EE386 Digital Signal Processing Lab **Jul-Dec 2021**

Experiment : 3

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This lab experiment covers various practicality of Digital Signal Processing such as plotting signal spectra, extraction of fundamental frequency of a signal, design of a keylock system using fundamental frequencies, temporal variations etc. Along with Python, I have used libraries such as numpy, pandas, scipy etc. The code to my entire work in this lab experiment is here. And the input files and my output files can be viewed here.

Please Note : I have used $\alpha = 3$ because my registration number is 191910.

Question 1 - Plotting Signal Spectra

(Subproblem - 1)

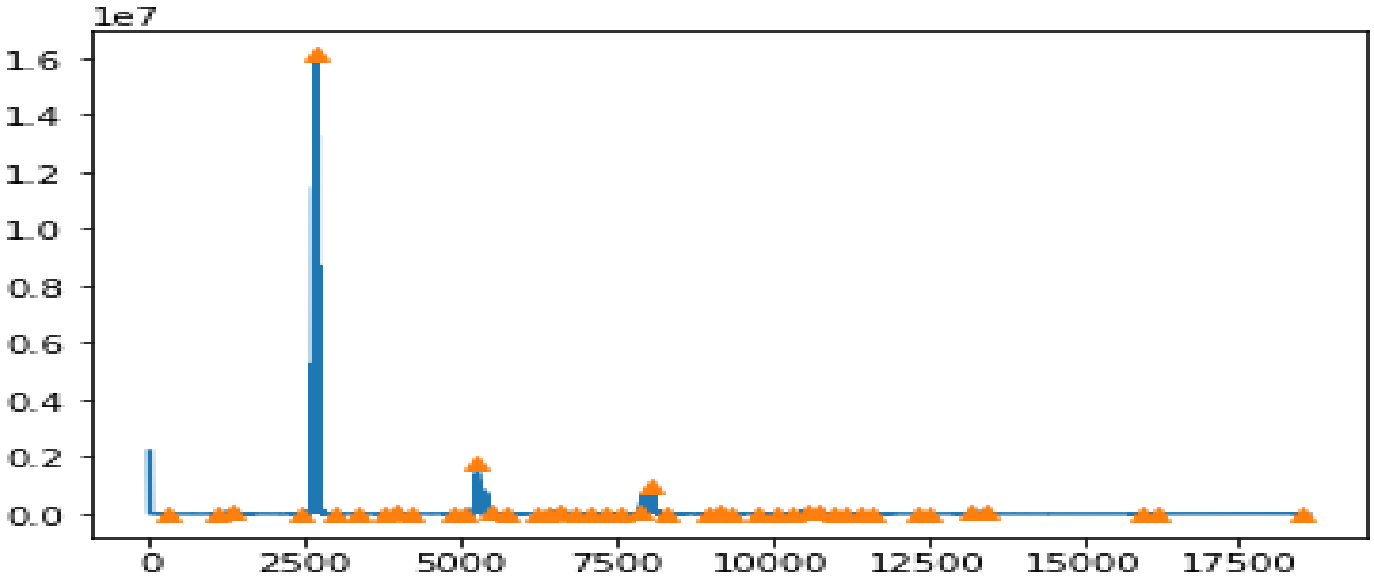
The question asks to plot the magnitude spectrum of a signal using the FFT function. We are supplied with the recordings of four different instruments (piano, trumpet, violin and flute). We also have to find the frequency value (in Hz) corresponding to fundamental harmonic (the peak) of the four different recordings and tabulate them.Also using the FFT algorithm and we have to plot magnitude (in dB scale) versus frequency (Hz).

$\alpha = \mathbf{3}$

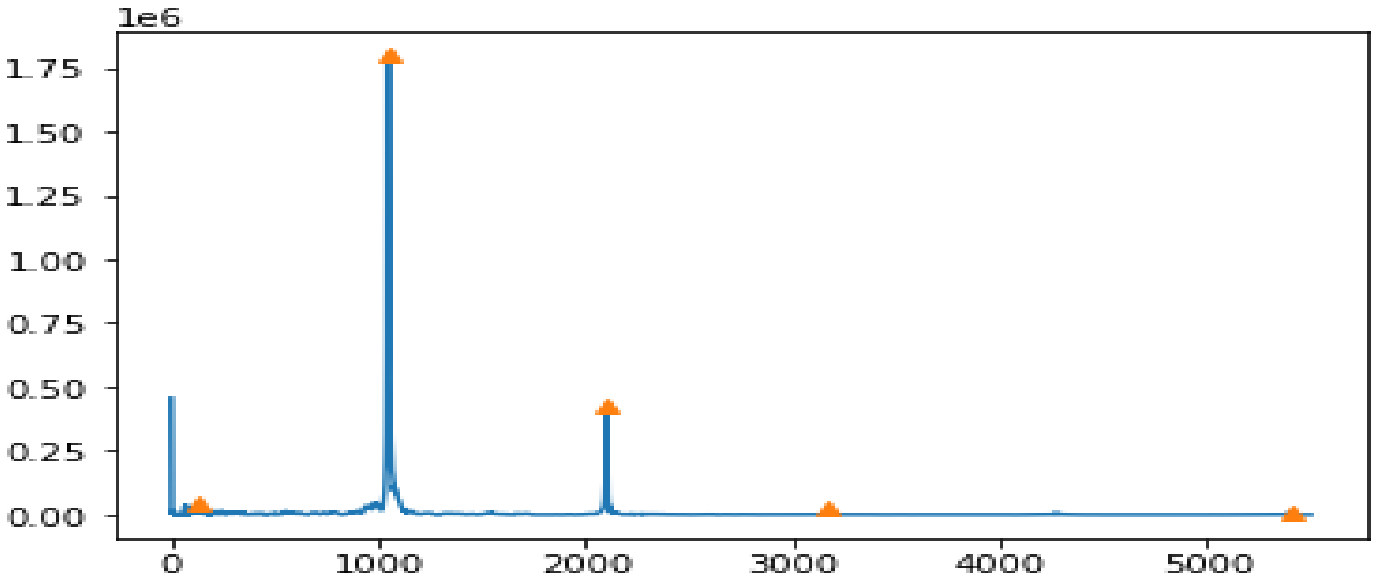
Instrument	Fundamental Frequency (in Hz)
Flute (flute3.wav)	79.32080536912751
Piano (piano3.wav)	129.2931818181818
Trumpet (trumpet3.wav)	6.749228659581761
Violin (violin3.wav)	67.00909090909092

The Peak plots are as follows

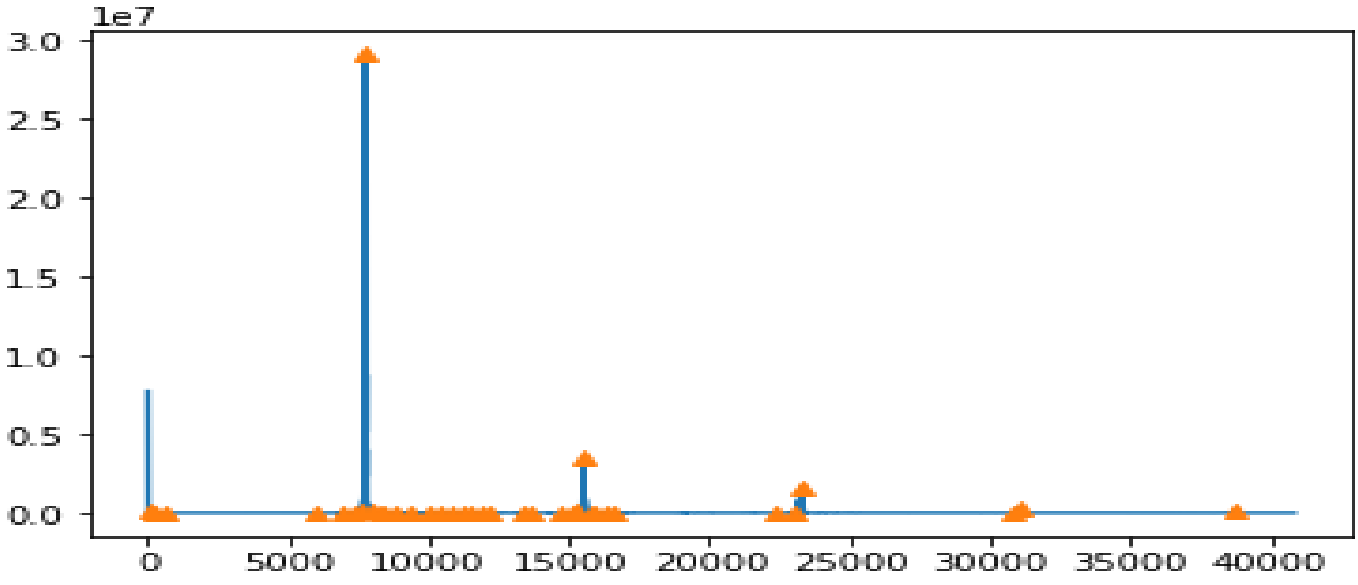
Fundamental freqeuncy of Flute is 79.3208053691275

