EE386 Digital Signal Processing Lab — Jul-Dec 2021

Experiment 3 Report

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The calculated value of α for the roll number : 191EE126 is

$$\alpha = 1 + mod(126, 4) = 3$$

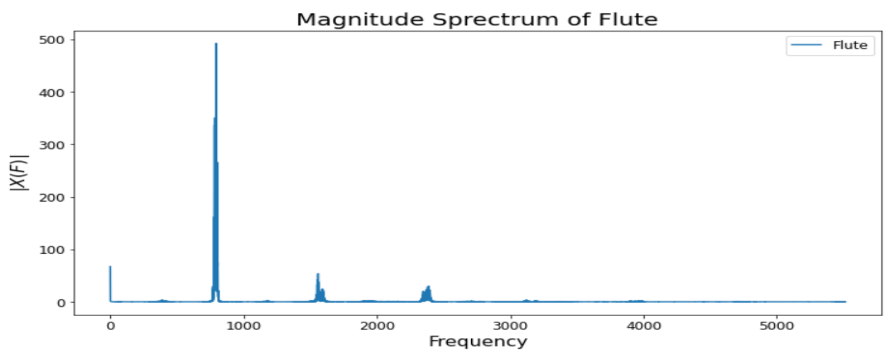
Problem 1

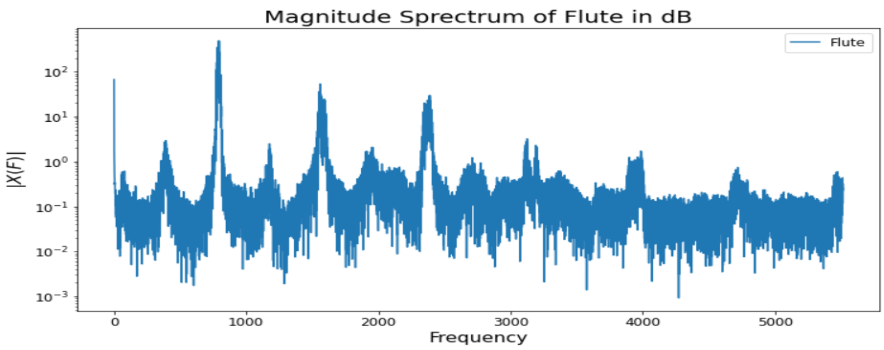
(Plotting Signals Spectra)

(Solution)

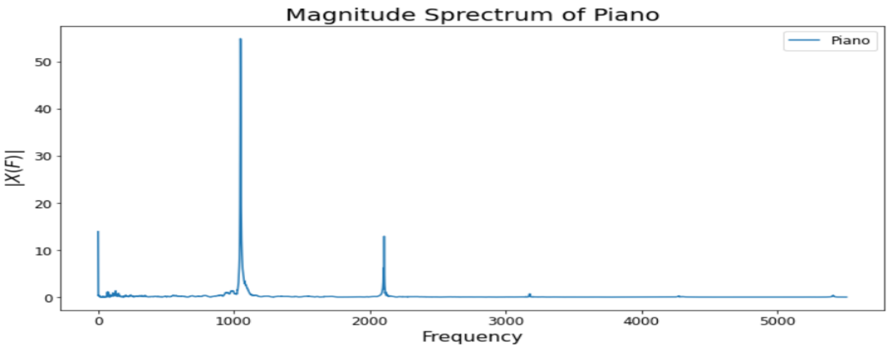
Given the recording of 4 instruments, namely flute, piano, trumpet and violin, magnitude spectra of each recording is plotted (in dB scale) against frequency (Hz). Each recording has a different fundamental frequency. To find the fundamental frequency, one has to look at the first dominant peak in the magnitude spectrum of the signal. It is not necessary for the peak to be global maxima in the signal. Fundamental Frequency is found using the function find fundamental harmonic and is plotted in dB scale using semilogy function.

