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Why Can't I sing Every Vowel on Every Pitch?

Ingo R. Titze, Ph.D.

National Center for Voice and Speech

Property of NCVS

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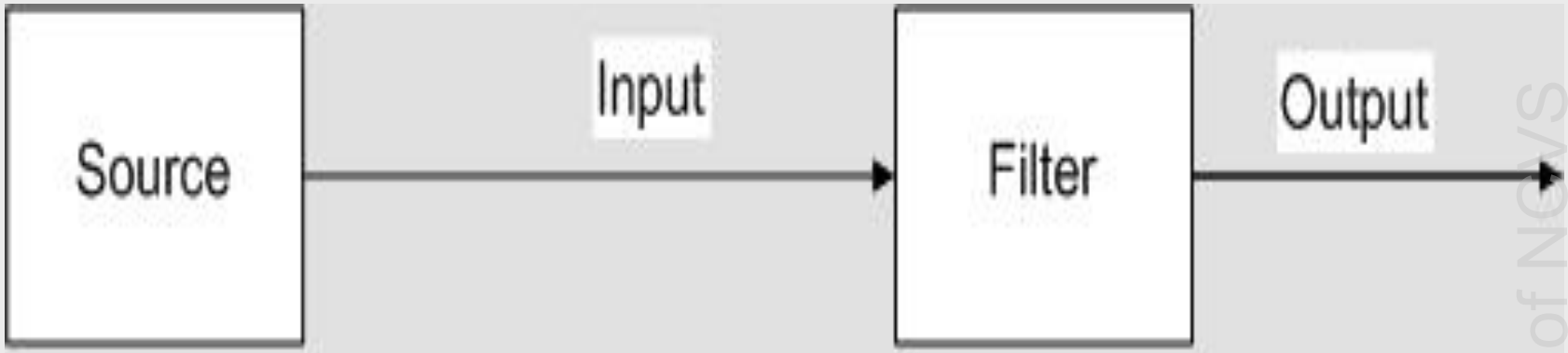
Linear Source-Filter Acoustics



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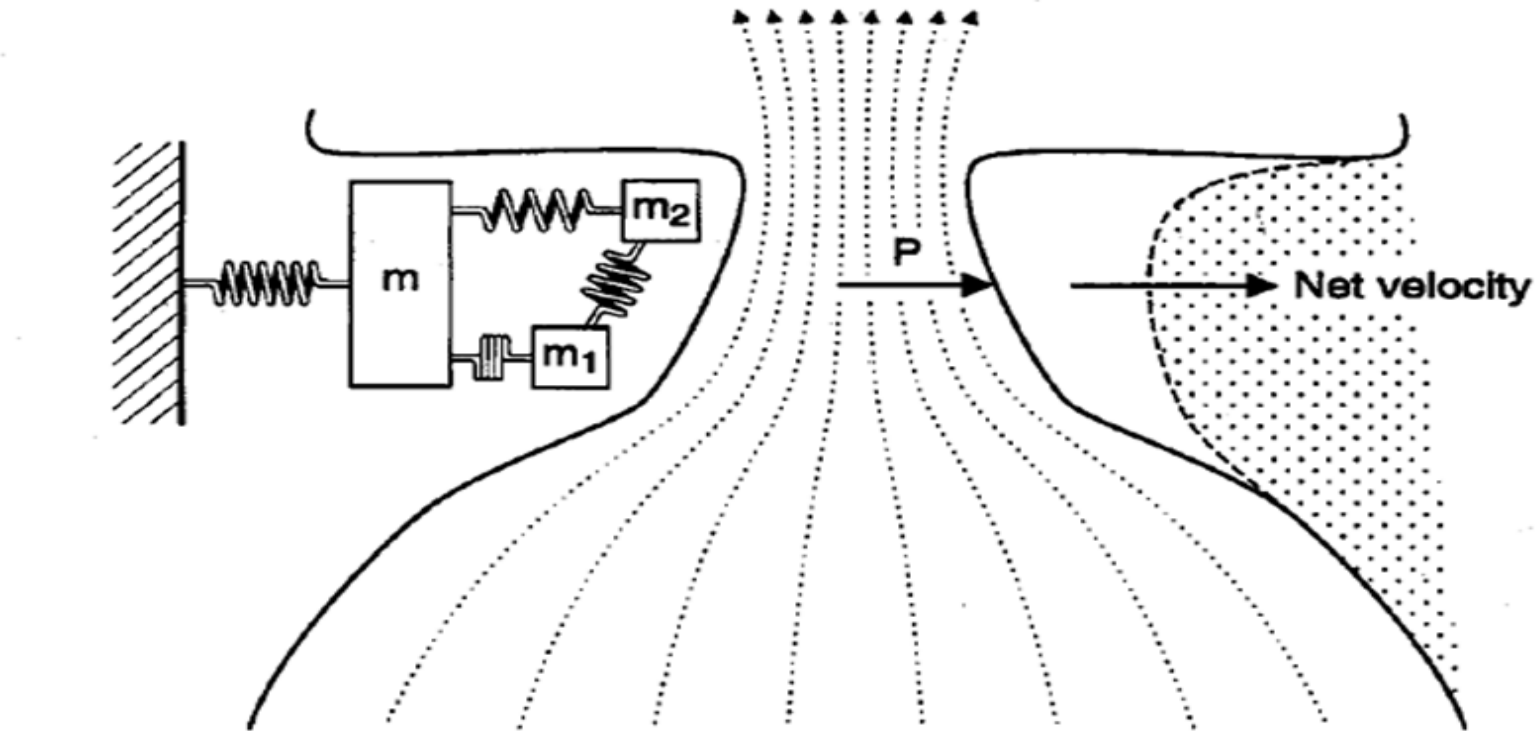
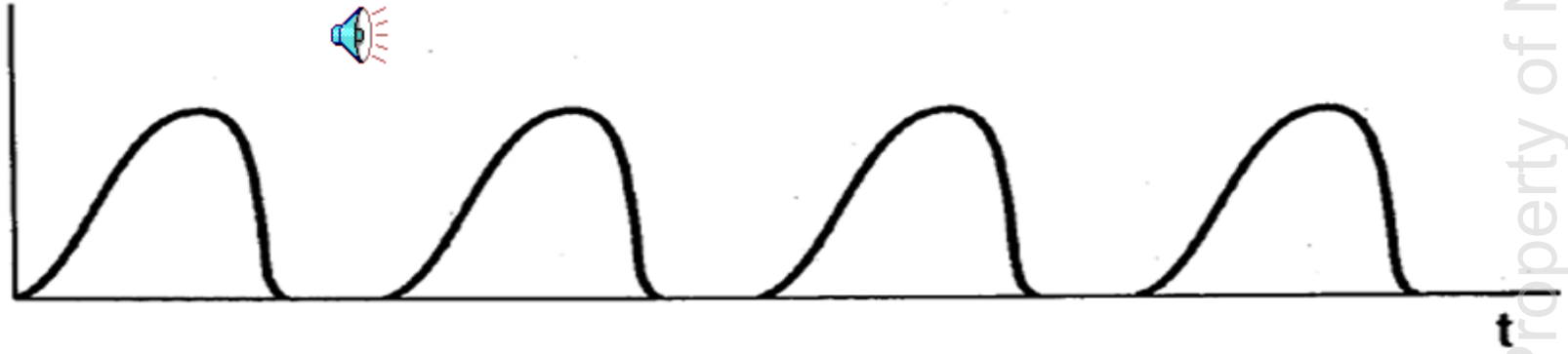
Tube(vocal tract)



Outward movement



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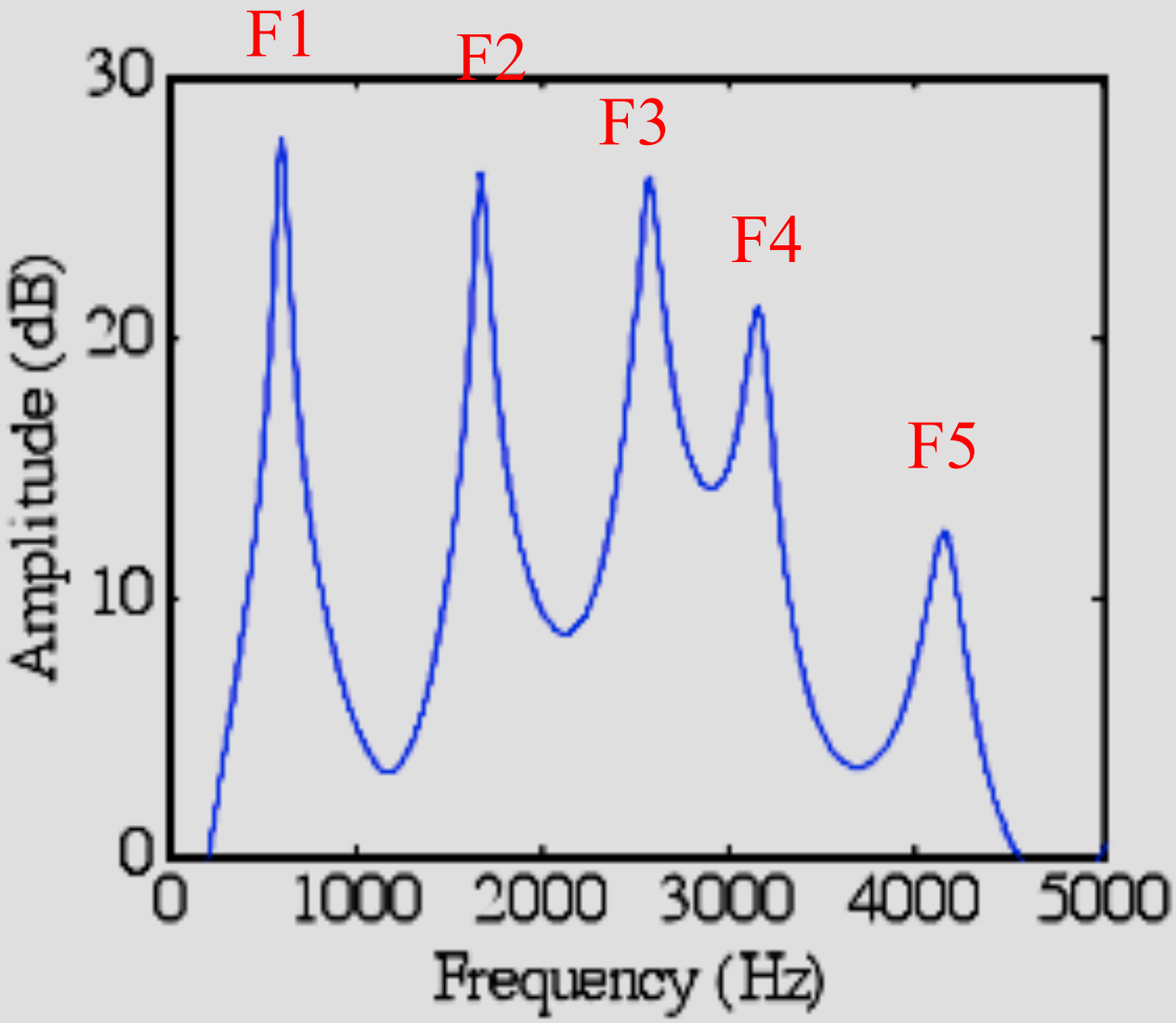
FILTER (RESONATOR) SPECTRUM



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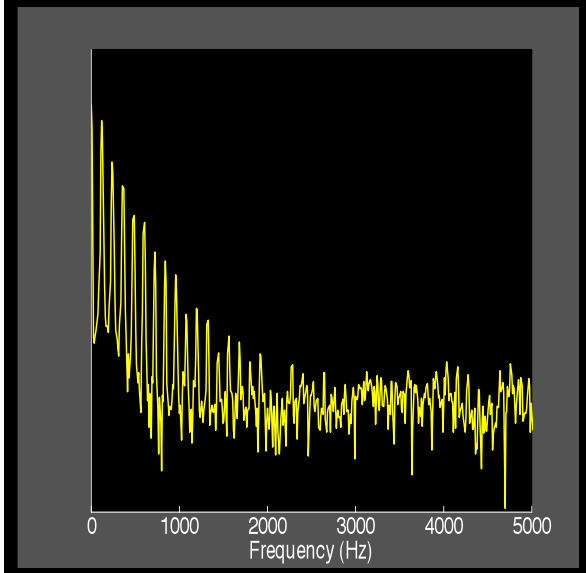
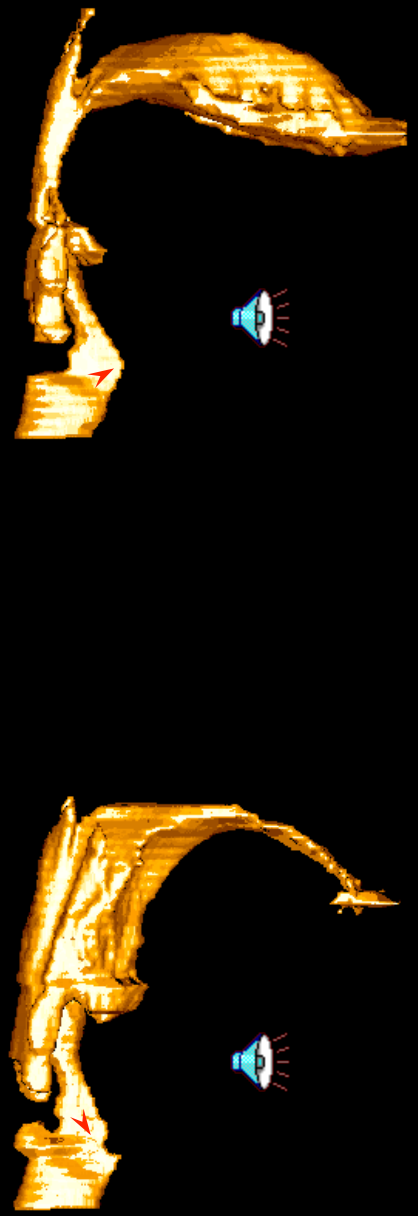
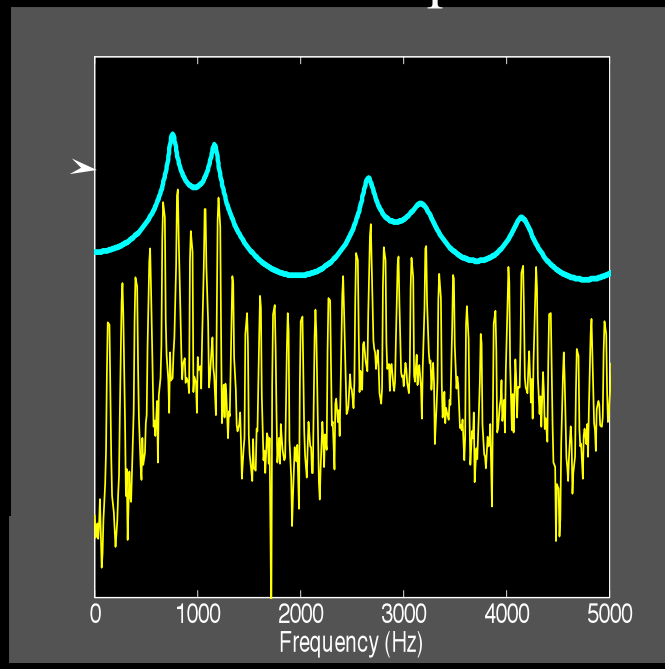
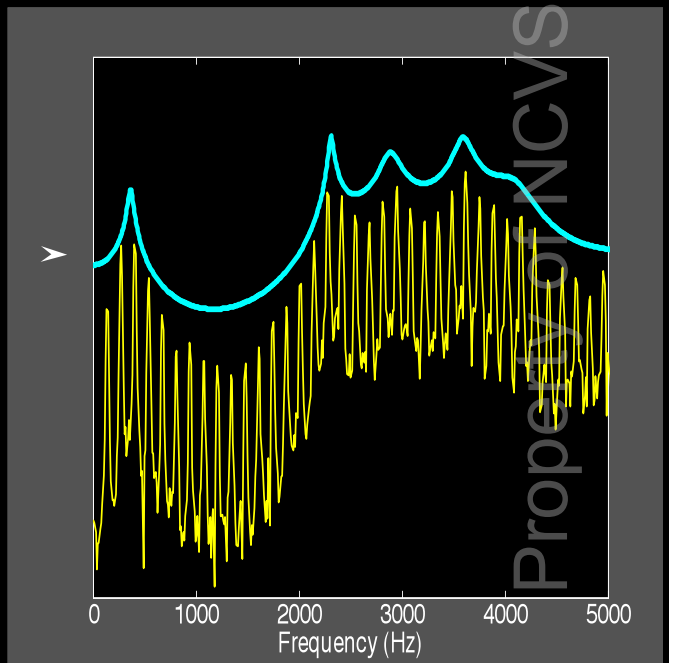
Sound Pressure Spectrum

Glottal Flow Spectrum









Property of NCVS

Why is source-filter interaction important?

