ECE 340 Lab 4

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Section D21

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1 Reading Audio File

To play and extract the sampling rate, bit-rate, and duration of the the audio file *love_mono22.wav*, the following MATLAB script was used:

```
%% First few words of love_mono22.wav:
% I love to love, I love to love you,
% So much I wanna share and do, wohohoh
% I love to love, I love to love you,
% I wanna find a way to you.

[x, Fs] = audioread('love_mono22.wav'); % Fs = sampling rate
[num_samples, num_channels] = size(x);

% Play the song
sound(x, Fs);

% Caclulate Bit Rate & Duration
bits_per_sample = 8;
bit_rate = Fs * bits_per_sample * num_channels;
duration = num_samples / Fs;

fprintf('Sampling Rate: %d Hz\n', Fs);
fprintf('Matrix Size: [%d][%d]\n', num_samples, num_channels);
fprintf('Bit-Rate: %d bits/sec\n', bit_rate);
fprintf('Duration: %.2f s\n', duration);
```

After running the script the following output was produced providing the requested data:

```
Sampling Rate: 22050 Hz
Matrix Size: [400000][1]
Bit-Rate: 176400 bits/sec
Duration: 18.14 s
```

2 Audio Specturm

The DFT of the audio signal was calculated and the first three coefficients where outputed using the *fft* function in the following MATLAB script:

```
X = fft(x); % Compute the DFT
fprintf('X[0] = %f + %fi\n', real(X(1)), imag(X(1))); % First coefficient
fprintf('X[1] = %f + %fi\n', real(X(2)), imag(X(2))); % Second coefficient
fprintf('X[2] = %f + %fi\n', real(X(3)), imag(X(3))); % Third coefficient
```

After running the script the following output was produced:

```
X[0] = -16.062500 + 0.000000i
X[1] = 0.778562 + -0.640574i
X[2] = 3.169748 + -1.670759i
```

To the scale all the coefficients $X[r]$ by $X'[r] = \frac{X[r]}{\sqrt{N}}$ the following MATLAB script was used:

```
N = num_samples; % Total number of samples from section 1
X_s = X / sqrt(N); % Scale the coefficients
```

Then to plot $x[k] = |X'[k]|$ in kHz the following script was used:

```
mag_scaled = abs(X_s); % Magnitude of the DFT
f_kHz = (0:N-1) * (Fs / N) / 1000; % Frequency in KHz
mag_dB = 20 * log10(mag_scaled); % Convert to dB

% Plot the magnitude spectrum
plot(f_kHz(1:floor(N/2)), mag_dB(1:floor(N/2)));
xlabel('Frequency (kHz)');
ylabel('Magnitude (dB)');
title('Magnitude Spectrum of the Audio Signal');
grid on;
```

Which produced the following plot:

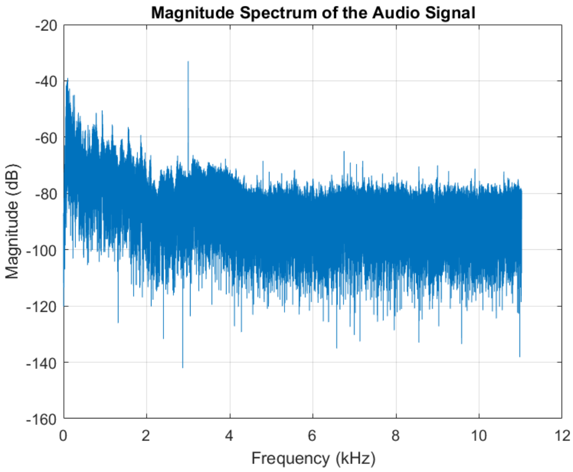

Figure 1: Magnitude specturm of $x[k] = |X'[k]|$.

The plot above depicts the magnitude spectrum of the audio signal from the *love_mono22.wav* file. The graph shows prominent peaks caused by variations in the sound signal, likely due to sudden changes in instrumentals, beats, or lyrics in the song. When we played the song in the previous section, a consistent ringing sound could be heard in the background. This ringing manifests as a relatively constant magnitude across the lower intensities. The lower frequencies of the plot (up to 0.25 kHz) exhibit higher energy levels, indicating that this song has a strong bass component.

3 Spectrum Estimation

To estimate the power spectral density of the signal *love_mono22.wav* and plot the spectrum the following MATLAB script was used:

```
N = 512;
[Px, F] = pwelch(x, N, [], N, Fs);
plot(F/1000, 10*log10(Px)); %Plots the power spectrum
%scaling F by 1000 will represent frequency in kHz
xlabel('Frequency (kHz) ');
ylabel('Power Spectral Density (in dB) ');
grid on;
```

It produced the following plot:

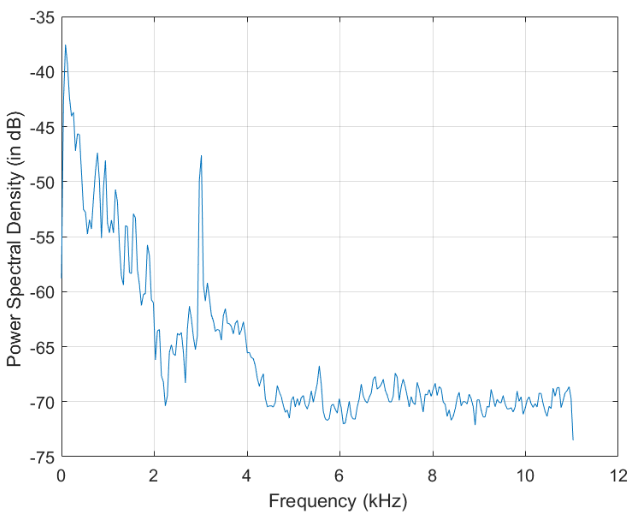

Figure 2: Power Spectral Density Plot of *love_mono22.wav*.

