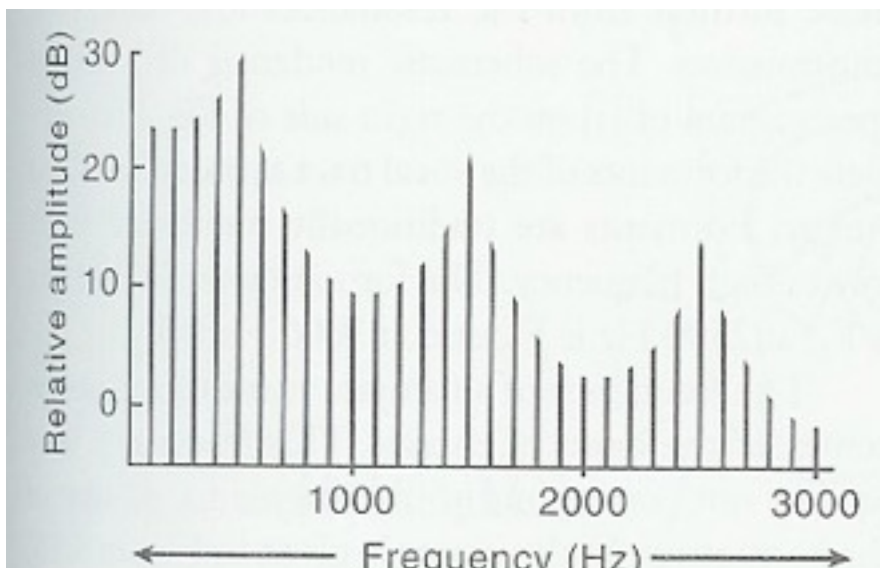
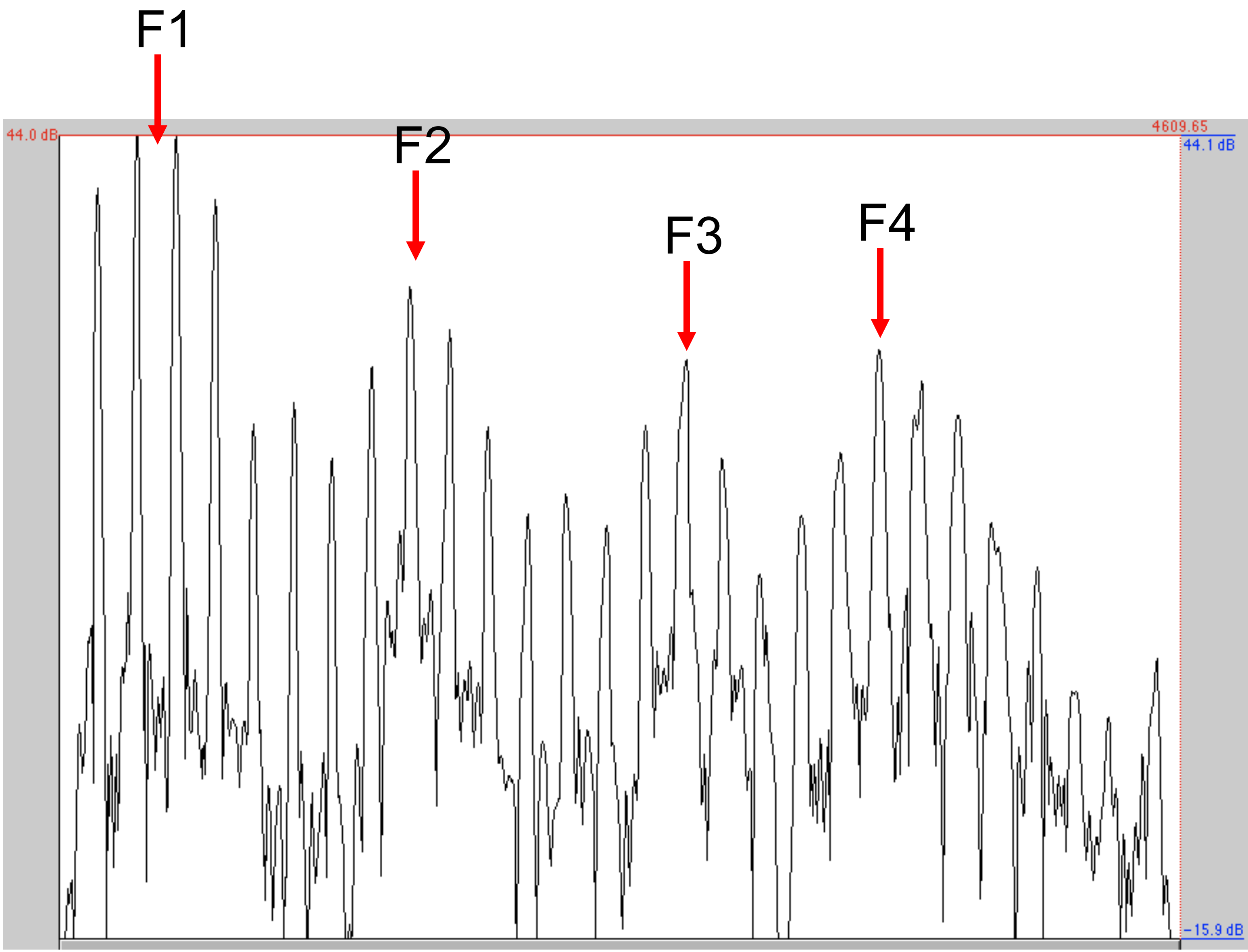


