ENGR 253 LAB #5 - Fourier Series Analysis

Objective
Exploring the use Fourier Series Analysis and Synthesis methods for periodic signals.

Resources
- Signals & Systems textbook by Oppenheim and Willsky
- Windows running MATLAB release 14 or later
- USB hard disk or other removable drives
  {Note: Lab computer data is lost after reboot}
- Course Lecture Material

Background
1) Fourier Series Representation of Periodic Signals Analysis and Synthesis

   o Continuous-time

$$x(t) = \sum_{k=-\infty}^{+\infty} a_k e^{jkw_0 t} = \sum_{k=-\infty}^{+\infty} a_k e^{jk(2\pi/T)t} \quad \text{Synthesis Equation}$$

$$a_k = \frac{1}{T}\int_T e^{-jkw_0 t} x(t)dt = \frac{1}{T}\int_T e^{-jk(2\pi/T)t} x(t)dt \quad \text{Analysis Equation}$$

   o Discrete-time

$$x[n] = \sum_{k=<N>} a_k e^{jkw_o n} = \sum_{k=<N>} a_k e^{jk(2\pi/N)n} \quad for\ k = m, m+1, ..., m+N-1 \quad \textit{Fourier Series Synthesis Eq.}$$

$$a_k = \frac{1}{N}\sum_{n=<N>} x[n]e^{-jkw_o n} = \frac{1}{N}\sum_{n=<N>} x[n]e^{-jk(2\pi/N)n} \quad \textit{Fourier Series Analysis Eq.}$$

   MATLAB functions, fft() & iff(t), implement Synthesis and Analysis equations. For the signal x[n] with the fundamental period N, two of the Discrete-Time Fourier Series (DTFS) related MATLAB are shown below:

```
a = (1/N) * fft(x)      % DTFS coefficients a_k for 0 ≤ k ≤ N-1
x = N * ifft(a)         % x[n] for 0 ≤ k ≤ N-1
```

2) Sample Data Files
   Standard MATHLAB installation contain data files that may be used as the input for experiments. These files are typically saved in the following directory:

   C:\Program Files\MATLAB704\toolbox\matlab\audiovideo

   The following sequence of MATLAB commands will load data file containing bird chirp, play the sound file and plot the data:

```
load chirp.mat      % load the chirp.mat data file into variable y (n-by-2 matrix)
sound(y,8192)       % output the value of y as an sound value with sample rate of 8192 (default)
plot(y)             % plot value stored in y
```

Experiment #1

Load the file Handel.mat and plot the file. Explain the plot horizontal axis, vertical axis and how does the graph relates to the physical data stored in the file?

Experiment #2

Synthesize a periodic discrete-time signal with period N=5 and the following DTFS coefficients

$$a_0 = 2, \quad a_2 = a_{-2}^* = e^{j\pi/4}, \quad a_4 = a_{-4}^* = e^{j\pi/3}$$

a) Based on the DTFS coefficients, do you expect x[n] to have complex-value, purely real, or purely imaginary? Explain your answer?

b) Using the DTFS coefficients given above, determine the values of a_0 through a_4.

c) Using MATLAB Synthesis function and values of a_k found in the pervious section to determine and plot the value of x[n] for $0 \le n \le 25$.

d) Determine and plot the value of x[n] using the synthesis equation directly {do not use ifft()}. What is the percent difference in x[n] energy between the direct method used here and MATLAB function used in part (c).

e) Plot x[n] magnitude, phase, real part and imaginary part using stem. Was your statement in part a correct?

Report Requirements

Reports must be prepared individually even if the experiments are performed as a team. All reports must be computer printed (Formulas and Diagrams may be hand drawn) and at minimum include:

For each Experiment

a) A clear problem statement; specifying items given and to be found.
b) Theory or process used.
c) Resulting circuits, calculation, tables, timing diagram, schematic and other relevant results.

For the report as a whole

a) Cover sheet with your name, class, lab, completion date and team members' names.
b) Lessons Learned from the experiments.
c) A new experiment and expected results which provide additional opportunity to practice the concepts in this lab.