Electrical Engineering 3TP3
Lab 4
Signal Analysis Using the Discrete Fourier Transform

In this lab we perform various experiments relating to signal analysis using the discrete Fourier transform (DFT). We first analyze the spectrum of a provided audio (wav) file using the fast Fourier transform (FFT). The information obtained is then used to synthesize the original waveform. In the second part of the lab you are given an audio (wav) file that is part of an intercepted secret message where information has been encoded into transmitted tone symbols. However, the quality of the received signal is very poor. Your objective is to use the DFT to recover the transmitted message.

1 Preparation

1. It is important that you attend the lectures which introduce the DFT and are familiar with using the FFT function in Matlab.
2. There are some files associated with this lab that you need to download from the course web site.

2 Part I

1. From the course web site, download the audio wav file `tones2019.wav` which contains a signal consisting of a combination of some sinusoidal tones.
2. Listen to the contents in the file using a media player on the PC or laptop that you are using. Describe what you hear.
3. Write a short Matlab M-file that displays the first 5 msec of the waveform in the file. This can be done using some Matlab code similar to that shown below.

```
% Read in the signal from the audio file
[signal, Fs, bits_per_sample] = wavread('tones2019.wav');
L = length(signal);
T = 1/Fs;
t = [0:L-1]*T;
% Plot the signal for t_plot msec
t_plot = 5;
msec_per_sec = 1000;
numSamples = t_plot*Fs/msec_per_sec;
```

```
plot(msec_per_sec*t(1:numSamples), signal(1:numSamples))
title('Plot of Input Signal')
xlabel('time (milliseconds)')
grid('minor');
```

4. Based on what you see in Part 3, estimate how many sinusoids make up the signal, and estimate their frequencies. Describe in detail how you made these estimations.

5. Using the fast Fourier transform (FFT), find and plot the discrete Fourier transform (DFT) of the audio signal. It is more convenient to plot the single-sided magnitude of the DFT. This can be done using the following Matlab code.

```
% Take the DFT
Y = fft(signal)/L;
f = Fs/2*linspace(0,1,L/2+1);
% Plot the single-sided magnitude spectrum.
plot(f,2*abs(Y(1:L/2+1)));
title('Single-Sided Magnitude Spectrum')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
axis([0 Fs/2 0 .5]);
grid('minor');
```

6. Using your results from Part 5, determine the frequencies and magnitudes of the sinusoids that make up the audio signal.

7. Write a short Matlab M-file that generates the signal that was used to create the audio file. Plot the first 5 msec of the signal and compare it to what you found in Part 3.

3 Part II

1. From the course web site download the audio wav file `SecretMessage2019.wav`. This file contains an intercepted secret message which was received over a very long communication link. The message is encoded using sinusoidal tones but the quality of the received signal is very poor and it is corrupted by a high level of noise. Your task is to determine what message is contained in the intercepted signal.

2. As before, listen to the received signal and see if you can hear the tones that were sent. Describe in detail what you hear.

3. Using procedures such as that discussed in Part I, determine all of the frequencies that are used in this signal.

4. The secret message in this file is encoded in multiple 1-second duration “symbol periods”, where each period contains a single message character, encoded by sinusoidal tones. To decode the message you need to determine which frequencies are contained in each symbol period. Download the file CodeBook.pdf which will help you to decode the message.

4 Write-up

Submit a write-up for the lab. Each group (of 2 maximum) may submit a single write-up. Include in your write-up a description of everything that you did. Include the plots and a listing of the Matlab programs with your write-up.