6.542J, 24.966J, HST.712J LABORATORY ON THE PHYSIOLOGY, ACOUSTICS, AND PERCEPTION OF SPEECH
Fall 2001

Lab 6 *09/25/01*

Formant Frequency Calculations from Area Function Data

References

Stevens, K.N. (1972), *The quantal nature of speech: Evidence from Articulatory-Acoustic data*, in **Human Communication: A Unified View**, E.E. David and P.B. Denes (eds.), New York: McGraw-Hill, 51-66.

Stevens, K.N. (1989), *On the quantal nature of speech*. **J. of Phonetics 17**, 3-45.

See also text, pp. 136-152.

Procedure

An algorithm for the estimation of formant frequencies from a specification of the cross-sectional area of the vocal tract from the vocal folds to the lips has been implemented by S. Maeda on a PC computer. The program accepts data in the form of a graph of the cross-sectional area values at specified increments from the glottis to the lips, and simulates each section of the tube by an incremental mass, compliance, and loss term. Program output consists of a printout of frequency and approximate bandwidth values for all formants below 5000 Hz corresponding to the specified area function.

This program can be used to check parts of the theory concerning the quantal nature of articulation (Stevens, 1972, 1989). Each group will carry out the topics described below, or you may wish to define your own project in place of **A** or **B** below.

A. Quantal Articulations for Vowels. The area function plotted in Fig. 1(a) is an idealized version of the articulation of [✌] as in **pot**. An idealization of [i] as in **beet** is shown in Fig. 1(b). Investigate the sensitivity of the lowest 3 or 4 formant frequencies to changes in the distance *d* in 1-cm steps. At what values of *d* are the formants least sensitive to perturbations in *d* for each vowel? Reduce the quantity A2/A1 in appropriate steps (e.g. times 0.6) to determine the point at which formants begin shifting to positions appropriate for the neutral vowel (uniform vocal tract). If time permits, assess the effect on the formants (for one of the configurations) as the lips are rounded. Rounding can be simulated by decreasing the cross-sectional area of the 1-cm section at the lip end of the vocal tract.

B. Quantal Places of Articulation for Consonants. During the production of a fricative consonant, the vocal tract assumes a configuration that is idealized in Fig. 2. The position of the constriction is given by the variable *d*. Plot the loci of the lowest 5 formants as d is varied from 12 cm (appropriate for the Arabic pharyngeal consonants) to 2 cm (typical of the English /s/) in 1 cm or ½ cm steps. Identify the front cavity resonances from your plot, and indicate the quasi-stable regions (quantal places of articulation a la Stevens).

If time permits, observe the effect of closing the lips for the configuration corresponding to /s/, with d = 2 cm. Closing the lips can be simulated by reducing the cross-sectional area of the ½ cm section at the front end of the vocal tract from 3 cm^2 to a small area like 0.2 cm^2 in logarithmically spaced steps. How does the front-cavity resonance change as the lips close? Is this change predictable from acoustic theory?

To use the vtcalcs program

In the labc account, type *matlab*.

Then type *vtcalcs*.

Click on *VT calculation*

For part A of lab, click on *2 tube model*.

The three windows will display the tube shape, the calculated transfer function, and the formant frequencies and bandwidths.

Change parameters by clicking on right panel. New calculations are made.

Click on *synthesize* to listen to steady-state vowel.

To construct a more complex area function (as in part B of lab), click on *area functions model*.

Modify area function by manipulating parameters in right panel.

Various constants associated with the tube are listed in *tract configuration* and *physical constants*.