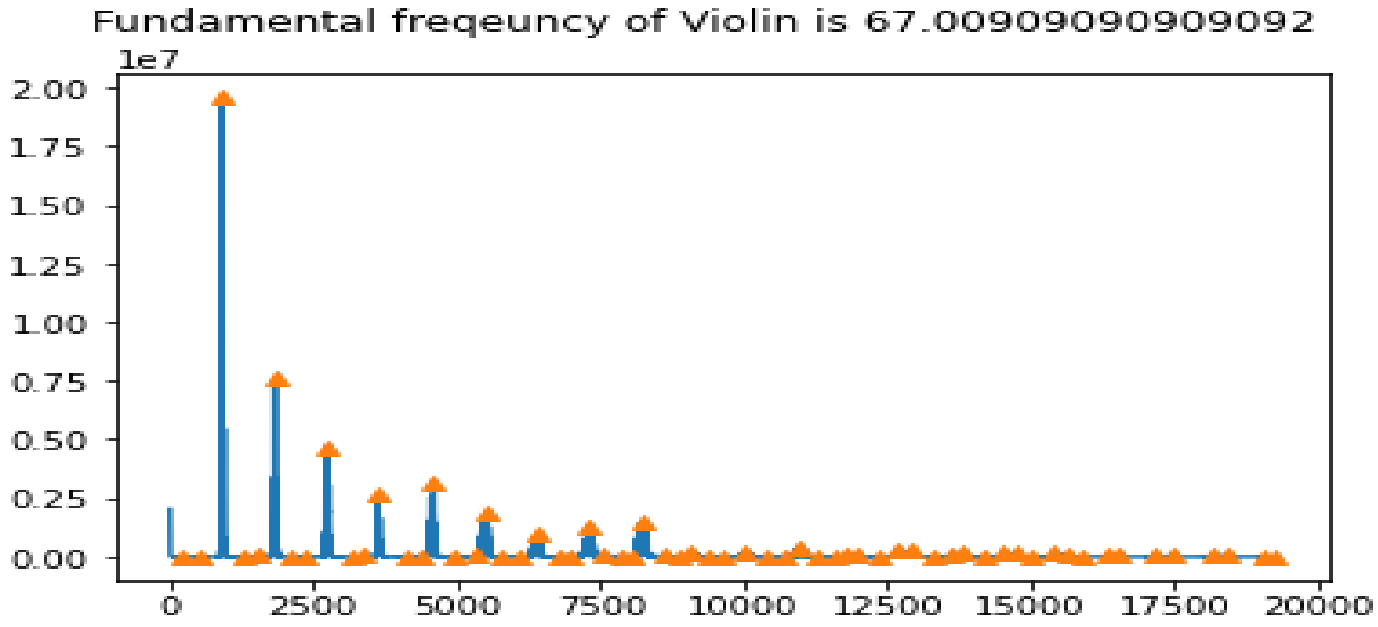


Fundamental freqeuncy of Piano is 129.2931818181818

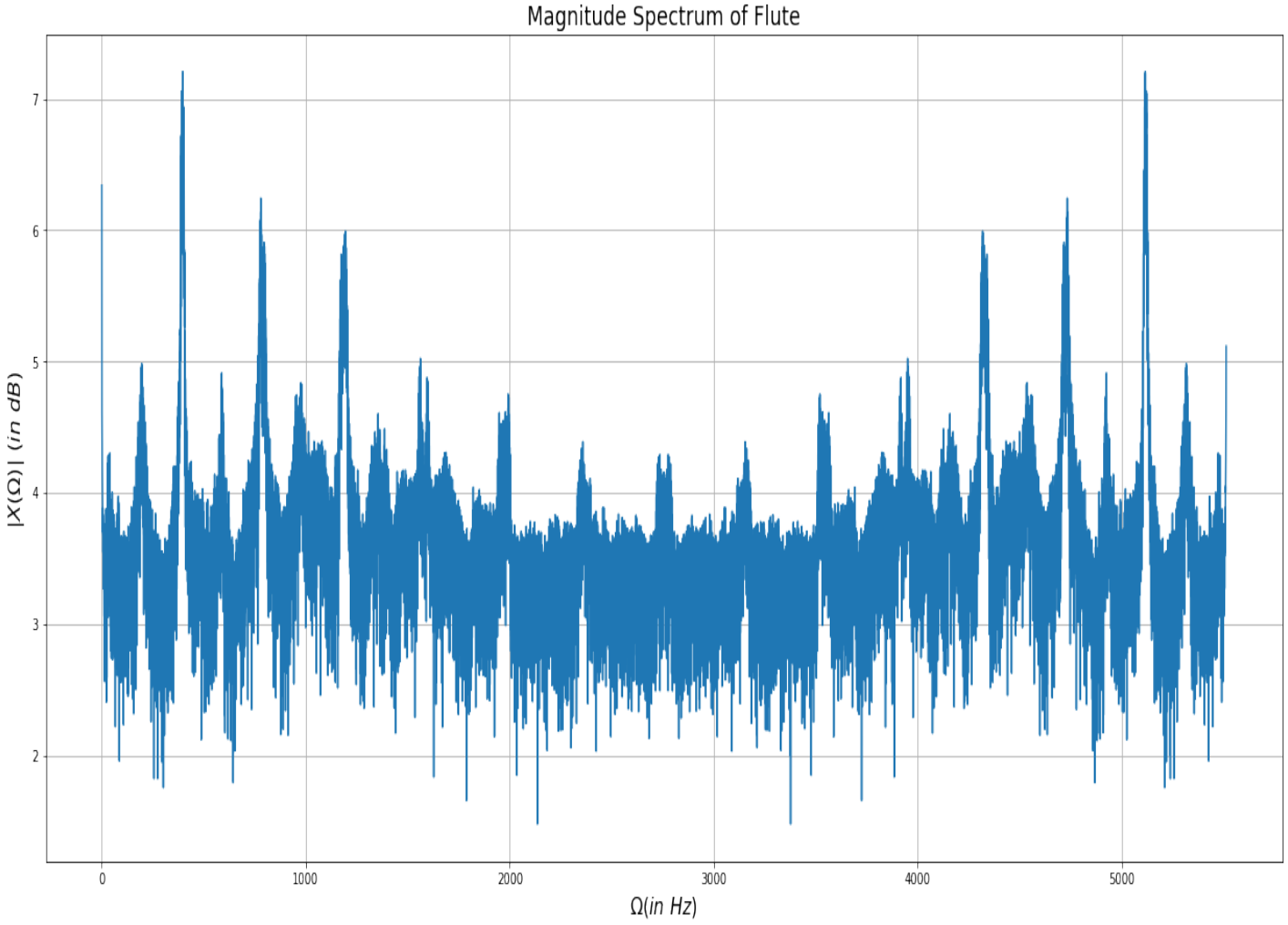


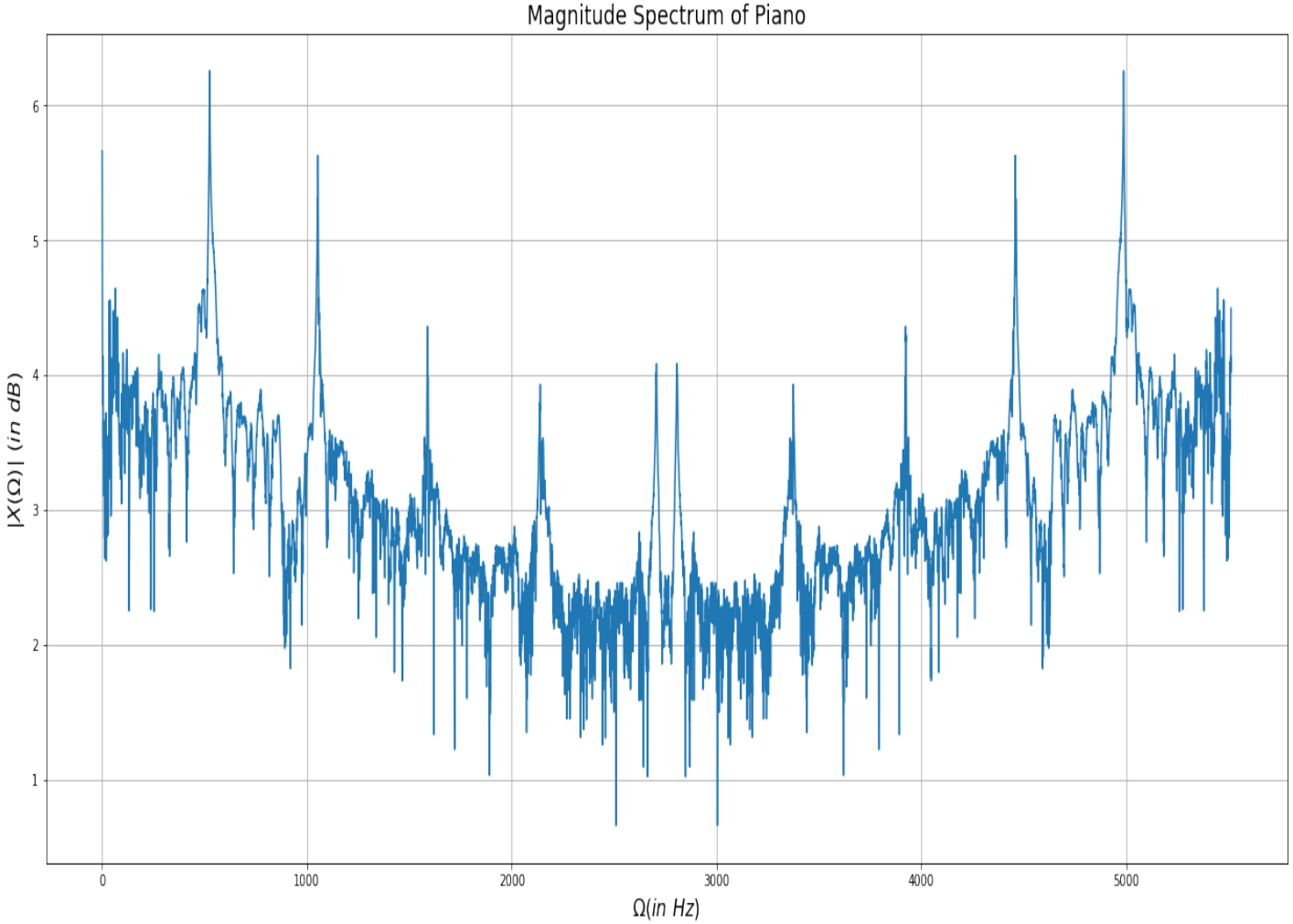
Fundamental freqeuncy of Trumpet is 6.749228659581761