- It is always present (to some degree)
- It can make the system more efficient (the source can be enhanced by the filter)
- It can create more spectral variety (vocal color, voice qualities)
- It can also create more instability (feedback always creates a potential for instability)

Property of NCVS

Source-filter interaction is in the form of feedback

- Reverse propagating acoustic waves from the airways above and below the vocal folds alter the glottal airflow (Level 1 interaction)

- Acoustic wave pressures above and below the vocal folds alter the intraglottal pressures, and therewith vocal fold vibration (Level 2 interaction)

Property of NCVS

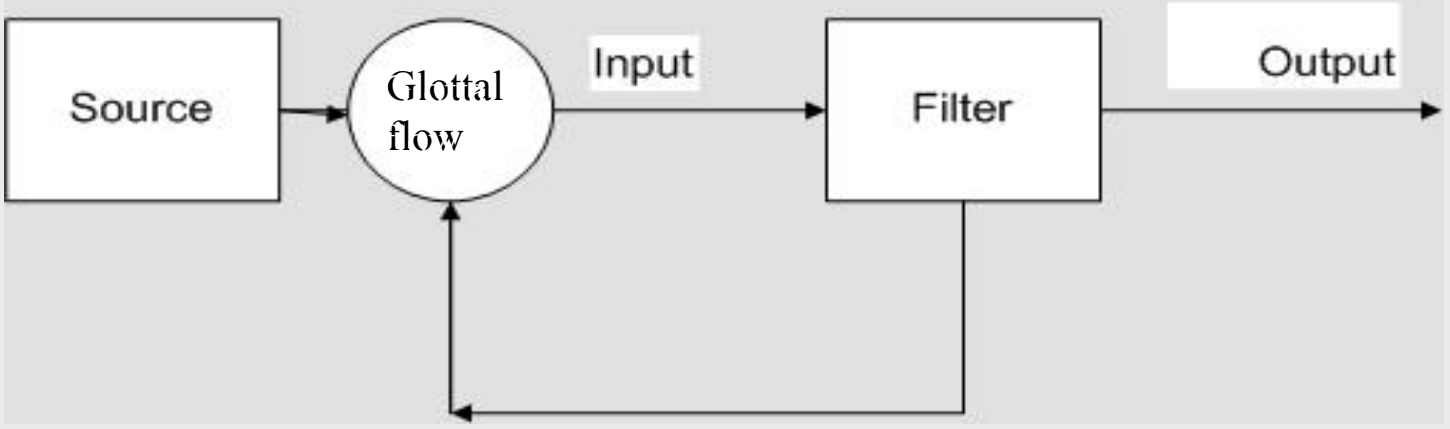
Level 1 Interaction

(acoustic pressures help drive the glottal flow)

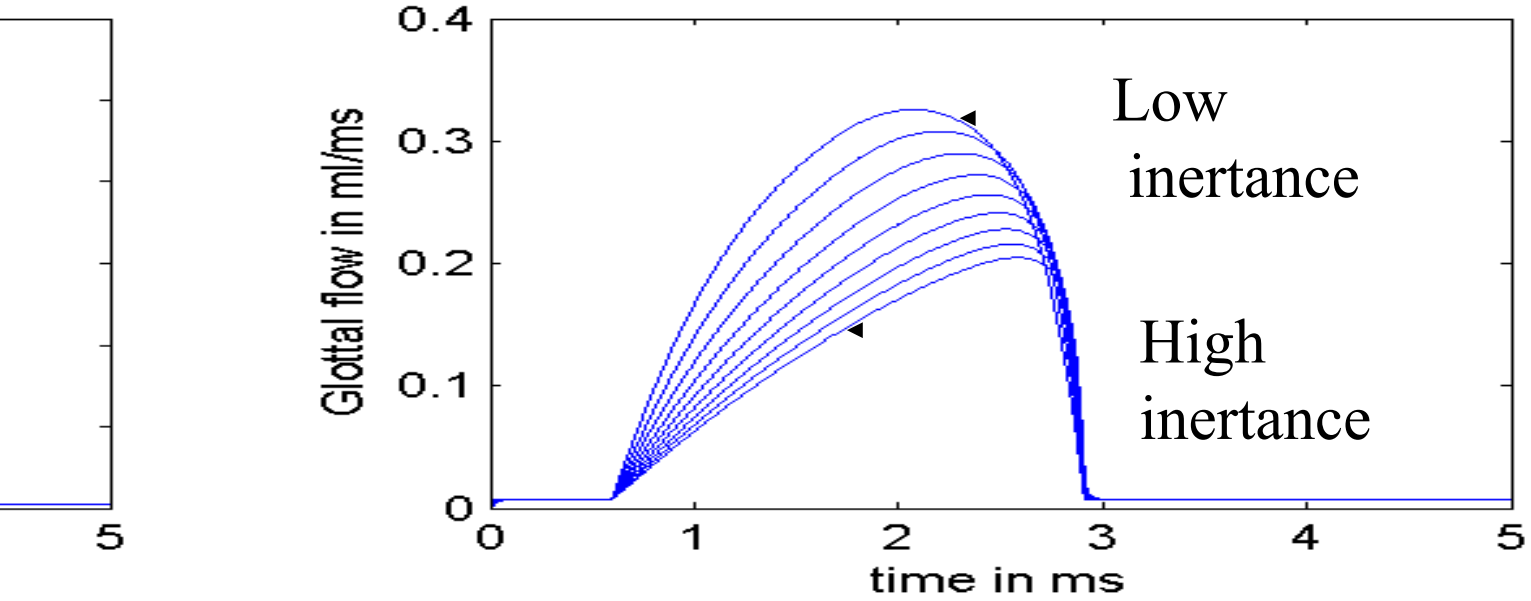
Property of NCVS

Linear Source-Filter Acoustics

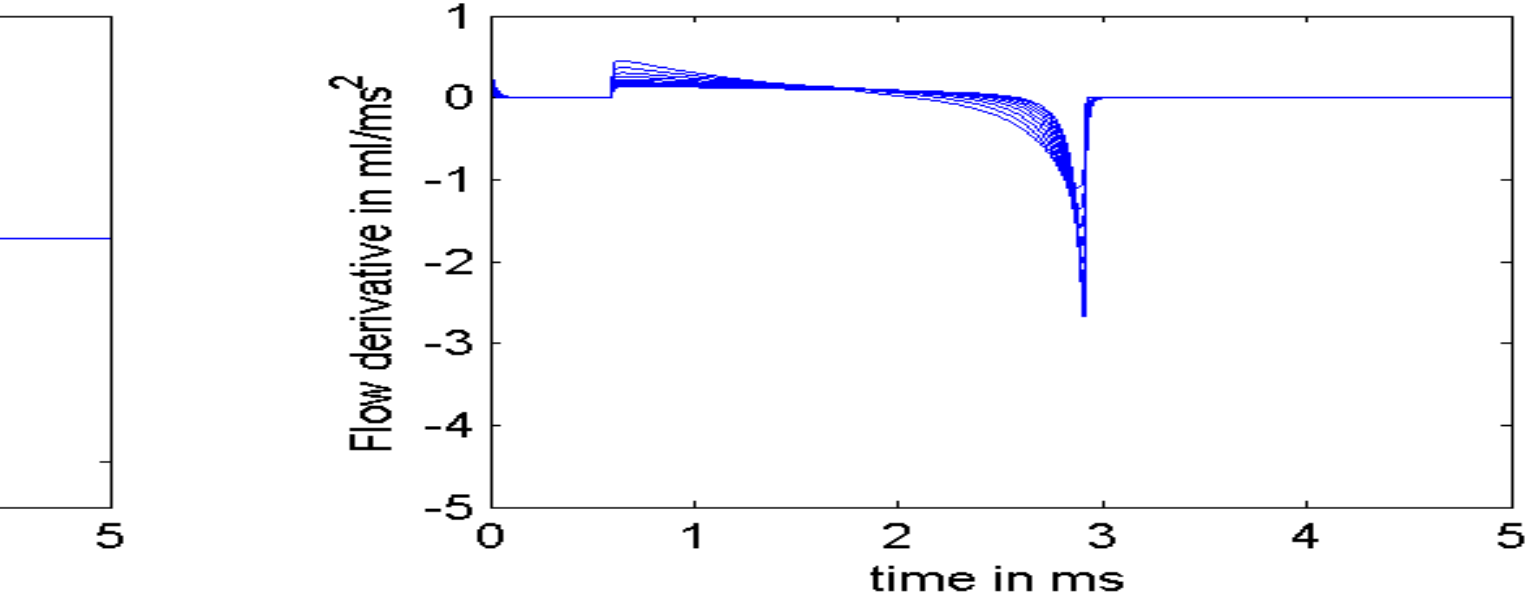
Level 1 Source-Filter Interaction



Property of NCVS



Pulse skewing



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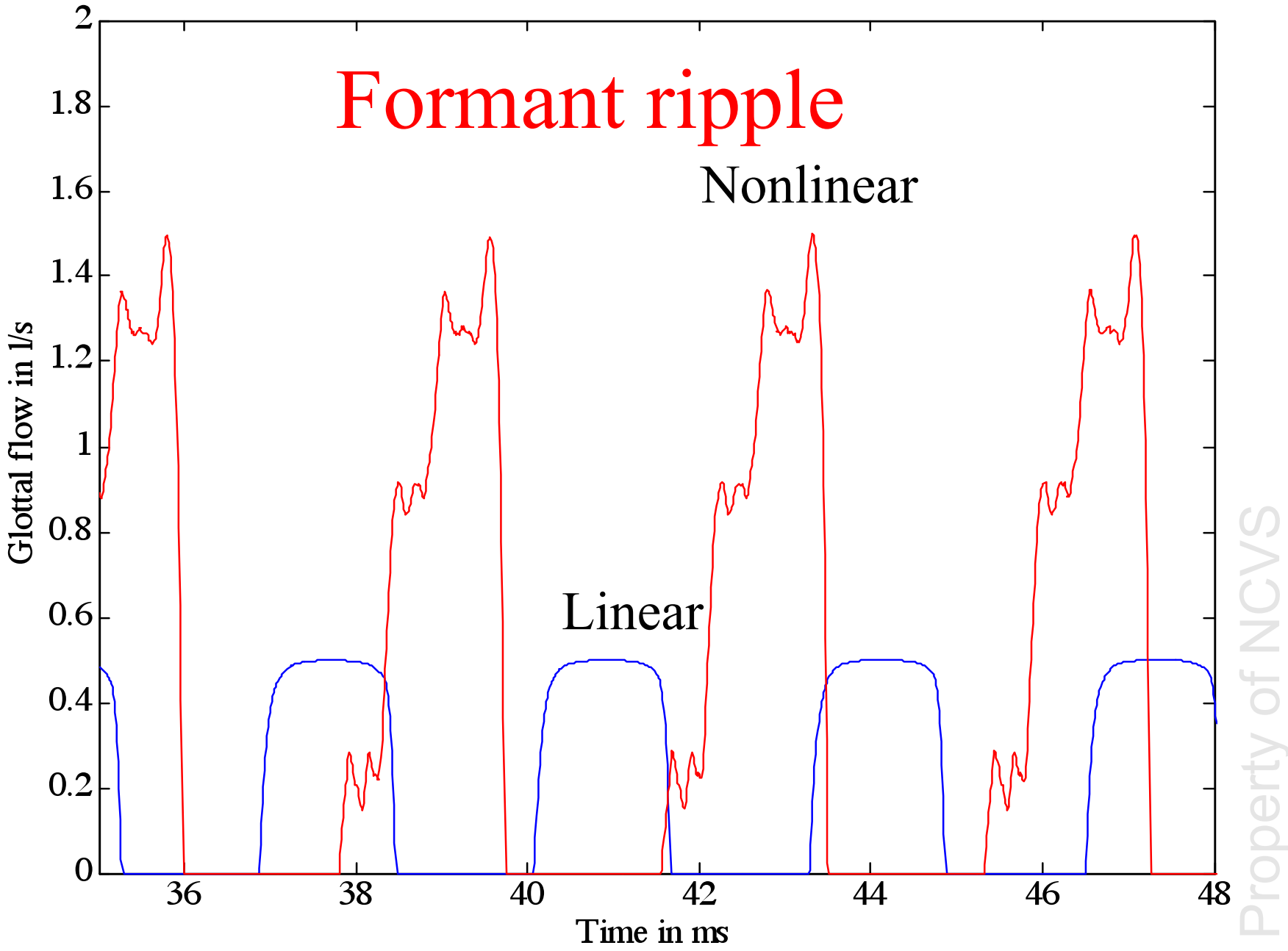

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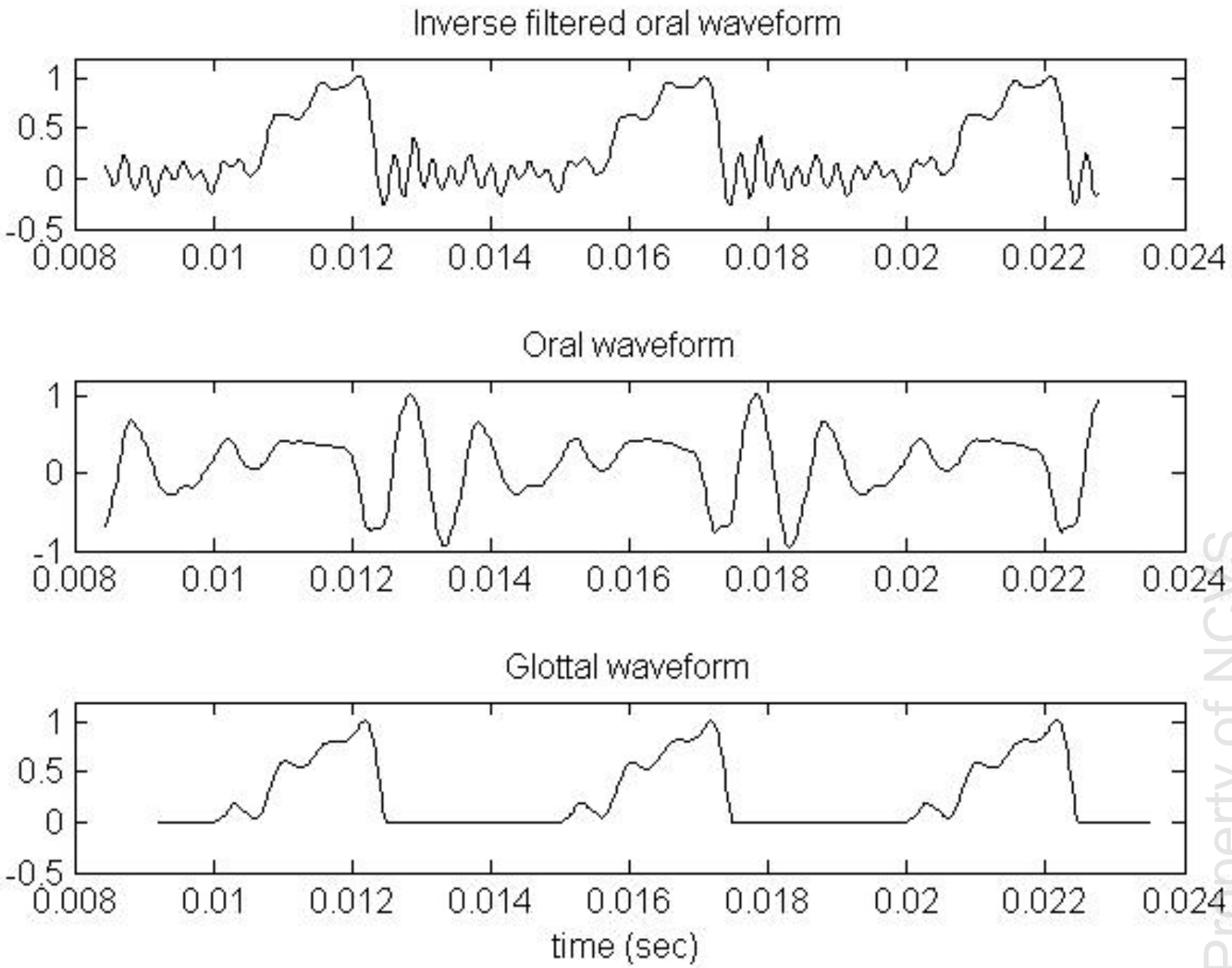