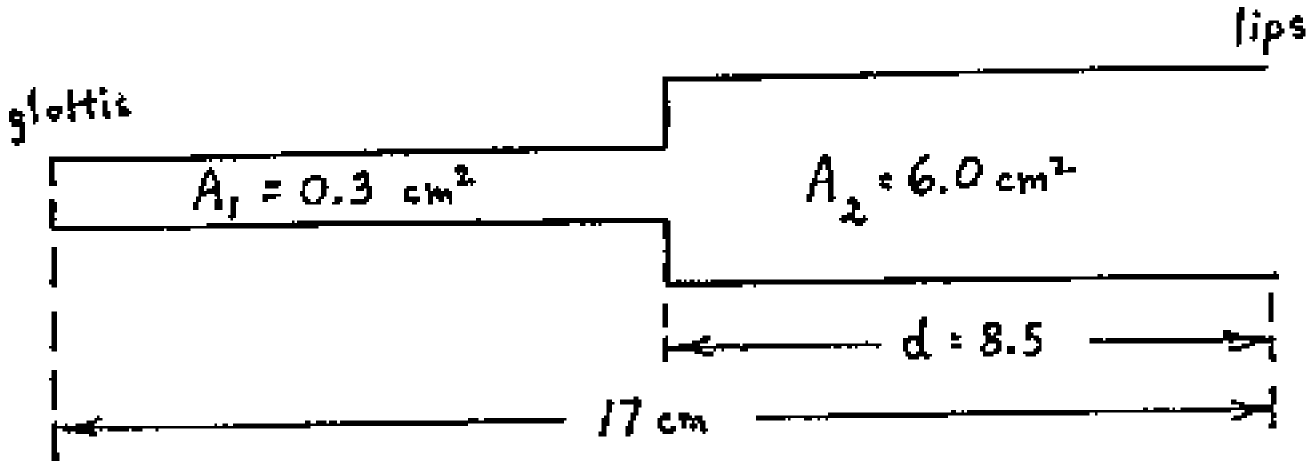

FIGURE 1a

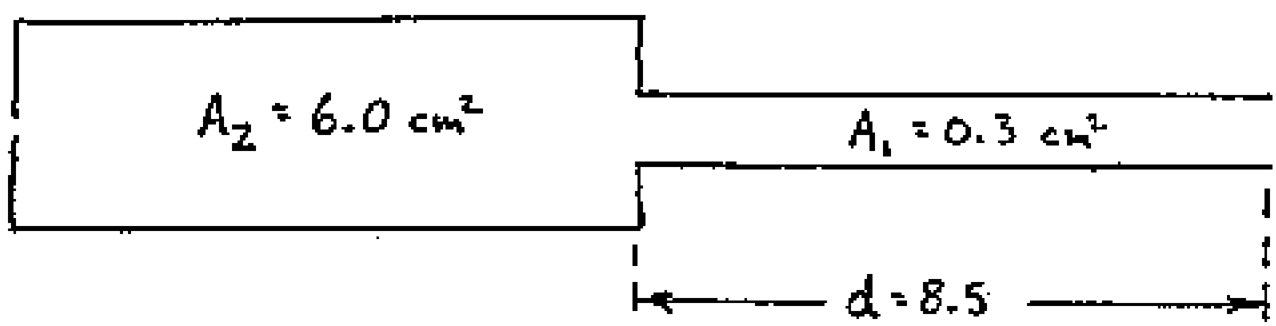

FIGURE 1b

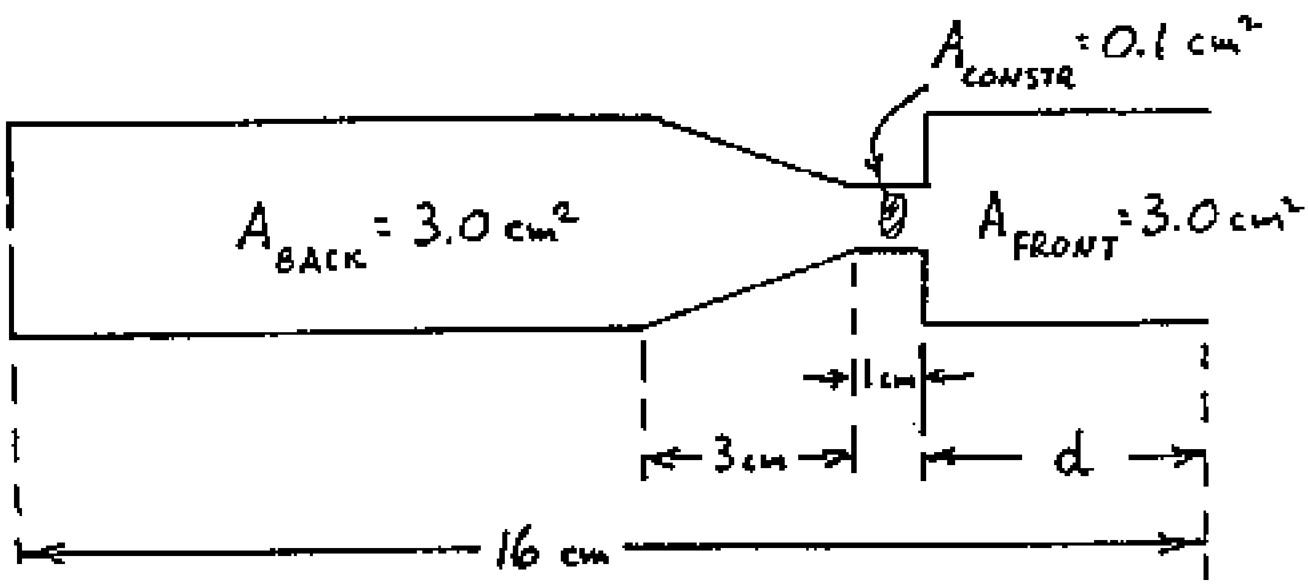

FIGURE 2