Applications of Fourier Transform

Learning Objective: The aim of this lab session is to get familiar with the Matlab function fft() and use it to analyze spectrum of some signals.

Experiments: In this lab we will determine the frequency spectrum of a one dimensional signals. You may use the fft() function of Matlab for this purpose. This lab session consists of the following problems:

1. Consider a signal that consists of sum of two sinusoidal signals
$$s(t) = a_1 \cos(2 \pi f_1 t + \theta_1) + a_2 \cos(2 \pi f_2 t + \theta_2)$$
   (a) Assume $\theta_1 = \theta_2 = 0$. Represent and plot this signal in Matlab. Notice that this is a continuous signal, hence you need to sample this signal appropriately.
   (b) Apply Fourier transform to this signal and plot magnitude and phase spectrum. Interpret your result. Hint: What is the values of the magnitude spectrum for frequencies other than f_1 and f_2? Is the phase value reliable at these points?
   (c) What is the value of the phase response at frequencies θ_1 and θ_2?
   (d) Repeat (a) to (c) for non zero values of θ_1 and θ_2.

2. Read three audio signals in Matlab. You are free to choose any audio file from any source, however, it may be noted that Matlab itself has many sample audio files. You can search for these files in "Matlab Documentation/Help". Your audio signal should not be too long, a signal of few seconds duration is sufficient.
   (a) Using the technique learnt in Problem 1, plot the magnitude spectrum of the three signals you have read.
   (b) Determine 5 most prominent frequencies in each of the three signals.
   Hint: You may find some Matlab functions like audioread(), sound() etc. useful for this problem. Refer to Matlab Documentation/Help for more details.
   Hint: If it is possible, interpret the spectrum of the signal you have plotted. For example, if you have sound from a string instrument, you may see some harmonics.

3. In this problem we will consider amplitude modulation. Consider a message signal $m(t) = \cos(2 \pi f_m t)$ and a carrier wave $c(t) = \cos(2 \pi f_c t)$.
   (a) Choose f_m and f_c such that $f_m < f_c$. Plot $c(t)$, $m(t)$ and the double side-band suppressed carrier amplitude modulated wave.
   (b) Plot the magnitude spectrum of the signals in (a).
   (c) The complete receiver has a coherent detector and a low pass filter. We will skip the low pass filter block, but plot the time domain signal and the frequency spectrum of the output of the coherent detector.
   (d) Repeat (a) to (c) for $f_m > f_c$. Do you see distortion in the output of the coherent detector compared to the original message signal?

Deliverables: You are allowed to discuss the problem with others but final code(s) and report should be your own individual work. **You should submit a soft-copy report by 20th January 2021 to Mr. Anurag Bohre**, anuragb@iiserb.ac.in , which includes:

1. The Matlab codes. You need not repeat the codes if you are only changing the parameters to produce a different set of graphs.
2. The output produced by your code: graphs, numerical output etc.

Useful Sources Where You Can Get Help: There are a lot of online and offline sources where you can learn about fft() function of Matlab:

1. The fft() documentation page in Matlab Help is a very good resource.
2. One of the many online resources, for example the Youtube tutorial video by David Dorran "Using Matlab's fft function", https://www.youtube.com/watch?v=dM1y6ZfQkDU can be consulted. This useful tutorial tells you how the frequency bins produced at the output of fft() should be interpreted.
3. To learn more about Discrete Fourier Transform and Fast Fourier Transform algorithm used to implement it, you may refer to "Signals and Systems Using Matlab" by Luis F. Chaparro.