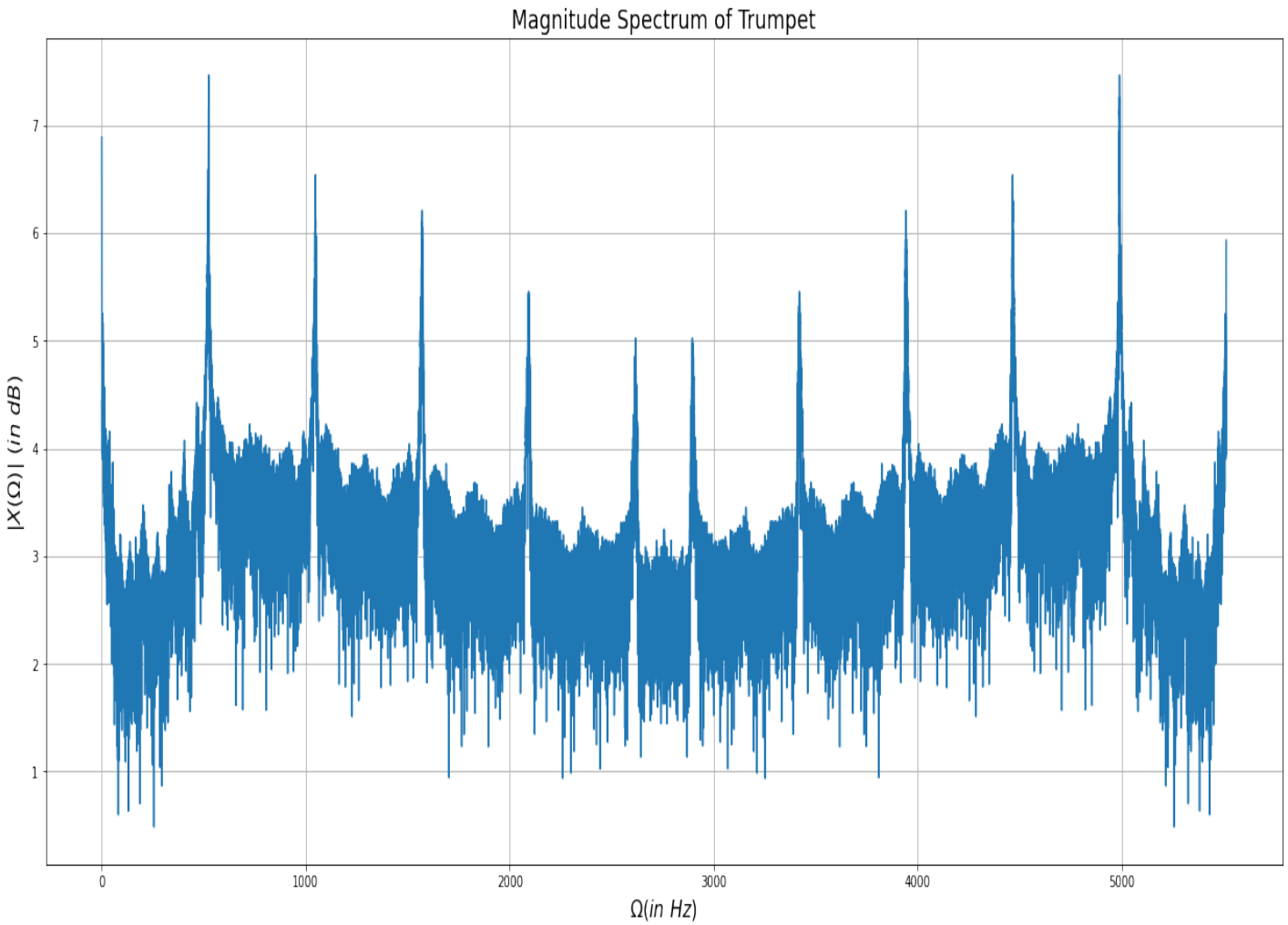


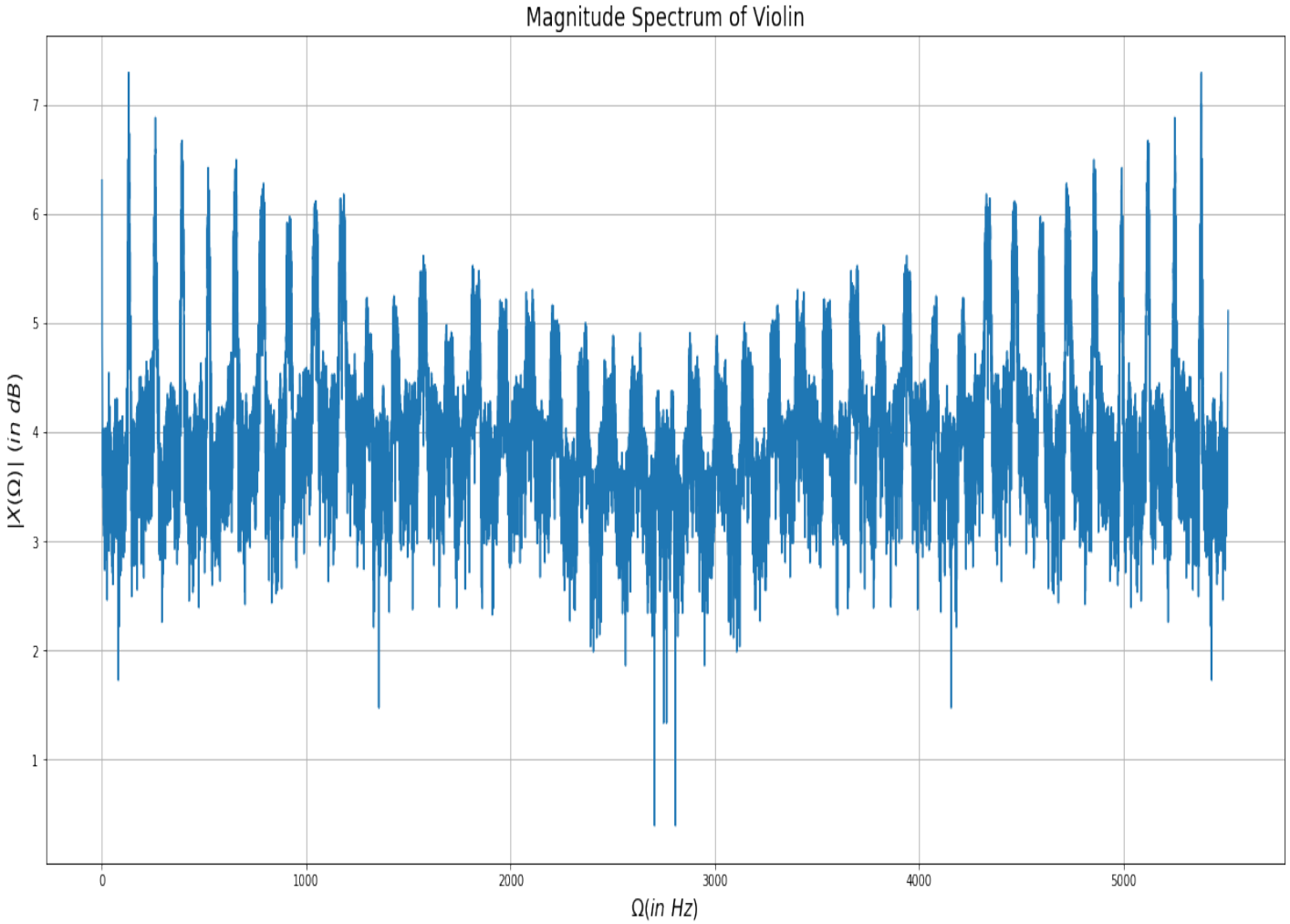


The following graphs show the relation between Magnitude in db scale of the 4 instruments (instrumentα.wav) with their frequency




Magnitude Spectrum of Piano
|X(Ω)| (in dB)
Ω(in Hz)
1
2
3
4
5
6
0
1000
2000
3000
4000
5000


Magnitude Spectrum of Trumpet
|X(Ω)| (in dB)
Ω(in Hz)
1
2
3
4
5
6
7
0
1000
2000
3000
4000
5000



(Subproblem - 2)

The question asked us to find β for the fluteβ.wav which is closest to your pianoα.wav in terms of the fundamental frequency.

We can compute the fundamental frequency of all four flutes and compare it with the piano3.wav (because $\alpha = 3$) as shown in my colab notebook.