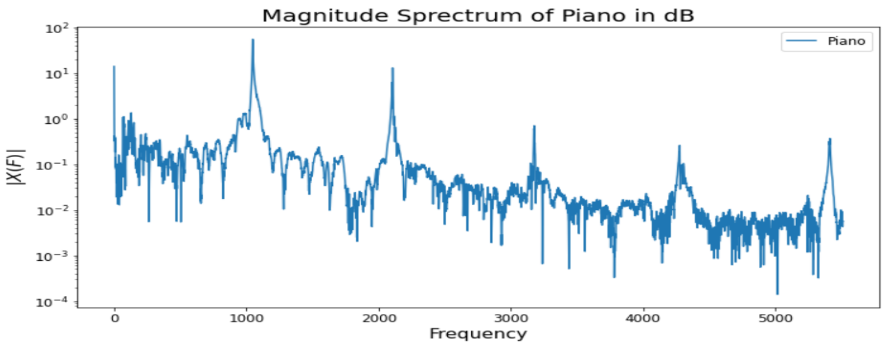
1. **Flute**



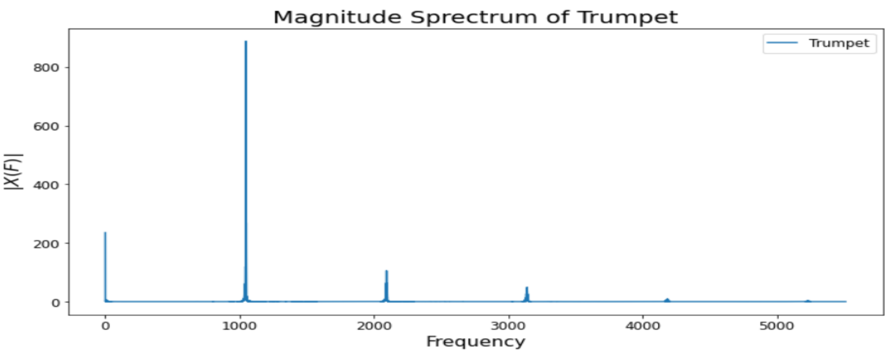


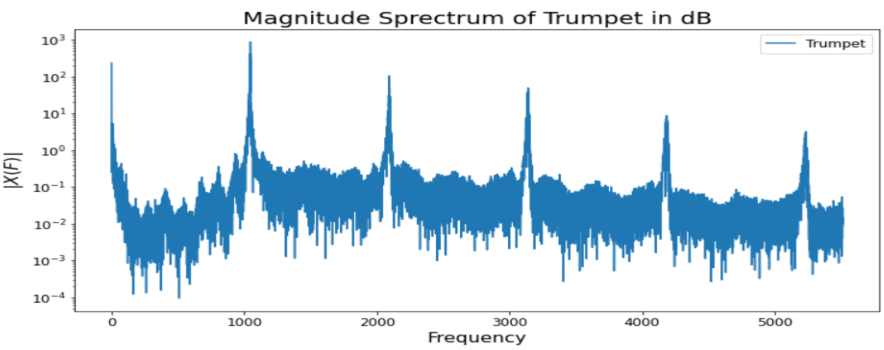
2. Piano



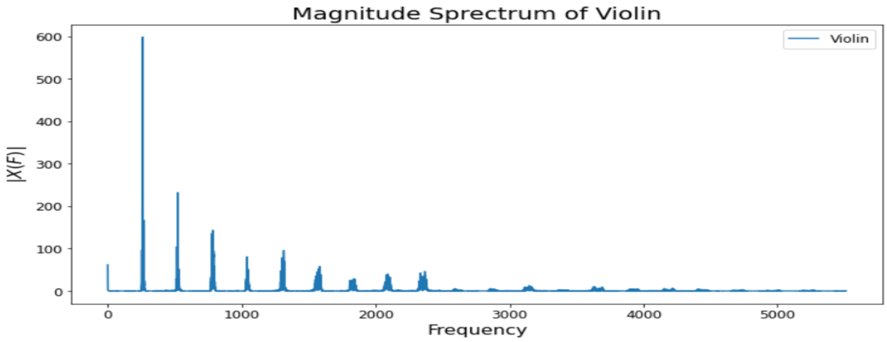


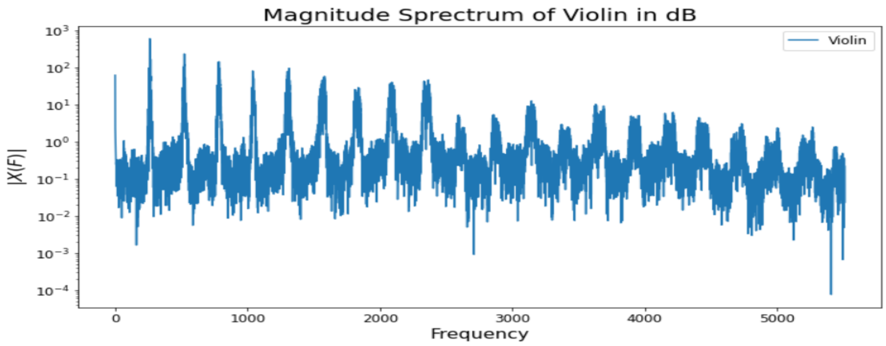
3. Trumpet





4. **Violin**





Each of the recording has its own fundamental frequency. The frequency corresponding to first peak in the magnitude spectrum is the fundamental harmonic. Fundamental frequencies of each instrument are :

Instrument	**Fundamental Frequency**
Flute	775.44 Hz
Piano	1048.37 Hz
Trumpet	1043.70 Hz
Violin	255.43 Hz

(Comparing Fundamental Frequencies of Different Signals)
(Solution)
The fundamental frequencies of 'piano3.wav' is compared to all the flute audio files, to find the one with closest fundamental frequency. It is found that 'flute1.wav' has the closest fundamental to 'piano3.wav',i.e, 1034.7 Hz and 1048.37 Hz respectively. Hence $\beta = 1$.

