24.963

Linguistic Phonetics

The acoustics of nasals and laterals

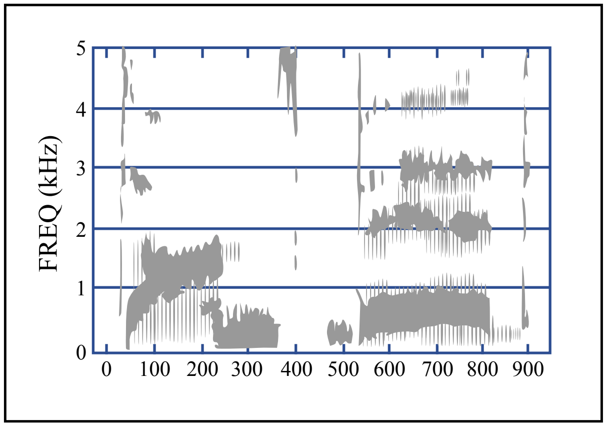


Image by MIT OCW.
Adapted from Stevens, K. N. *Acoustic Phonetics*.
Cambridge, MA: MIT Press, 1999, chapter 6.

Assignments

- Talk to me about a paper topic, this week or next.

Damping and bandwidth

- When an input of energy sets a body vibrating, the resulting vibrations die out as energy is dissipated through friction, transmission of energy to surrounding air, etc.
- A wave of this type is described as **damped**.

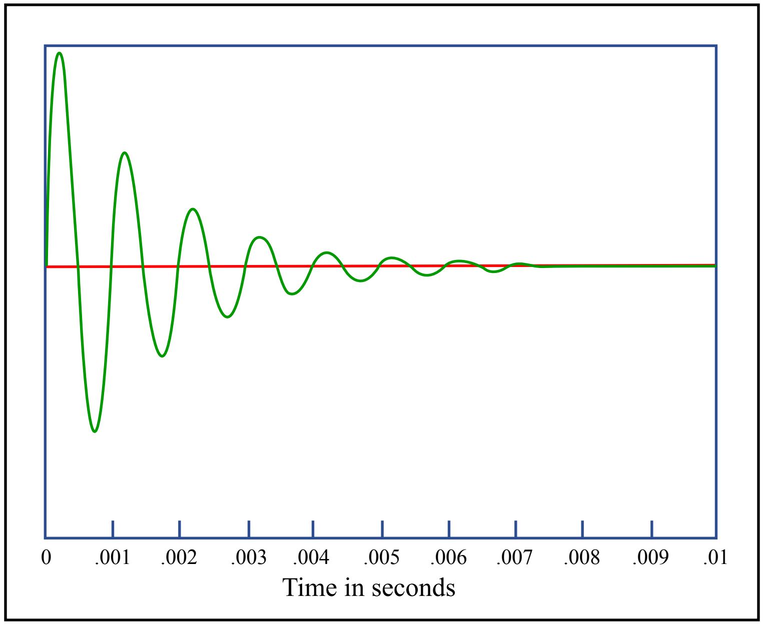
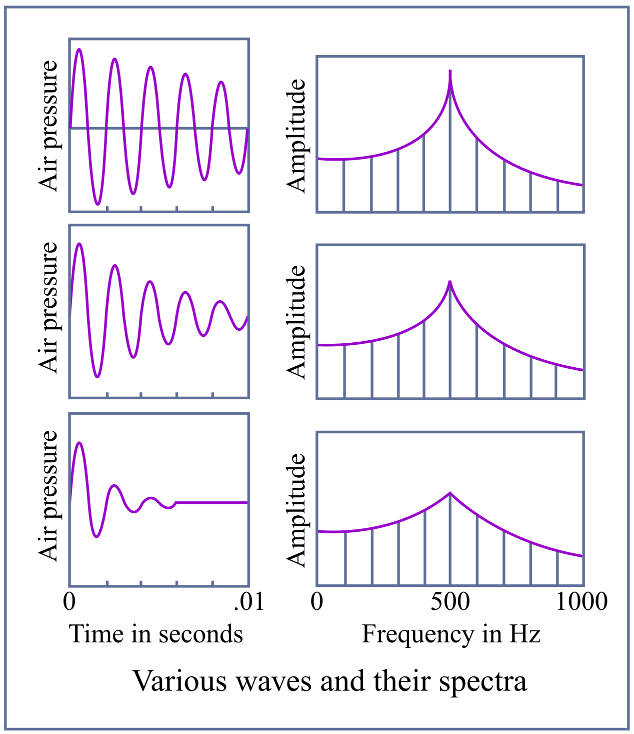


Image by MIT OCW.
Adapted from Ladefoged, Peter. *Elements of Acoustic Phonetics*.
Chicago, IL: Univeristy of Chicago Press, 1962.

Damping and bandwidth

- The more heavily damped a sinusoid is, the wider the bandwidth of its spectrum.
- A wider bandwidth implies a lower spectral peak, other things being equal, since the energy in the wave is distributed over a wider range of frequencies.



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Adapted from Ladefoged, Peter. *Elements of Acoustic Phonetics*. Chicago, IL: Univeristy of Chicago Press, 1962.