- By checking all the flute files we can see that.
- Fundamental Frequency of piano3.wav (i.e pianoα.wav) is 1048.3772727272726
- Fundamental Frequency of flute1.wav (i.e fluteβ.wav) is 1063.2
- So Flute1.wav is closest to piano3.wav in terms of the fundamental frequency.
- Therefore $\beta = 1$

Question 2 - Whistling Keylock

(Subproblem - 1)

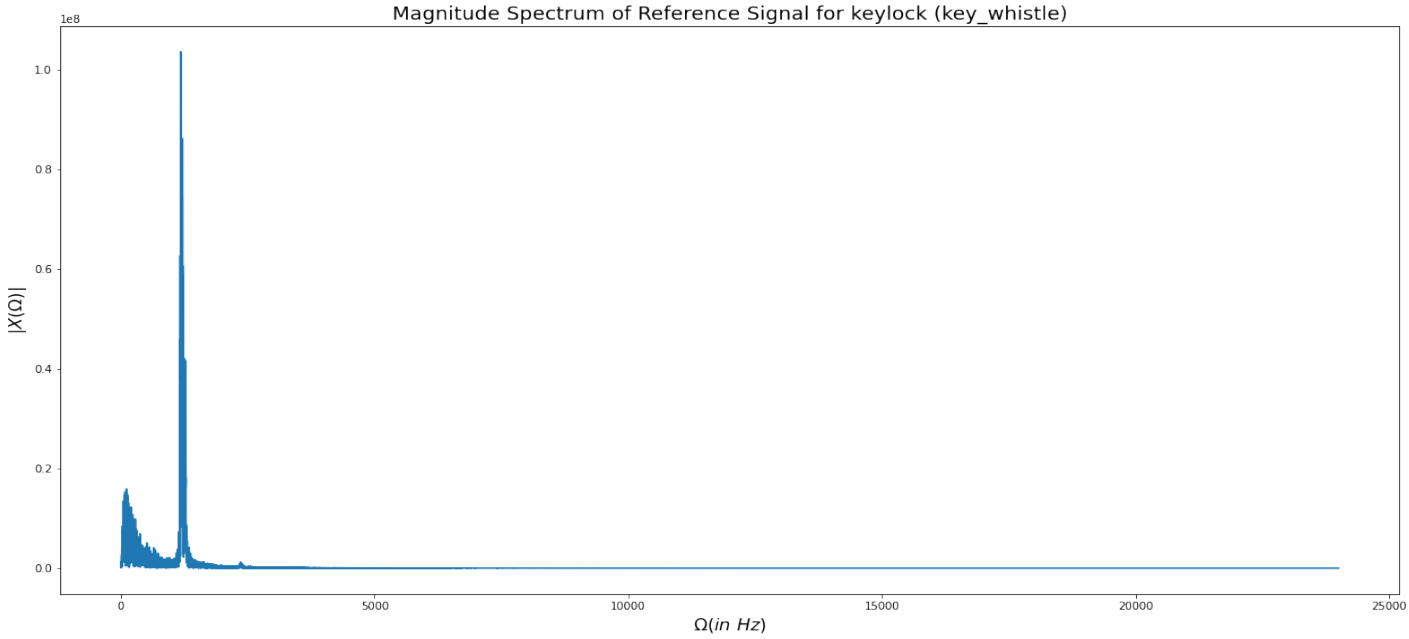
This subproblem asks us to record a 3 second snippet of us whistling and this be used as the

keylock reference. So I recorded myself whistling for 3 seconds, which can be found in the 'Whistle Inputs' folder in my drive link.

(Subproblem - 2)

The question asks us to plot the spectrum and find the fundamental frequency using peak picking.

So after plotting the spectrum for the reference to the keylock, it looks like :



After peak picking, I found the **fundamental frequency** to be **1175.6198347107438**

(Subproblem - 3)

This subquestion asks us write a function to record 3 second audio clips that output "ACCESS GRANTED" when the fundamental frequency of the recorded audio matches with the fundamental frequency of the reference within a 5% error, and "ACCESS DENIED" otherwise.

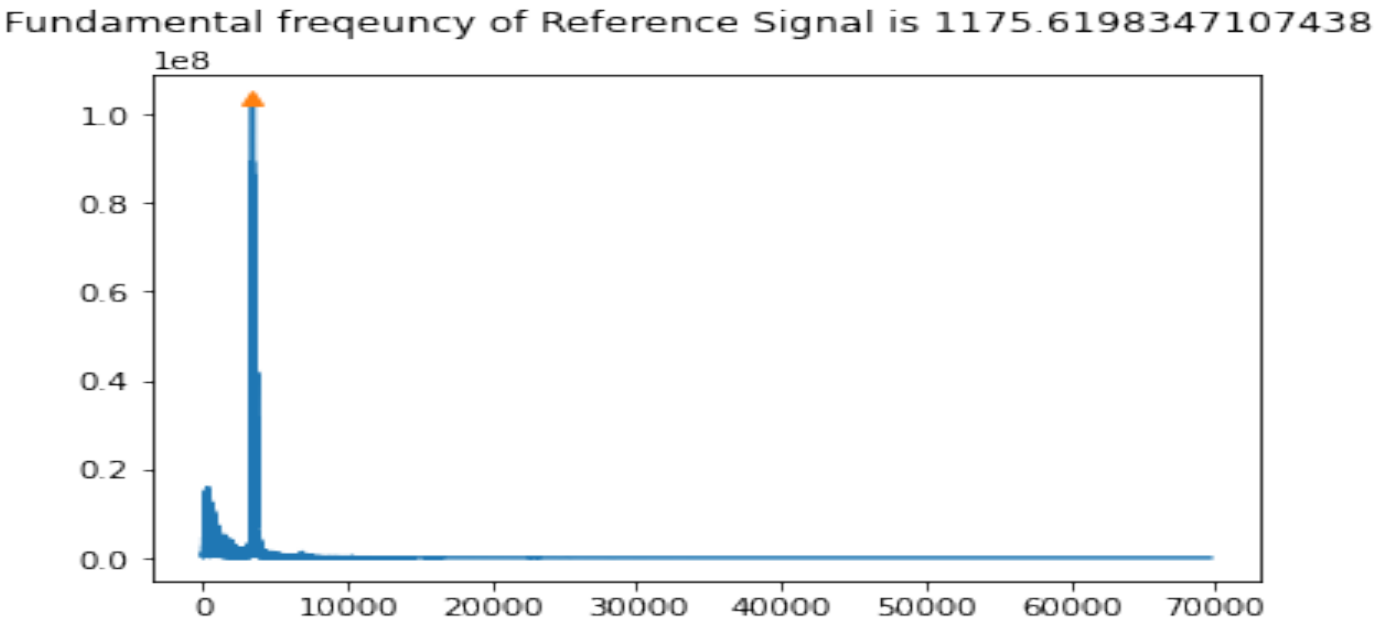
Test/Key	Fundamental Frequency (in Hz)	Access
Key	1175.6198347107438	Access Granted
Test1	161.66666666666666	Access Denied
Test2	92.0	Access Denied
Test3	92.0	Access Denied

Working on this problem I realised a few things :

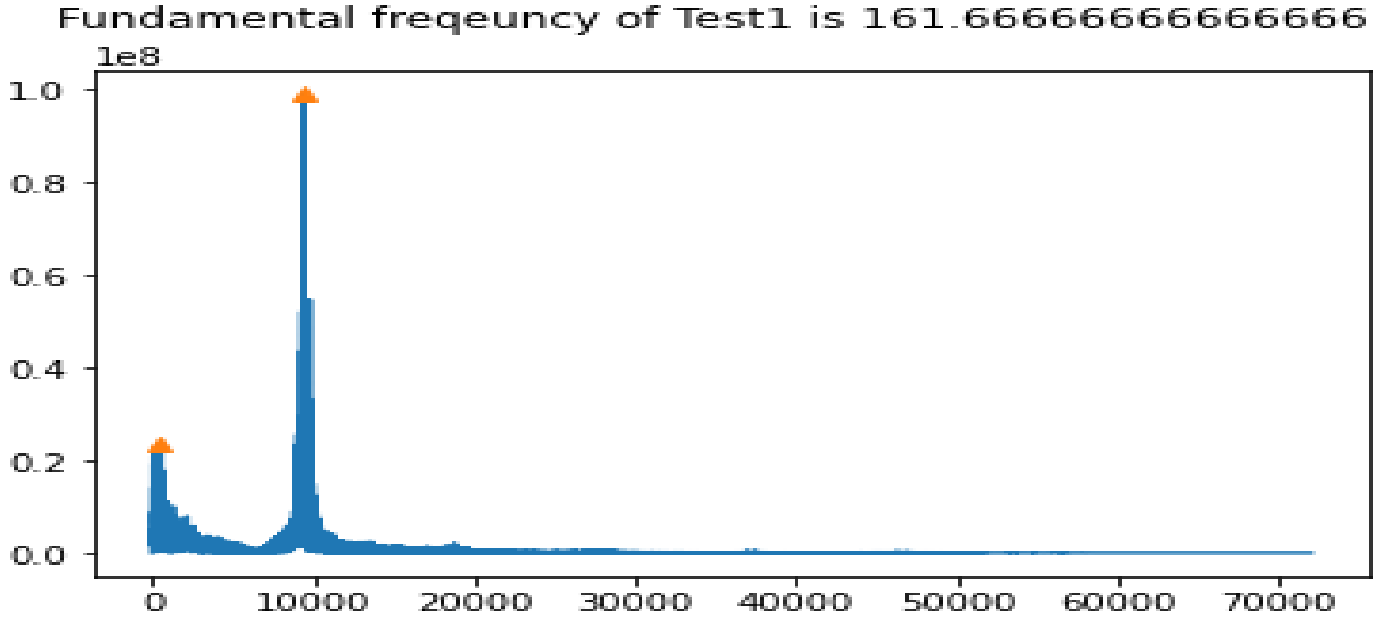
- A whistle has 1 clear peak for every peak of the whistle
- Most of the peaks in a whistle are similar because that is when you have whistled multiple times in that audio file.
- The ones with low peaks are noise.
- So this can be used to differentiate between different people that whistle differently.