Problem 2

(Fundamental Frequency of Key Whistle)

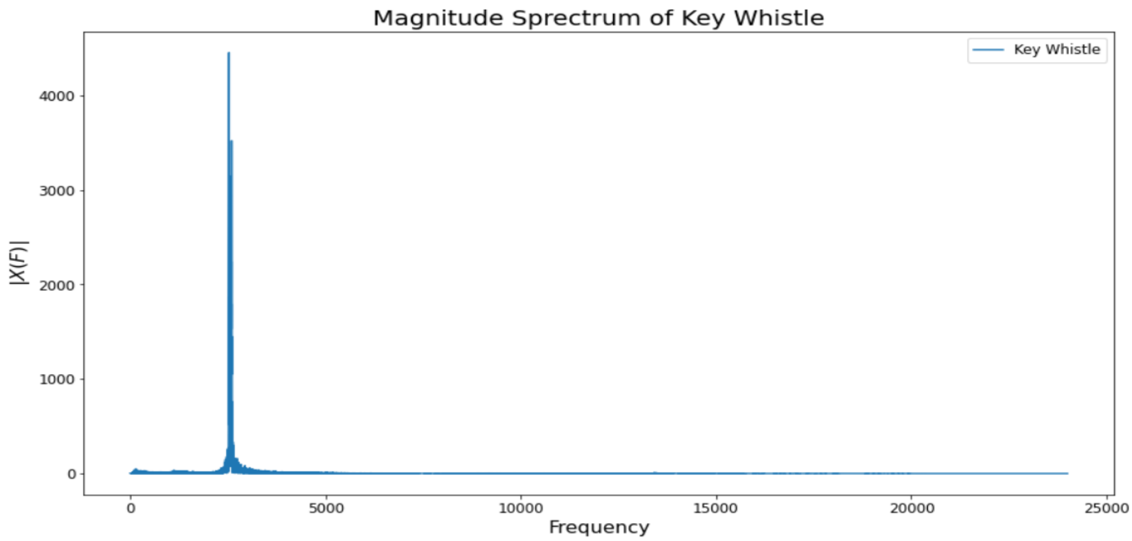
(Solution)

The key whistle is stored in the file key_whistle.wav. The fundamental frequency of the this signal is calculated and found to be 2513.095 Hz. This frequency acts as the authentication key. Any whistle with a 5% error with in the fundamental frequency should act as a key.

(Magnitude Spectrum)

(Solution)

The magnitude spectrum of the key whistle is plotted :



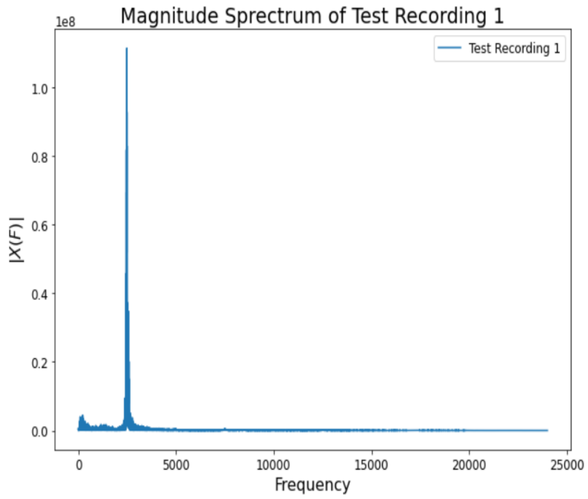
(Testing Password)

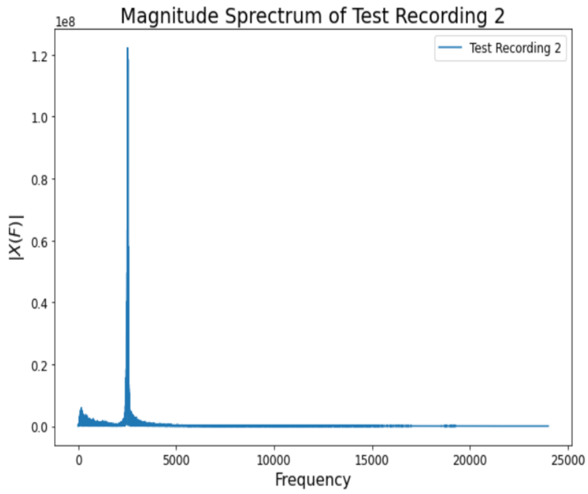
(Solution)

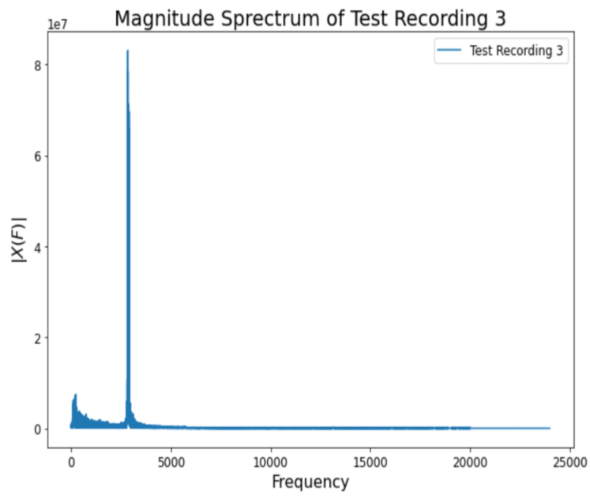
A total of 4 tests were made. All the whistles are recorded during runtime. Hence the code could be used for testing multiples audio files easily and quickly. The x^{th} test is stored in testfilex.wav. The authentication process only grants access if the test file has a fundamental frequency within 5% error of the fundamental frequency of the key whistle. The fundamental frequency of the this signal is calculated and found to be 2513.095 Hz. The outputs and the fundamental frequencies for each of the test files are as shown :

