Assignment 4

Objective:

Signal analysis and operations in frequency domain (Spectral domain)

Part 1:

Q1. Understand the basics

I. Calculate the Discrete Fourier transform (DFT) for the following single tone(frequency) sinusoidal signal.

y[n] = sin(2*pi*(f/fs)*n)

where, signal frequency (f) is 17Hz, sampling frequency(fs) is 64Hz and signal length is of 64 samples.

Use MATLAB 'fft' function to calculate DFT for N=128. Plot and analyse magnitude and phase response of DFT. What is the frequency resolution(in Hz) for N=128? Compare your results mathematically.

Are you getting a single tone after DFT? If not, please explain the reason intuitively and mathematically. What should be done to achieve the desired result?

II. Calculate the inverse Discrete Fourier transform using MATLAB function 'ifft', and compare the original signal and reconstructed signal. Does both signals match? If not, why is this so ?

III. Please plot **approximate** DTFT for given signal 'y'. Analyse the DTFT sampling at different values of N.

IV. Use MATLAB function 'window' and analyse different window functions (e.g. rectangular, Hamming, Gaussian, Kaiser etc.) through MATLAB function 'wvtool'. Now, multiply different window functions to given signal 'y' in time domain and compare the DFT of signal y with and without window functions.

V. Use your knowledge gathered so far in this assignment to solve the following problem.
We have a signal,

y[n] = sin(2*pi*(f1/fs)*n) + 0.5*sin(2*pi*(f2/fs)*n)

which consists of two different frequencies f1=17.1Hz and f2=17.5Hz, and, the sampling frequency is 64Hz. Find out the optimal window function, value of signal length and frequency samples (N) such that we can easily differentiate f1 and f2 in discrete Fourier domain.

VI. Let's take a rectangular signal,

$$y[n] = 1 \text{ for } n = 0 \text{ to } M-1$$

Understand convolution in time domain and frequency domain. Next, convolve this signal by itself in time domain and frequency domain (use equivalent convolution property in Fourier domain). Compare both outputs and explain whether they should be same or not? If not, what should be done to achieve same output.

VII. Calculate and plot the output of the system for given input x[n] and impulse response h[n] in time domain and frequency domain.

Input signal is,

$$x[n] = \sin(2*pi*(f1/fs)*n) + \sin(2*pi*(f2/fs)*n)$$

where f1 is 4Hz, f2 is 20Hz and sampling frequency(fs) is 50Hz. Signal length is 128 samples.

Impulse response is,

$$h[n] = 1/M \text{ for } n=0 \text{ to } M-1 \text{ (Take } M=5 \text{ in this example)}$$

Which filter does this impulse response correspond to ?

Q2. DTMF Decoder in spectral domain.

For recap, we have developed an algorithm in assignment 2 to segment our DTMF signal into desired content and undesired content using average energy criteria. Each desired segment is corresponds to a telephone pressed key having two different frequencies. In assignment 3, we designed DTMF decoder in time domain through correlation approach.

Now, in this assignment we will use frequency domain approach to decode the keys from the signal.
In first approach,

Use DFT as a tool to identify dominant frequency components present in the signal.

In second approach,

Use Goertzel algorithm (MATLAB function 'goertzel') to compute the signal strength only for few required values of frequencies.

As per industry standard, use maximum 320 samples per segment for analysis. Use audio file given with this assignment to verify your algorithm.

Part 2:

Objective:

To learn and design Radar for determining the speed of target using Doppler and frequency spectrum concepts.

Understand the basics

I. Find the Doppler frequency of an airborne target detected by a stationary radar for the following specification

- **a.** Aircraft speed = 1 mach, 2 mach and 3 mach.(1 mach = 330 m/s approx)
- **b.** Aircraft is approaching the Radar (Positive Doppler frequency)
- **c.** Centre frequency (f0) of transmitted signal = 3 GHz

II. For the specification given below ***calculate and plot*** the ***discrete frequency spectrum*** of the given signal and also find the maximum target velocity detectable by the Radar

i. **Aperiodic** rectangular discrete pulsed signal
   1. Total duration = 10 milli second
   2. On time = 1 milli second (Duty cycle=10%)
   3. Choose appropriate sampling frequency
   4. Use DFT

   Note: Inbuilt Matlab functions can be used.

ii. Aperiodic pulsed sine wave signal of centre frequency of 30 MHz.

   (The specifications of (i) holds good here)

iii. Periodic pulsed sine wave signal of pulse duration with centre frequency of 30 MHz and PRF = 100 Hz
   1. The specifications of (i) holds good here
   2. Consider 64 pulses for computation of DFT
   3. PRF (Pulse repetition Frequency)

iv. Periodic pulsed sine wave signal with centre frequency of 30 MHz and PRF = 20 KHz

    1. On time of each burst(pulse) = 10 % of total duration
    2. Consider 64 pulses for computation of DFT