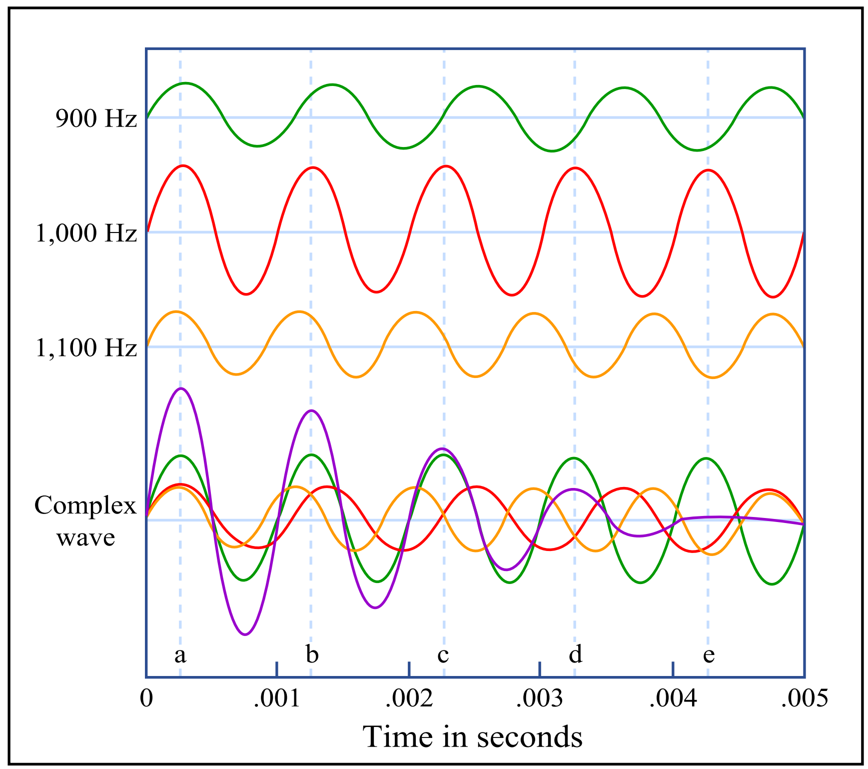


Image by MIT OCW.
Adapted from Ladefoged, Peter. *Elements of Acoustic Phonetics*. Chicago, IL: Univeristy of Chicago Press, 1962.

Damping and bandwidth

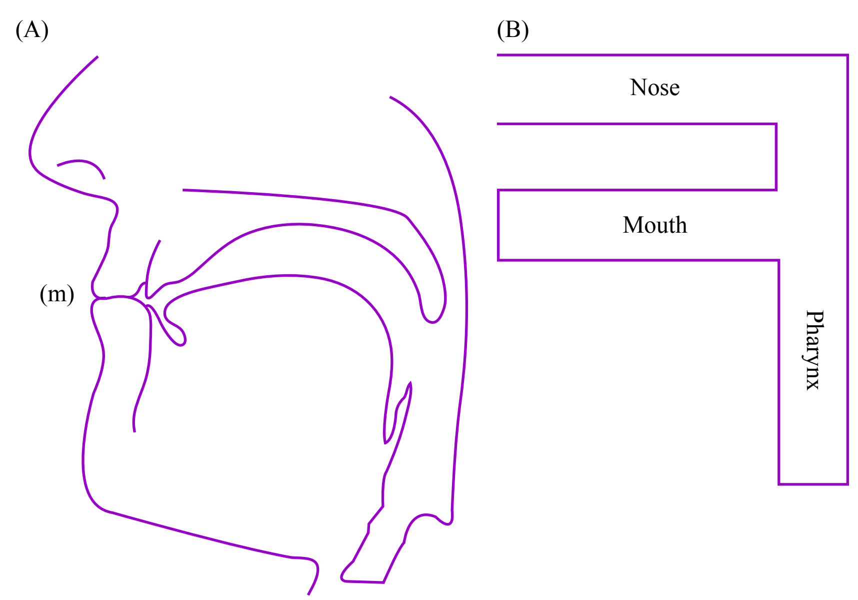
- Standing waves in the vocal tract are damped due to friction, radiation losses to the outside air, absorption of energy by the elastic vocal tract walls etc.
- Greater surface area results in more damping (and broader formant bandwidths).
- Coupling the nasal cavity to the vocal tract in in nasal sounds increases the surface area of the vocal tract.

Nasal stops

- A uvular nasal can be modeled in terms of a tube which is closed at the glottis and open at the nostrils.
- It is not a uniform tube.
- The effective length of the tube is greater than the length from glottis to lips
  - 21.5 cm (Johnson) or 20 cm (Stevens) vs. 16 cm.
- So the resonances of the tube are at lower frequencies (and closer together) than in a vowel.

Nasal stops

- In nasal consonants formed with an oral constriction further forward than the uvula, the oral cavity forms a side branch on the pharyngeal-nasal tube.
- This side branch is longest in labials, shortest in velars.