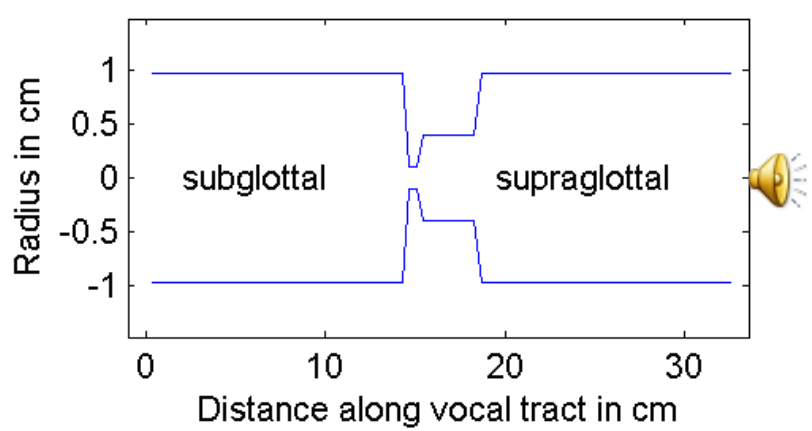
Property of NCVS

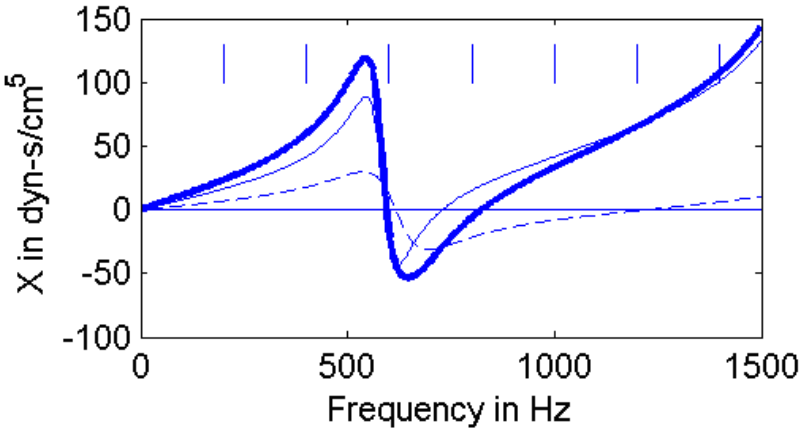
An amazing possibility:

- The entire glottal source spectrum of frequencies can possibly be created without vocal fold collision
- Strong source-filter interaction is needed to do this

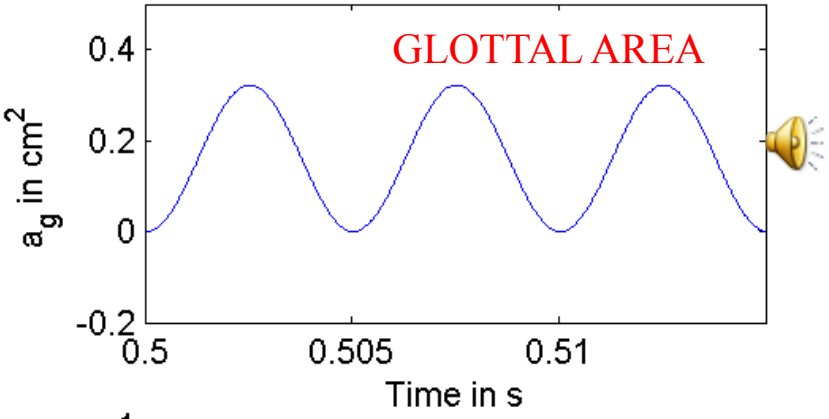
Property of NCVS

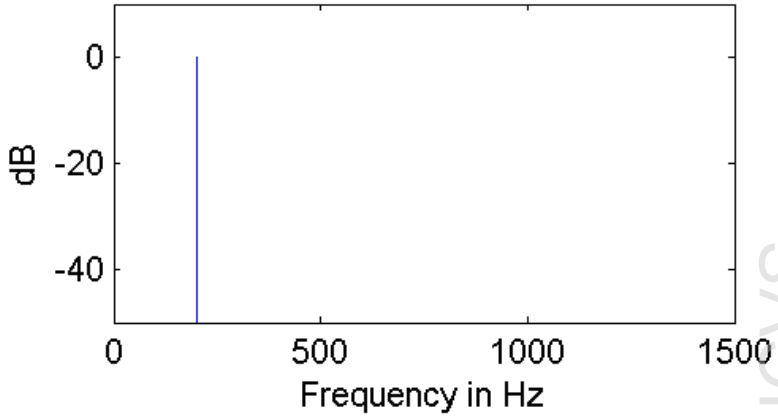
REACTANCE



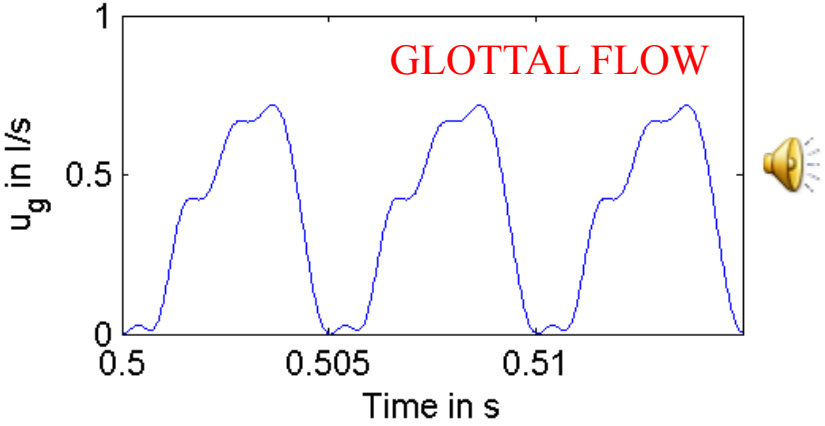


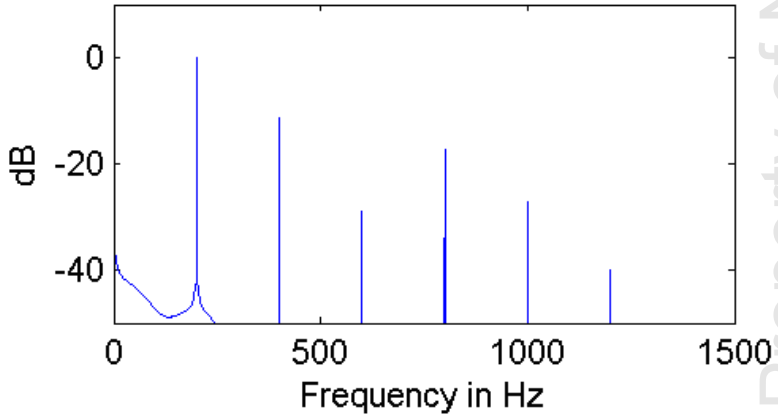
GLOTTAL AREA





GLOTTAL FLOW





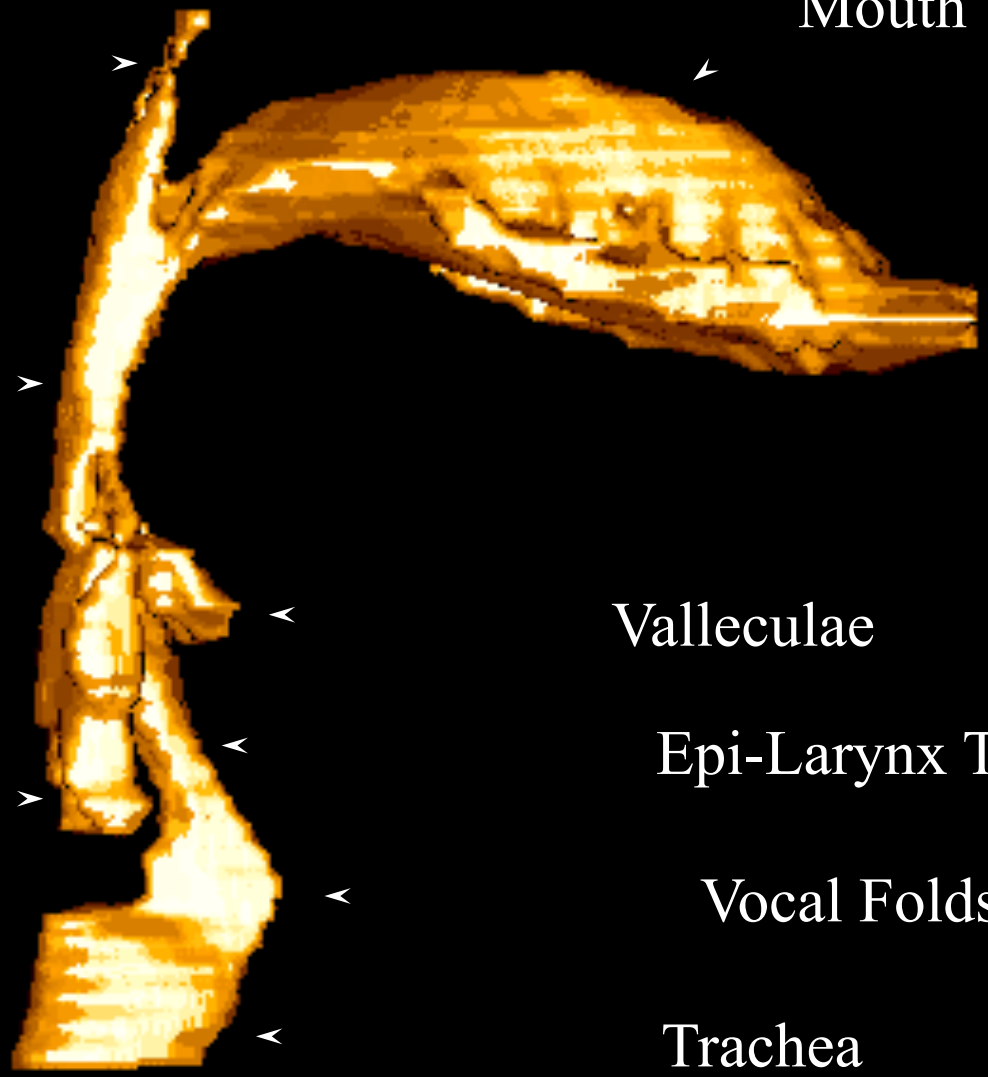
Property of NCVS

The epilarynx tube diameter largely determines the degree of nonlinear source-filter interaction

Property of NCVS

Property of NCVS

Vowel /*a*/ as in "hot" - *male*



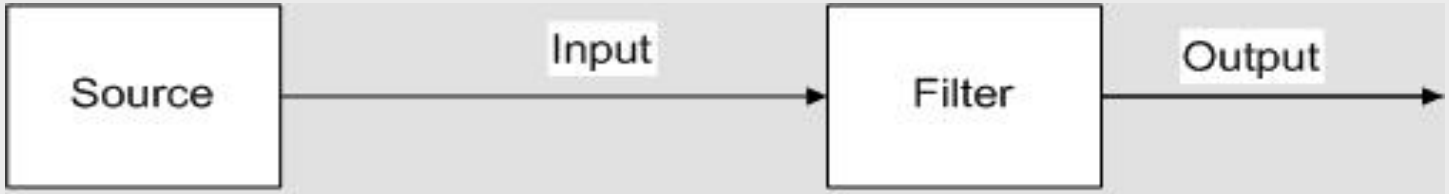
Property of NCVS

Level 2 interaction

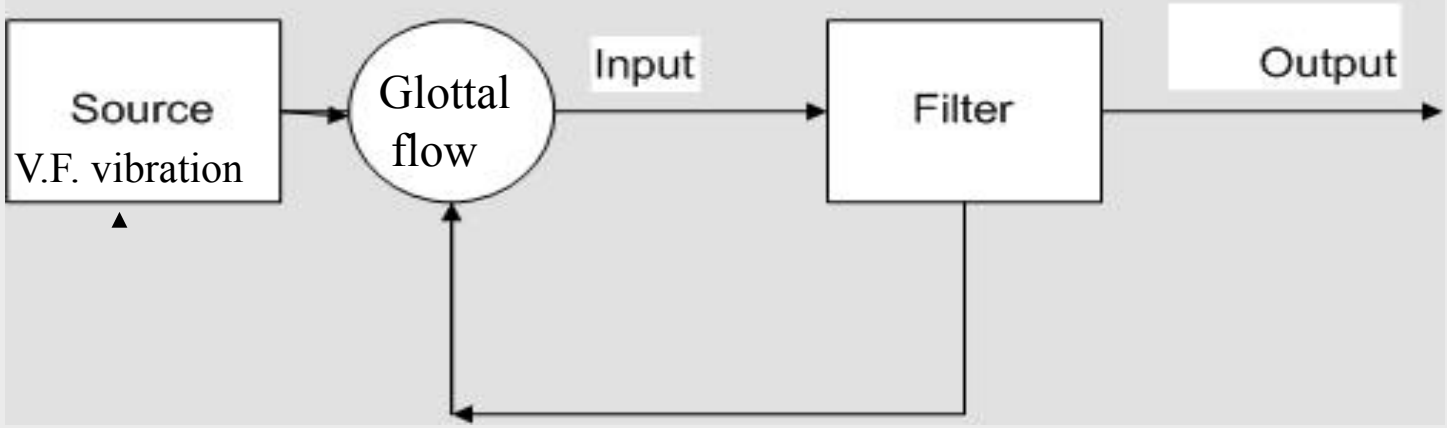
(acoustic pressures help drive the vocal folds)