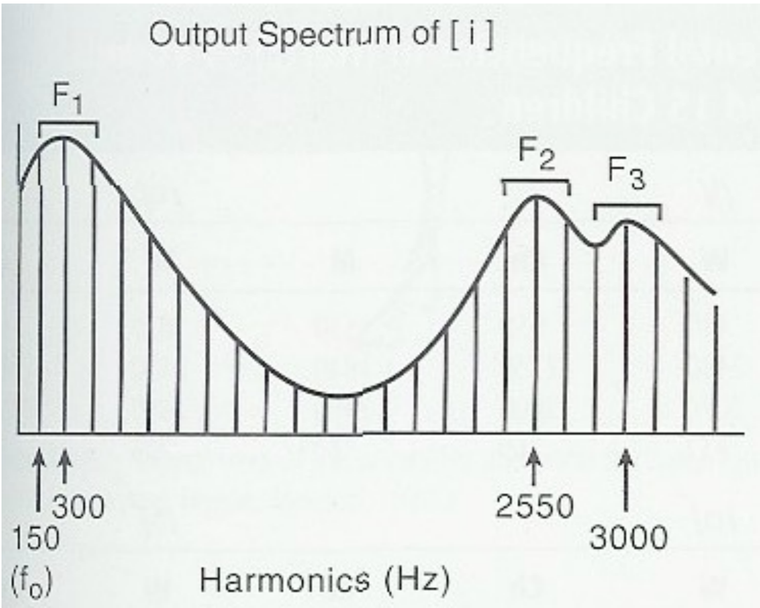
A Vowel Spectrum

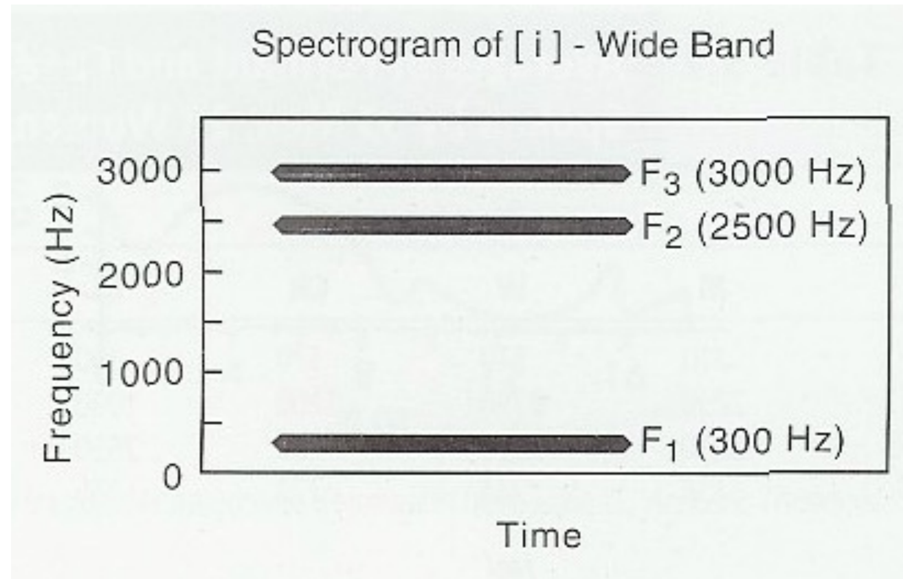


Note:

F0 ≈ 160 Hz

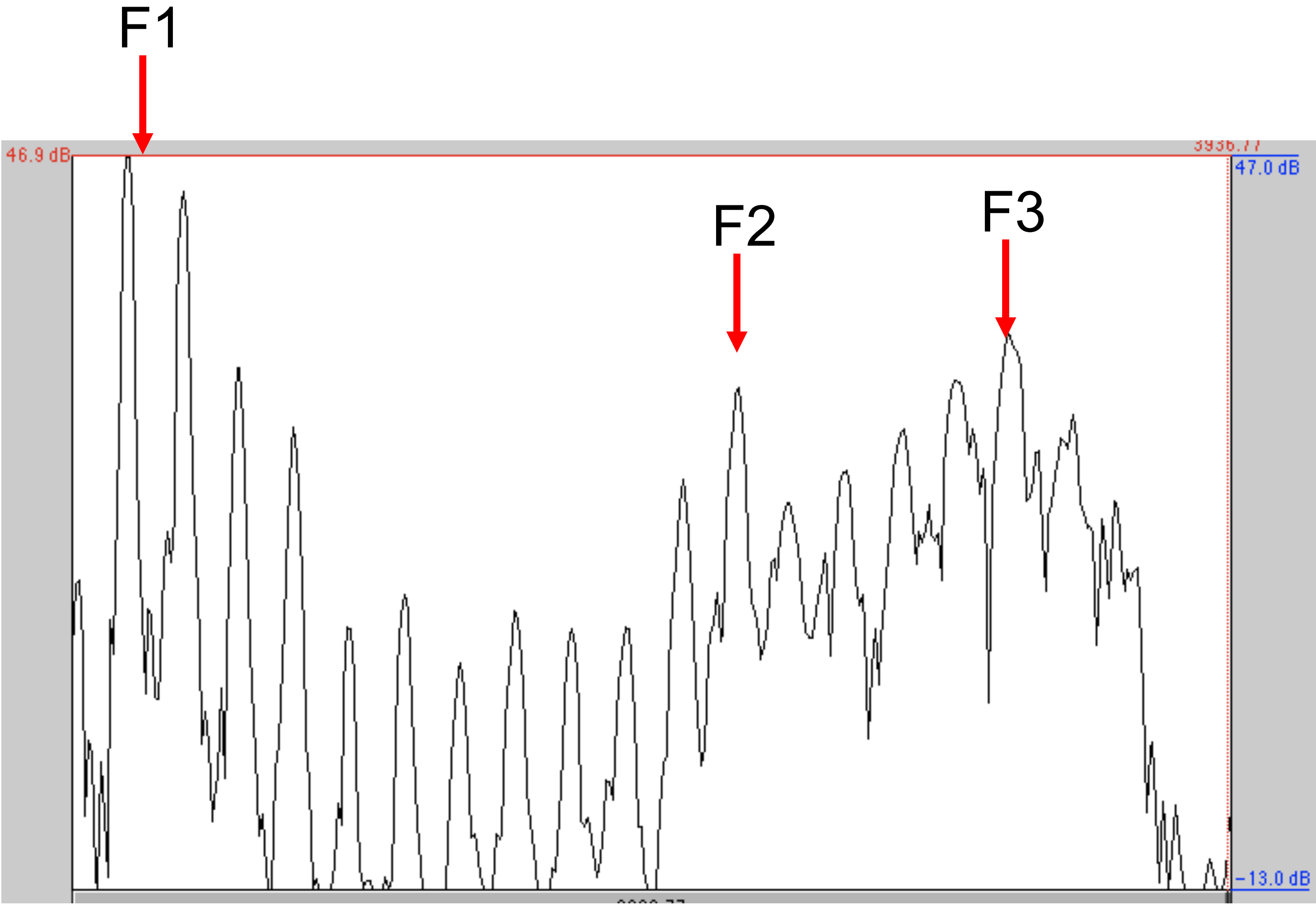
Output Example: [i]