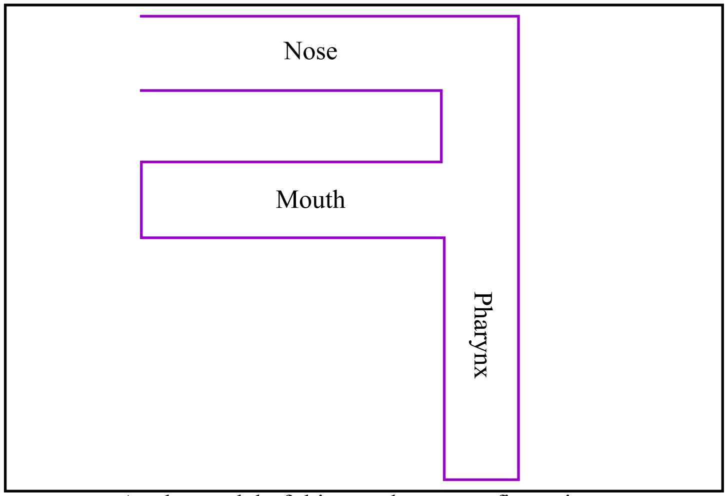


(A) An X-ray tracing of the positions of the articulators during (m).
(B) A tube model of this vocal tract configuration.

Image by MIT OCW.
Adapted from Johnson, Keith. Acoustic and Auditory Phonetics. Malden, MA: Blackwell Publishers, 1997.

Nasal stops

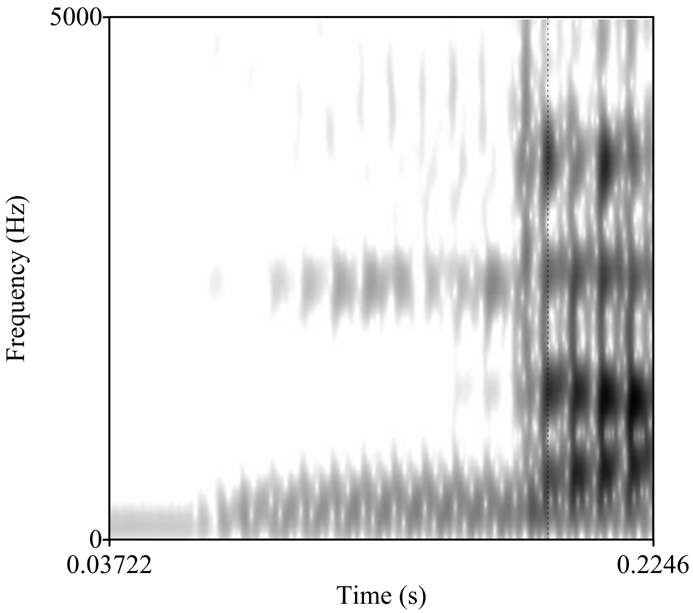
- The side branch is a tube open at one end and resonates accordingly.
- The side branch is not coupled to the outside air. Its resonances are zeros in the signal radiated from the nose - i.e. those frequencies are attenuated.
- Zeroes also reduce the amplitude of higher frequencies, so nasals are characterized by less high frequency energy than vowels.
- Frequencies of the zeroes depend on the size of the side branch, e.g. 8 cm for [m], 5.5 cm for [n].



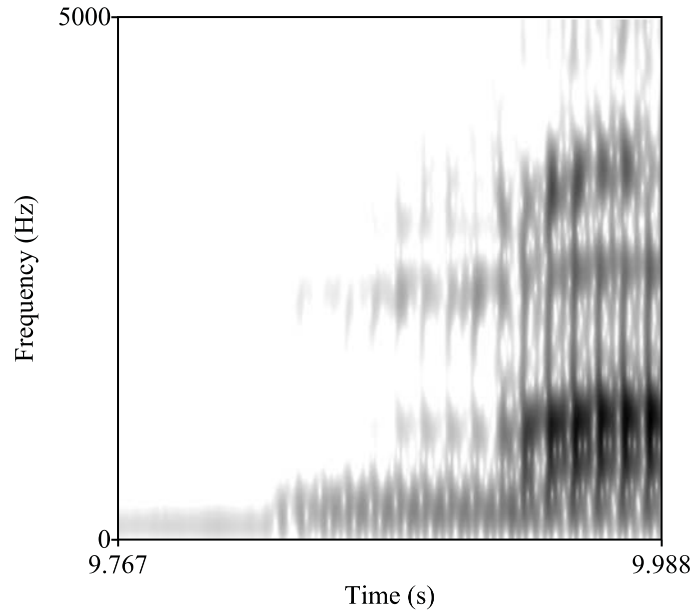
A tube model of this vocal tract configuration.

Image by MIT OCW.
Adapted from Johnson, Keith. Acoustic and Auditory Phonetics. Malden, MA: Blackwell Publishers, 1997.

Nasal stops



[n] nigh



[m] my

Cues to place in nasal stops

- Formant transitions – as in oral stops
- Nasal murmur differs according to place of articulation, but in itself is a weak cue – murmur is relatively quiet.
- But the interval around the release of the nasal may provide significant place cues:
  - Nasal place is identified more accurately from 6 periods centered around release compared to 6 periods of the murmur or formant transitions (Kurowski & Blumstein 1984)
  - But the differences are small: 12% vs. 13% vs. 20%
- The interval around the onset of nasal closure does not provide comparable cues to place (Repp & Svastikula 1988)

Laterals

- Laterals also have a side branch - the pocket behind the tongue tip is a side branch to the main tube(s) passing around the side(s) of the tongue.