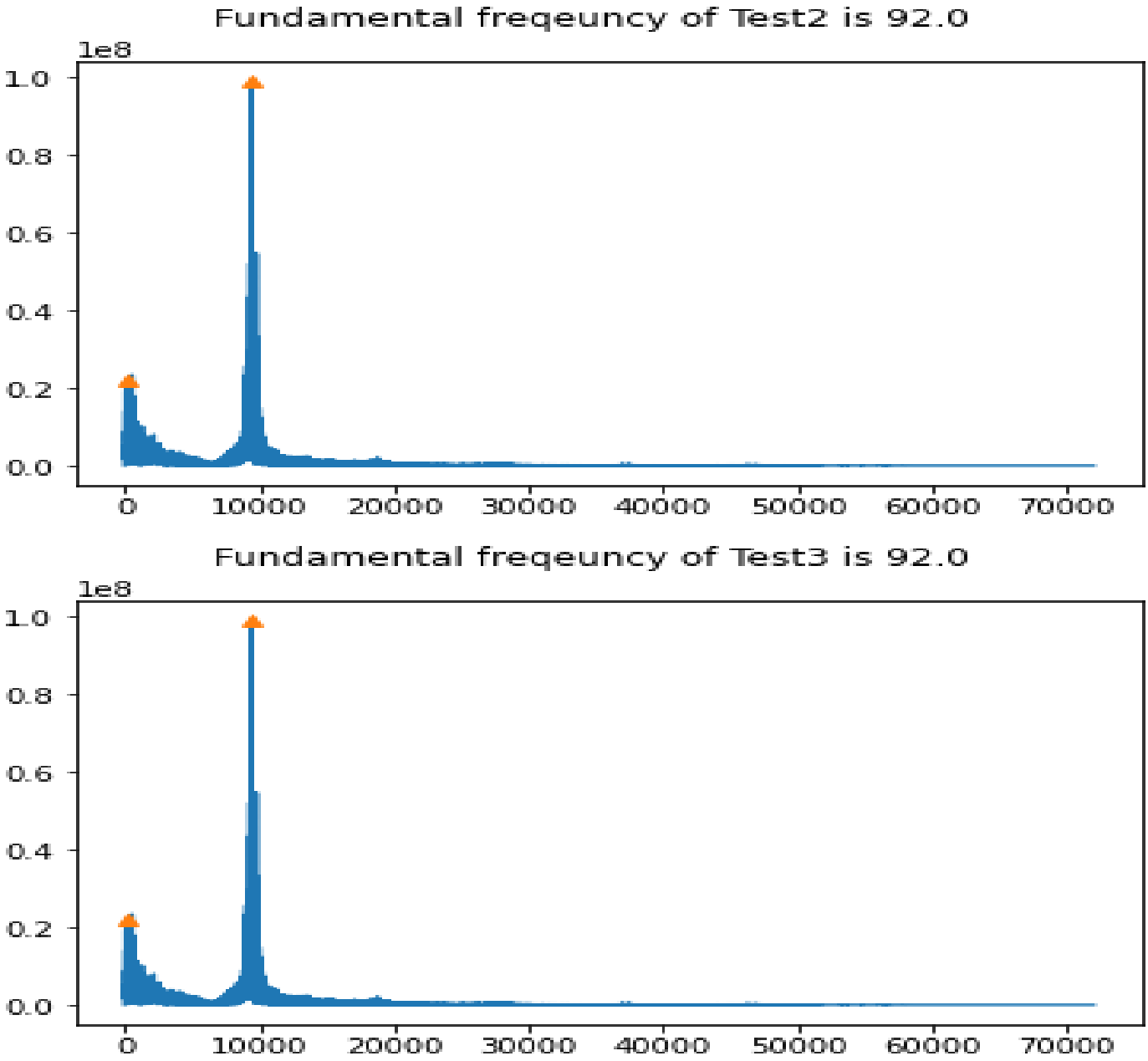
(Subproblem - 4)

The spectral plot of the reference for the keylock is :



The spectral plots of the various test cases are as follows :

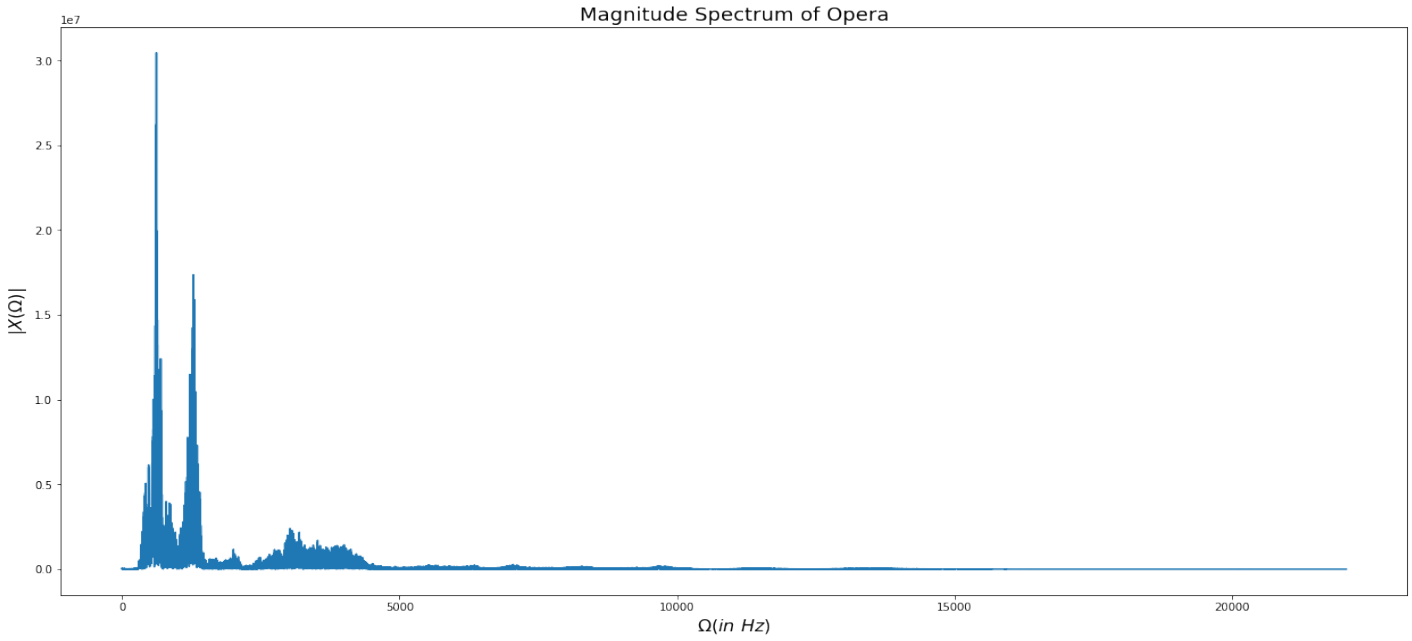




Question 3 - Simultaneous time and frequency representations

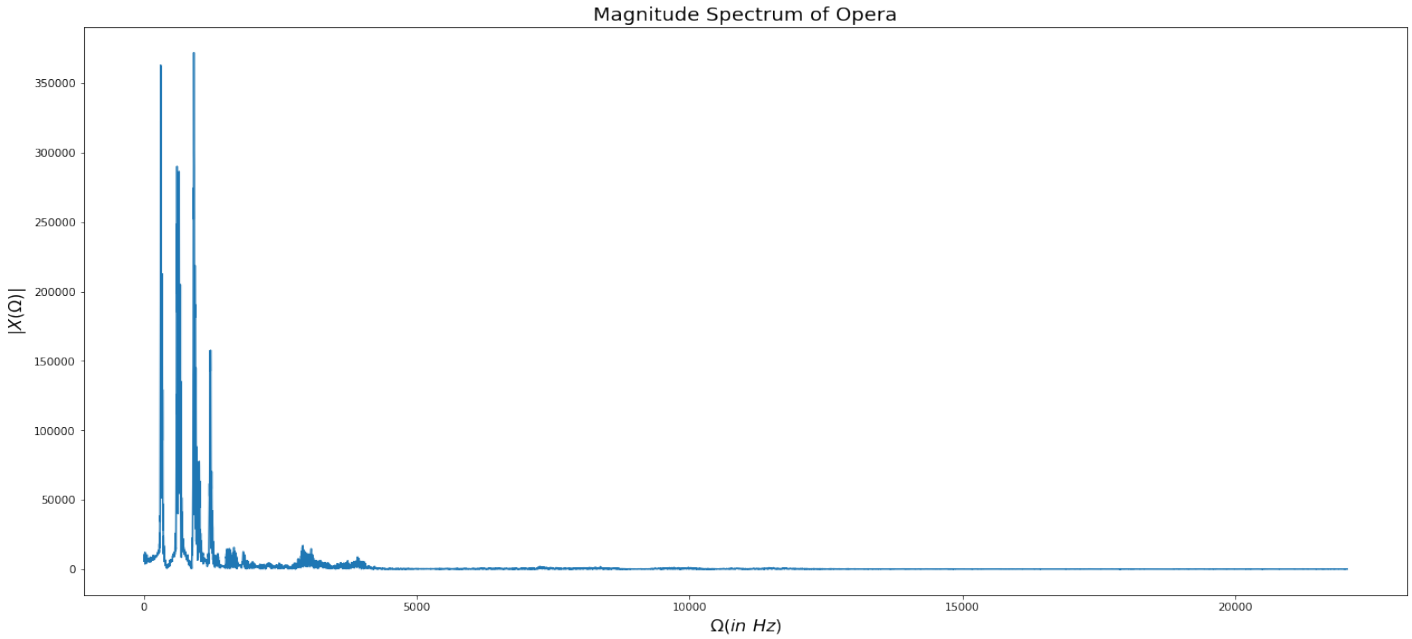
The question asked us to plot the spectrum of opera.wav and capture the temporal variations also.