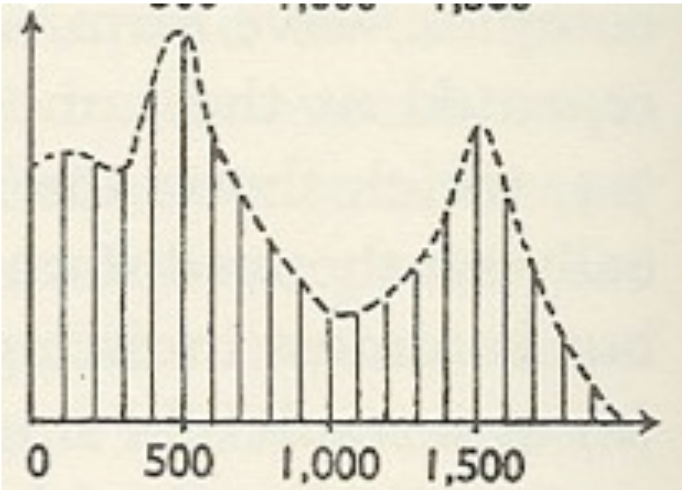
- Different vowels are characterized by different formant frequencies.
- These reflect changes in the shape of the **sound filter**.
  - (the vocal tract)

Vowel Spectrum #2: [i]

