B.Sc. Engg. CSE 6th semester

29 October 2019

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION **SUMMER SEMESTER, 2018-2019**
DURATION: 3 Hours **FULL MARKS: 150**

CSE 4631: Digital Signal Processing

Programmable calculators are not allowed. Do not write anything on the question paper.
There are 8 (eight) questions. Answer any 6 (six) of them.
Figures in the right margin indicate marks.

---

1. a) Two major challenges of *Spectral Analysis* are depicted in Figure 1. Figure 1(a) shows, tails appear near peaks when the frequency of the peak is in between two basis functions. Figure 1(b) captures two neighboring peaks overlapping each other. Discuss possible solutions to these problems. Your answer should include the trade-offs. 10

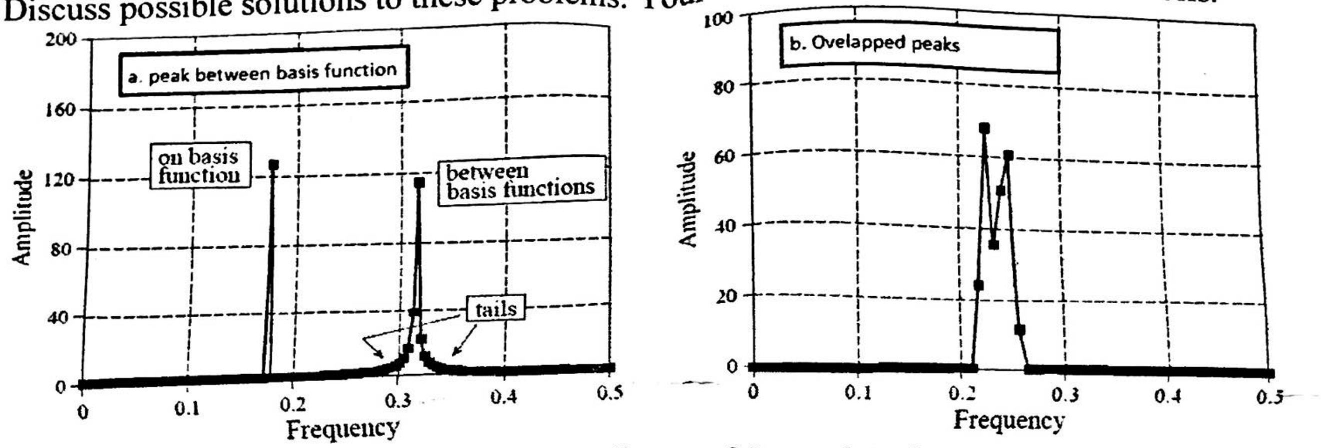

Figure 1: Major challenges of *Spectral Analysis*

b) If $x(n)$ has the frequency domain: Xmag[f] and Xphase[f], and $y(n)$ has the frequency domain: Ymag[f] and Yphase[f], calculate the frequency domain of the following signals: 9

i. $x(n-2)$
ii. $1.2\,x(n-1)$
iii. $y[n+2]/10$

c) If there are N samples entering the DFT, and N+2 samples exiting, where did the extra information come from? 6

2. a) For each of the following input-output relations, determine whether the corresponding system is linear: 9

i. $\mathrm{y(t)} = \mathrm{t}^2\, x(\mathrm{t}-1)$
ii. $\mathrm{y[n]} = x[n-2]$
iii. $\mathrm{y[n]} = x[n+1] - x[n-1]$

b) Though writing a program to convolve one signal by another is a simple task, executing the program is time costly. The problem is the large number of additions and multiplications required by the algorithm, resulting in long execution times.
Discuss common ways to handle this longer execution time. 6

c) RADAR is one of the most important applications of DSP. Radar is an acronym for *RAdio Detection And Ranging*. Figure 2 depicts basic operation of a RADAR. One major challenge in this operation is the presence of random white noise.
Briefly discuss how **Matched Filtering** is used for the RADAR operation and how it overcomes the random white noise challenge. 10

