LABORATORY MANUAL

CE3007: Digital Signal Processing
Hardware Lab 1 (Location: N4-01a-03)

SESSION 2019/2020
SEMESTER 2
COMPUTER ENGINEERING COURSE

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
NANYANG TECHNOLOGICAL UNIVERSITY

LAB – 3

Discrete Time Fourier Transform

1. OBJECTIVE

In this laboratory exercise, we will continue to use python for Fourier Analysis of discrete time signal. Fourier Analysis remains one of the most important topic in Engineering [2].

Snippets of python code which can help in this laboratory is provided in Lab3Example.py

2. Tasks

2.1 Revision of Theory. Prepare brief answers to the following questions.

1. Given a periodic sequence x[n] with period N samples, state and write the Fourier Analysis equations which can be applied to it to represent it in the frequency domain?

2.2 Practical – Python

2. Develop your own python routine to generate the forward and inverse DTFS (Discrete Time Fourier Series) and DFT (Discrete Fourier Transform) representation of a given periodic sequence x[n]. Your routine should have prototypes as follows:

```
Xdtfs[k]  = myDTFS(ipX, N)
X_Idtfs  = myIDTFS(Xdtfs)

Xdft[k]   = myDFT(ipX, N)
X_Idft    = myIDFT(Xdft)
```

where ipX is a real vector representing a single period of a periodic sequence, and N the length of Fourier Transform. See scipy.fftpack.fft for description. Compare your results to scipy.fftpack.fft

a. How is myDTFS different to myDFT?
b. Find Xdtfs[k] and Xdft[k] for ipX = [1,1,0,0,0,0,0,0,0,0,0,0]. Plot the magnitude and phase representations for the found Fourier analysis values. Clearly label the x-axis values and interpret the corresponding ω (radian/sample) value for each k.
c. Show that your myIDTFS and myIDFT will generate the given ipX from the evaluated Xdtfs and Xdft coefficients found.

d. Evaluate

   i) Xdtfs2[k] of ipX2 = [0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0]
   ii) Xdtfs3[k] of ipX3 = [10, 10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]

   Compare the magnitude and frequency spectral to Q2b. What are the differences? Hint i) is a time shifted version of Q2b. ii) is an amplified version of Q2b.

3. Write the DFT forward analysis using matrix notations. Each row of the analysis matrix W has a particular meaning. Plot the phase of each element of W for each row. Hence suggest the characteristic of each row. Hint- it is related to the index k.

4. It is not possible to computationally realise the DTFT solution of a discrete sequence. E.g, if the ipX sequence is aperiodic, ipX = [1,1,1,1,1,1,1,0,0,0,0,0,0,0,….],
   a. Explain why it is not possible to write a routine to analyse it. Hint: we can only generate a sampled version of DTFT.
   b. Truncate ipX sequence to have different lengths, e.g, N = 12, 24,48,96. Apply DTFS on the truncated ipX. Plot the resultant Fourier magnitude coefficients with respect to x-axis being k (integers) as well as ω. Hence interpret the relationship between DTFS to DTFT.

5. Write your own routine to perform convolution of two sequences in Fourier domain.

   y = myDFTConvolve (ipX,impulseH)

   Compare your results using scipy fftconvolve [1], as well as your convolution routine developed in Lab 2. Note – you should assume that the length of ipX and impulse are different, hence you will need to take care of zero padding.

5. References

[1] Scipy's convolution in frequency domain, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.fftconvolve.html

[2] Many notes here: http://complextoreal.com/wp-content/uploads/2013/04/fft5.pdf