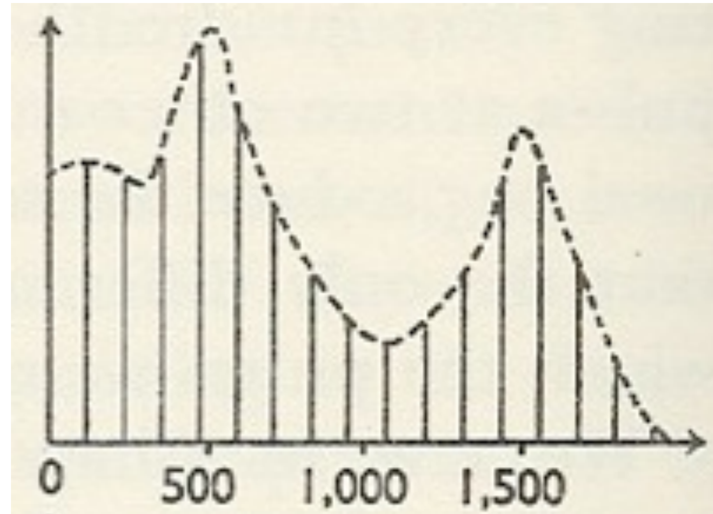


F0 =
185 Hz

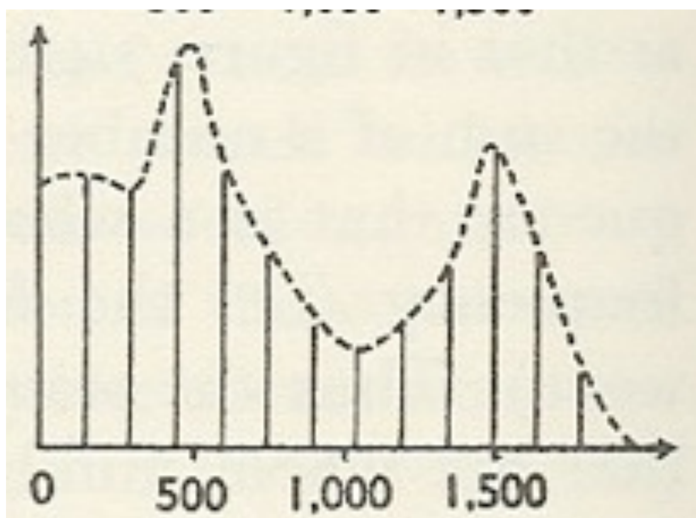
[ə] at different pitches



100 Hz



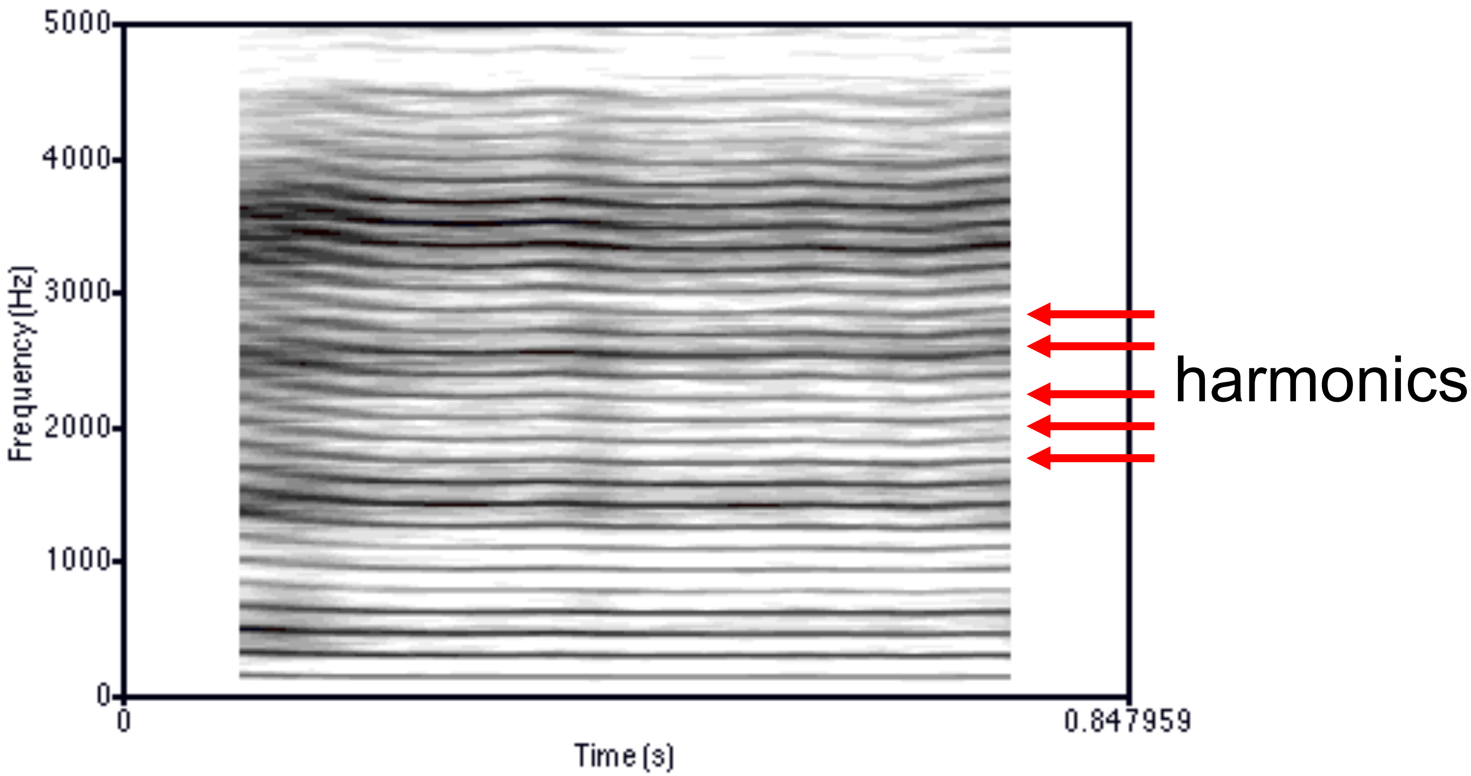
120 Hz



150 Hz

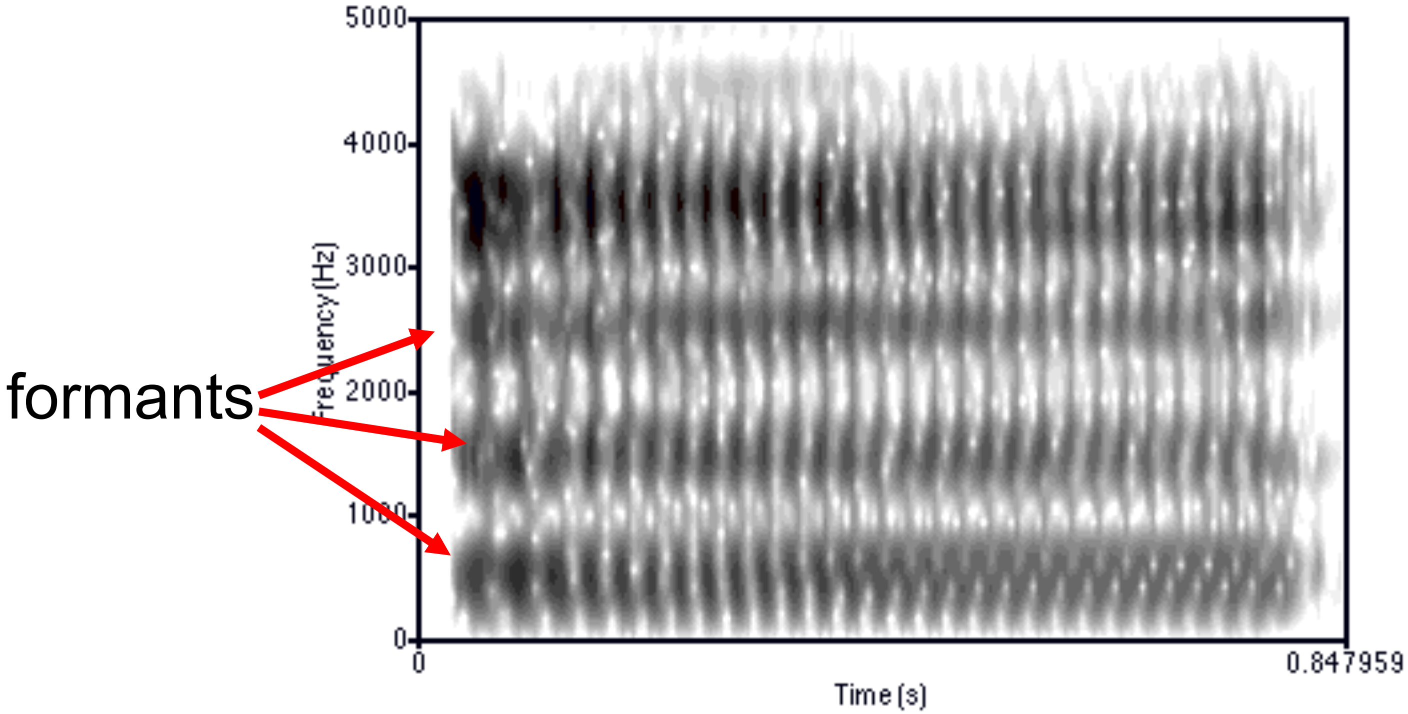
Narrow-Band Spectrogram

- A "narrow-band spectrogram" clearly shows the harmonics of speech sounds.