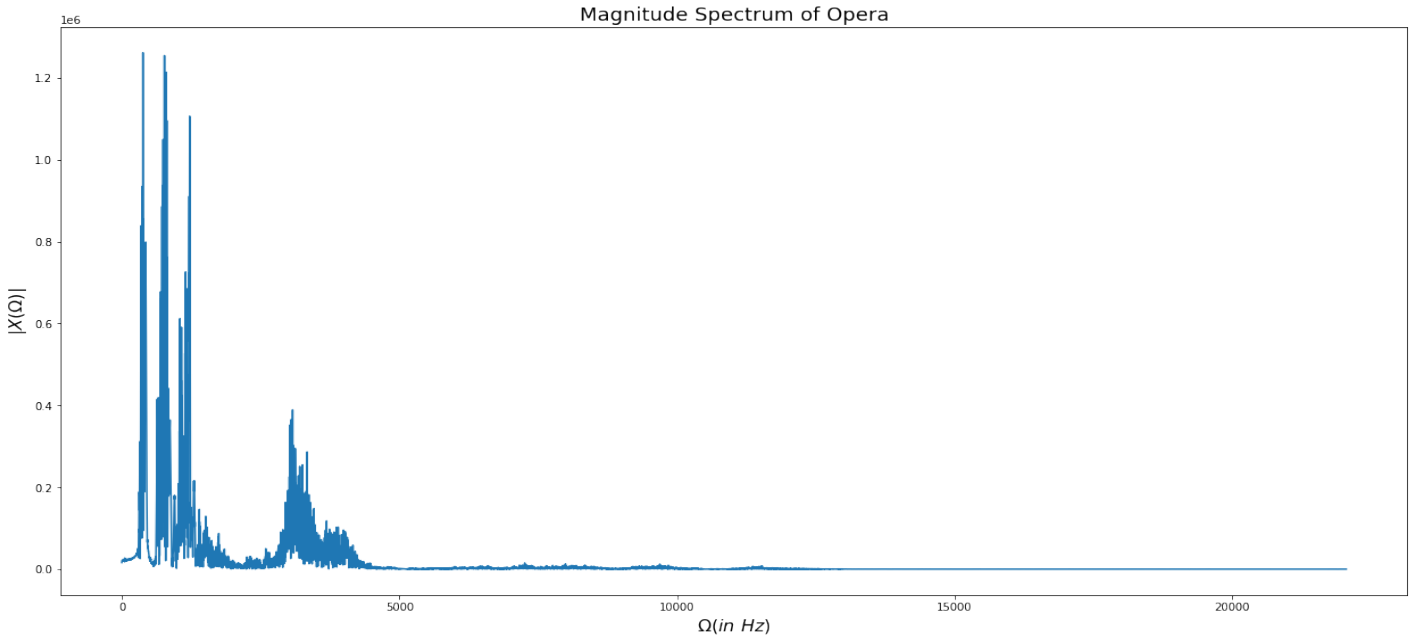
The magnitude spectrum of the opera.wav file is :

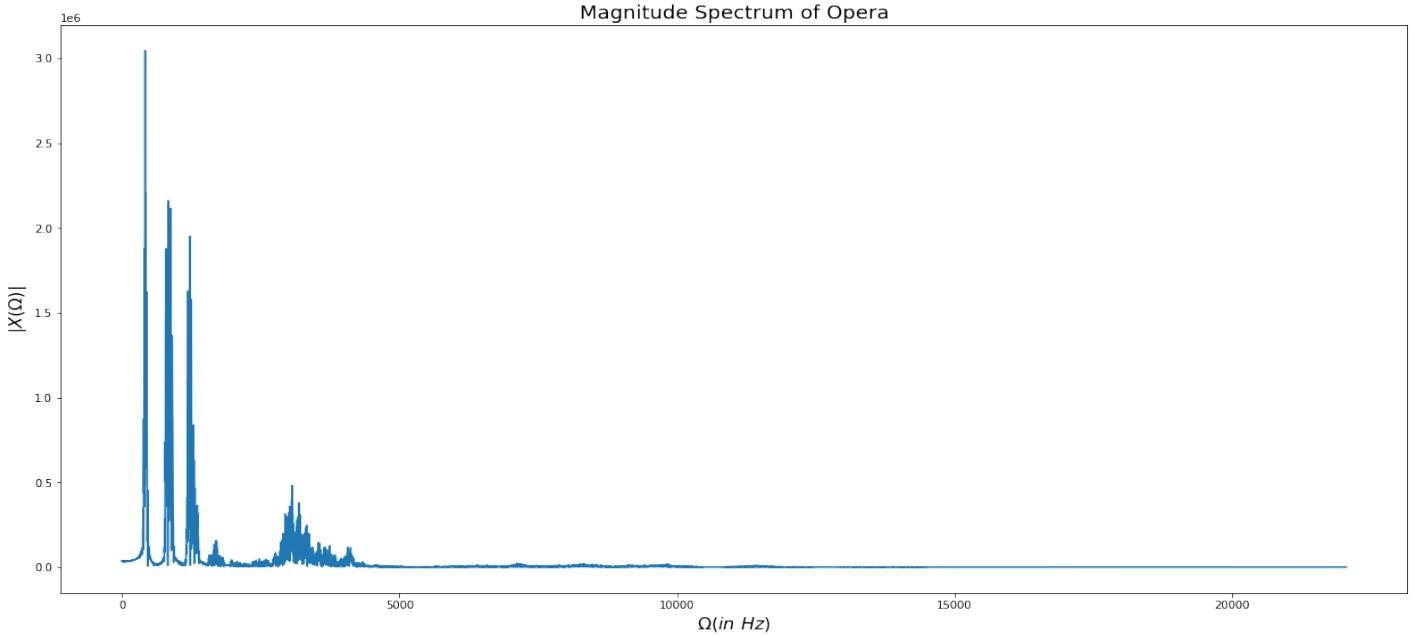


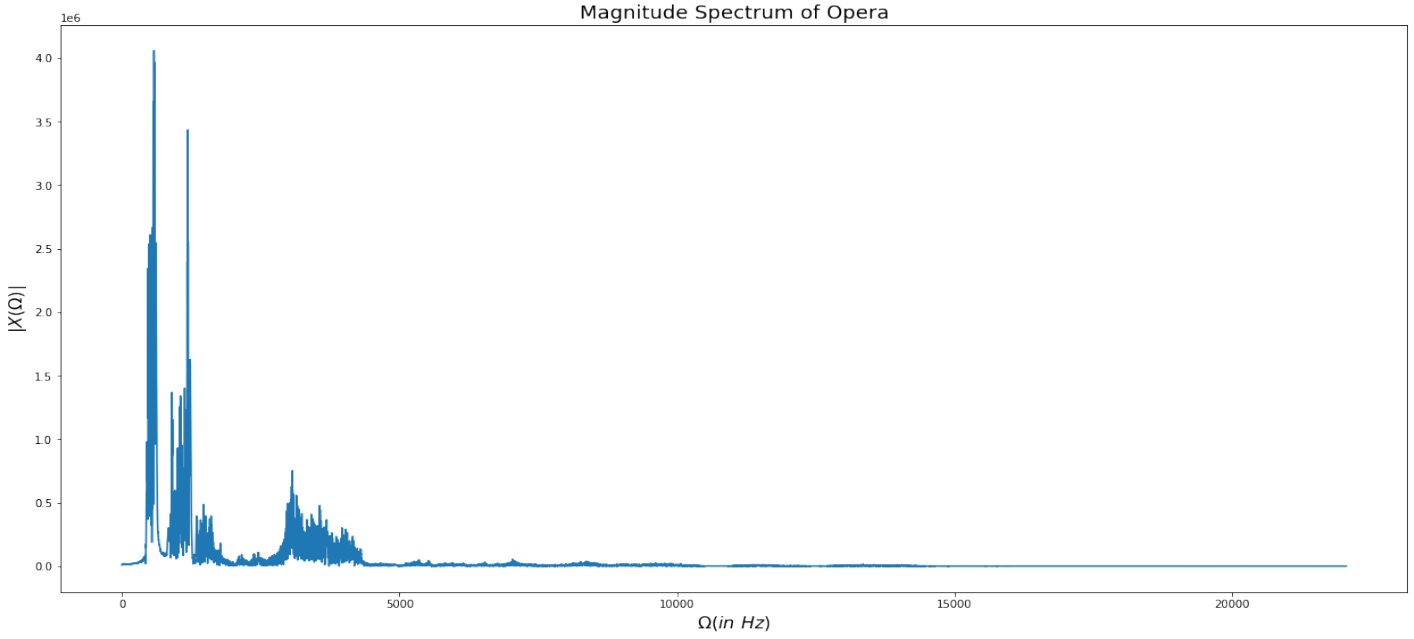
- I'm able to observe that the dominant peaks oscillate between a set of frequencies depending on the nature of the interval. If the ith interval is an odd or even numbered interval.

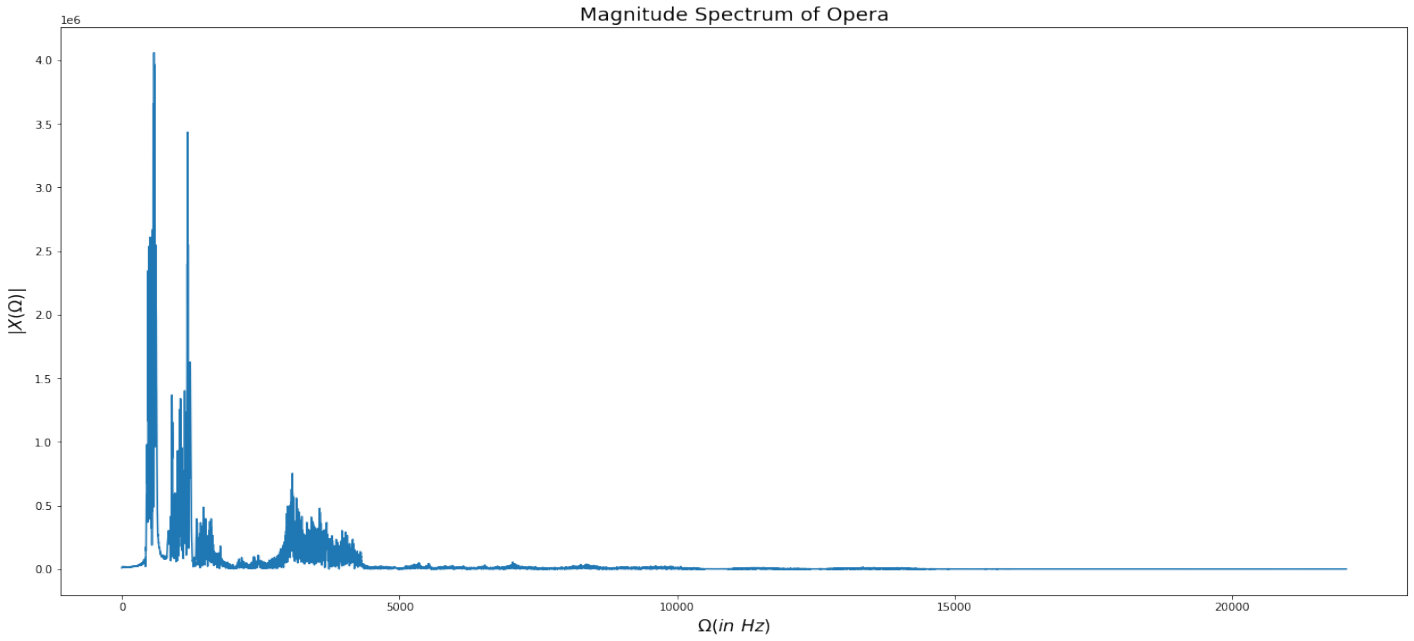
The 10 different spectra are :