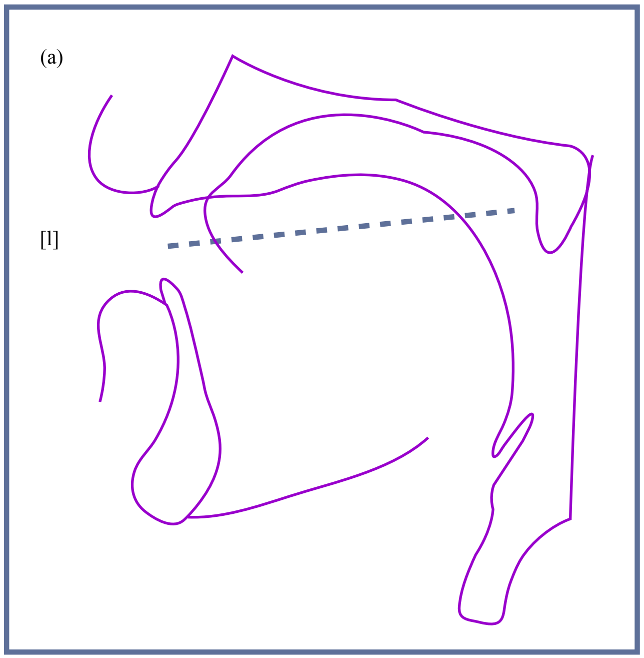


Image by MIT OCW.
Adapted from Johnson, Keith. Acoustic and Auditory Phonetics Malden, MA: Blackwell Publishers, 1997.

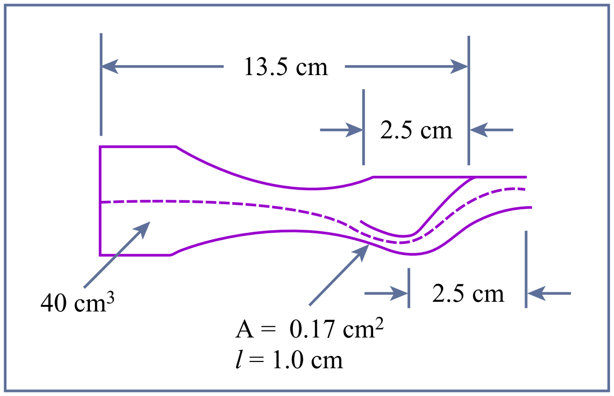
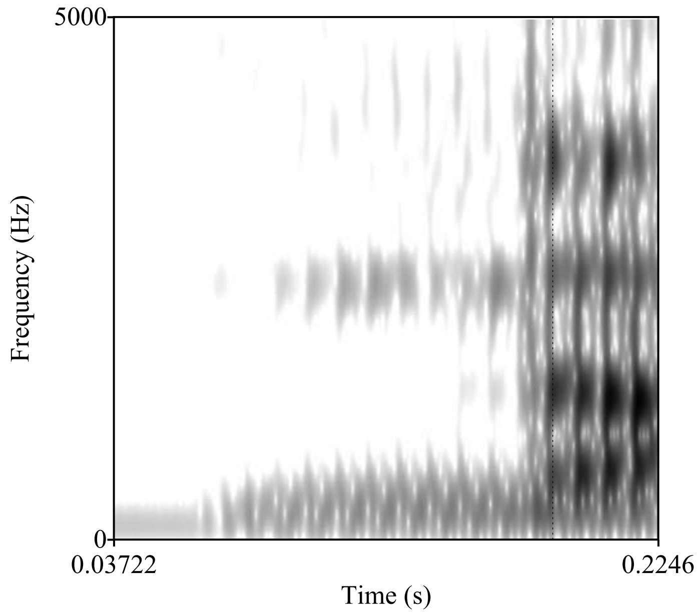


Image by MIT OCW.