    - …but the formants are less distinct.



Wide-Band Spectrogram

- By changing the parameters of the Fourier analysis, we can get a “wide-band spectrogram”
  - This shows the formants better than the harmonics.



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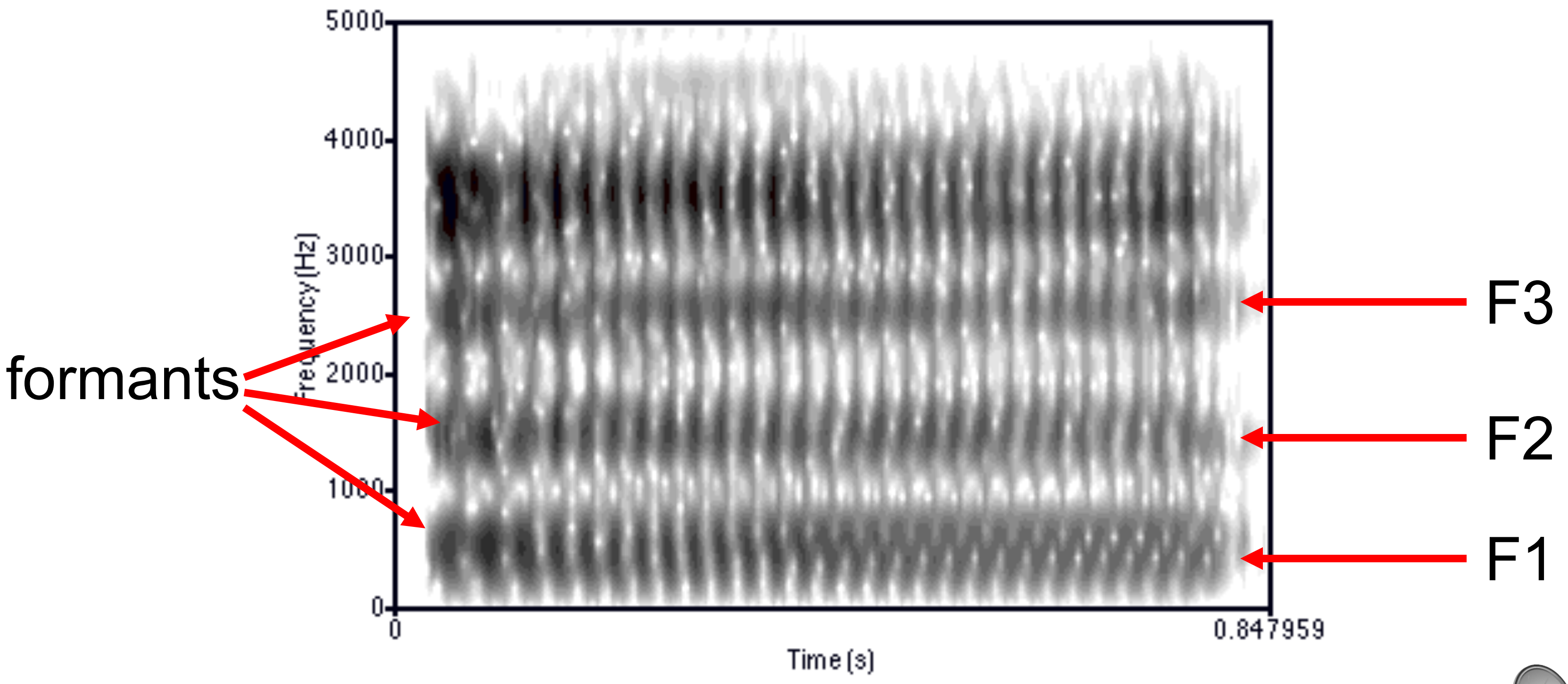