Property of NCVS

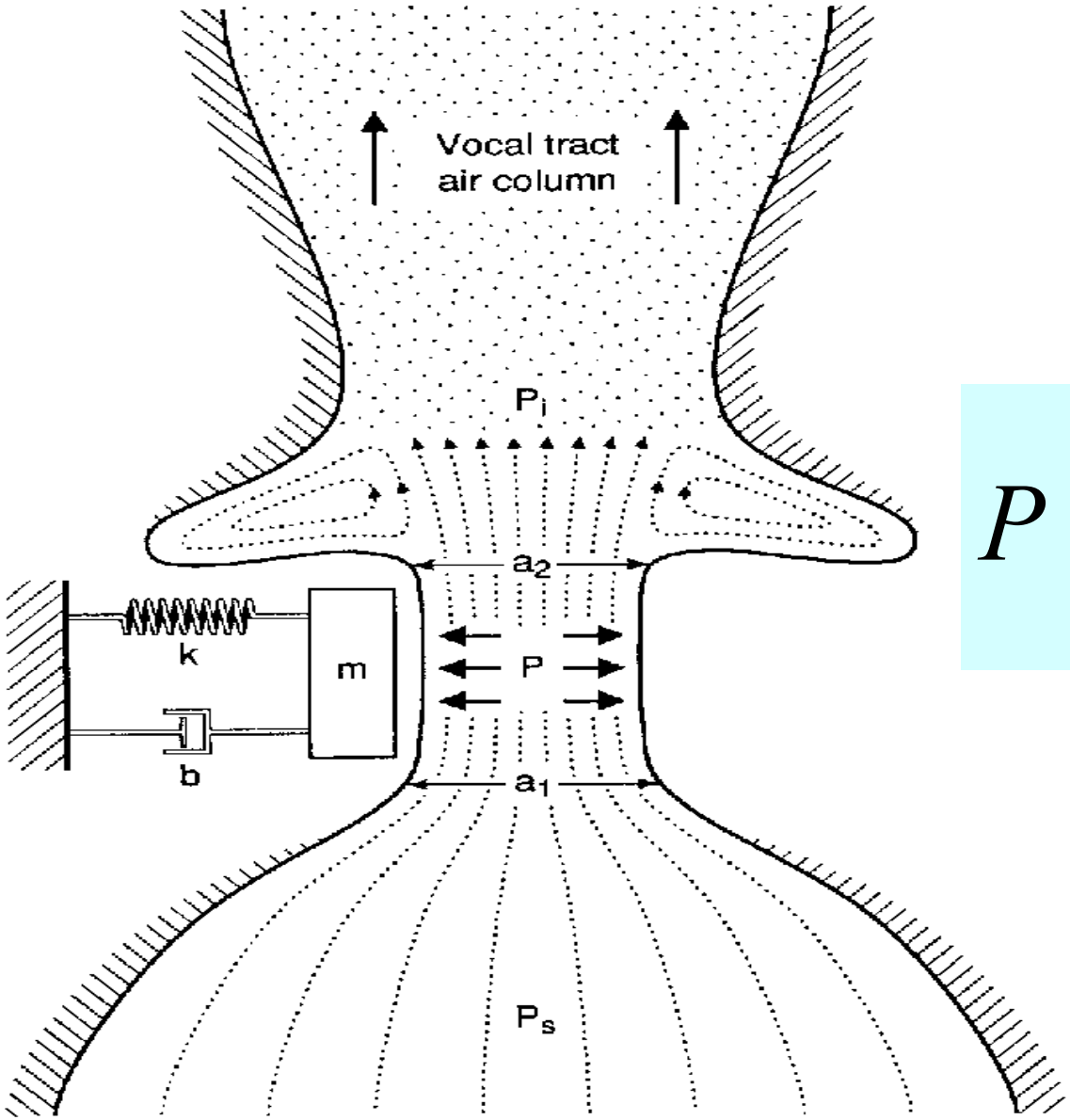
Linear Source-Filter Acoustics



Level 2 Source-Filter Interaction



Property of NCVS



$$P = I \frac{dU}{dt}$$

Property of NCVS

Pitch glides in which vocal fold vibration is destabilized by crossing formants (Level 2 interaction)

Property of NCVS

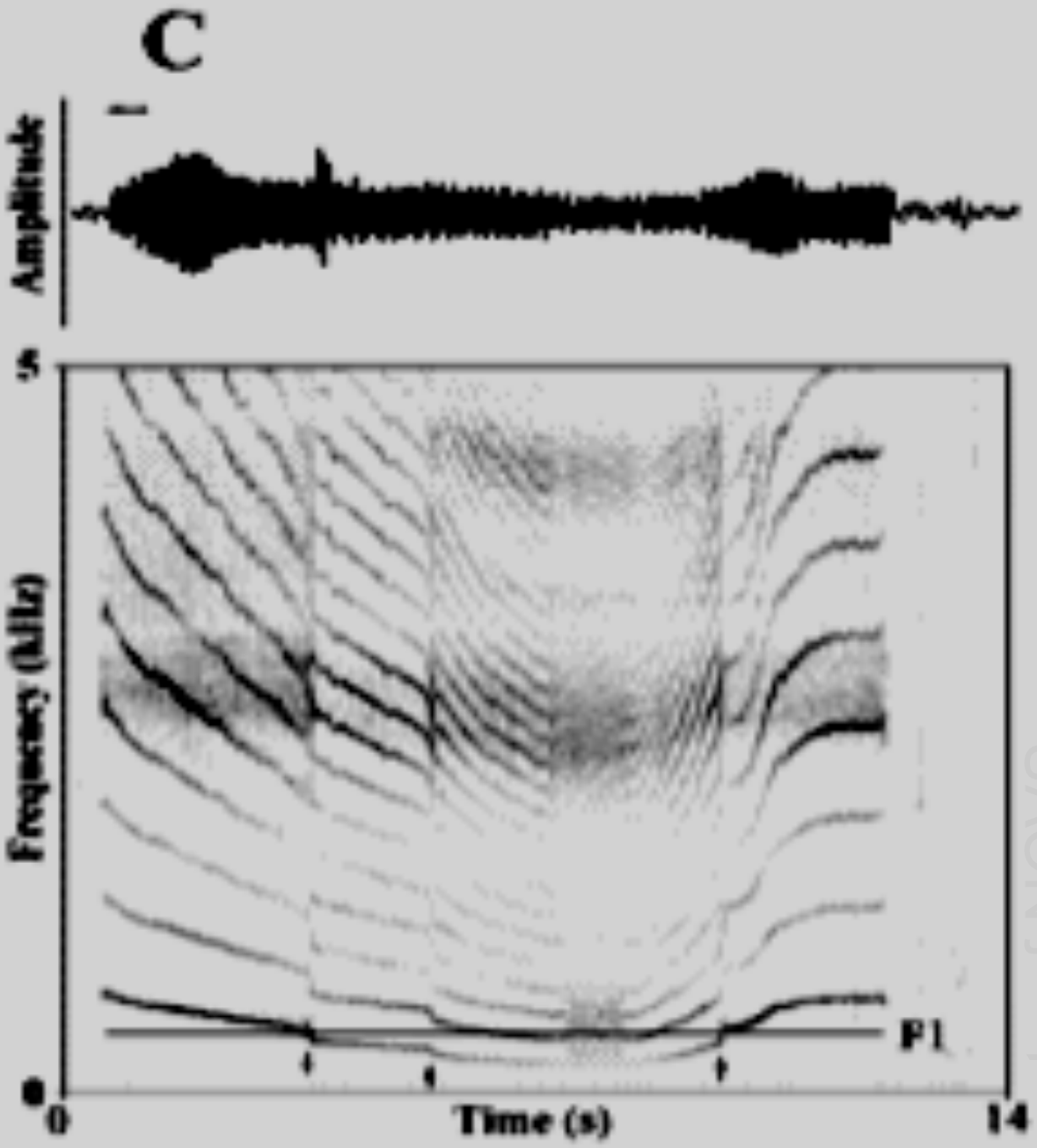
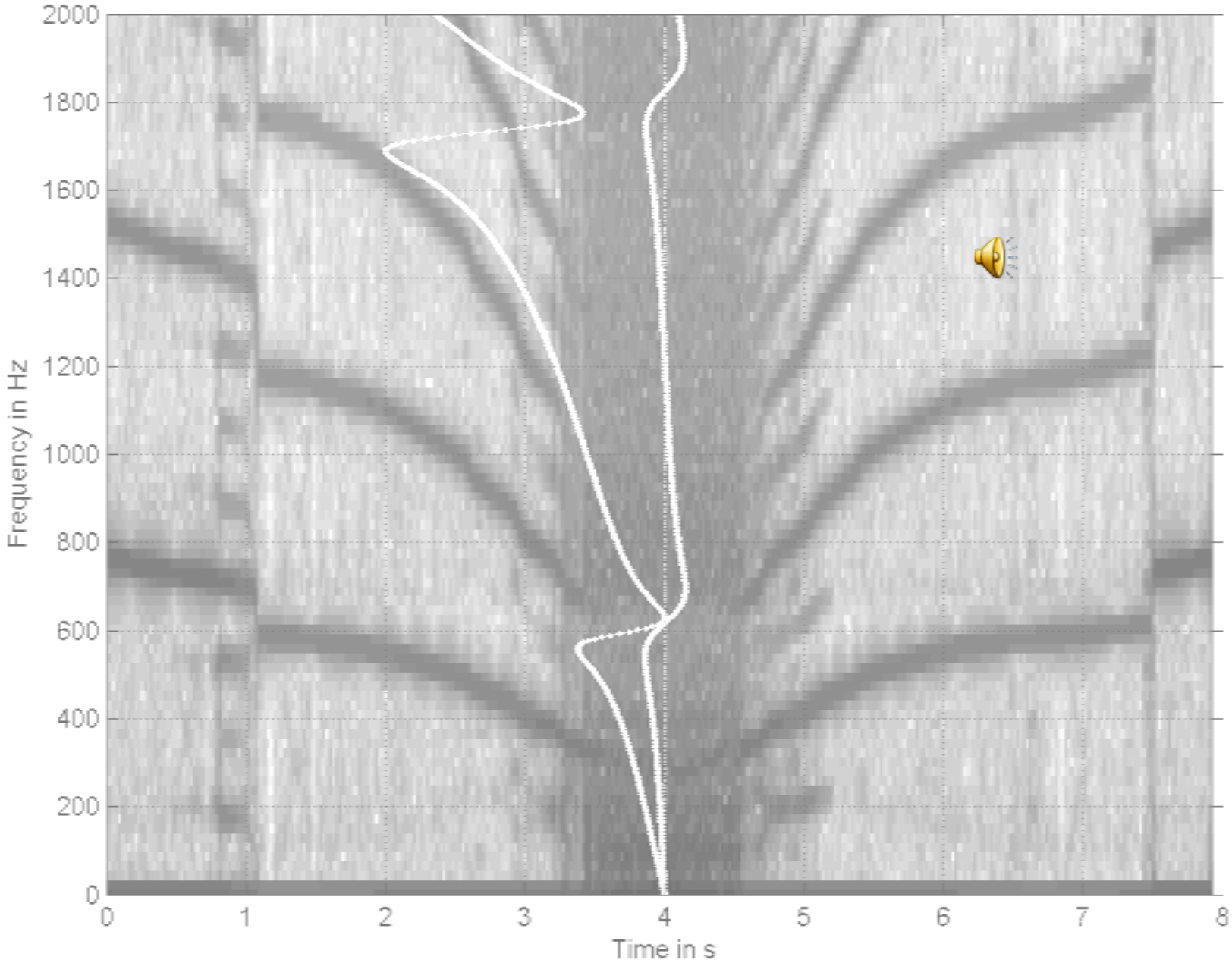


Fig 4.

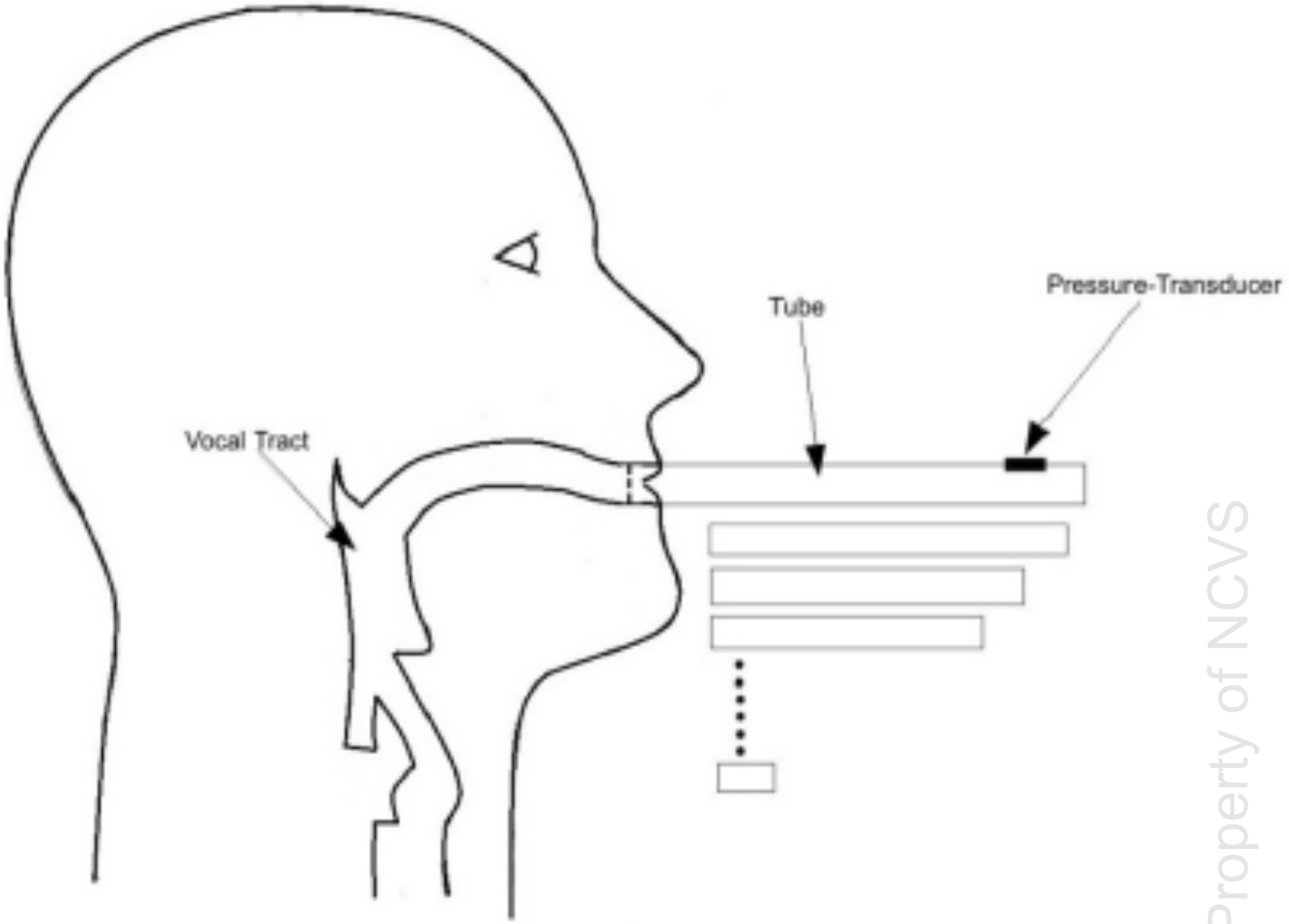
Property of NCVS

*Fo glides simulated with a high-dimensional point-mass model (7*5*5=175 masses) with and without vocal tract interaction*