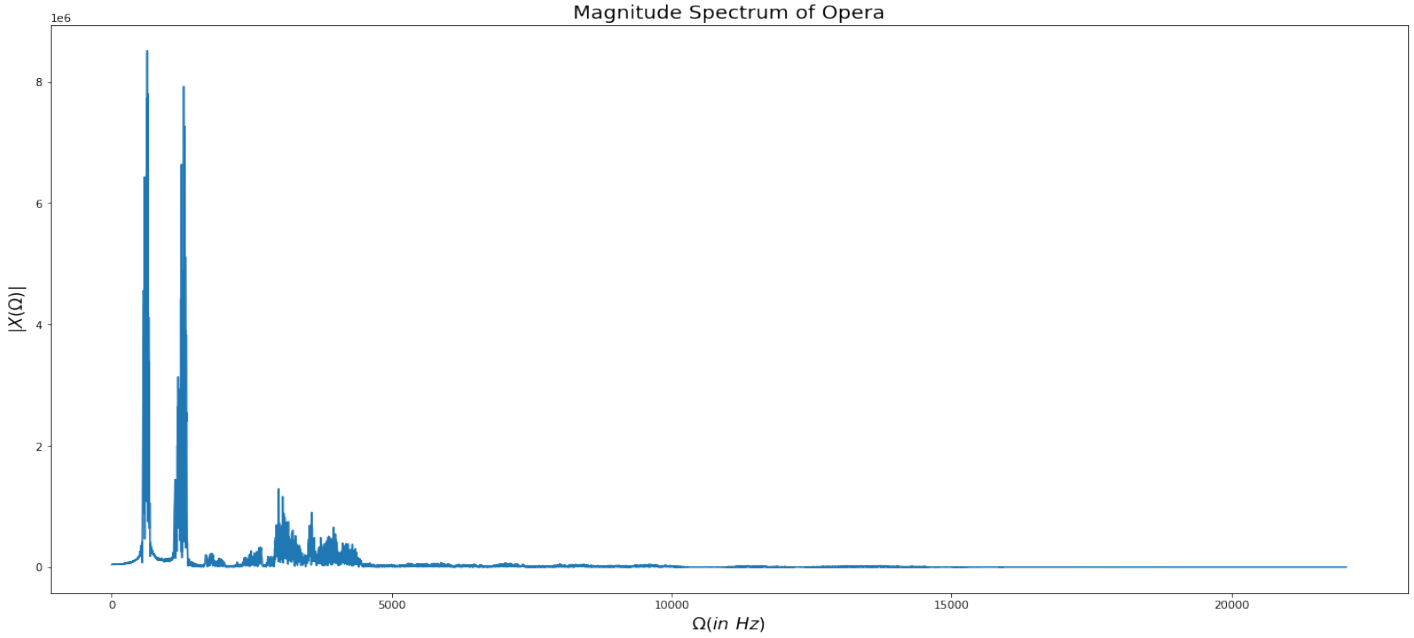


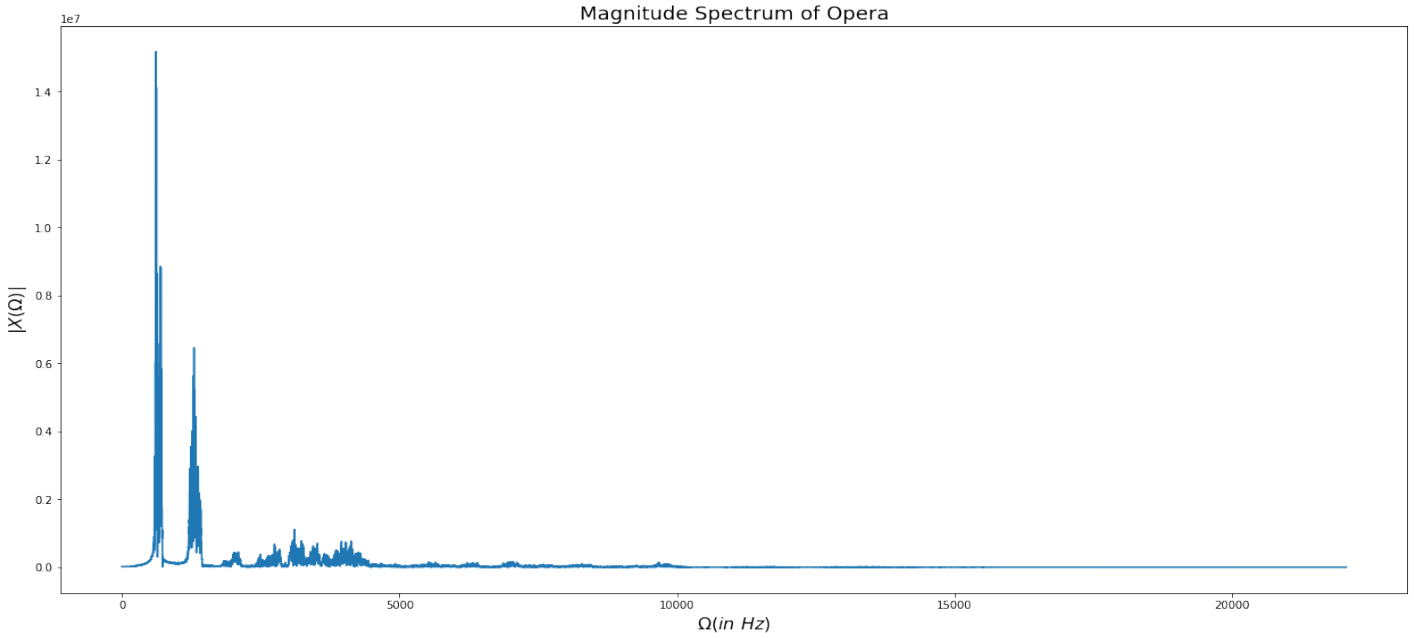

Magnitude Spectrum of Opera
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)

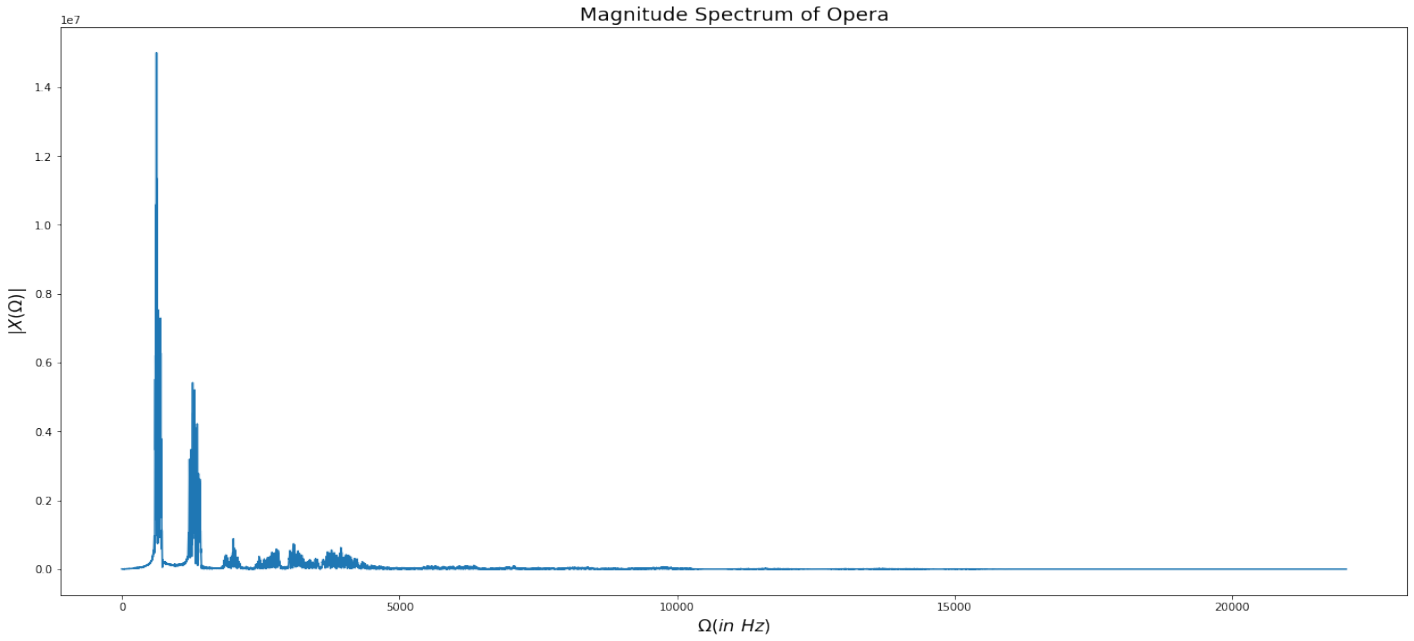

Magnitude Spectrum of Opera
1e6
3.0
2.5
2.0
1.5
1.0
0.5
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)