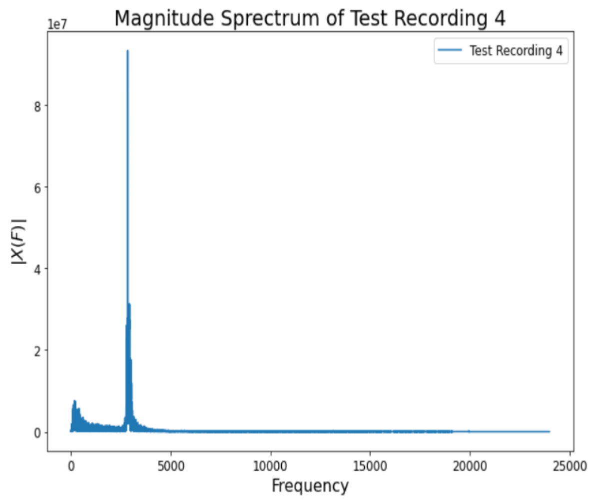
Test Case	Fundamental Frequency	Output
1	2433.33 Hz	ACCESS GRANTED
2	2436.36 Hz	ACCESS GRANTED
3	2803.09 Hz	ACCESS DENIED
4	2776.40 Hz	ACCESS DENIED

Magnitude Spectra of Test Whistles







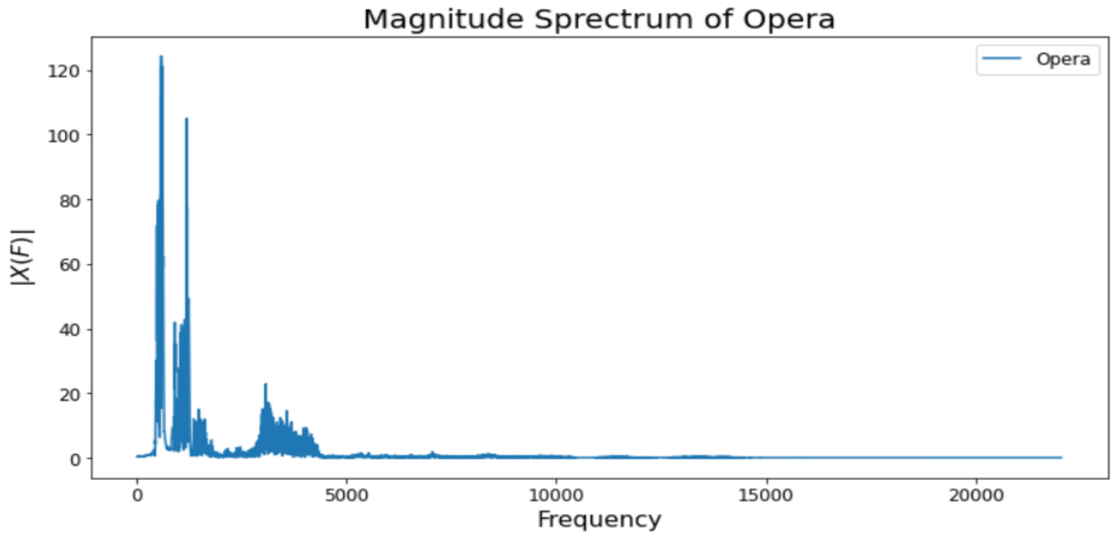


Problem 3

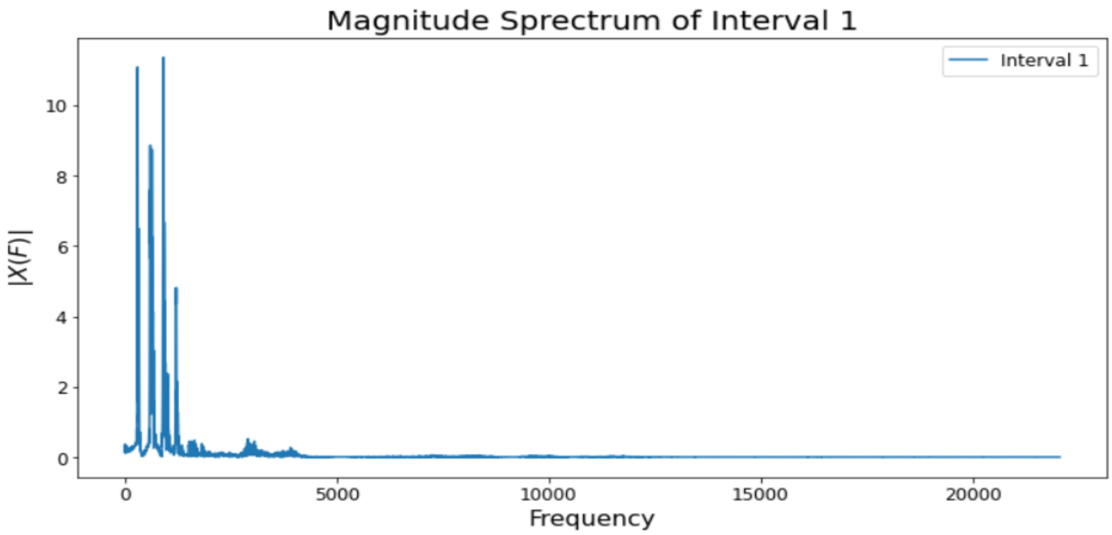
(Simultaneous Time and Frequency representations)