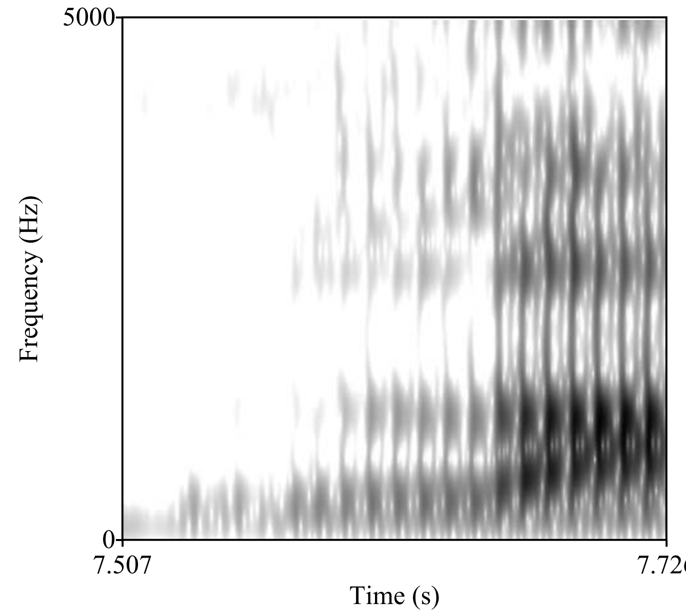
Laterals

- Laterals also have a side branch - the pocket behind the tongue tip is a side branch to the main tube(s) passing around the side(s) of the tongue.
- Laterals are thus also characterized by zeroes - the lowest appears between F2 and F3, often significantly reducing the amplitude of F2.
- The presence of zeroes and the coronal constriction reduce the intensity of laterals compared to most vowels.
- On spectrograms, laterals look similar to nasals, but differ in the location of formants and zeros, and in their effects on neighboring vowels.

Laterals

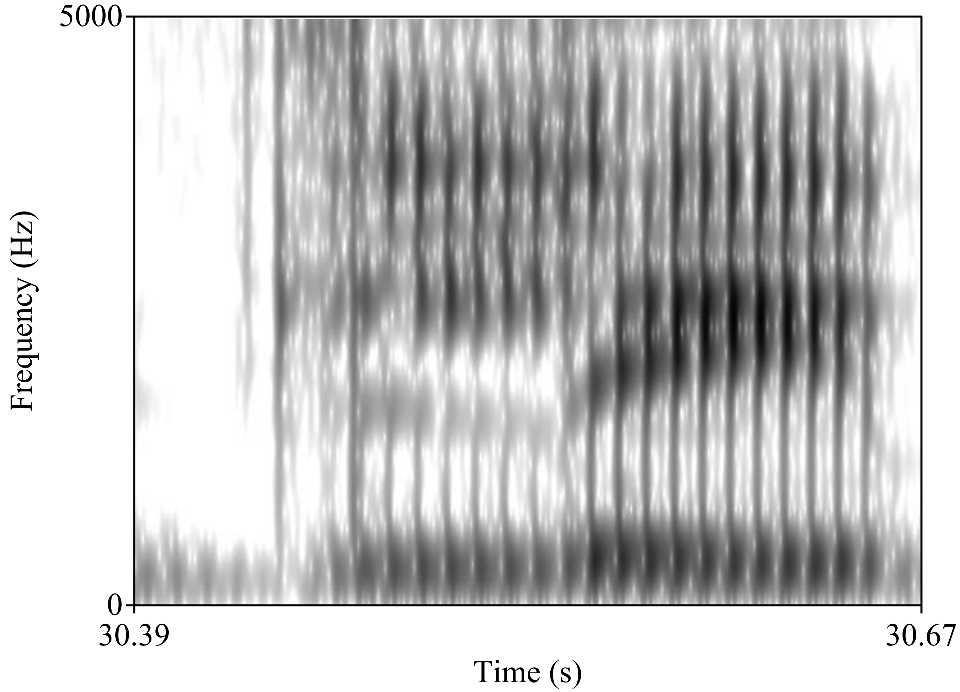


[n] nigh



[l] lie

Laterals



[dli(ma)] (Hebrew)

Nasalized vowels

- Nasalized vowels involve a complex vocal tract configuration.