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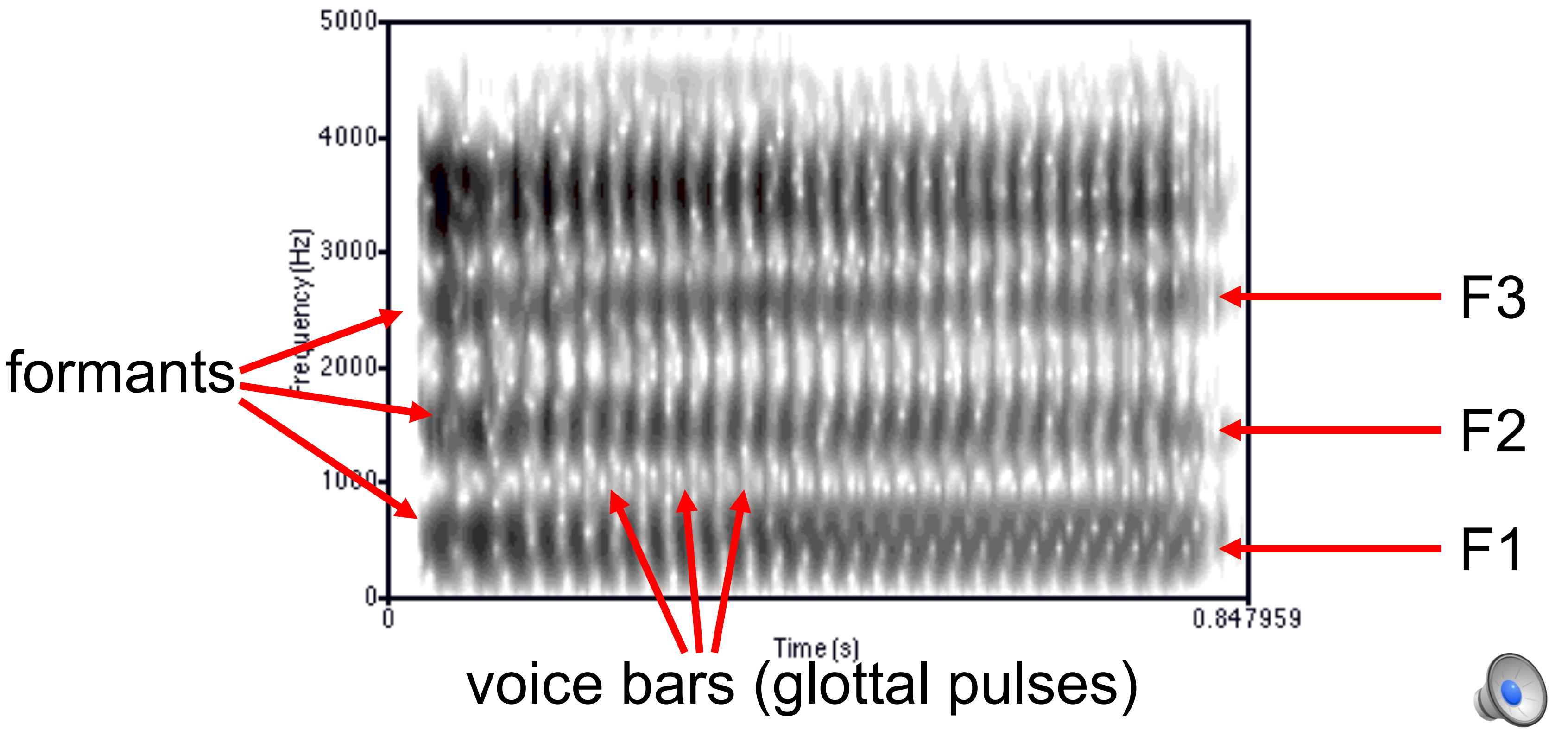
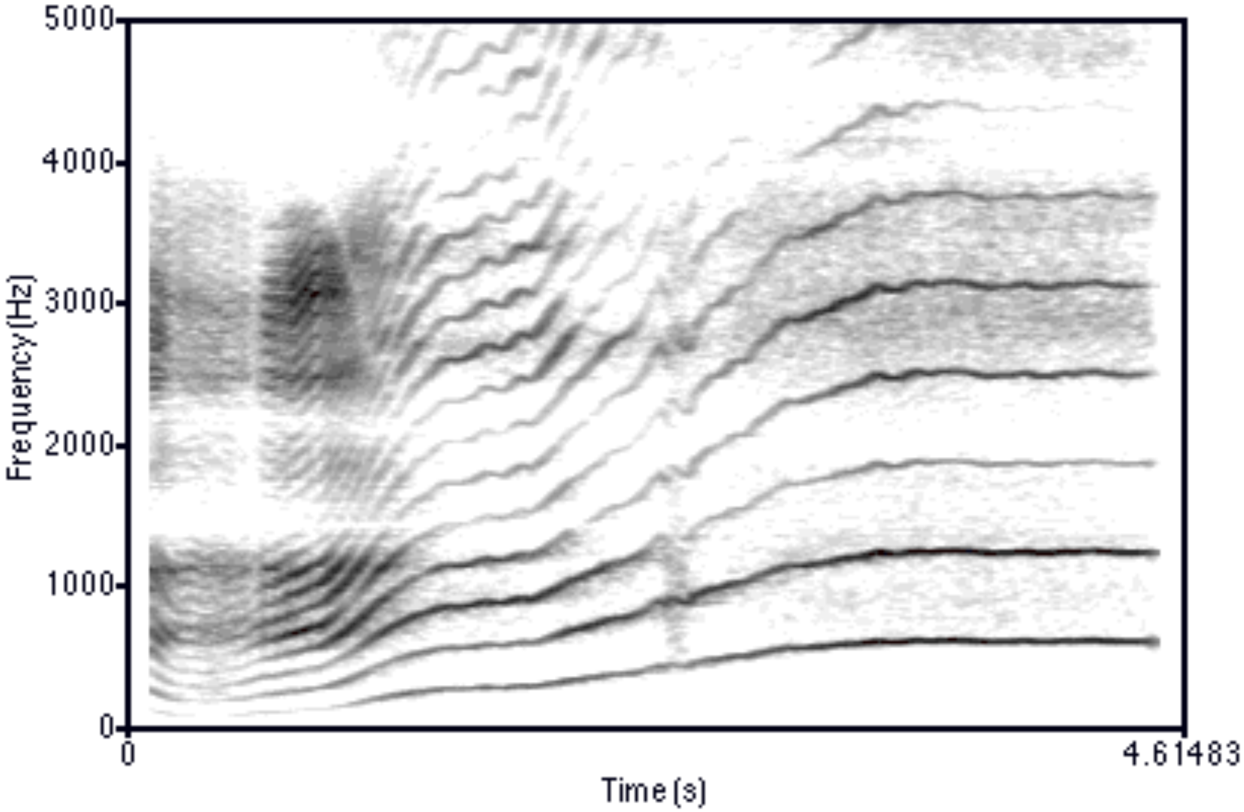