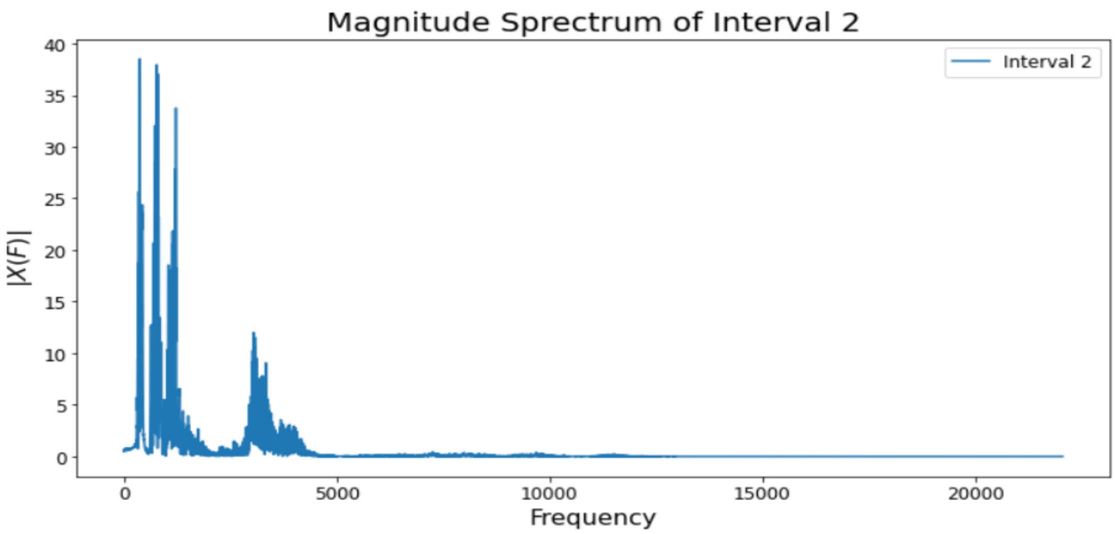
(Solution)

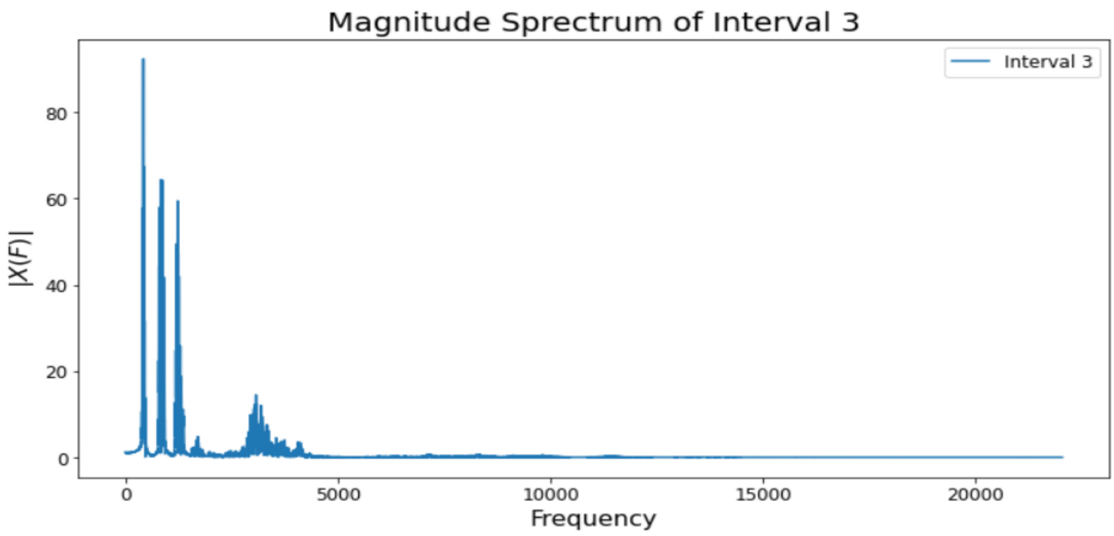
The signal is read from the opera.wav file. The audio signal consists of about many different notes. Each of these notes have their own frequencies and amplitudes. When the magnitude spectrum of the fourier transform of the complete signal is examined, all the frequencies and their amplitudes are merged. Hence it is not possible to examine the temporal variations in fundamental frequencies. To solve this, the given signal can be partitioned into 10 parts. Then it can be stored in an array and the plots of magnitude spectrum can be plotted for each of these signals.