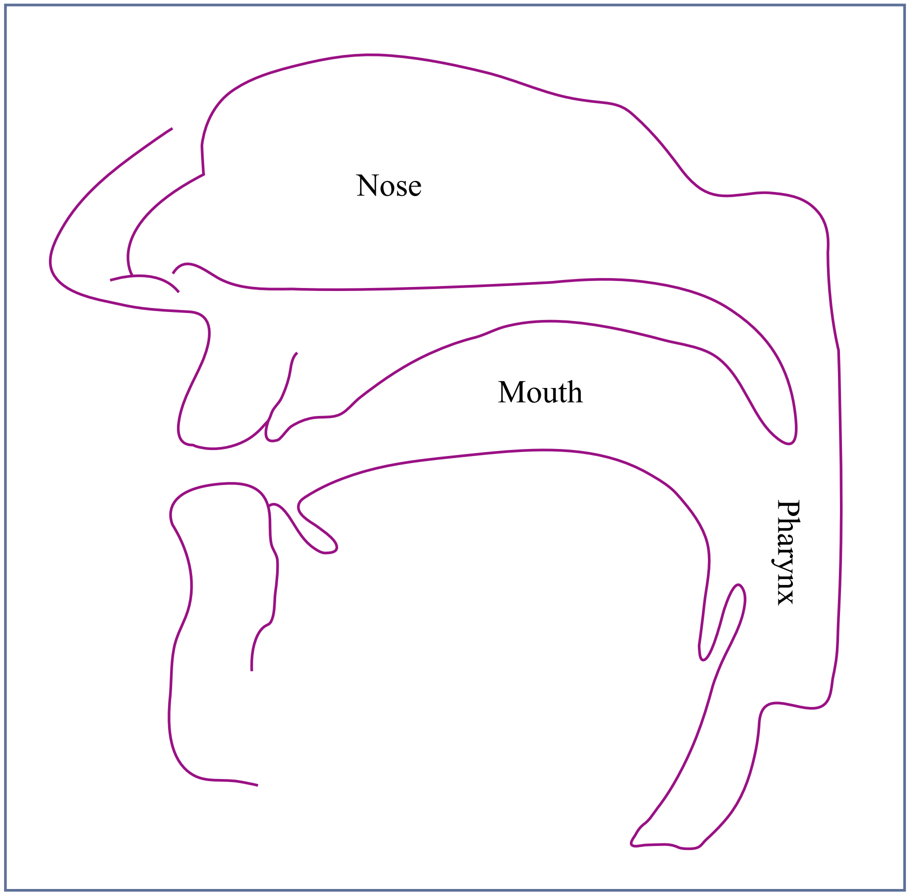


Image by MIT OCW.
Adapted from Johnson, Keith. Acoustic and Auditory Phonetics. Malden, MA: Blackwell Publishers, 1997.

Nasalized vowels

- The coupled nasal cavity contributes both formants and anti-formants (poles and zeroes) which combine with the formants of the oral tract.
- The net acoustic effect of velum lowering depends on the locations of the formants in the corresponding oral vowel (Maeda 1993)

Nasalized vowels

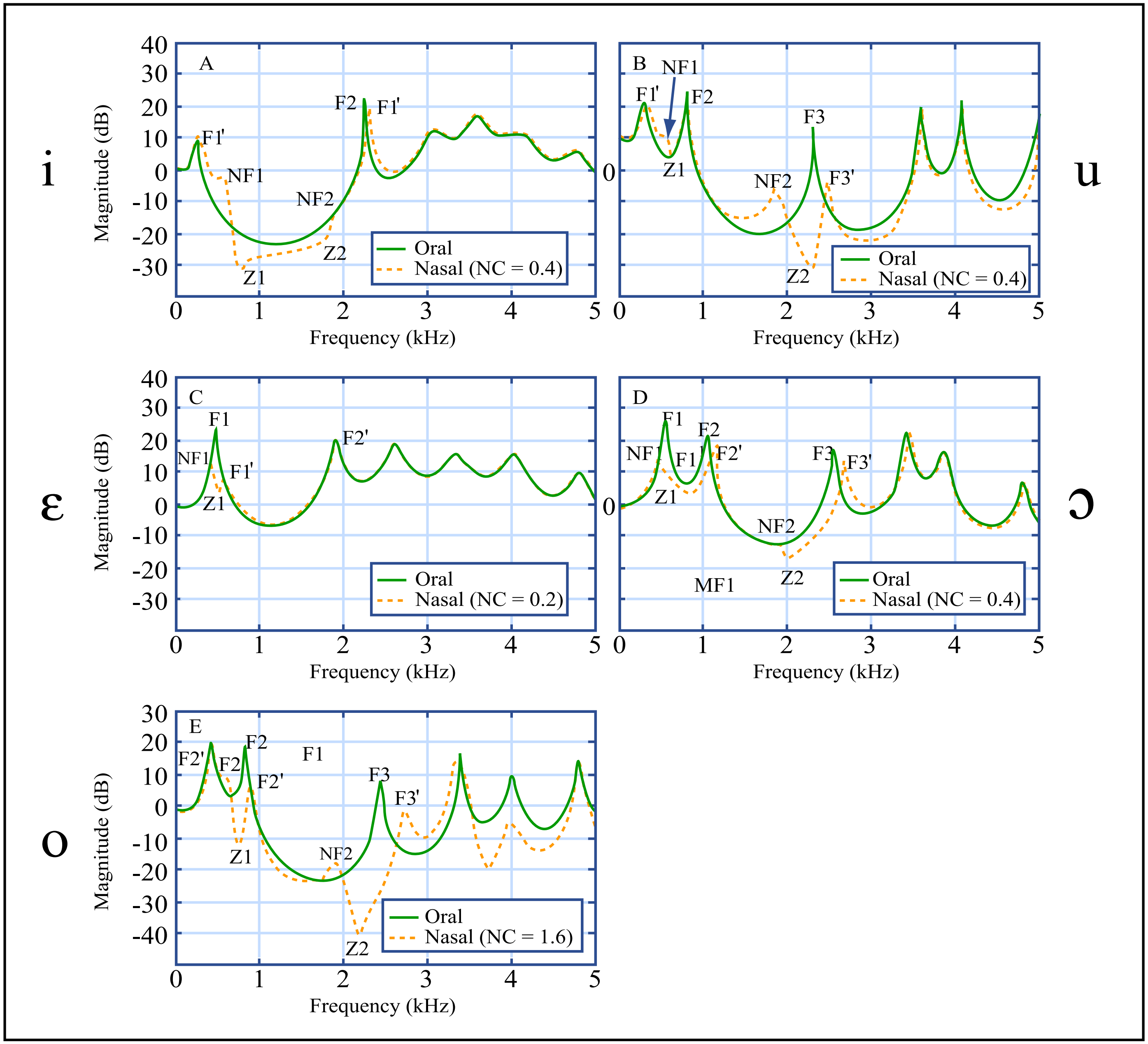


Image by MIT OCW.