Spectrographically

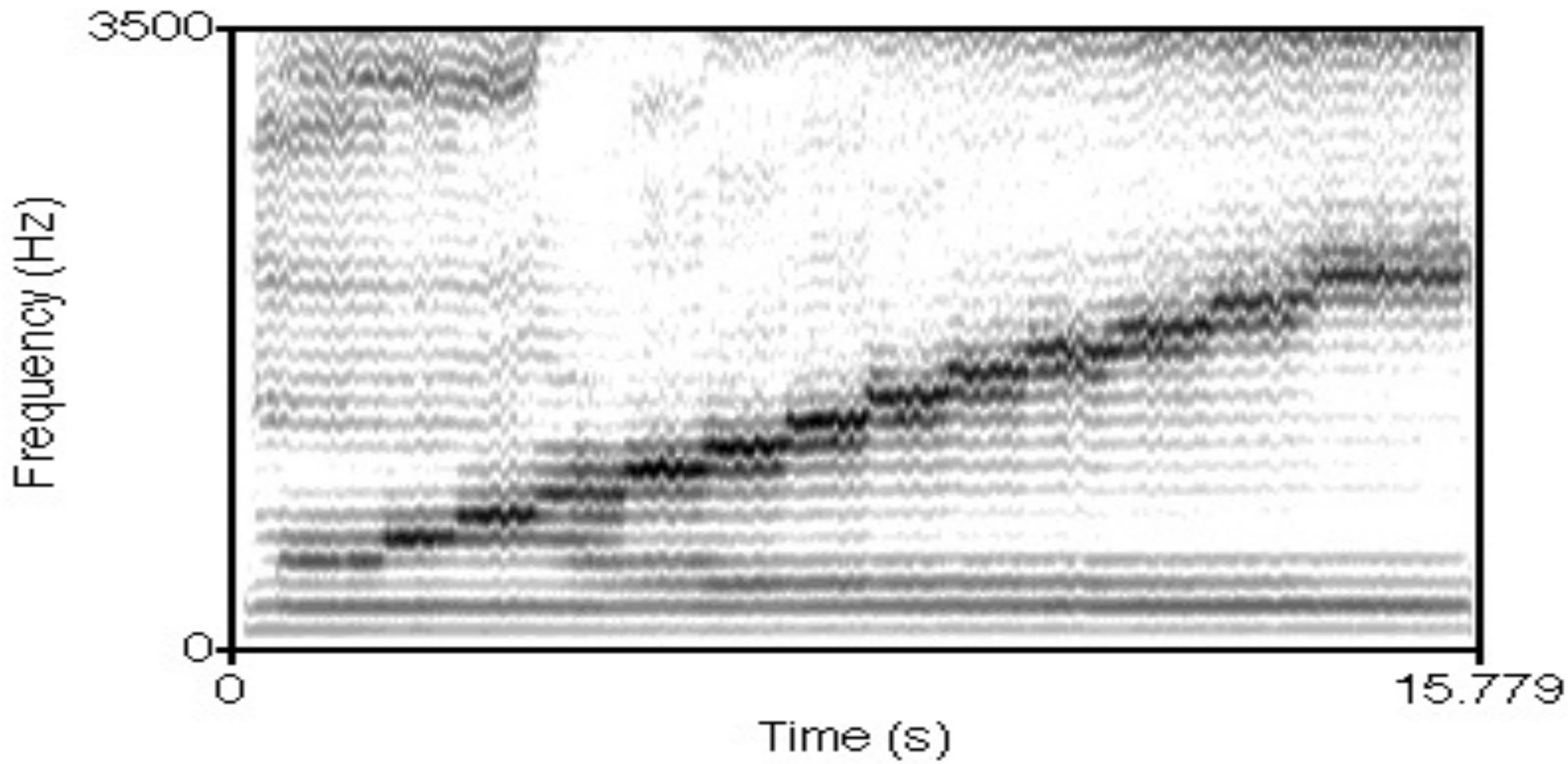
• This is what it looks like when you change the **source** independently of the **filter**.



• The formants stay the same, but the F0 and harmonics change.