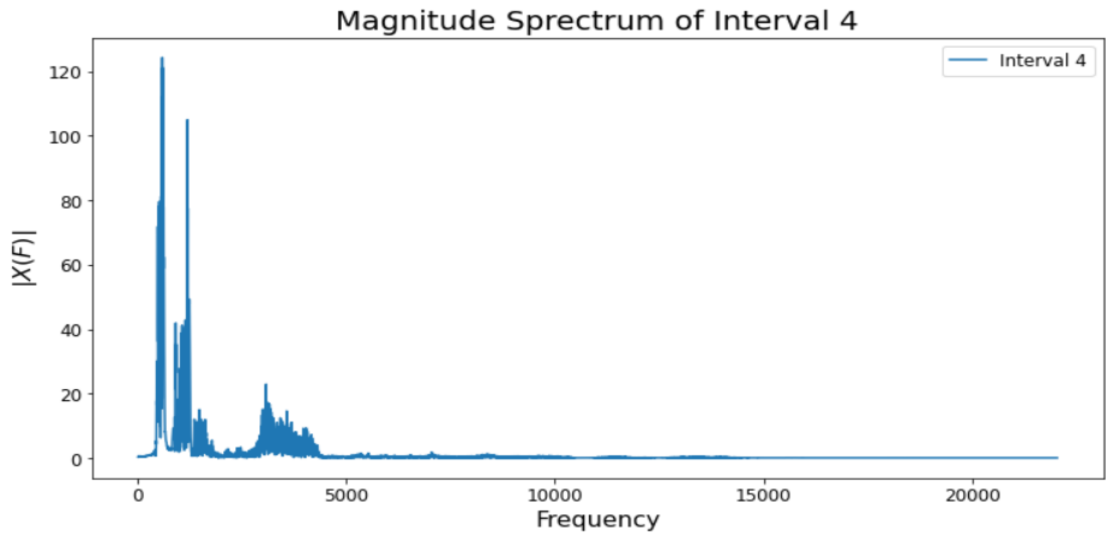


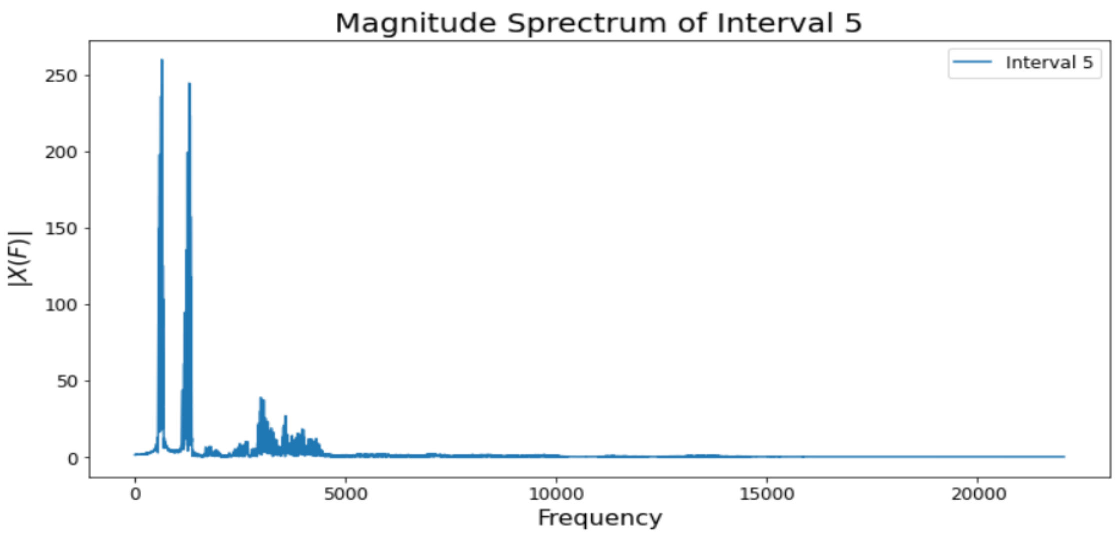
Magnitude Spectra of Intervals

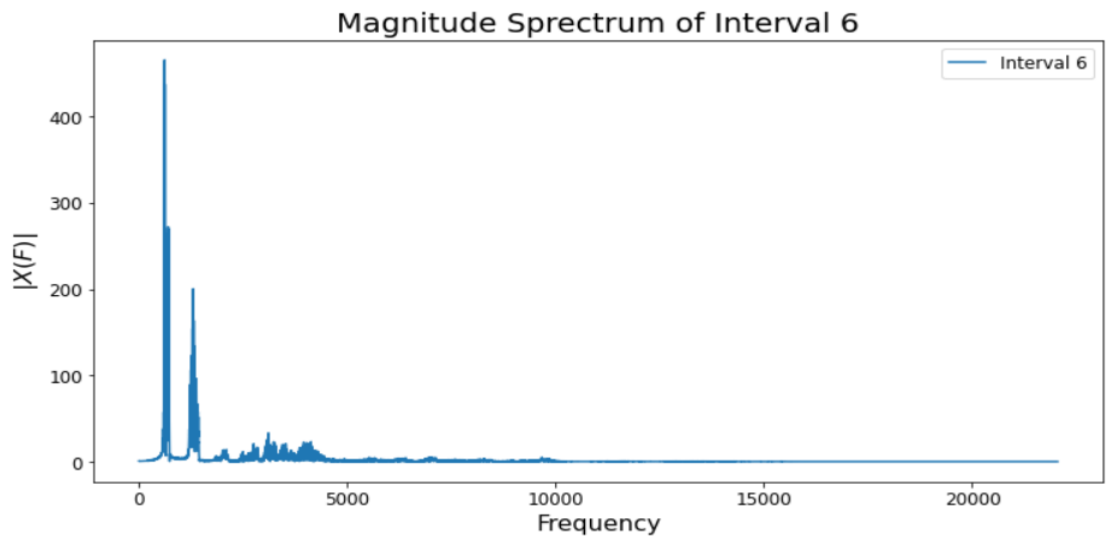