Adapted from Maeda, Shinji. "Acoustics of vowel nasalization and articulatory shifts in French nasal vowels."In *Nasals, Nasalization and the Velum*. Edited by M. Huffman and R. Krakow. New York, NY: Academic Press, 2003, pp. 147-170.

Nasalized vowels

- As a result it is difficult to give a general acoustic characterization of nasalization on vowels.
- Maeda: nasalized vowels generally have a flat, low intensity spectrum in the low frequency region.
  – Addition of the lowest nasal formant in combination with broad bandwidth F1 can create a broad, low frequency prominence.

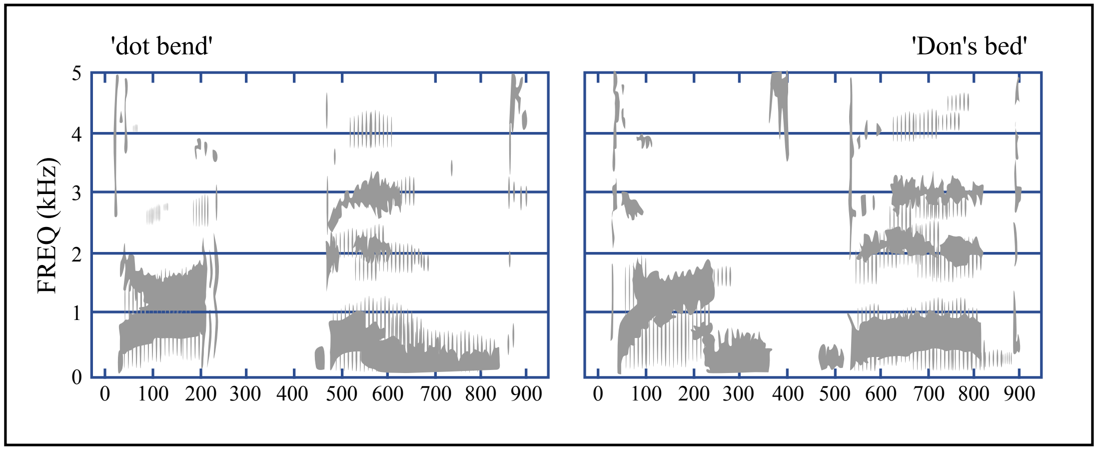


Image by MIT OCW.
Adapted from Stevens, K. N. *Acoustic Phonetics*. Cambridge, MA: MIT Press, 1999.

Nasalized vowels

- Chen (1997) proposes the measures A1-P0 and A1-P1 to quantify nasalization.
  - A1 is amplitude of F1
  - P0 is amplitude of the low frequency nasal peak.
  - P1 is amplitude of a higher nasal peak, between F1 and F2.

- A1 amplitude of F1
- P0 amplitude of lower frequency nasal peak - intensity of harmonic with greatest amplitude at low frequency.
- P1 amplitude of nasal peak - measured as amplitude of highest harmonic near to 950 Hz.
- These measures are sensitive to vowel quality - Chen proposes corrections to adjust for this.