After examining the power spectral density plot, it is clear that the lower frequencies contain the most energy, particularly in the range of 0 kHz to 2 kHz, after which there is a sharp drop with another smaller peak between approximately 3 kHz and 4 kHz. The energy peaks slightly above 0 kHz, reaching around -37 dB. Beyond 4 kHz, the energy levels average out. Going back to the (annoying) noise heard in the audio file, the most likely frequency corresponding to it is the sharp spike at approximately 3 kHz mentioned previously.

4 Power Spectrum of 2D Images

Upon inspecting the provided TIF image file, *ayantika.tif*, a very distinct and uniform grid artifact is visible across the image:

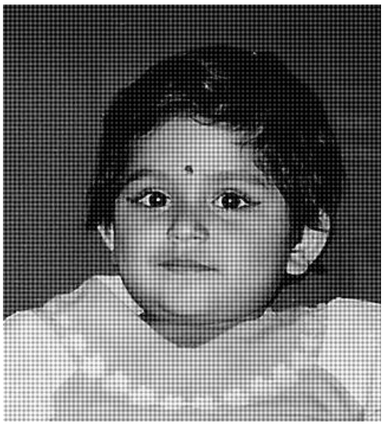

Figure 3: ayantika.tif

After running the provided 'q4.m' script the following plot was produced:

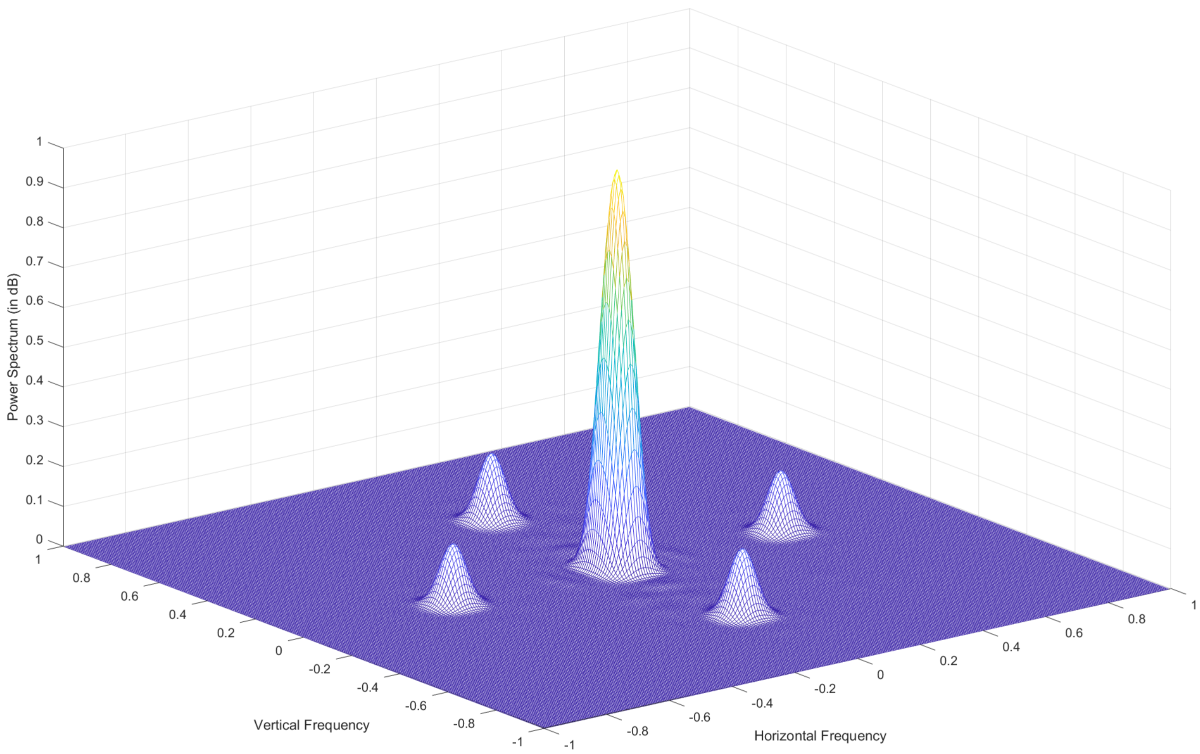

Figure 4: Spectrum plot produced by 'q4.m'.

By examining the plot, the main lobe is found to peak at (0, 0, 1). Then the four other peaks are located at (-0.5, 0, 1.5), (0, -0.5, 1.7), (0.5, 0, 1.5), and (0, 0.5, 1.7).