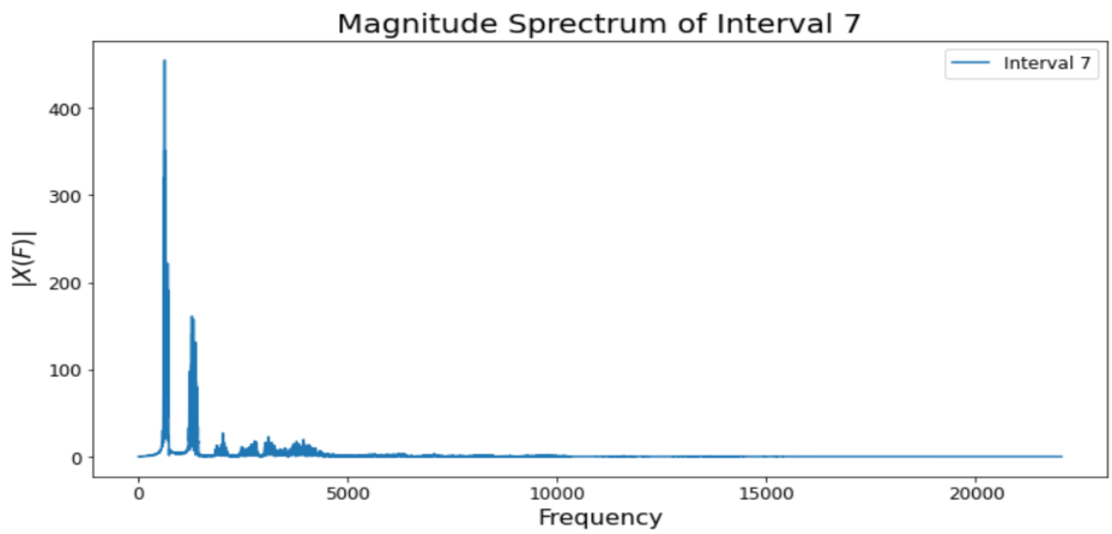


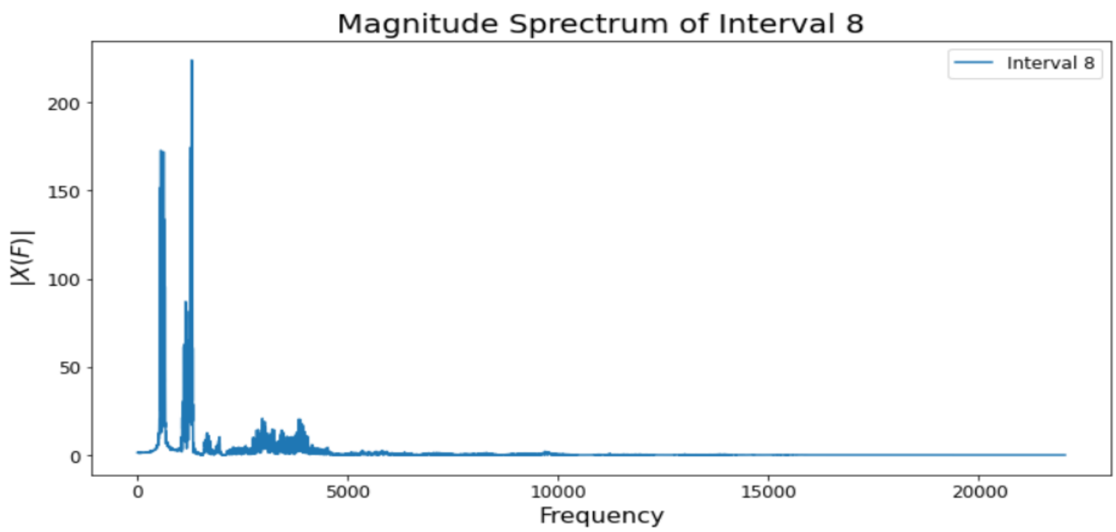

Magnitude Sprectrum of Interval 3
Interval 3
|X(F)|
Frequency
0
20
40
60
80
0
5000
10000
15000
20000