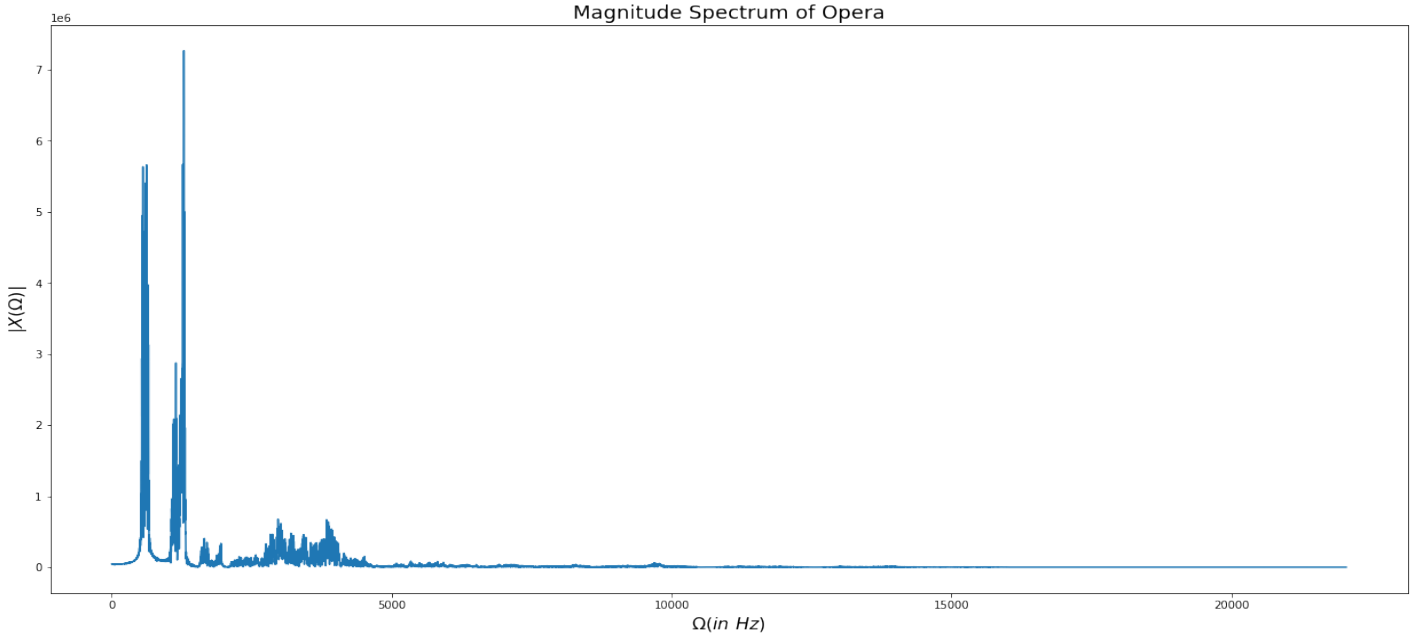

Magnitude Spectrum of Opera
1e6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)

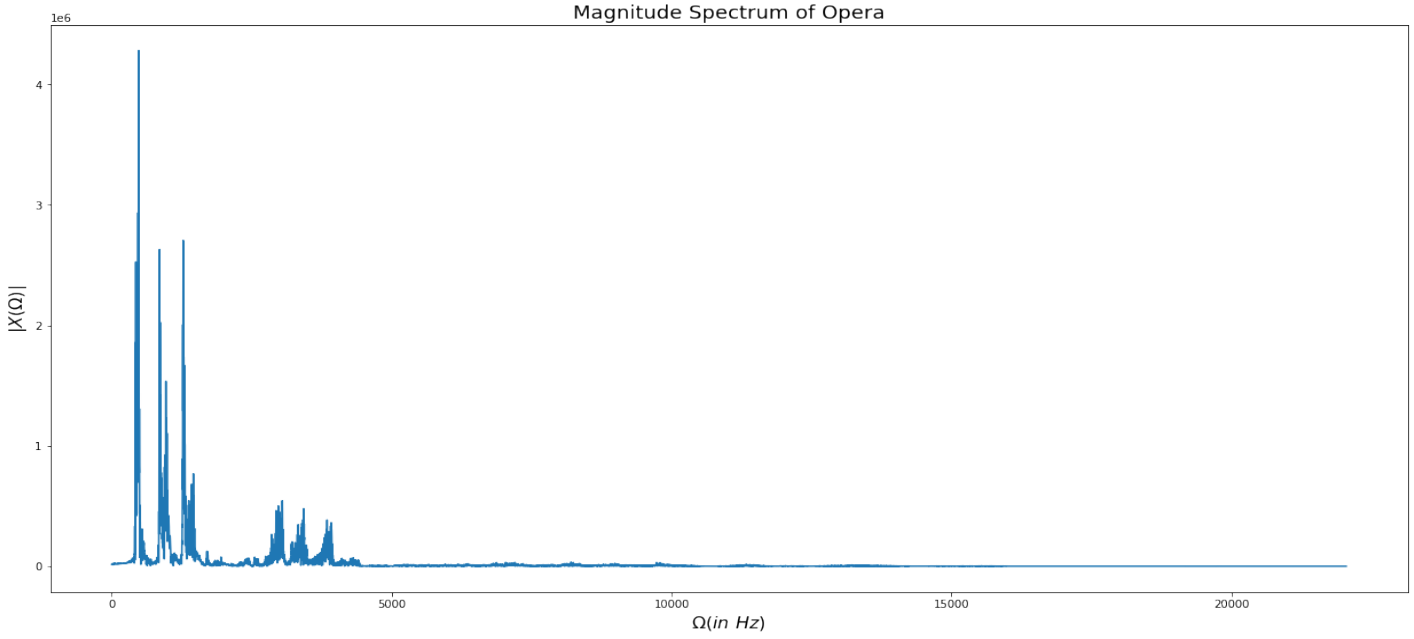

Magnitude Spectrum of Opera
1e6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)

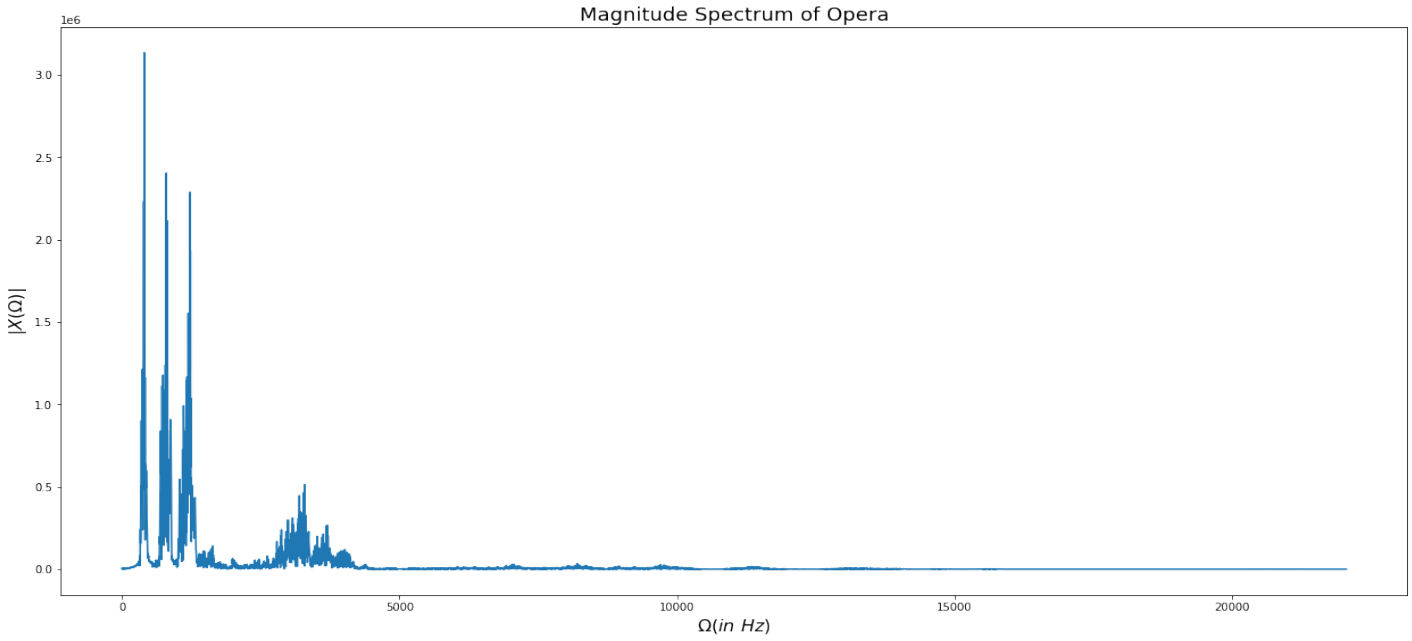

Magnitude Spectrum of Opera
1e6
8
6
4
2
0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)


Magnitude Spectrum of Opera
1e7
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)


Magnitude Spectrum of Opera
1e7
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)


Magnitude Spectrum of Opera
1e6
7
6
5
4
3
2
1
0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)


Magnitude Spectrum of Opera
1e6
4
3
2
1
0
|X(Ω)|
0
5000
10000
15000
20000
Ω(in Hz)



1 Appendix

- Note : I have used $\alpha = 3$ because my registration number is 191910. Since $\alpha = 1 +$ mod(910,4) = 1 + 3
- The link to all the code is here
- The link to all input and output files are here
- The Github repo to all code and previous experiments can be found here