The Flip Side

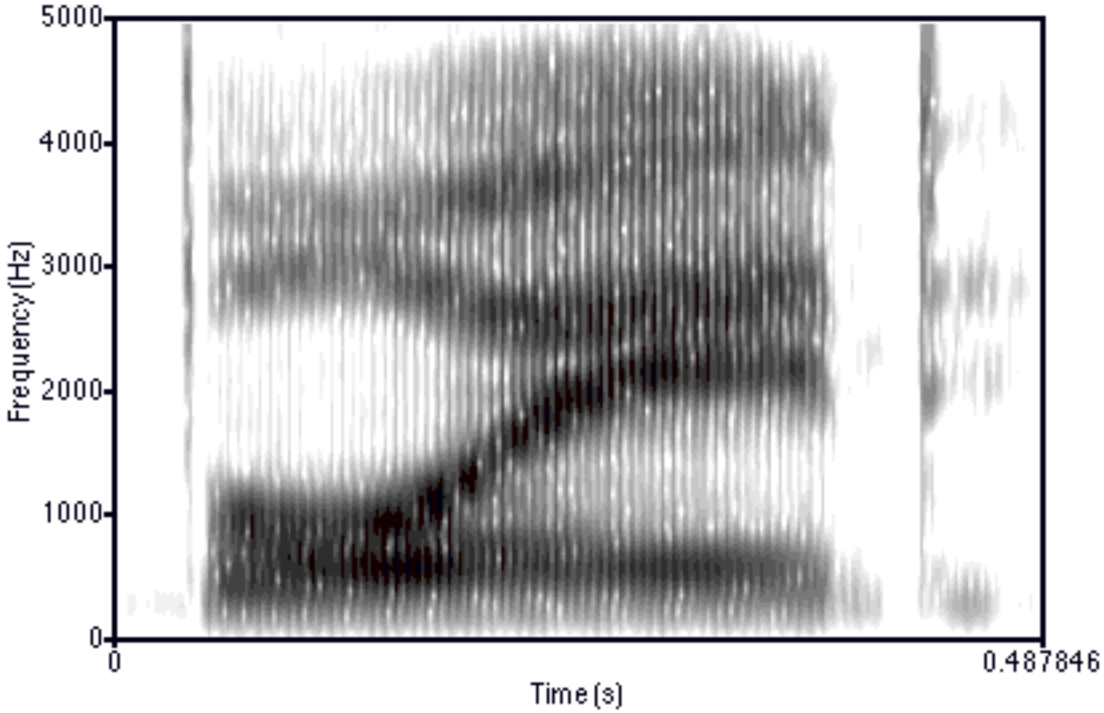
• This is what it looks like when you change the **filter** independently of the **source**.



• The resonating frequencies change, but the F0 and harmonics stay the same.

More Relevantly

- In diphthongs, the **filter** changes while the source can remain at the same F0.



“Boyd”

[bɔ͡ɪd]

- Check out the narrow-band spectrogram…

Source/Filter Summary

Sound source	**Sound filter**
vocal folds	vocal tract
fundamental frequency	resonant frequencies (formants)
F0	F1, F2, F3…
harmonics	standing waves
pitch of voice	vowel quality

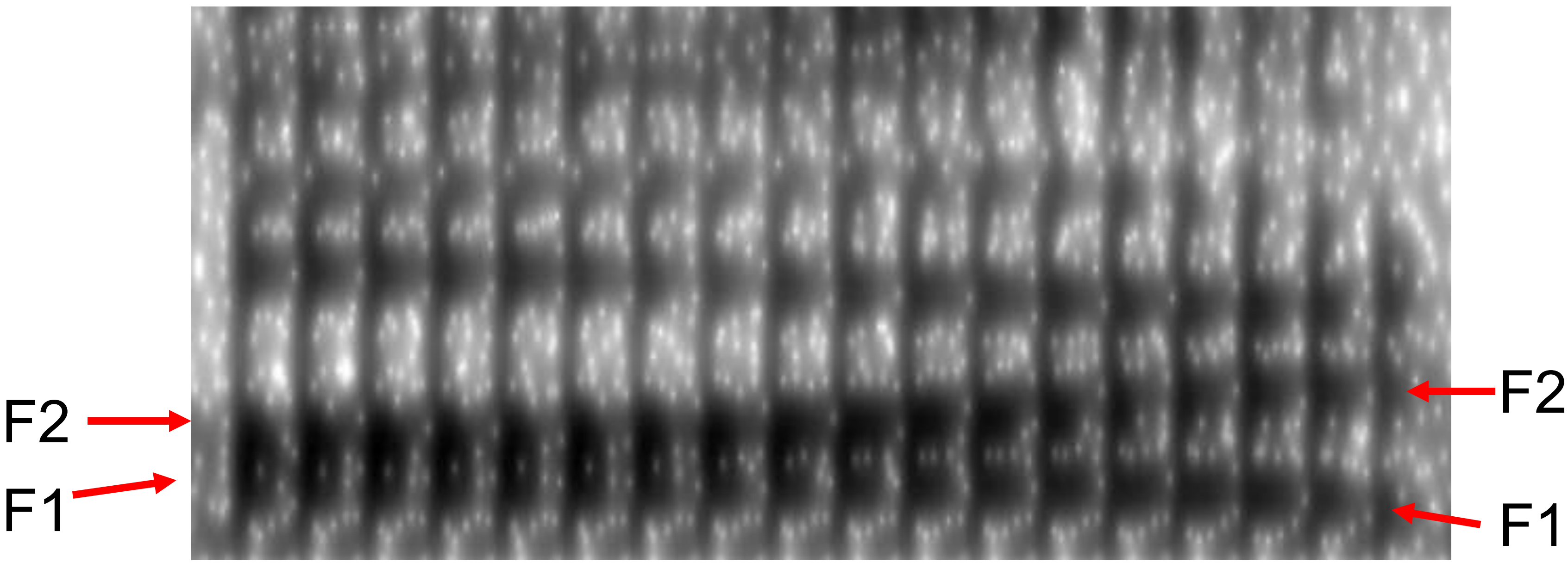
in a (wide-band) spectrogram:

vertical striations	horizontal dark bands

a musical analogy:

strings	body (of guitar, violin, etc.)

Another Problem: Dynamics



“hod”

- vowel formants are typically not “steady-state” for very long

More Music

- With (most) musical instruments, we can only change the frequency of the sound **source.**
- **Timbre** is a musical term for the “quality” of a sound.
  - I.e., its characteristic resonances.
  - E.g., compare the same note played by a trumpet vs. a violin.
- In speech, you can independently change both source and filter frequencies <u>at the same time</u>.
  - Like changing the size of a piano…
  - As you press different keys on the keyboard.
- This makes the acoustics of speech <u>at least twice as complex</u> as the acoustics of music.