

SPEECH COMMUNICATION
6.541J-24.968J-HST710J
Spring 2004

Problem Set 6

Assigned: 04/06/04

Due: 04/13/04

Problem 1

Figure 1.1 shows an idealized model of the vocal-tract shape for an alveolar stop consonant. The back-cavity length ℓ_b is 13 cm and the length ℓ_f of the cavity in front of the constriction is 1.9 cm. Neglect any end effect at the open end at the right of the tube, i.e., assume the sound pressure at the termination is zero. Assume the constriction size is very small.

- (a) What is the second-formant frequency for this configuration?
- (b) What is the frequency of the front-cavity resonance? Which formant number is this resonance?
- (c) Consider now the excitation of the front cavity by a sound-pressure source p_s at a distance ℓ_s from the constriction, as schematized in Fig. 1.2. This is an approximate model of the production of the frication noise in a consonant like /s/ or /d/. The cross-sectional area A is 1 cm².

Let U_o be the acoustic volume velocity amplitude at the opening. We are interested in the transfer function U_o / p_s . At low frequencies (up to, say, 6000 Hz) this transfer function can be approximated by

$$\frac{U_o}{p_s} = Ks \frac{s_p s_p^*}{(s - s_p)(s - s_p^*)} \quad (1)$$

where s_p and s_p^* represent the conjugate pair poles corresponding to the lowest natural frequency of the front cavity, K is a constant, and $s = j\omega = j2\pi f$. The magnitude of the transfer function for the pole term (without Ks) has been given in the text in Fig. 3.2, and is shown here as Fig. 1.3. For this transfer function, the frequency of the pole is F_n . Note that the peak value of this transfer function is F_n / B_n , where B_n is the bandwidth. ($B_n = F_n / 12$ in Fig. 1.3.)

- (i) What is the frequency of the pole for the configuration in Fig. 1.2?

- (ii) What is the constant K in equation (1)? Note that at very low frequencies, U_o / p_s reduces approximately to K , and the configuration in Fig. 1.2 reduces to a lumped circuit (a source p_s in series with an acoustic compliance).
- (iii) Sketch the magnitude of U_o / p_s (in dB) versus frequency, up to a frequency of 6000 Hz. Assume the bandwidths of the pole and zero to be $F_n / 12$ as in Fig. 1.3.
- (iv) Describe how your result in (iv) would change if $\ell_s = 0.5$ cm instead of 1.0 cm. (Note that the transfer function depends on the distance of the source from the constriction in Fig.1.1.)

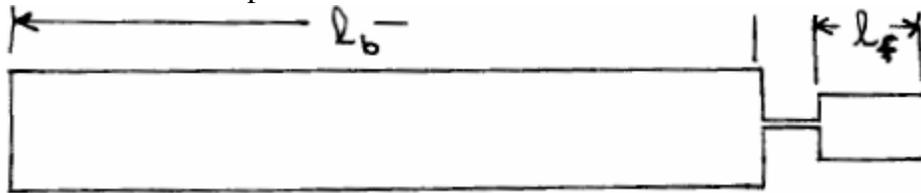


Figure 1.1

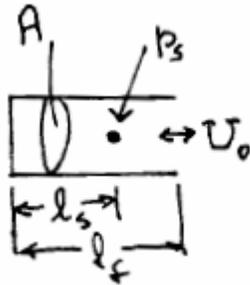


Figure 1.2

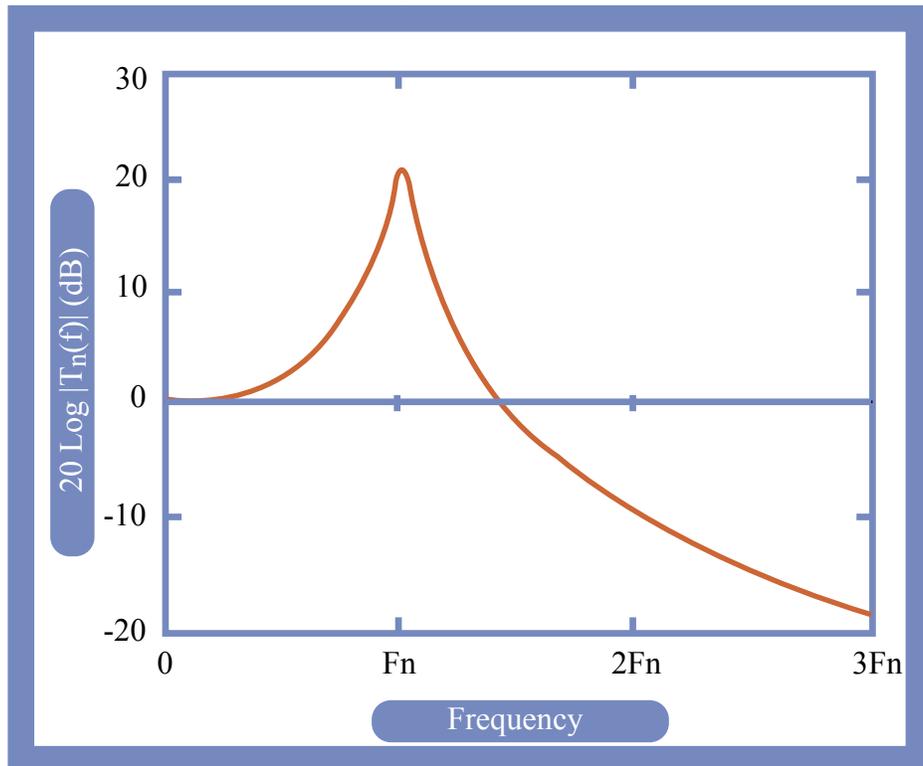


Figure 1.3

Problem 2

Figure 2.1 shows a spectrogram of a speaker saying the word **dime**. Three arrows are shown under the spectrogram, designating three points in time within the word.

