EEL6586 – Spring 2003

Exam 1 March 3, 2003

**NAME:** ______________________________

This exam is open-book and calculator. You may use any books or papers that you like. There are four problems on this exam, you have two full class periods. State your assumptions and reasoning for each problem. Justify your steps and clearly indicate your final answers.

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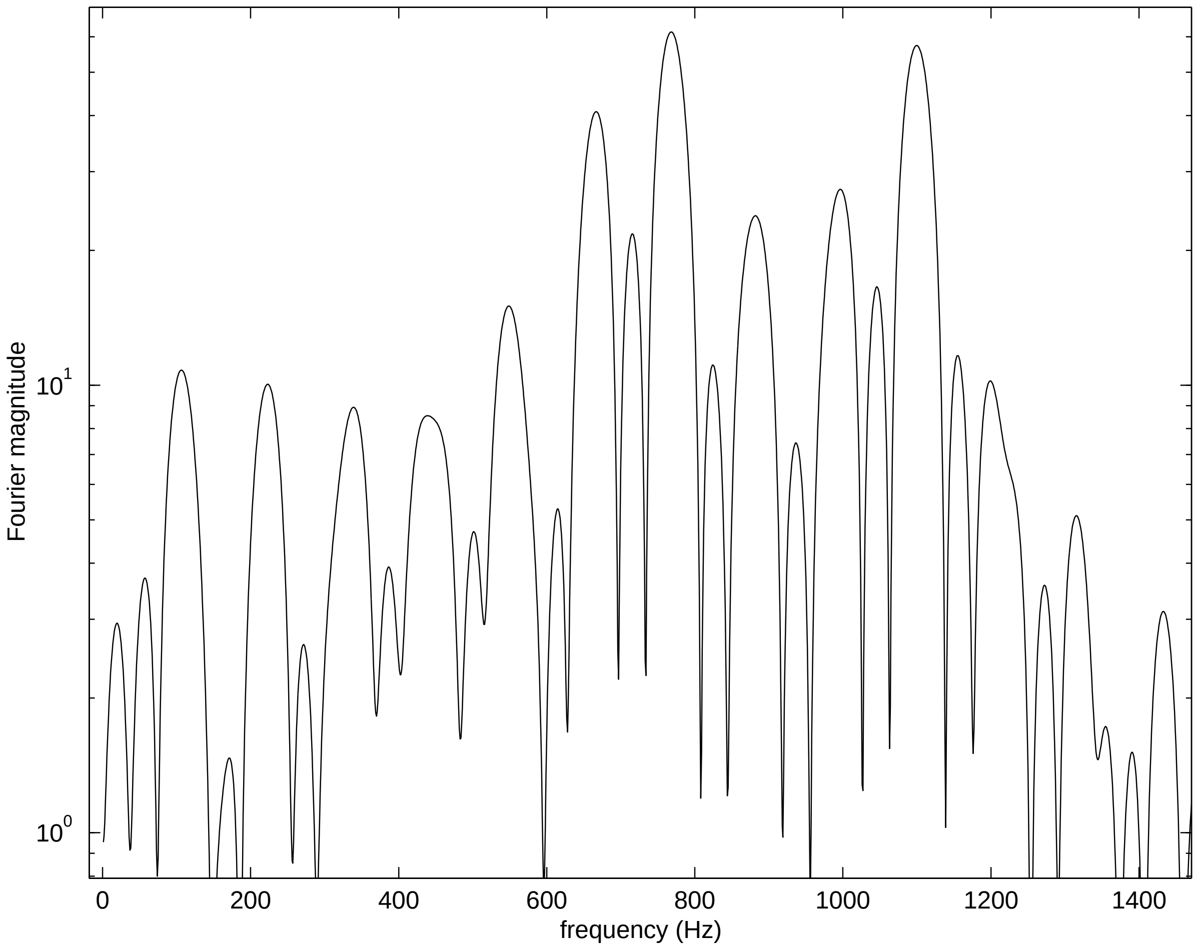
|---|---|
| **1** | **/25** |
| **2** | **/25** |
| **3** | **/25** |
| **4** | **/25** |
| **TOTAL** | |

1. (25 points) A train of impulses is fed through a simple all-pole model to produce a stationary voiced phoneme. The resulting sequence is windowed by a rectangular window and its Fourier magnitude is plotted as shown below. The sampling rate is 10KHz. Answer the following questions.




(a) (5 points) Estimate the frequency of the first two formants (F1 and F2) in Hz.

(b) (10 points) Estimate the pitch of the voice in Hz.

(c) (10 points) Estimate the size of the rectangular window (in ms) used in processing the speech. Explain your answer.

2. (25 points) Assume that white noise excitation $w(n)$ is filtered by a single-pole vocal-tract model $H(z) = 0.5/(1 - 0.5z^{-1})$ to produce a signal $s(n)$. $w(n)$ is defined:

$$E\{w(n)w(m)\} = \begin{cases} \sigma^2 & m = n \\ 0 & m \neq n \end{cases}$$

In this problem you will use LPC to analyze $s(n)$.

(a) (5 points) Derive the difference equation for $s(n)$.

(b) (5 points) Compute the autocorrelation value $r(0)$ of the speech signal $s(n)$.

(c) (5 points) Compute the autocorrelation values $r(1)$ and $r(2)$ for $s(n)$.

(d) (10 points) Compute the first two LPC coefficients by solving the resulting system of equations ($p = 2$). Show all of your work.

3. (25 points) Answer the following problems involving the cepstrum.

   (a) (5 points) Derive the complex cepstrum of

$$s(n) = \left(\frac{1}{2}\right)^{n+1} u(n)$$

(b) (10 points) Derive and sketch the real cepstrum of

$$s(n) = \left(\frac{1}{2}\right)^{n+1} u(n)$$

(c) (10 points) Derive the complex cepstrum of

$$s(n) = \left[\left(\frac{1}{2}\right)^{n+1} - \left(\frac{1}{4}\right)^{n+1}\right] u(n)$$

4. (25 points) Short Answer.

   (a) (5 points) Describe the two major differences in the voice signal characteristics of a child's speech compared to an adult's.

   (b) (5 points) Why should pre-emphasis be applied before computing linear prediction coefficients?

(c) (5 points) Consider the problem of all-pole filtering of ideal white noise excitation. What happens if we try to compute linear prediction coefficients when we slightly over-estimate the order of the model? What do you expect the values of the coefficients to be?

(d) (5 points) Sketch a very rough black and white narrowband spectrogram for the two syllable word "easy." Use quantitative labels on the axes.

(e) (5 points) Suppose independent, identically distributed white Gaussian noise with average power of 1 is filtered by the following linear system:

$$H(z) = \frac{0.5}{1 - 0.5z^{-1}}$$

What is the average power of the resulting signal?