Multiple tube vowels

2. Constrictions and multiple tubes:

A schwa is the only vowel that can be modeled as a simple tube closed at one end.

Some vowels such as /a/ with a pharyngeal constriction can be modeled as 2 tubes that are closed at one end: a back cavity, and a front cavity.

Most vowels involve a relatively narrow constriction at some point along the vocal tract with a back cavity and a front cavity on either side of the constriction. For these vowels the front cavity is a tube closed at one end, the back cavity is a tube closed at both ends, the narrow constriction together with the back cavity act as a Helmholtz resonator. In Helmholtz resonators the column of air in the constriction acts like a piston that moves back and forth in the constriction.

2. Tubes and their resonances: There are three types of tubes used to model the vocal tract: tube closed at both ends, tube closed at one end, Helmholtz resonator

A tube closed at one end is a quarter wave resonator: the lowest frequency standing wave that will excite it has a wavelength that is 4 times as long as the tube. Higher formants (F_n) are odd number multiples (2n-1) of the first formant (F_1).

\[ F_n = \frac{(2n-1)c}{4L} \]

\( F_n \) = formant, \( c \) = speed of sound, \( L \) = tube length

tube open at one end: \( F_n = \frac{(2n-1)c}{4L} \)

back tube \( F_n = \frac{(2n-1)c}{4L_b} \)  front tube \( F_n = \frac{(2n-1)c}{4L_f} \)

\[ L_b = L - L_f \]
A tube closed at both ends is a half wave resonator: its lowest frequency resonant has a wavelength that is twice as long as the tube. Higher formants (Fn) are whole number multiples of the first formant (F1).

\[ Fn = \frac{nc}{2L} \]

Fn=formant, \(c=\)speed of sound, \(L=\)tube length

A Helmholtz resonator acts like a piston coupled with a back cavity with the air resonating in and out of the constriction.

Helmholtz resonator

\[ F = \frac{c}{2} \sqrt{\frac{Ac}{Ab \times Lb \times Lc}} \]

closed at both ends: \(Fn=nc/2L\)

open at one end: \(Fn=(2n-1)c/4L\)