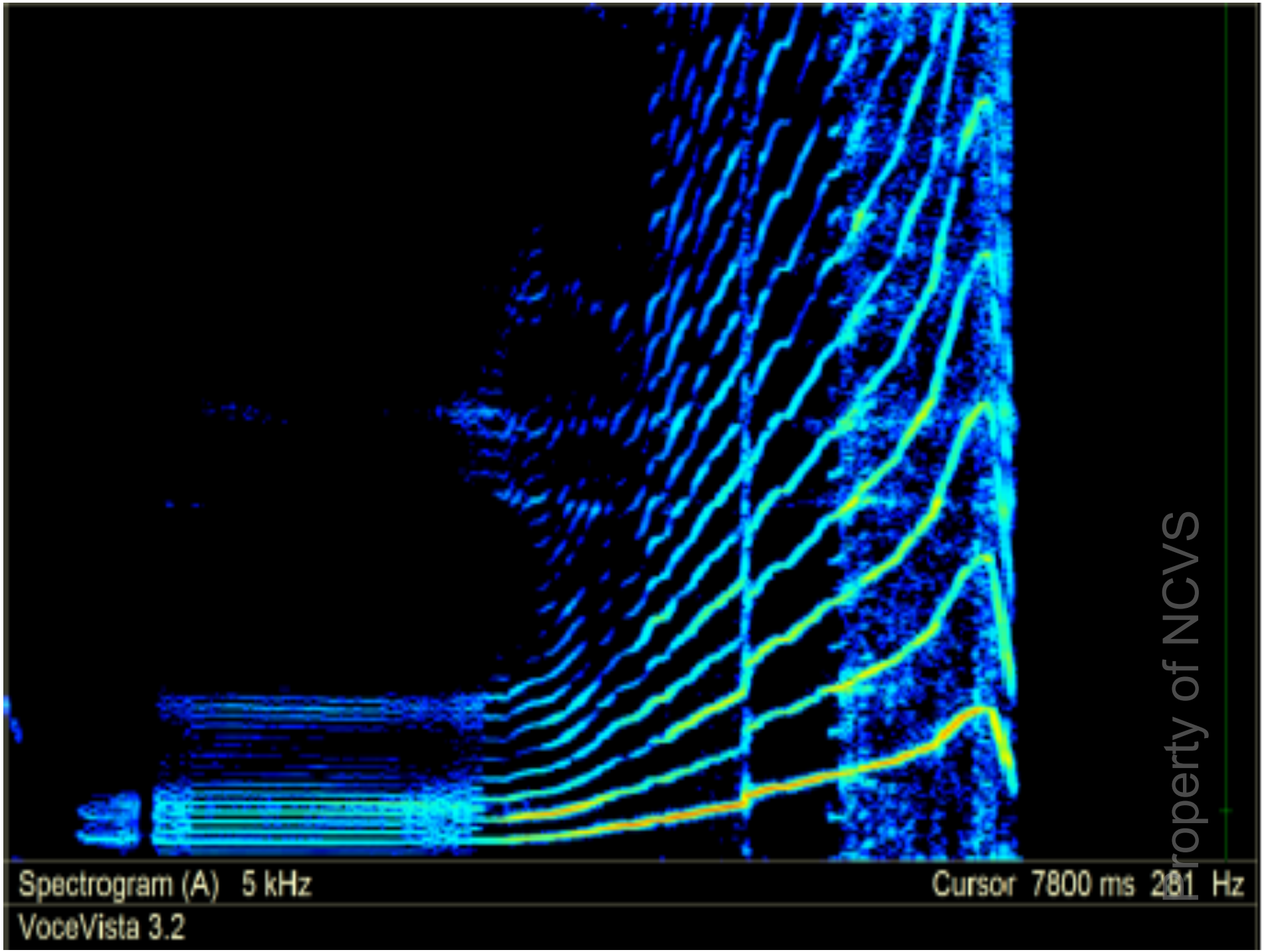
Property of NCVS

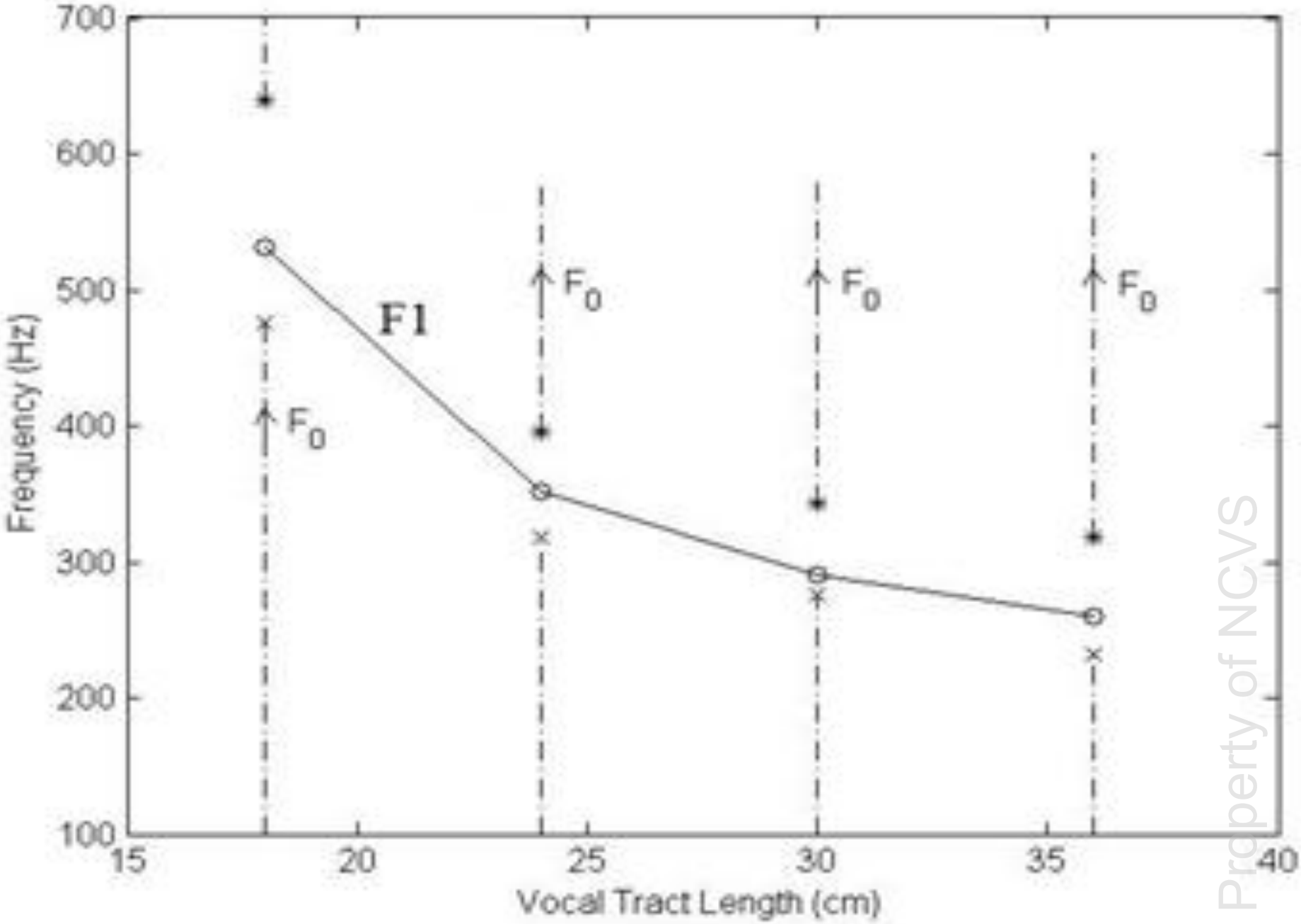


Property of NCVS



Property of NCVS


Spectrogram (A) 5 kHz
Cursor 7800 ms 281 Hz
VoceVista 3.2
Property of NCVS

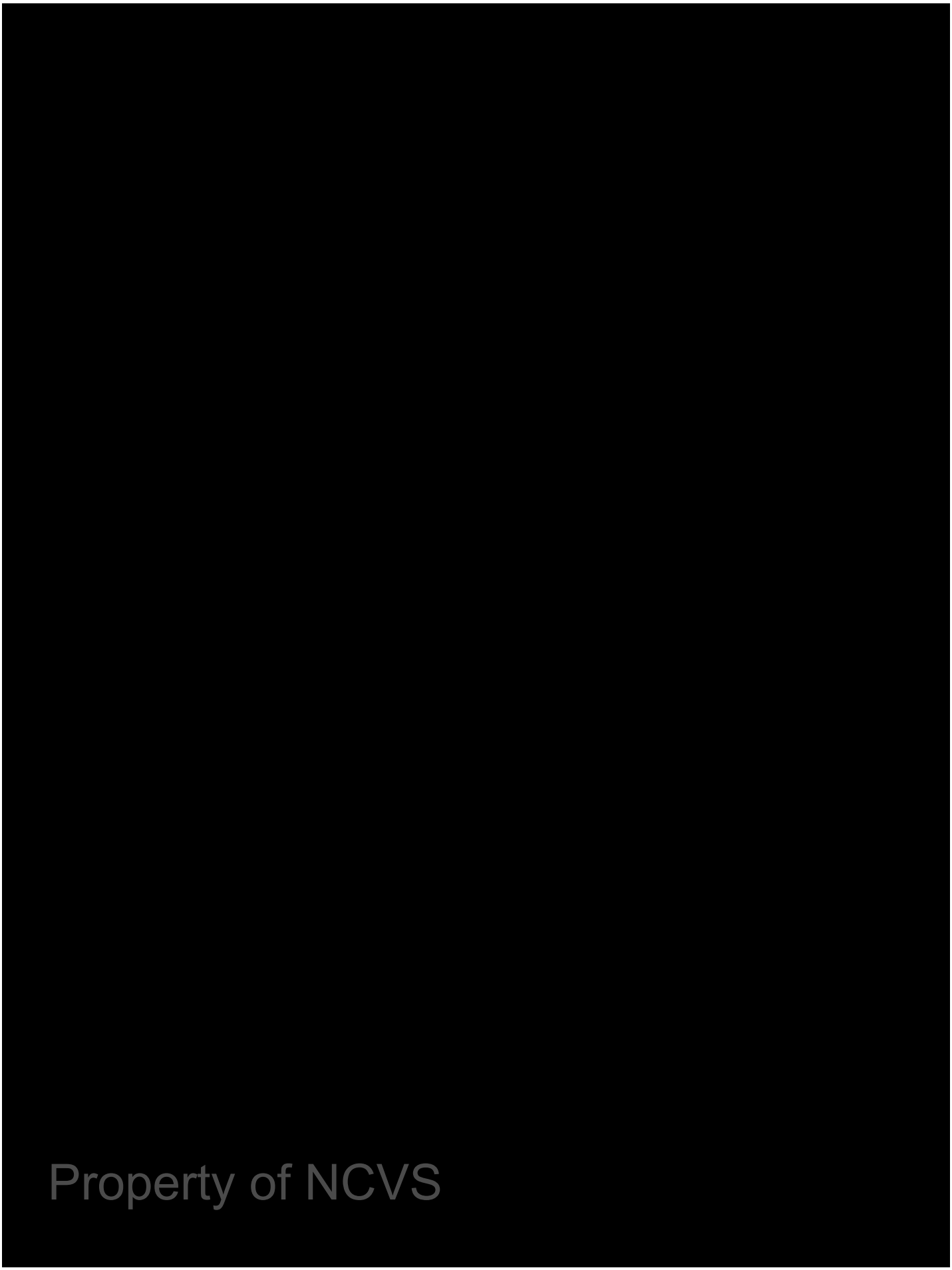


Property of NCVS

Bifurcations are observed in human phonation, animal vocalization, and simulation models when a high-energy harmonic is within 1-2 bandwidths of a low formant (F1 or F2)

- Sudden pitch jumps
- Subharmonic frequencies
- Aphonic segments
- Chaotic regimes

Property of NCVS


Property of NCVS

Vocal tract shapes for singing styles

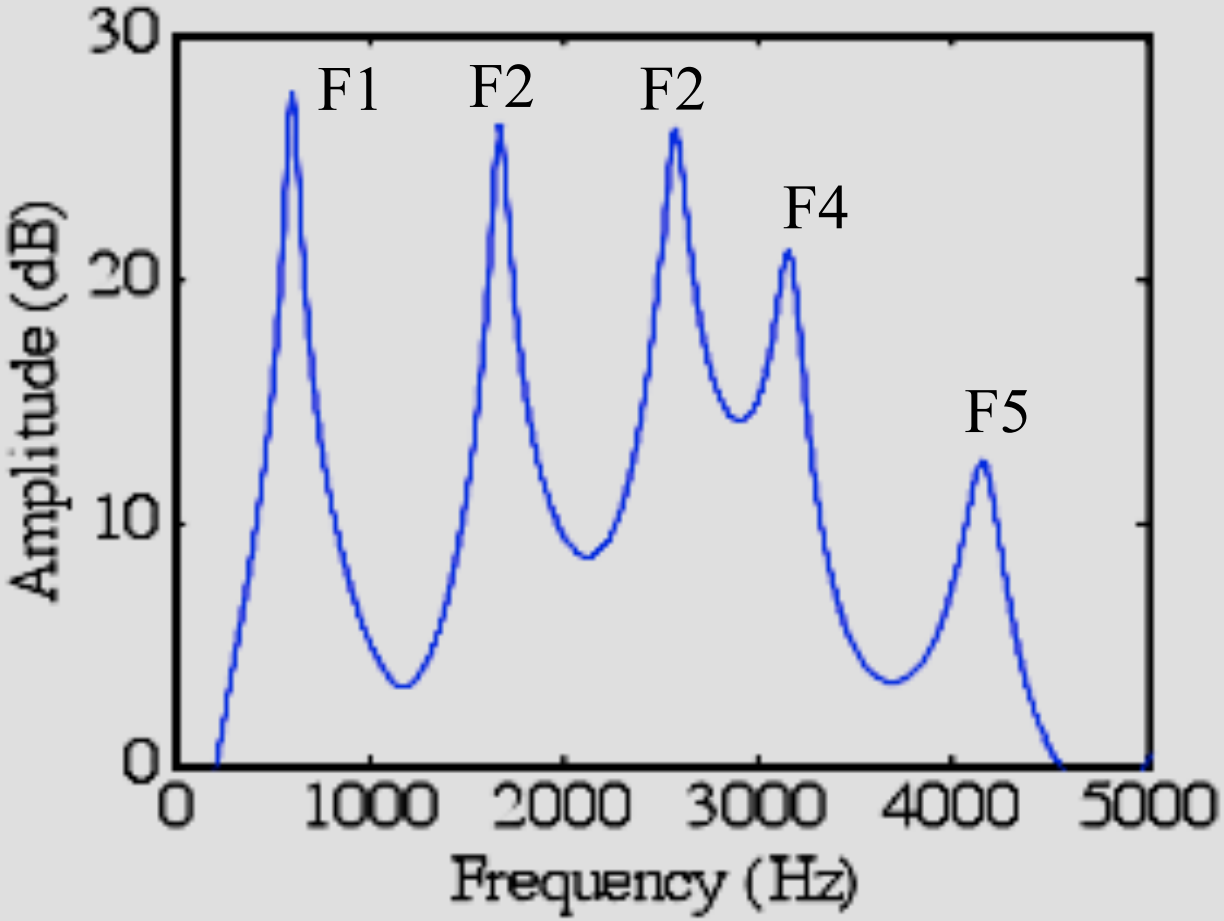
(Pitch-Vowel interaction)
or
(Source vocal tract interaction)

Property of NCVS

Wind instruments with long tubes or horns can reinforce many harmonics of the source by “tuning” horn resonances to the harmonics