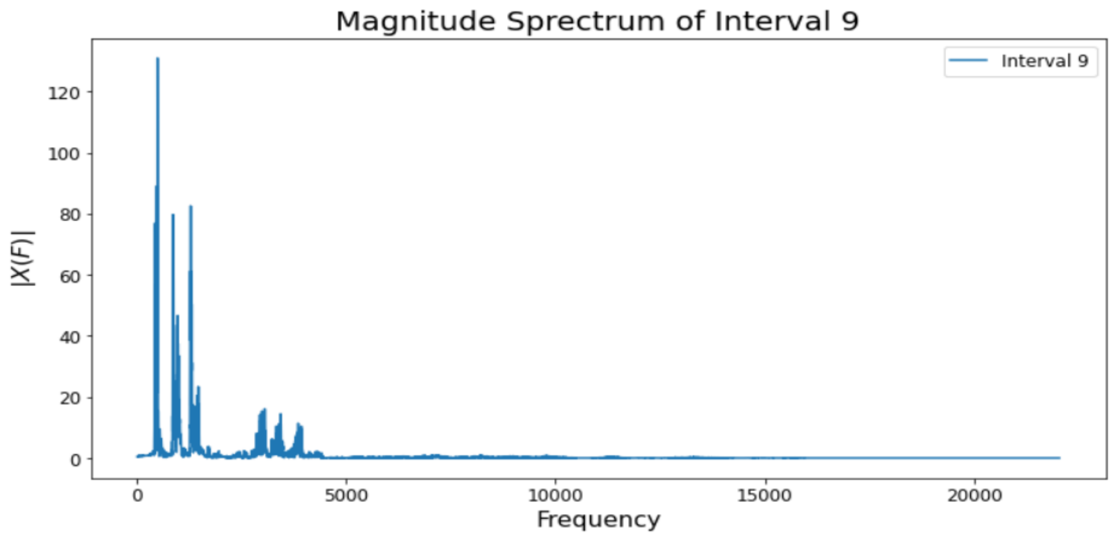

Magnitude Sprectrum of Interval 4
Interval 4
|X(F)|
Frequency
0
20
40
60
80
100
120
0
5000
10000
15000
20000

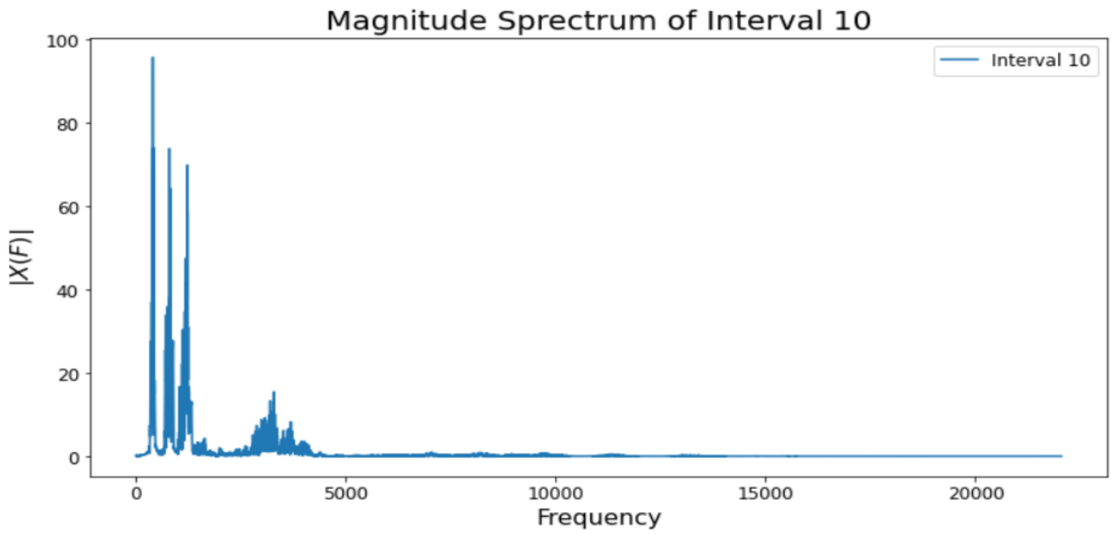

Magnitude Sprectrum of Interval 5
Interval 5
|X(F)|
Frequency
0
50
100
150
200
250
0
5000
10000
15000
20000


Magnitude Sprectrum of Interval 6
Interval 6
|X(F)|
400
300
200
100
0
0
5000
10000
15000
20000
Frequency


Magnitude Sprectrum of Interval 7
Interval 7
|X(F)|
400
300
200
100
0
0
5000
10000
15000
20000
Frequency


Magnitude Sprectrum of Interval 8
Interval 8
|X(F)|
200
150
100
50
0
0
5000
10000
15000
20000
Frequency





The fundamental frequencies of the 10 intervals are :

Interval	**Fundamental Frequency**
1	294.000 Hz
2	312.014 Hz
3	386.017 Hz
4	444.020 Hz
5	566.025 Hz
6	592.026 Hz
7	596.027 Hz
8	528.023 Hz
9	418.018 Hz
10	344.015 Hz

In the given audio signal, the voice increases its intensity and shrillness from 0s to about 3s - 3.5s and then it decreases till 5s. By observing the magnitude spectra and fundamental frequencies of the 10 intervals, it can be concluded that :

1. The amplitude of the voice in the plots increases from the 1^{st} interval till 7^{th} interval and then there is a decrease till the end. This is due to intensity of the voice which shows similar increasing pattern in the range 0s - 3.5s and then a decrease in 3.5s - 5s.

2. A pattern similar to the amplitude is also displayed in the fundamental frequencies. The fundamental frequencies of the intervals increases from 1 to 7. This is followed by a decrease till the 10^{th} interval. This can be explained by the increasing notes from 0s to 3.5s and then there is an decrease till 5s.

Code Repository

The code, input and output of all the problems is in the following repository :
`https://github.com/KaranTejas/DSP-Lab/tree/main/Experiment3`.