MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.003: Signals and Systems—Fall 2003

Computer Lab 1

Issued: September 4, 2003 Due: October 8 , 2003

Problems to be handed in: In this lab, you will complete the Basic, Intermediate, and Advanced Exercises for the Echo Cancellation problem considered in Section 2.10 on pages 44–46 of Buck, Daniel, and Singer (BDS). For all of the exercises, please include your Matlab code. As stated in the General Information Sheet, we do not expect a formal lab report, but it is still important that you present your results clearly and in an organized manner. Specific items which should be turned in are listed below.

Note: Signals y, y2 and y3 are contained in column vectors. Thus, using the second to last line of code given on page 46 of BDS will give an INCORRECT answer, since the fliplr() command operates on rows. Thus, substitute "Ryy=conv(y,flipud(y));" into the second to last line of code on page 46.

To load the appropriate data file into `Matlab`, type:

```
>> cd /mit/6.003/data
>> load lineup
```

Alternatively you can obtain the data file from the course web page.

Basic Problems

(a) Turn in a plot of the impulse response of the echo system, contained in the vector `he`.

(b) In this part, you are asked to verify that the echo removal system is indeed the inverse of the echo system. For the derivation of this, do not derive the overall difference equation. Instead, analytically compute the impulse response of the echo system and the impulse response of the echo removal system, and convolve the two impulse responses to get the impulse response of the cascaded system. The result of this convolution should be the unit sample $\delta[n]$.

Intermediate Problems

(c) Turn in a plot of the approximated impulse response, contained in the vector `her`.

(d) Turn in a plot of the filter output, contained in the vector `z`.

(e) Turn in a plot of the overall impulse response, obtained by convolving `he` with `her`. Also, explain why the result is not the unit impulse.

Advanced Problem

(f) For this part, you should determine the parameters of all three signals, `y`, `y2`, and `y3`. This means that you should include estimates of N and α for the signals `y` and `y2`, and estimates of N_1, α_1, N_2, and α_2 for the signal `y3`. To justify your results, you should include plots of the autocorrelations, $R_{yy}[n]$, $R_{y_2y_2}[n]$, and $R_{y_3y_3}[n]$. In addition, turn in a description of your procedure for estimating both N and α. This description should include the mathematical expression of $R_{yy}[n]$ in terms of $R_{xx}[n]$.

In order to estimate the value of α, you should assume that you know $x[n]$ for all values of n. This is in fact a fairly reasonable assumption. In many communications systems, a test signal (which is known by the receiver) is often sent out, in order assess the effects of the communications channel. In this problem, $x[n]$ may be obtained from your answer to part (d) (*i.e.* $z[n] = x[n]$).

Hints:

- To determine the value of N, use the hint given in BDS (*i.e.* examine the autocorrelation function $R_{yy}[n]$). A property of the autocorrelation function that you might find useful is the following: given any signal $w[n]$, the autocorrelation $R_{ww}[n] = w[n] * w[-n]$ satisfies the inequality $R_{ww}[0] \geq R_{ww}[n]$ for all values of n.[†] This is essentially because the two signals "line up" at $n = 0$.

- To estimate the value of α, assume that you know $x[n]$. Then, you should be able to obtain an estimate by solving a simple linear equation. For the signal `y3`, you will need two such equations.

- If at any time, we find it necessary to provide additional hints concerning the lab, we will post a notice on the course web page:

  `http://web.mit.edu/6.003/www`

  For more important announcements, we will also send a message using the 6.003 mailing list.

Optional Exercises (just for fun)

- The approach for estimating α, as suggested in part (f), would not in fact be very accurate in the real world, because of the effects of noise. A better model for the system given in Equation (2.21), might be $y[n] = x[n] + \alpha x[n - N] + w[n]$, where $w[n]$ is a noise source. To investigate the effects of noise, try creating a noisy version of the signal `y`, by using the following command:

  ```
  >> ynoisy = y + 0.2*randn(size(y));
  ```

  To increase the level of noise, make the value 0.2 larger. Investigate the effects of this

[†]You may find the proof of this inequality to be an interesting exercise.

noise on your estimates of N and α. To get a better estimate of α you may want to try an averaging scheme, using several data points, instead of just one.

- You may want to experiment with estimating the value of α, assuming that you do not know $x[n]$. What types of approximations can you make, so that you get reasonable estimates of α? Consider using the autocorrelation $R_{yy}[n]$.

- In the process of experimenting, if you discover a novel solution to the questions above or if you have suggestions for other thought-provoking exercises, e-mail the head TA He will place your suggestions on the 6.003 web page.

Special Instructions: Since you are required to listen to several speech signals in this lab, we request that you use headphones while in the public MIT server clusters. If you decide to work in the fifth floor lab headphones are not required but may be advisable due to the noisy environment. To use headphones on Athena Workstations, make sure that you plug the headphones into the jack located on the back panel of the machine or on the left side on some O2's, but not into the jack located below the CD-ROM.