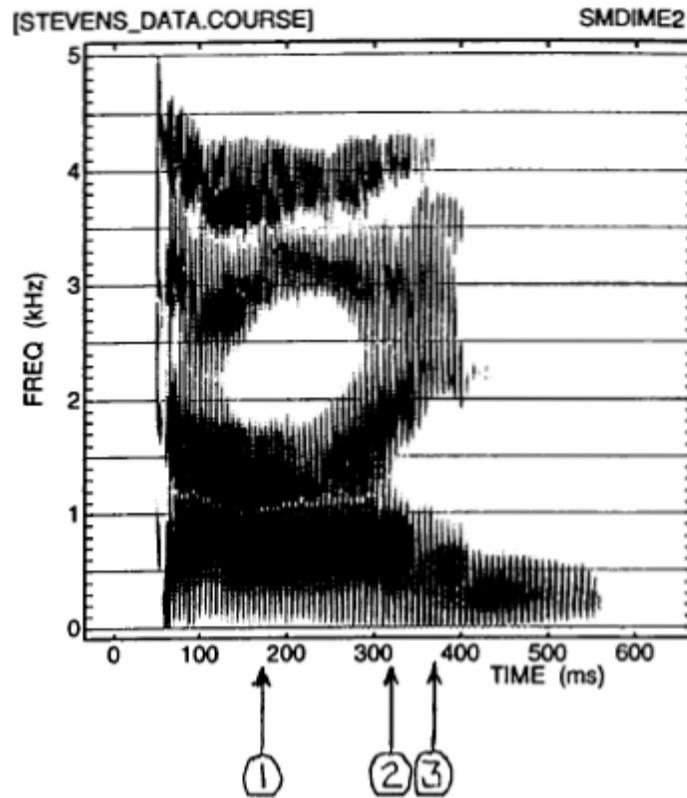
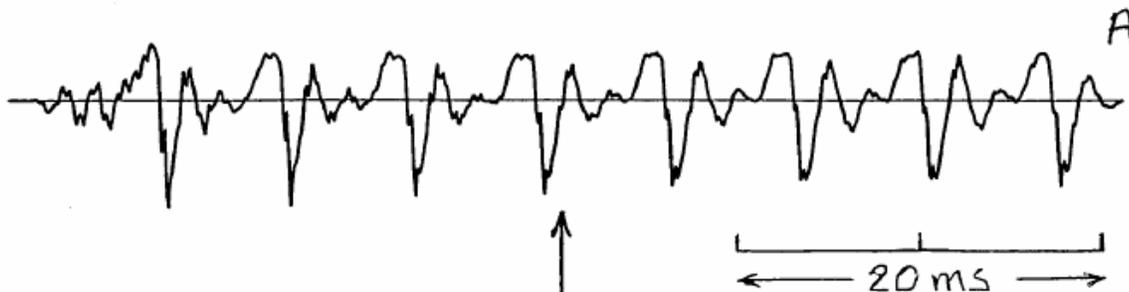


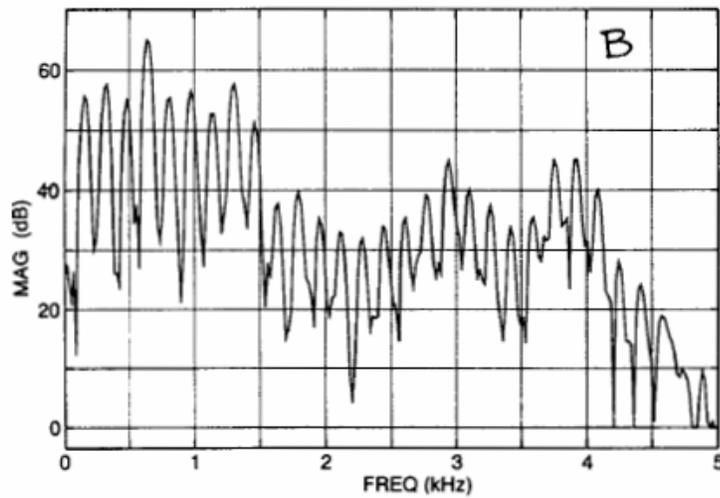
Fig. 2.1

(a) Given below are different pieces of information each of which is sampled at one of these three points. Match each of the figures below (A, B and C) with one of the points (1, 2, or 3) and give your reasons. (There is not necessarily a match to all three points.)

- A. A waveform of the sound pressure (the corresponding sampling point is given by the arrow)
- B. A spectrum of the sound pressure
- C. A vocal-tract shape



- (b) What is the fundamental frequency corresponding to the spectrum in B below?
- (c) Estimate the approximate vocal-tract length for this speaker.



Problem 3

Make up three sentences in which all of the consonants are sonorant consonants. Each sentence should contain at least five words.

1. -----
2. -----
3. -----