EE386 Digital Signal Processing Lab | Jul-Dec 2021

Experiment 5 Report

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The calculated value of α for the Roll Number : 191EE126 is

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

Problem 1

(Generating Chirp Signal)

(Solution)

The Chirp signal to be generated which is of the form $x_a(t) = sin(2\pi F(t)t)$. The frequency F(t) is a frequency which increases linearly from $2 + 2\alpha$ Hz to $5 + 5\alpha$ Hz. The continuous time signal is sampled at rate of 100 samples. The signal is plotted against time for 10s as shown in the Figure 1.

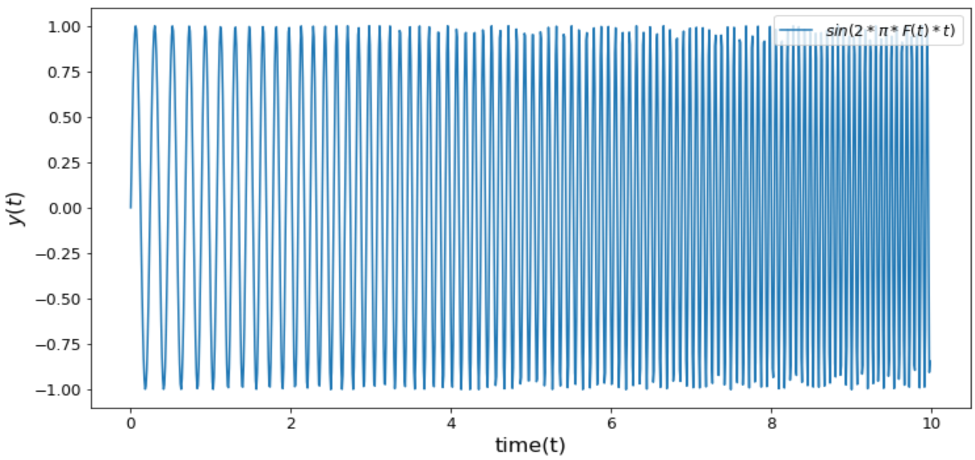

Figure 1: Generated Chirp Signal

(Plotting Frequency Spectrum)

(Solution)

The magnitude spectrum of the Fourier transform is calculated using Fast Fourier Transform (FFT). It is plotted against frequency as shown in the Figure 2.

