EE3210 Signals and Systems

MATLAB Exercise 2

Hands-On Learning for Discrete-Time Signal Processing

Intended Learning Outcomes:

On completion of this MATLAB exercise, you should be able to

- Analyze discrete-time signals in the frequency domain
- Apply signals and systems in frequency estimation and sunspot cycle estimation

Deliverable:

- Each student is required to submit a **short report** which includes your answers for questions and findings for this computer exercise on or before **8 November 2023**.

Procedure:

1. Download the file "one2nine.dat" at Canvas. This file contains the waveform of the numbers "1" to "9" and the sampling frequency is 22000 Hz. Try the following MATLAB code:

```
load one2nine.dat
soundsc(one2nine, 22000)
```

   Examine the operation of the code. Change the number "`22000`" to "`15000`" and "`30000`". What do you hear for the three cases? Briefly explain the differences.

2. Type the following MATLAB code:

```
clear all
Fs=8000;
Ts=1/Fs;
t=[0:Ts:0.5];
F_A=440;
A=sin(2*pi*F_A*t);
sound(A,Fs);
[freq_resp,freq_index]=freqz(A,1,50000,Fs);
plot(freq_index,abs(freq_resp))
xlabel('Frequency in Hz')
```

   Examine the operation of each command line and answer the following:

   (a) What is the frequency range in the plot?
   (b) What is the meaning of `50000` in the command `freqz`?
   (c) Use the plot and/or `abs(freq_resp)`, determine the dominant frequency of the signal. For the former, you can press the Zoom In button in the figure, while the command `max` can be utilized in the latter.

Then type the MATLAB code:

```
New_Fs=4000;
sound(A, New_Fs);
[freq_resp,freq_index]=freqz(A,1,50000, New_Fs);
plot(freq_index,abs(freq_resp))
xlabel('Frequency in Hz')
```

(d) Use the plot and/or `abs(freq_resp)`, determine the modified value of the signal dominant frequency. Briefly explain the change in frequency.

3. A discrete-time sinusoid has the form of $x[n] = A\cos(\omega n + \phi)$ where $A > 0$, $\omega \in (0, \pi)$ and $\phi \in [0, 2\pi)$ represent the amplitude, frequency and phase, respectively. Applying trigonometric identities, it can be shown that

$$x[n] = 2\cos(\omega)x[n-1] - x[n-2] \Rightarrow \omega = \cos^{-1}\left(\frac{x[n] + x[n-2]}{2x[n-1]}\right)$$

That is, the frequency ω can be computed with the use of 3 discrete-time samples. A feature extraction system can be interpreted as follows: the input is the sinusoidal signal while the output is the frequency. Three sinusoidal samples are collected and they have the values of $x[0] = 0.3042$, $x[1] = -0.8509$, and $x[2] = -1.9444$.

(a) Find the value of ω.
(b) Using the result in (a) as well as the sinusoidal samples, find the values of A and ϕ.
(c) Suppose $x[n]$ is obtained by sampling a continuous-time signal $x(t)$ with sampling interval 0.002s. Determine the frequency of $x(t)$ in Hz.

4. In the field of astronomy, an application is to find the sunspot cycle using the sunspot number [1]. Download “SN_m_tot_V2.0.txt” at [1]. Remove “$*$” and then save it as “spot_num.txt”. Try the following code:

```
load spot_num.txt
ssn = spot_num(:,4);
ssn = ssn-mean(ssn);
[freq_resp,freq_index]=freqz(ssn,1,50000,1);
plot(freq_index,abs(freq_resp))
```

(a) Examine the operation of the commands. Determine the dominant frequency which is relative to one month.
(b) Based on the result of (a), determine the sunspot cycle estimate in terms of number of months.
(c) Repeat the above code without the command `ssn = ssn-mean(ssn)`. Describe how to estimate the sunspot cycle from the plot.
(d) What is the purpose of the command `ssn = ssn-mean(ssn)`?

Reference:

[1] https://solarscience.msfc.nasa.gov/SunspotCycle.shtml