24.910 Topics in Linguistic Theory: Laboratory Phonology
Spring 2007

Acoustics Assignment 2: Due 3/6

1. We are planning to digitize a recording. We need to be able to measure the first three
   formants of a 'schwa' vowel produced by the speaker, who has a vocal tract of about
   15 cm in length. What is the lowest sampling rate that we could use? (Explain your
   answer).

2. Sound waves reach the eardrum through the ear canal (or external auditory meatus).
   Given that the ear canal is a tube of about 2.5cm long, open at one end, what effect
   will it have on the sound wave at the eardrum? (Be as precise as possible - i.e. use a
   simple calculation to estimate the effect).

3. Liljencrants & Lindblom (1972) make crucial use of an estimate of the range of
   vowel formant patterns that can be produced by the human vocal tract. This is shown
   as regions in F1×F2 and F2×F3 spaces on p.840. Note that these figures plot the
   formant frequencies on a non-linear (mel) scale and the axes are not arranged to
   mirror a vowel chart. The F1×F2 space is plotted on linear Hz scales on p.843, and
   the coordinates of points on the edge of the space are given on the same page.

   This vowel space is based on a fairly complex model of articulation and its acoustic
   consequences developed by Lindblom & Sundberg. The assignment here is to try to
   explain the shape of the vowel space using simple tube models of vowels. I don't
   expect you to be able to derive the shape of the whole space, but see if you can
   account for key features of the space.
   In particular: How do you achieve minimum and maximum F1 and F2 values? What
   determines the values of these maxima and minima? Why does the range of possible
   F2 values narrow as F1 increases (i.e. why is the F1×F2 vowel space approximately
   triangular)?

   Tube models for vowels are discussed in Johnson pp. 102-107.
   The model in fig. 6.1 is mainly suitable for modeling low vowels.
   The model in fig. 6.3 is suitable for modeling high and mid vowels. Bear in mind that
   the area of the constriction (A_c) can be varied as well as the tube lengths.

   Johnson doesn't say much about lip rounding. The effect of a constriction at the lips
   is equivalent to lengthening the front cavity (1-2cm is probably a reasonable amount,
   or you can estimate the lengthening required to produce formant values similar to
   those assumed by Liljencrants & Lindblom).