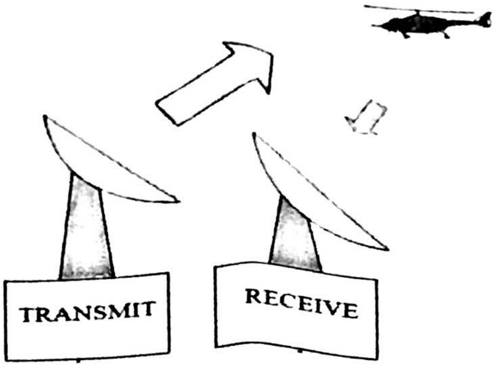

Figure 2: Block diagram of a RADAR

3. a) What is aliasing? How does the time domain and frequency domain aliasing differ from each other? 6

b) Contrast between the information that is stored in the magnitude and the phase of a signal. Discuss a method that can demonstrate the type of information that is stored in the phase of a signal. 2+7

c) Figure 3 shows the corresponding phase change of a signal resulting from time domain shifting. Inspect this carefully and answer the following questions: 10

   i. Why is there no change of phase in zero frequency?
   ii. How much is the phase change at the highest frequency for one sample shift in time domain? Why is it so?
   iii. Observe that for all the other frequencies between 0 and 0.5, the phase change is linear. Why is it so?

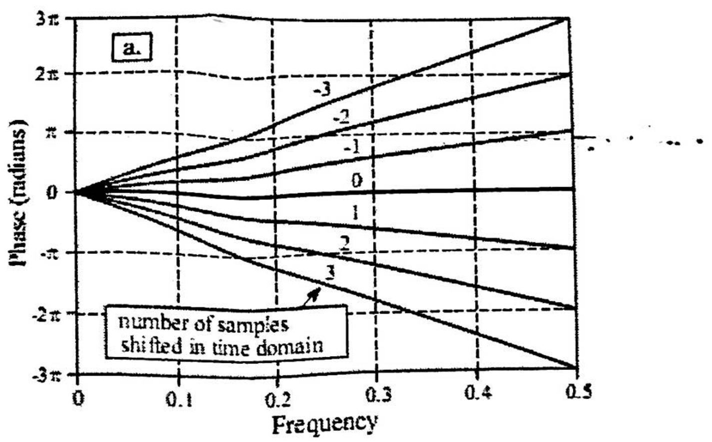

Figure 3: Phase change with respect to time domain shifting

4. a) A gym instructor was kidnapped from Boardbazar. To solve the case, the Police have retrieved a number of clues. Among the clues, most important one is a recording of a phone call. But the recording contains two voices- a male and a female, talking simultaneously. To separate the voices Police asked help from DSP engineers of IUT. As a DSP engineer, your task will be to design necessary filters to separate the voices. 16

The call is sampled at 4000 Hz, the transition bandwidth is 3 Hz.

The voiced speech of a typical adult male will have a fundamental frequency from 85 to 140 Hz, and that of a typical adult female from 165 to 255 Hz.

Determine $h(i)$ for $i = \{-3, -2. -1, \mathbf{0}, 1, 2\}$, where $h(i)$ is the impulse response of a Windowed-Sinc filter using Blackman window. Use the following equation:

$$h[i] = K \frac{\sin(2\pi f_C (i - M/2))}{i - M/2} \left[0.42 - 0.5\cos\left(\frac{2\pi i}{M}\right) + 0.08\cos\left(\frac{4\pi i}{M}\right)\right]$$

4

…fine FIR filters and IIR filters. 5

You want to purchase a new power amplifier for the sound system in your room. You want an 800-watt amplifier but can only afford a 350-watt amplifier. How many dB of sound are you going to sacrifice using the smaller amplifier?