Property of NCVS

Long Tube



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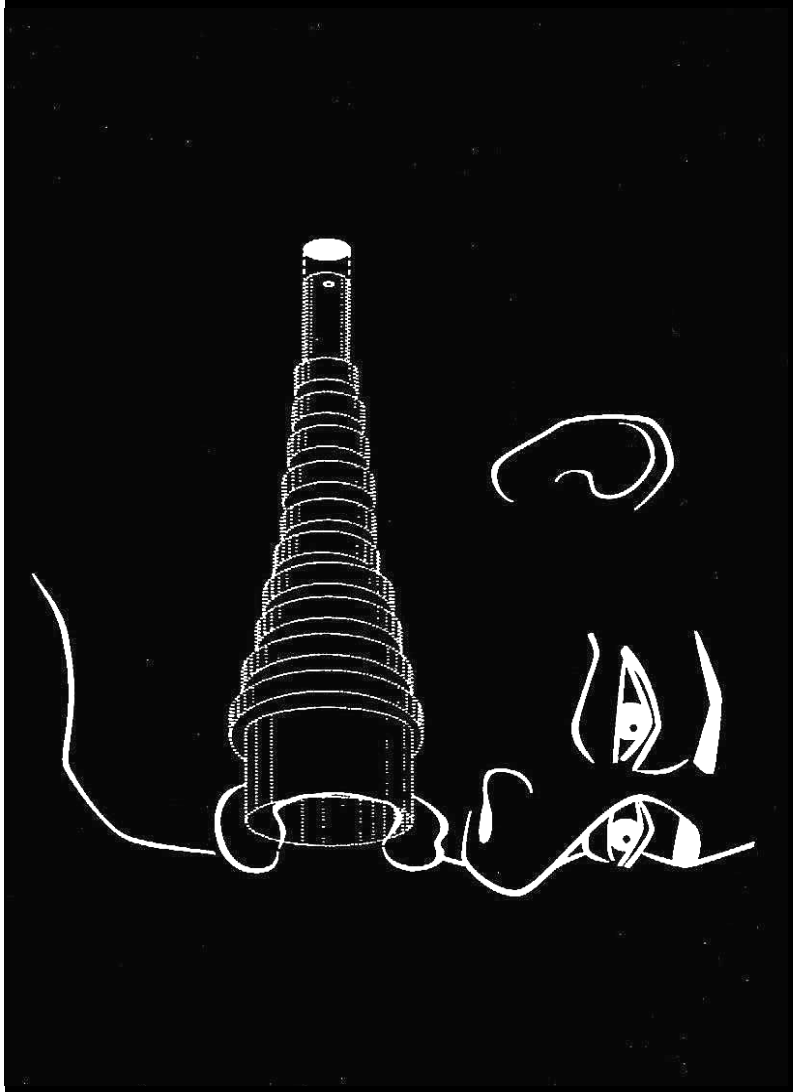
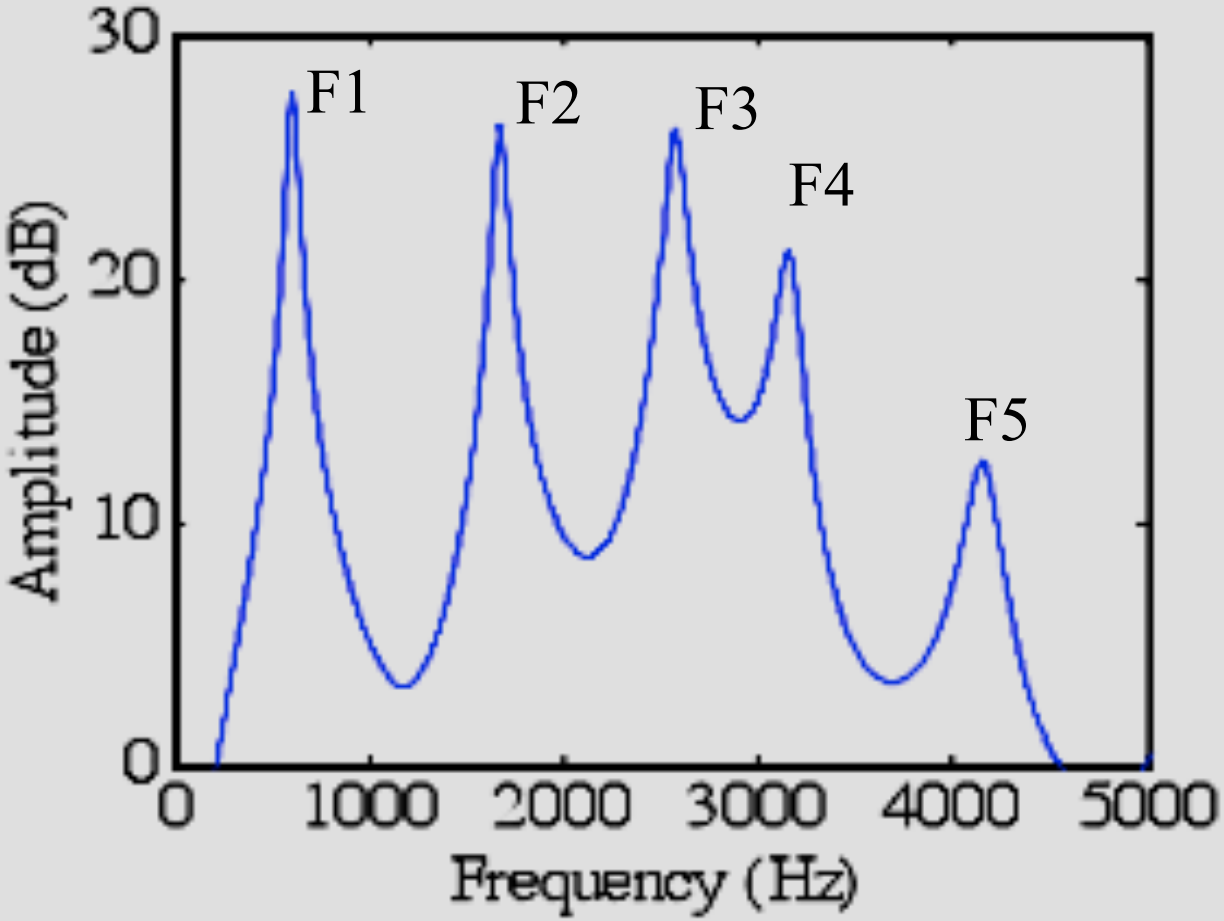


Property of NCVS

With a short and variable vocal tract, different “resonance” strategies need to be sought

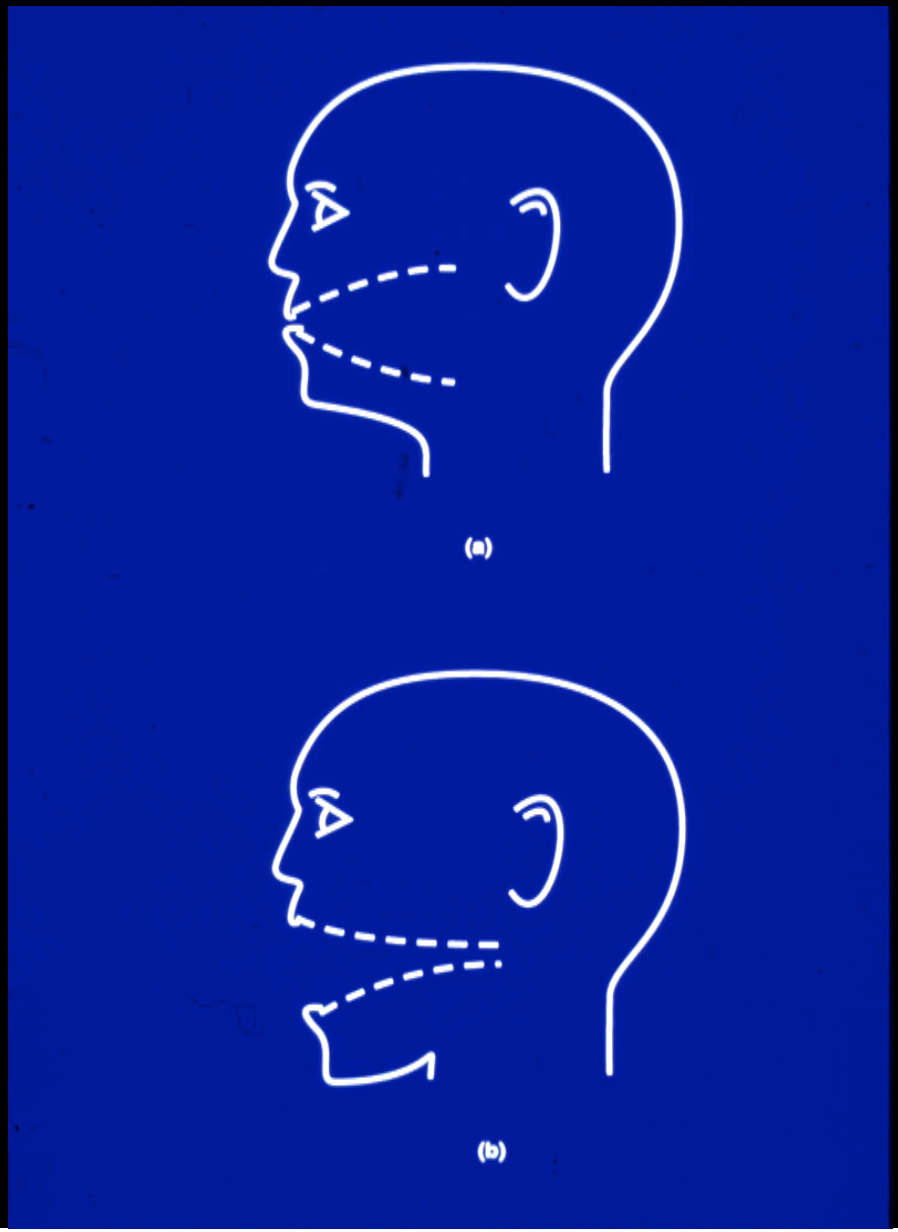
Property of NCVS

- Short Tube



Property of NCVS

Two basic vocal tract shapes:



- The inverted megaphone mouth shape

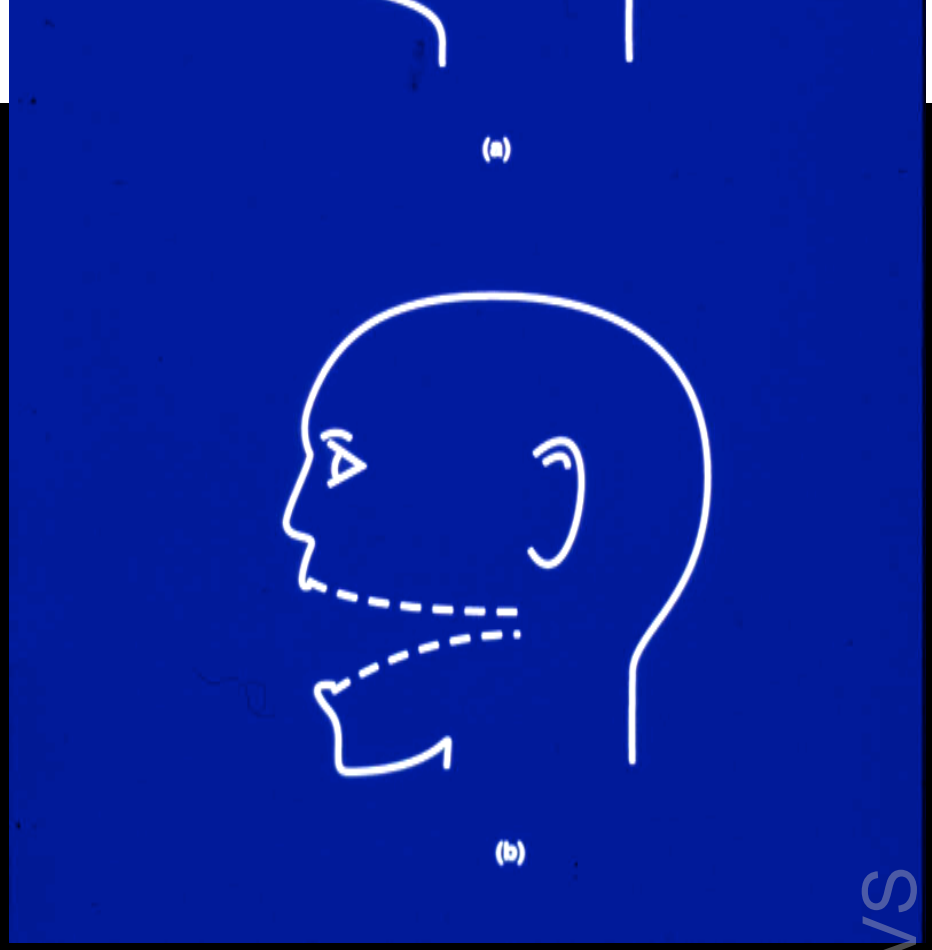
- The megaphone mouth shape

Property of NCVS

The vocal tract has acoustic *reactance* that can help or hinder vocal fold vibration

Property of NCVS

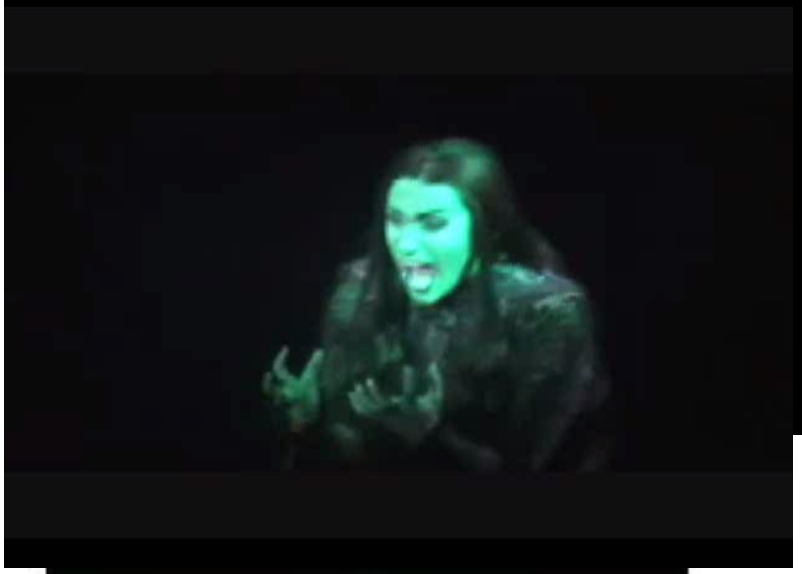
Singing with a megaphone mouth shape helps the modal register, female belt, and high-pitched coloratura



