MEMO Number CMPE323-Lab08
DATE: November 18, 2016
TO: CMPE323
FROM: EFC LaBerge
SUBJECT: Using the Fast Fourier Transform

1 INTRODUCTION

This lab explores the use of the Fast Fourier Transform (FFT) to do spectrum analysis of sampled data systems. The FFT is an extremely efficient algorithm for computed the Discrete Fourier Transform (DFT).

2 EQUIPMENT

For this lab, you need a laptop with MATLAB installed.

For the purpose of CMPE323, please use the following naming conventions for all output files:

CMPE323F16_Lab<Lab#>_<Your Campus ID>

For the purpose of CMPE323, please use the following naming conventions for MATLAB scripts or functions that you are required to submit.

<function name>_<Your Campus ID>

Examples will be given in the lab description. Follow the instructions exactly, or you may not get graded!

3 LAB TASKS

You might find it useful to use the MATLAB function `diary` to capture your inputs and outputs.

3.1 Computing the Fourier Transform of the basic pulse

Using a time array from [-4.096: 0.001: 4095], use your basic anonymous pulse function to compute the pulse(t+tau/2,tau) for $\tau = 1$. Then shift that pulse by $-\tau/2$ (to the right) and $+\tau/2$ (to the left). Plot all three pulses on separate subplots using professional practice.

If we assume that each of your time records is one period of a periodic waveform, what is the period, T? How many sample points are contained in T? What will the frequency resolution be in Hertz? In radians per second? Does this number of points satisfy the condition for optimum FFT computation?

Compute the DFT of the basic symmetric pulse ($p(t+\tau/2)$) use the MATLAB function **`fft`.** For the purpose of this exercise, the DFT (computed by the FFT) is

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-j\frac{2\pi kn}{N}} \tag{1}$$

where $X[k]$ is the result at $f = \frac{k}{T}, k = 0,1,2\ldots, N-2, N-1$, and

$x[n] = x(n\Delta t),\ n = 0,1,2,\ldots, N-2, N-1$.

Plot the magnitude and phase of the result and compare them to the theoretical result for the symmetric pulse. Do the amplitude and phase match the theoretical amplitude and phase? Talk with others in your group and explain the differences. What do you need to do to the amplitude and phase to have things work out?

Once you have come up with your suggested adjustments, make the adjustments and again compare with the theoretical/analytical result. If the results don't match now, repeat the process until they do.

To test your adjustments, repeat the process with advanced and delayed pulses, too. Do your results match the theory? If not, why not?

3.2 The Complex Modulation Property

Take your three pulse functions ($p_1(t),\ p_2(t),$ and $p_3(t)$) and multiply each of them by

$$c(t) = e^{j2\pi f_c t}. \tag{2}$$

with $f_c = 5.0049$ Hz. Call the new pulses $x_1(t),\ x_2(t),$ and $x_3(t)$, and use FFTs and the corresponding analytical results. Plot all three pulses on separate subplots using professional practice.

On separate graphs, plot the magnitude and phase for each of the three DFTs Fourier Transforms and, on each of the graphs, the corresponding parameter of the analytical result. In particular, comment on any slope or jaggedness to the shape of the computed (as opposed to analytical) result. Indicate how well your computation matches the theory. Use professional practice on your plots.

3.3 The Cosine Modulation Property

A corollary to the Complex Modulation Theorem is the Cosine Modulation Property, which uses the Euler expansion of the cosine and applies the Complex Modulation Property. Take your original pulses (from 3.1, not from 3.2) and multiply them by

$$m(t) = \cos(2\pi f_c t), \tag{3}$$

with $f_c = 4.9438$ Hz. Call the new pulses $w_1(t),\ w_2(t),$ and $w_3(t)$, and us them to compute the corresponding DTFTs and the corresponding analytical results. Plot all three pulses on separate subplots using professional practice.

On separate graphs, plot the magnitude and phase for each of the three Fourier Transforms and, on each of the graphs, the corresponding parameter of the analytical result. In particular, comment on any slope or jaggedness to the shape of the computed (as opposed to analytical) result. Indicate how well your computation matches the theory. Explain any differences in terms of the discrete nature of the FFT results. Use professional practice on your plots.

4 LAB SUBMISSIONS

Submit the following via the Blackboard assignment Lab 7.

Using this lab description document as a template, create a single PDF file named in accordance with the output naming conventions given above. The content must include

a. The outputs and discussions generated in 3.1.

b. The outputs and discussions generated in 3.2.

c. The outputs and discussions generated in 3.3.

Professional, high quality writing, math, and graphic (that is plots) presentation is expected, and must be provided for you to earn full credit.