a) Name the time domain and frequency domain parameters for evaluating filter performance. Describe an example scenario where you would need a filter which works well both in time domain and frequency domain. 6+4

b) Why is step response of a filter more important than the corresponding impulse response even though they represent identical information? Explain. 5

c) The original filter kernel of a low-pass filter is given below and the original frequency response is shown in Figure 4. The bold sample denotes the center of the symmetry. 10

Original filter kernel = $\{-2,-1,0,1,2,3,4,\mathbf{5},4,3,2,1,0,-1,-2\}$

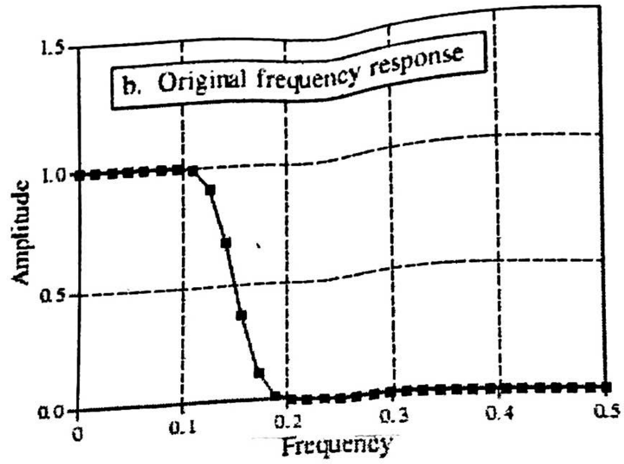

Figure 4: Filter kernel of a low-pass filter

Calculate the filter kernel and draw the frequency response for the following two cases:

i. The original filter is converted to high-pass filter using spectral inversion
ii. The original filter is converted to high-pass filter using spectral reversal

6. a) In comparison with Gaussian and Blackman filters, the moving average filter (MAF) will run like lightning in your computer. In fact, it is the *fastest* digital filter available. the Gaussian and Blackman filters are excruciatingly slow, because they must use convolution. Which is not the case for MAF. Give an implementation of Moving average filter, where it does not need convolution. 7

b) Suppose you are asked to isolate a 1 nanovolt signal riding on a 10 volt power line. The only filter that you have at your disposal is the standard windowed-sinc filter using the Blackman window (which has a stopband attenuation of -74 dB) and having a kernel length of 301. 10

i. How can you design a filter that serves the purpose?
ii. What is the stopband attenuation and filter kernel length of your final filter?

c) What is circular convolution? How can you avoid it? 8

7. a) The following signal x(n) is in time domain. You are supposed to apply Fast Fourier Transform (FFT) on it. Find 16 different 1-sample Frequency domain signals from the following 16-sample time domain signal. 7

$x(n) = \{5,2,8,10,3,11,18,0,6,15,19,20,17,1,13,25\}$

b) Discuss the synthesis step of FFT with appropriate figures. 10

c) Define *Complex Conjugate*. Give some examples of how the complex conjugate is used in DSP. 8

8. A *gamma ray detector* as illustrated in Figure 5, this device is composed of two parts, a *scintillator* and a *light detector*. A scintillator is a special type of transparent material, such as sodium iodide or bismuth germanate. These compounds change the energy in each gamma ray into a brief burst of visible light. This light is then converted into an electronic signal by a light detector, such as a photodiode or photomultiplier tube. Each pulse produced by the detector resembles a *one-sided exponential*, with some rounding of the corners. This shape is determined by the characteristics of the scintillator used. When a gamma ray deposits its energy into the scintillator, nearby atoms are excited to a higher energy level. These atoms randomly *deexcite*, each producing a single photon of visible light. The net result is a light pulse whose amplitude decays over a few hundred nanoseconds (for sodium iodide). Since the arrival of each gamma ray is an *impulse*, the output pulse from the detector (i.e., the one-sided exponential) is the *impulse response* of the system.