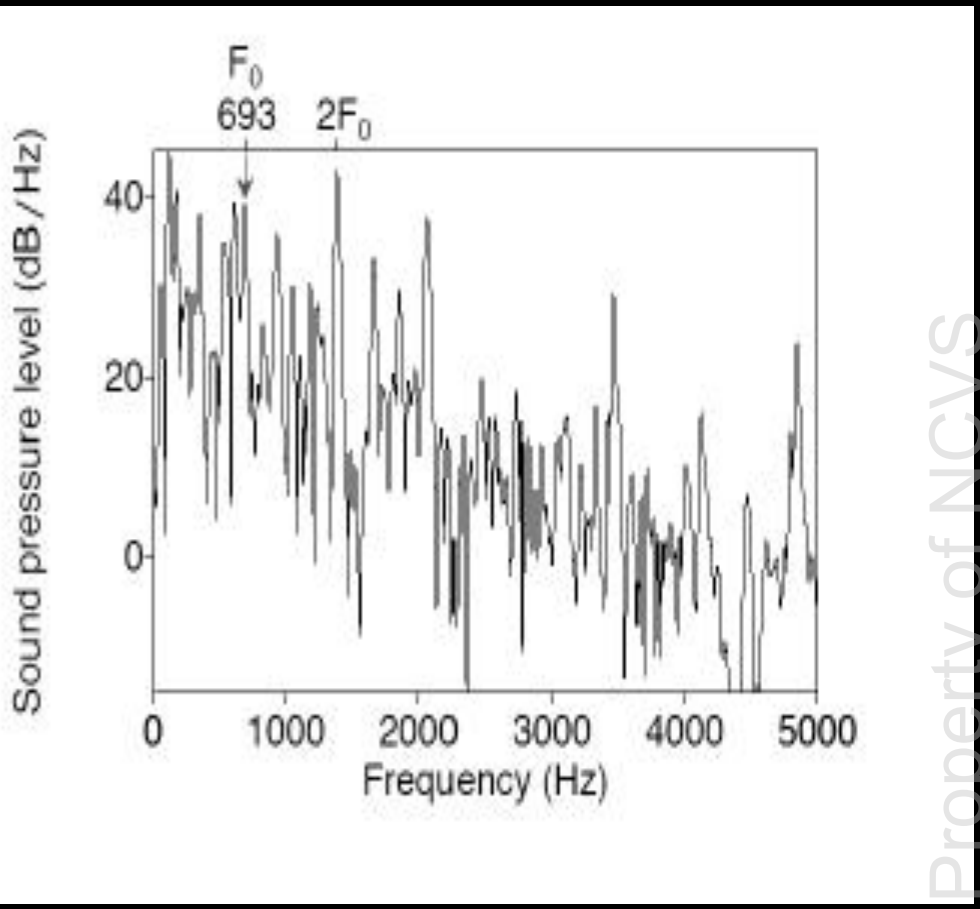
Property of NCVS

Musical theatre belters around D5-F5

Property of NCVS

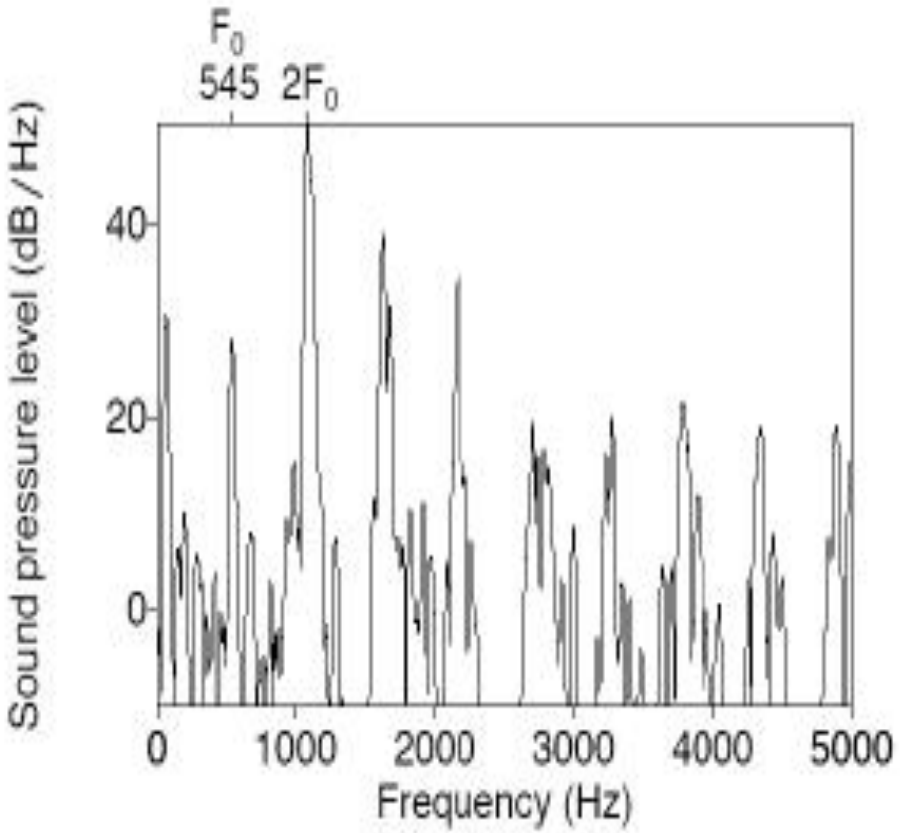


Espinosa



Property of NCVS

Menzel



Property of NCVS

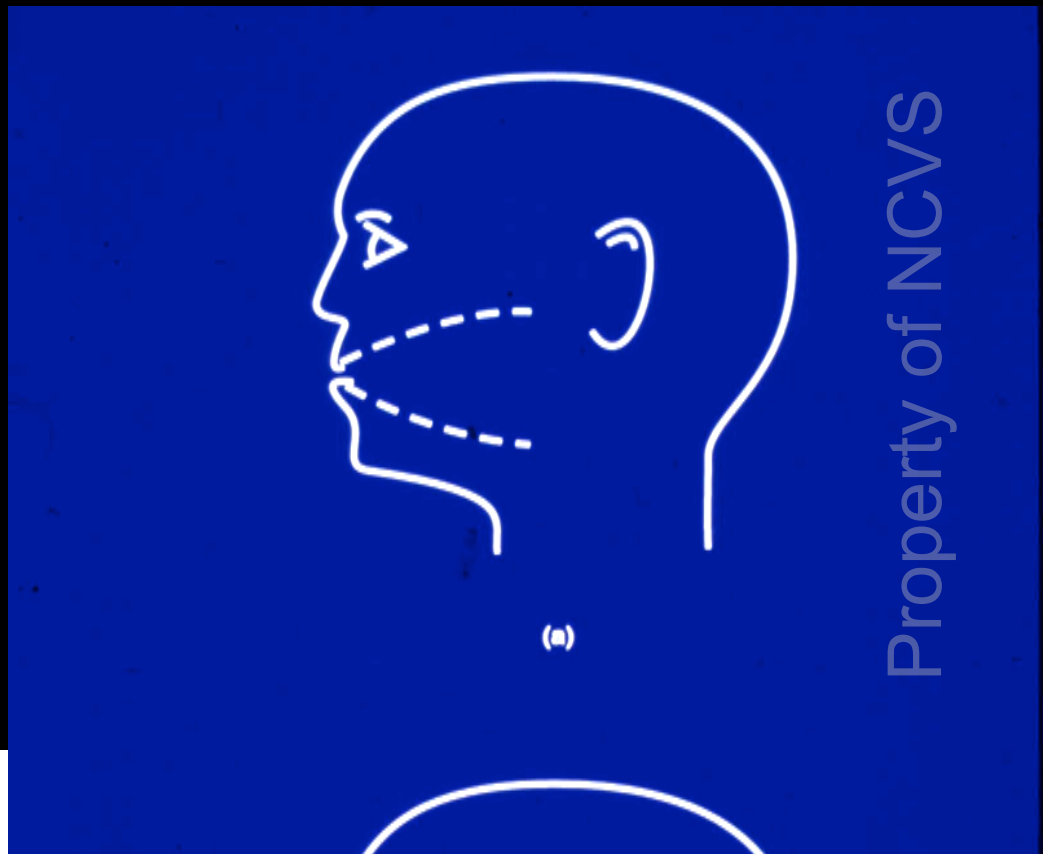
Theatre belt vowels

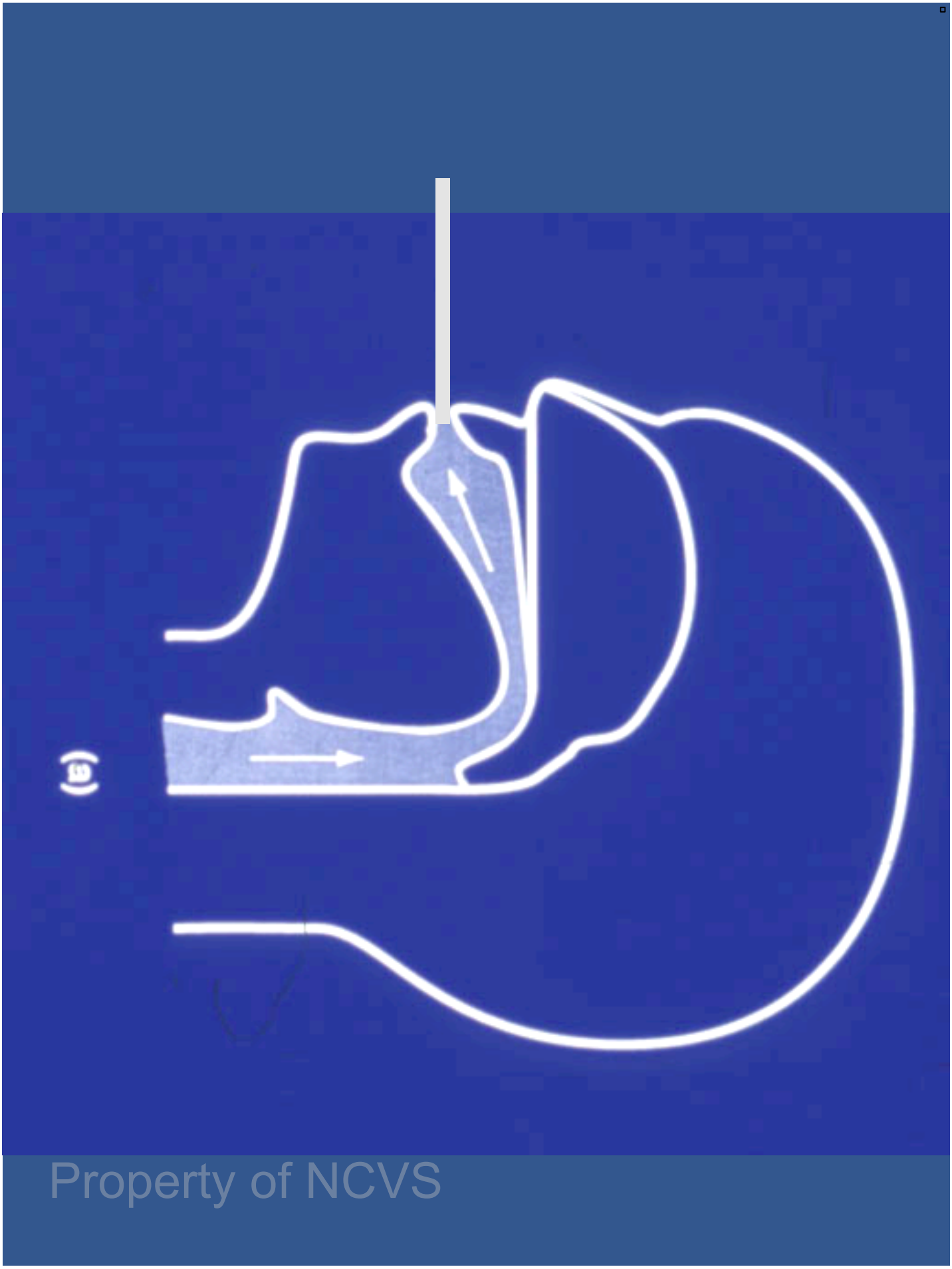
- Up to E5, belting is done on bright vowels such as /a/ and /ae/. These vowels have a high first formant frequency, allowing the second harmonic to stay below it. The mouth is wide open and the corners of the mouth are spread and retracted

Property of NCVS

Singing with an inverted megaphone mouth helps to establish moderate adduction in the mixed register (medium high female and high male)

It is trainable with semi-occluded vocal tract techniques



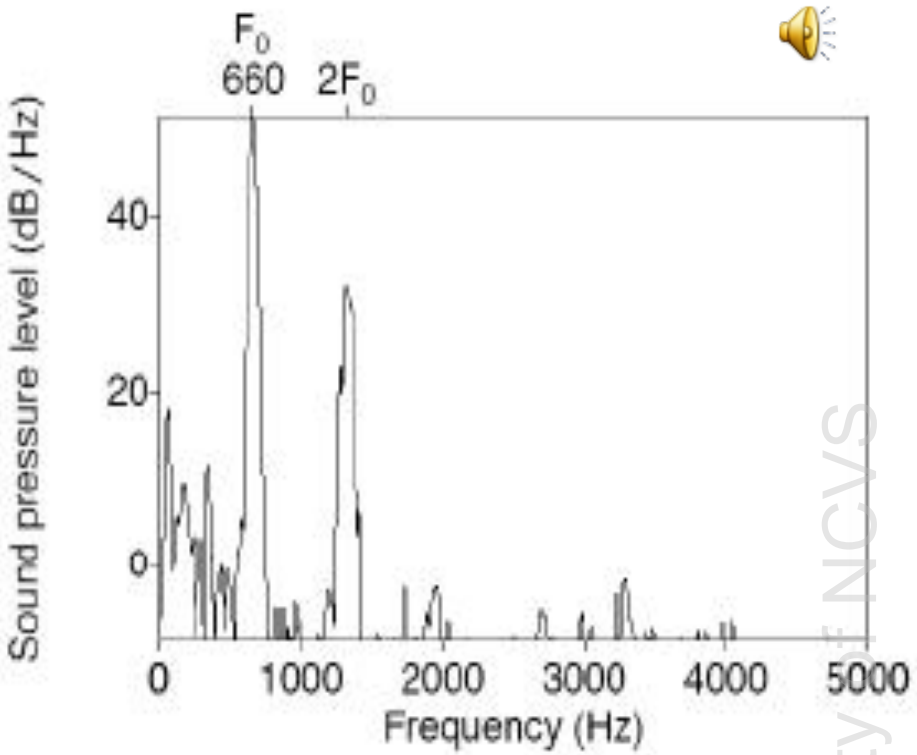


Property of NCVS

Classical singers on about the same pitch as the belters (around D5)

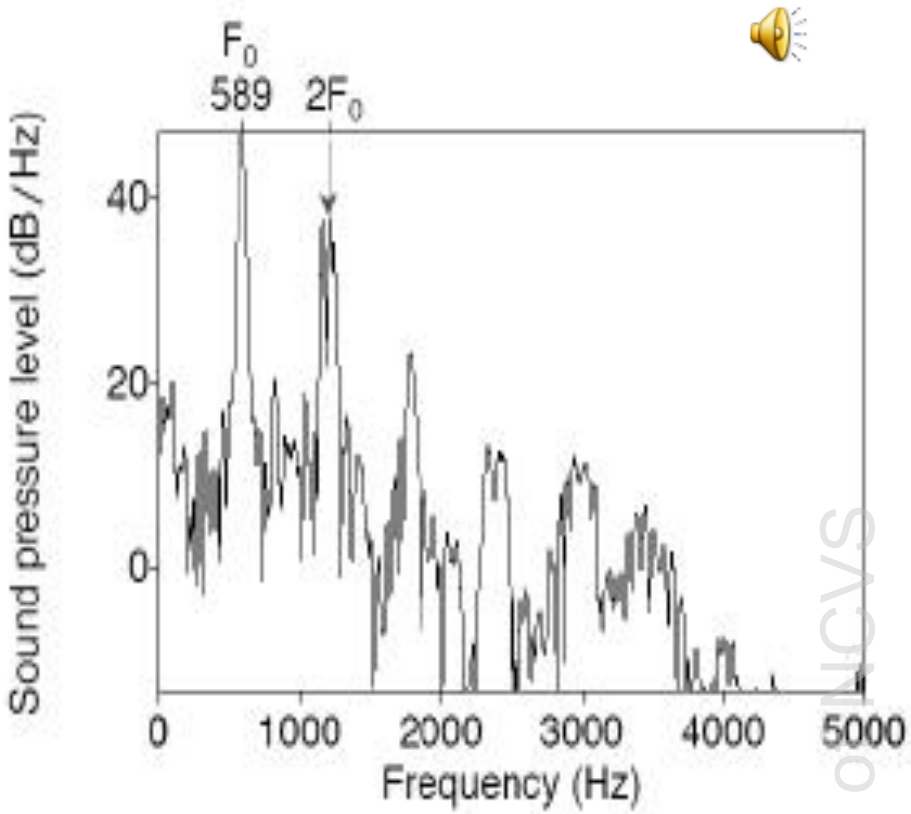
Property of NCVS

Dessay



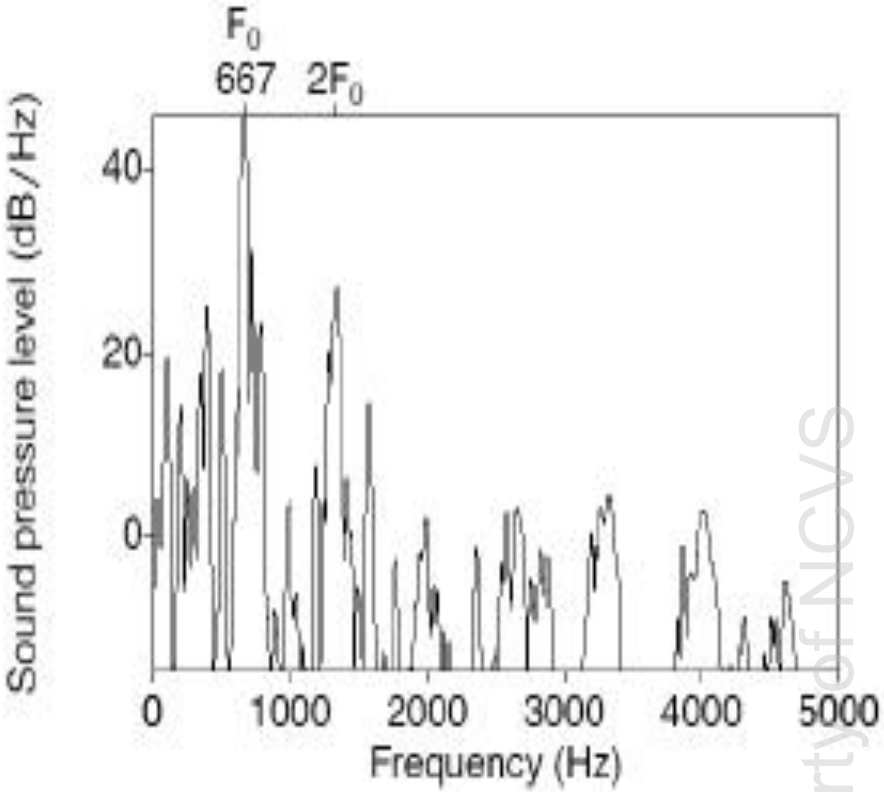
Property of NCVS

Fleming



Property of NCVS

Sutherland



Property of NCVS

Opera vowels:

- Up to E5, opera is done on darker vowels such as /U/ and /o/. These vowels have a low first formant frequency, allowing the second harmonic to lift over it. The mouth is less open, and the lips are sometimes rounded or protruded.

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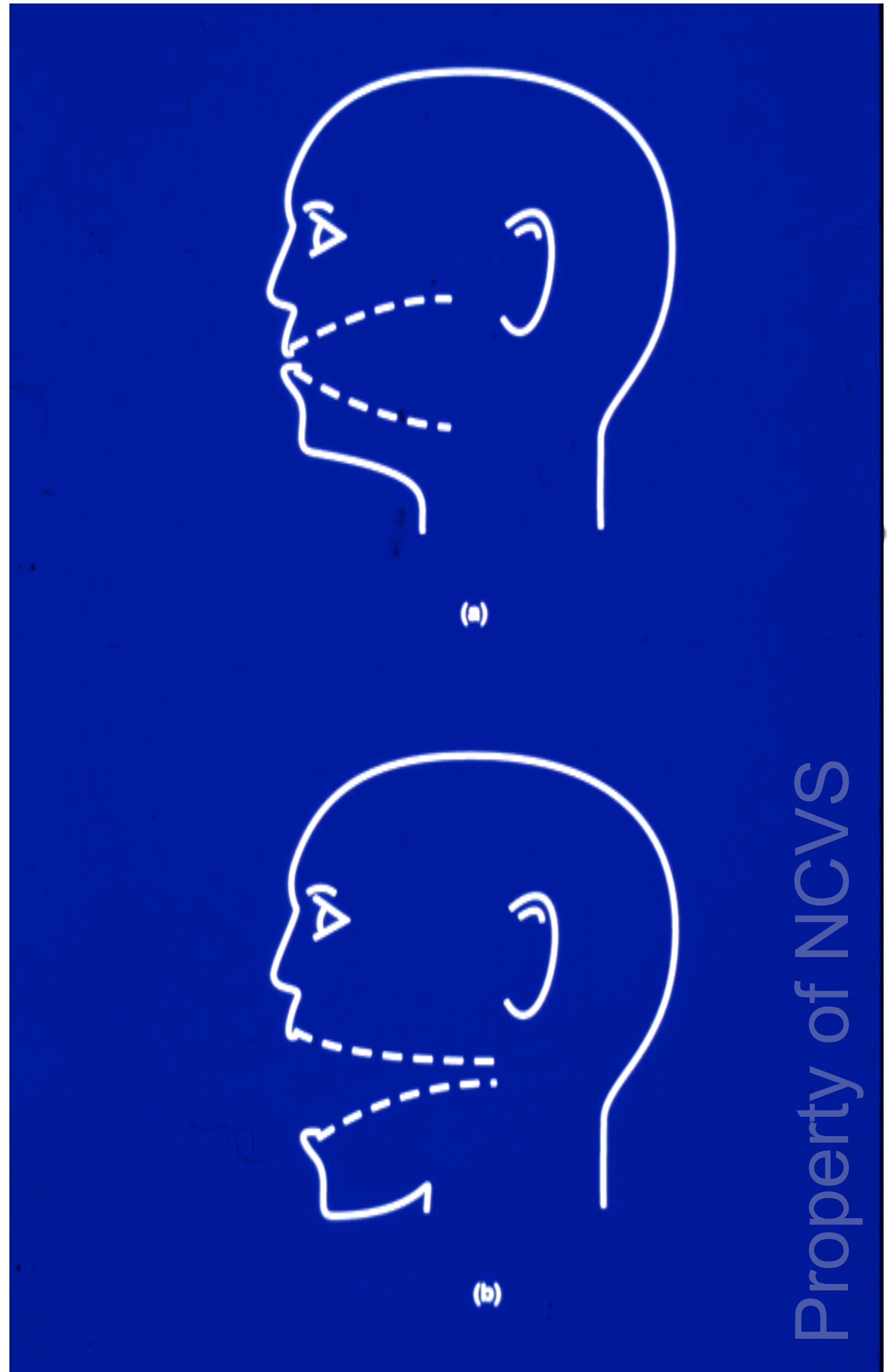
Do males do the same thing in this pitch range?

Property of NCVS

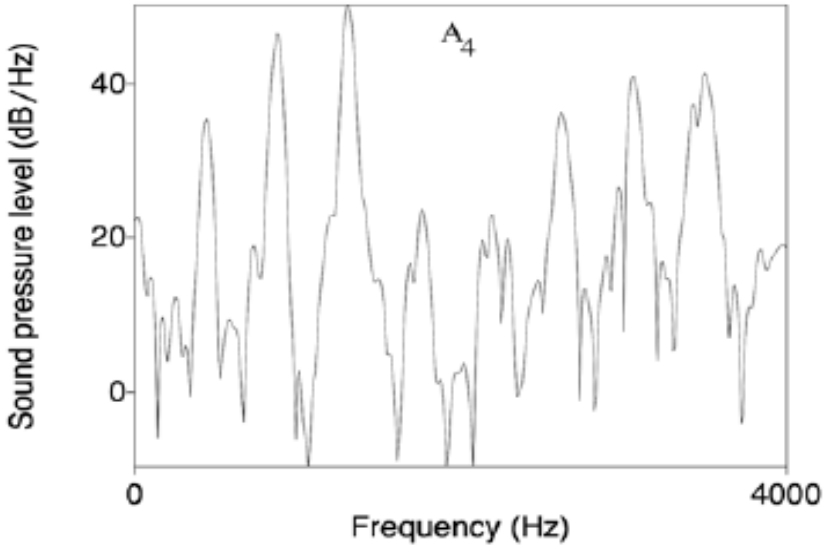
(a)

(c)



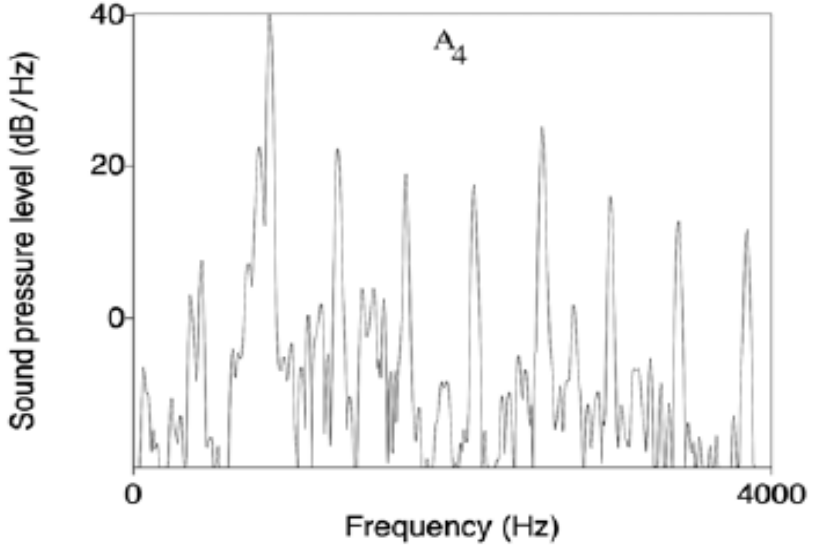
Property of NCVS

(a)



(b)

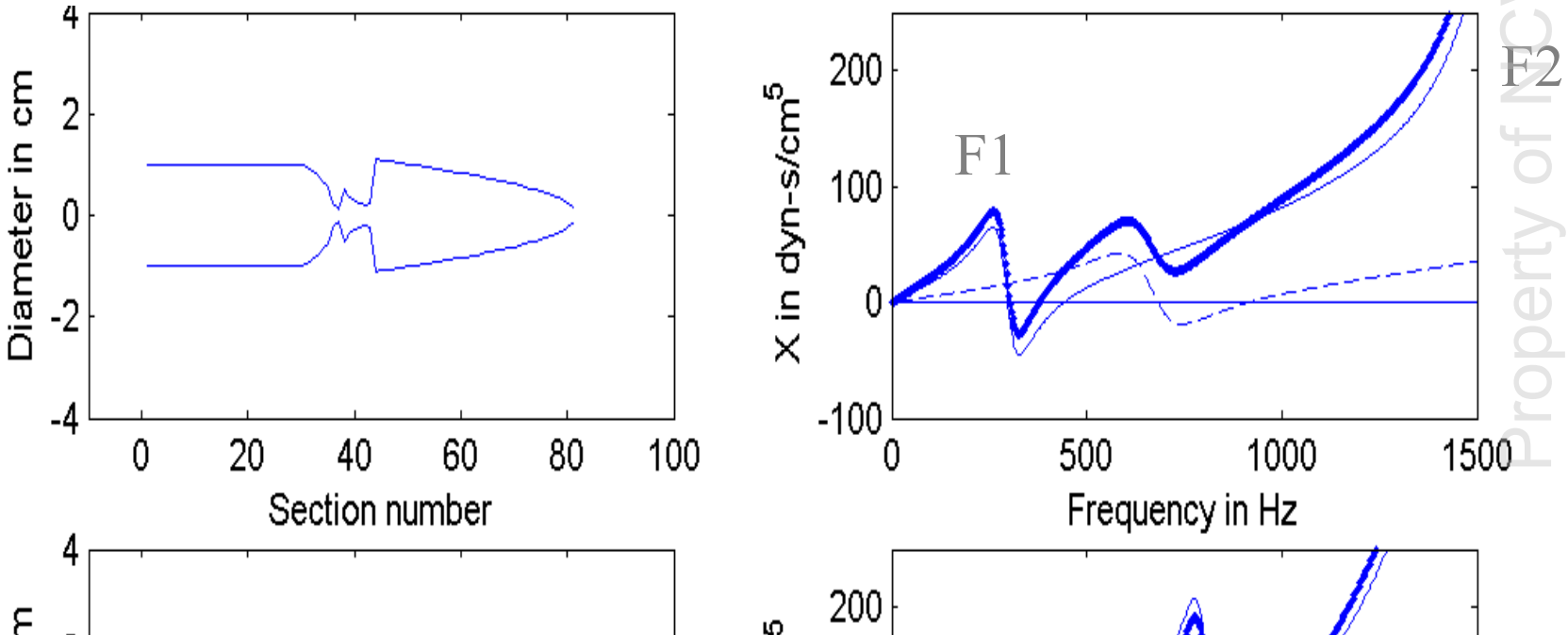
(c)



(d)

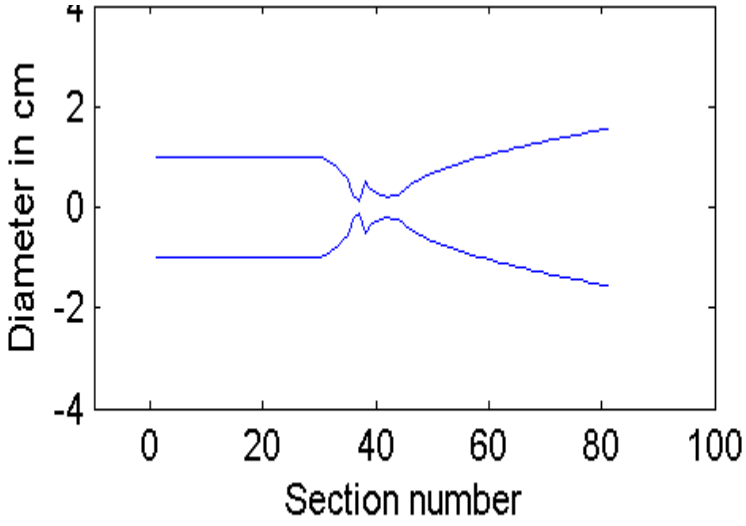
Property of NCVS

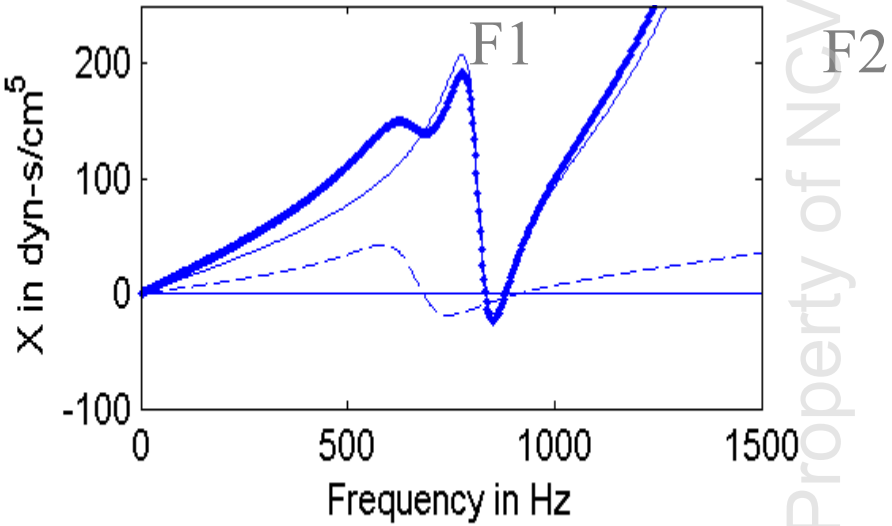
Male and female mixed register



Property of NCVS

Males and female belters





Property of NCVS

Conclusions

Property of NCVS

Source-filter interaction:

- Can make the system more efficient (source harmonics can be enhanced by the filter)
- Can create more spectral variety (vocal color with distortion frequencies, subharmonics, or chaotic vibration)
- Can also create more instability (feedback always creates a potential for instability)

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The End

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