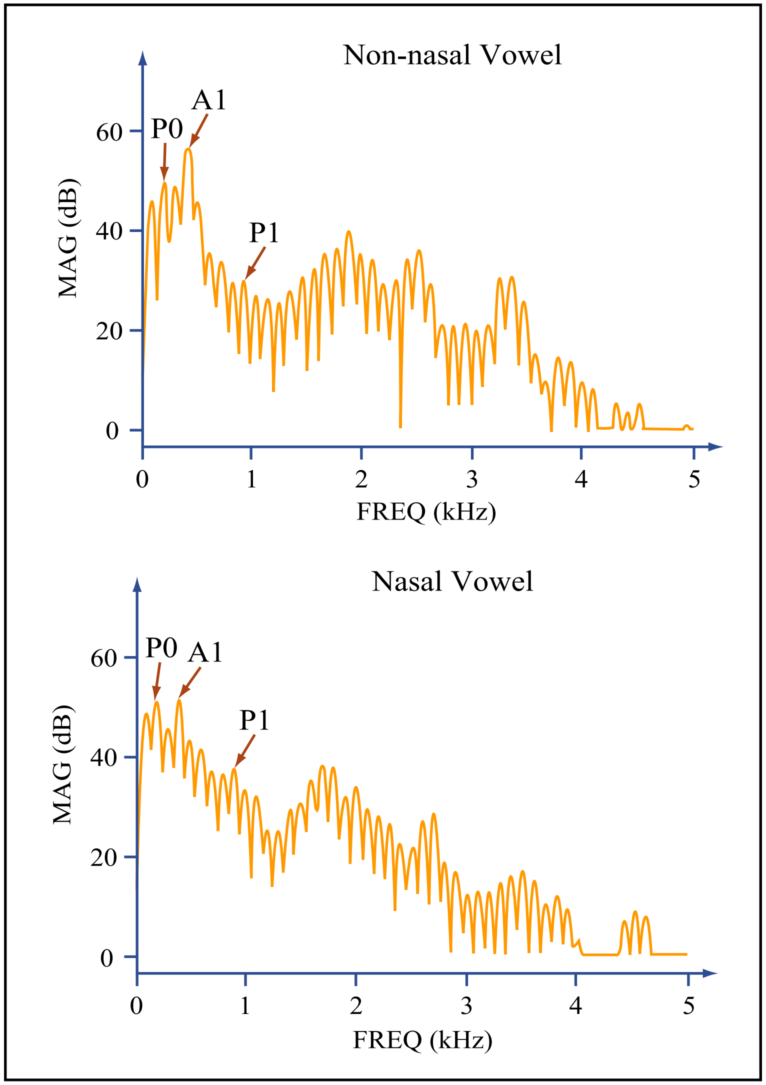
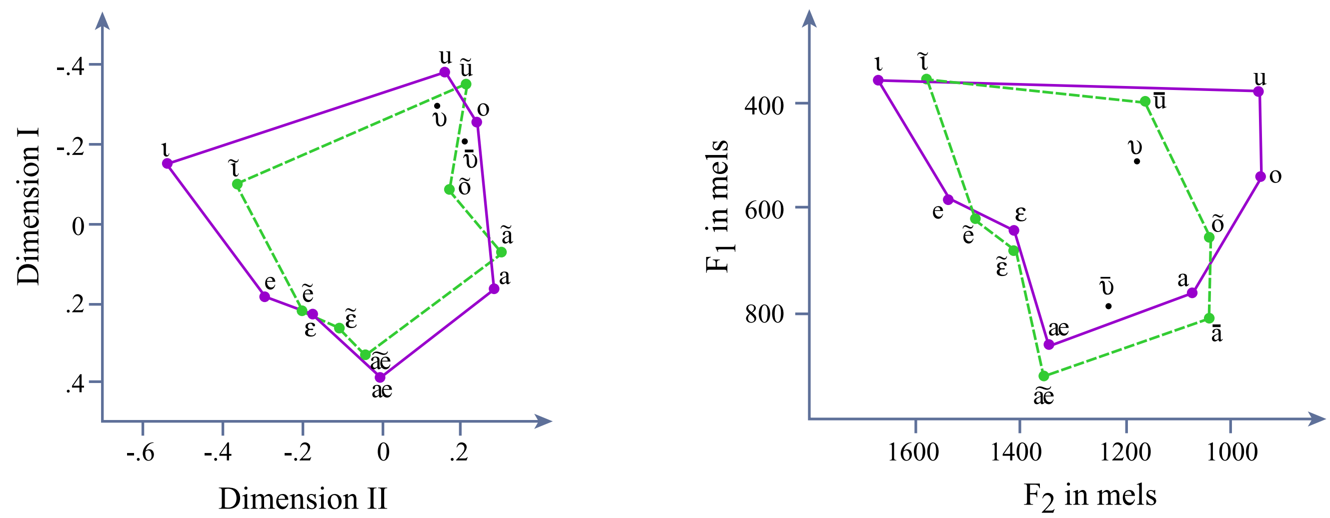


Image by MIT OCW.
Adapted from Chen, Marilyn Y. "Acoustic correlates of English and French nasalized vowels." *The Journal of the Acoustical Society of America* 102 (1997): 2360.

Nasalized vowels

- Perceptually, nasal vowels are less distinct from each other than oral vowels, both in terms of confusability (Bond 1975) and similarity judgements (Wright 1986).



The first two dimensions in the perceptual space as determined by INDSCAL

F_1 versus F_2 plot of the mel values of the stimuli

Image by MIT OCW.

Adapted from.Wright, James T. "The behavior of nasalized vowels in the perceptual vowel space." In *Experimental Phonology*. Edited by J. J. Ohala and J. J. Jaeger. Orlando, FL: Academic Press, 1986, 45-67.

Nasalized vowels

- More specifically, high nasalized vowels are perceived as lower than their oral counterparts and low nasalized vowels are perceived as higher than their oral counterparts.
- Wright speculates that this may be related to the fact that FN1 is below F1 in low vowels and above it in high and mid vowels in his stimuli.

Nasalized vowels

- This greater confusability is reflected in the fact that, in languages with contrastive vowel nasalization, the nasal vowel inventory is always the same as or smaller than the oral vowel inventory, never larger (Ferguson 1963, Ruhlen 1973).

Beembe (Congo)

i	u	ĩ	ũ
e	o	ẽ	õ
a		ã	

Dakota (Yankton-Teton)

i	u	ĩ	ũ
e	o		
a		ã	

Portuguese (Continental)

i	u	ĩ	ũ
e	o	ẽ	õ
ɛ	ɔ		
a		ã	

Ebrie (Niger-Congo)

i	u		
e	o	ẽ	õ
a		ã	

Image by MIT OCW.

pin-pen neutralization

- Southern US (and Bakersfield) accents:
  - *pin-pen*, *him-hem* are homophonous, *pit-pet* contrast.

Phonological map of the US removed due to copyright restrictions.
Source: http://www.ling.upenn.edu/phono_atlas/home.html.

- Vowels are substantially nasalized before nasals in English.
- Nasalization reduces the distinctiveness of F1 contrasts
- Oral [ɪ]-[ɛ] are sufficiently distinct, nasalized [ɪ̃]-[ɛ̃] are not.