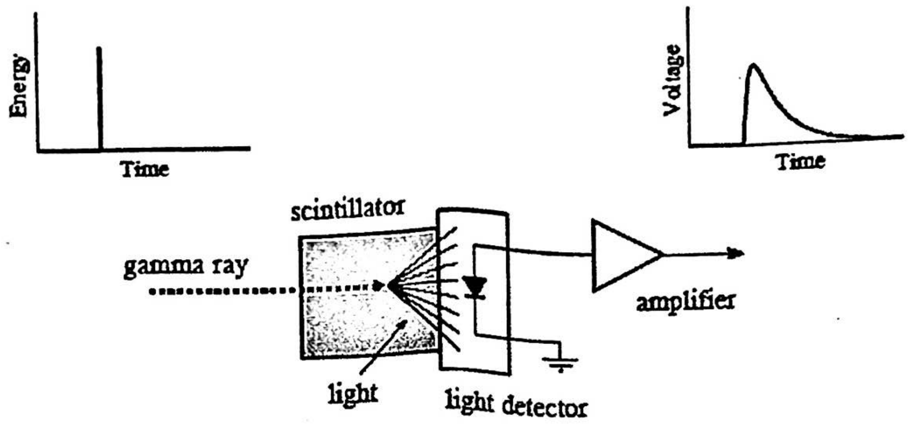

Figure 5: Gamma Ray detector

Figure 6(a) shows pulses generated by the detector in response to randomly arriving gamma rays. The information we would like to extract from this output signal is the amplitude of each pulse, which is proportional to the energy of the gamma ray that generated it. This is useful information because the energy can tell interesting things about where the gamma ray has been. For example, it may provide medical information on a patient, tell the age of a distant galaxy, detect a bomb in airline luggage, etc. Everything would be fine if only an occasional gamma ray were detected, but this is usually not the case. As shown in Figure 6(a), two or more pulses may overlap, shifting the measured amplitude. One answer to this problem is to deconvolve the detector's output signal, making the pulses narrower so that less pile-up occurs. Ideally, we would like each pulse to resemble the original impulse. As you may suspect, this isn't possible and we must settle for a pulse that is finite in length, but significantly shorter than the detected pulse. This goal is illustrated in Figure 6(b).

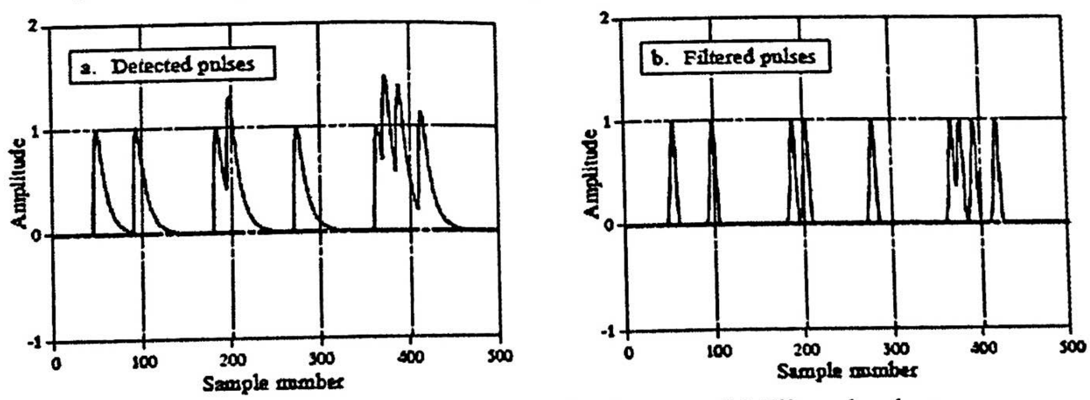

Figure 6: (a) pulses generated by the detector, (b) Filtered pulses

a) Propose a filter to convert the detected pulses into impulse-like pulse. Your answer should include the following aspects: 18
   i. Problem formulation
   ii. Solution (Mathematical equations)
   iii. Necessary Conditions

b) Is it possible to create pure impulse with your proposed filter? If not, explain why. How far is achievable? 4+3