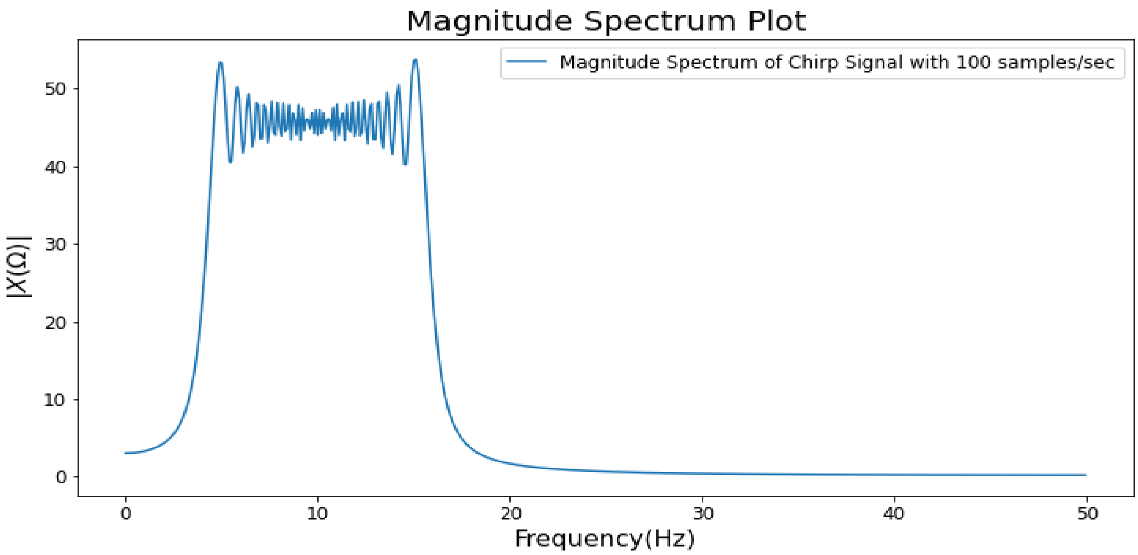

Figure 2: Magnitude Spectrum of Chirp Signal

We can see the amplitude of frequency is distributed continuously for a certain interval, but cannot find a definite frequency components for the signal. We can find the frequency components for small intervals of time using spectrogram.

(Plotting Spectrogram)

(Solution)

A spectrogram is a visual representation of the spectrum of frequencies of a signal as it varies with time. The Power Spectral Density of the Short Time Fourier Transform (STFT) is plotted against time and frequency. The continuous STFT is defined as:

$$STFT\left\{x(t)\right\}(\tau,\omega) \equiv X(\tau,\omega) = \int_{-\infty}^{\infty} x(t)w(t-\tau)e^{-i\omega t}dt$$

The discrete STFT is given by:

$$STFT\left\{x[n]\right\}(m,\omega) \equiv X(m,\omega) = \sum_{n=-\infty}^{\infty} x[n]w[n-m]e^{-i\omega m}$$

The magnitude squared of the STFT yields the spectrogram representation of the Power Spectral Density of the function:

$$spectrogram\left\{x(t)\right\}(\tau,\omega) \equiv |X(\tau,\omega)|^2$$

The spectrogram of the chirp signal is plotted using *specgram()* function from *matplotlib* library.

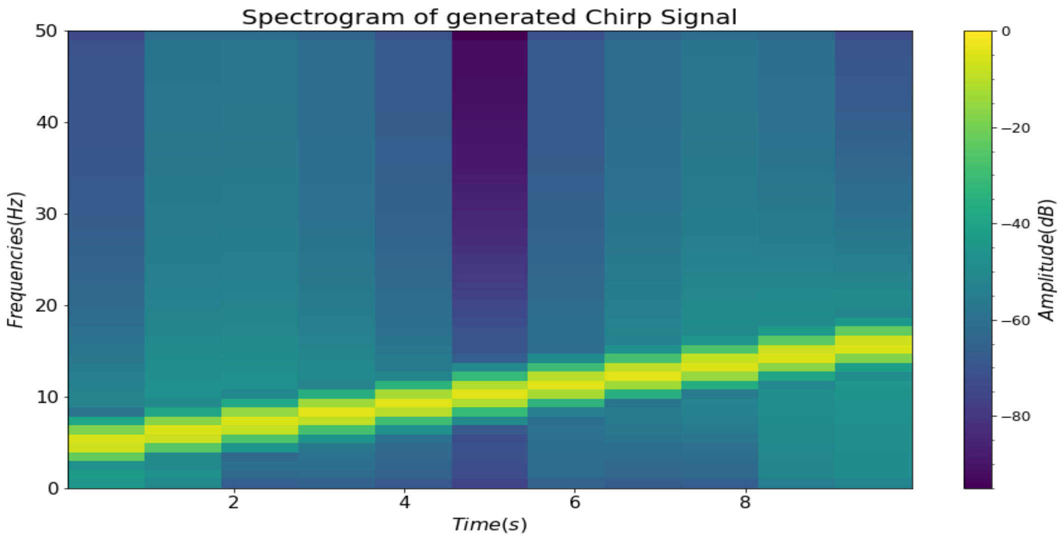

Figure 3: Spectrogram of the Signal

In the spectrogram plot, the frequency spectrum can be seen during different time intervals which helps us to analyze the signal. It can be seen that the frequency with maximum amplitude increases with time which is evident from the function F(t). Hence the spectrogram is better than he normal frequency spectrum, since the frequency components may change in the signal as time progresses, which is captured in spectrogram but not in frequency spectrum.

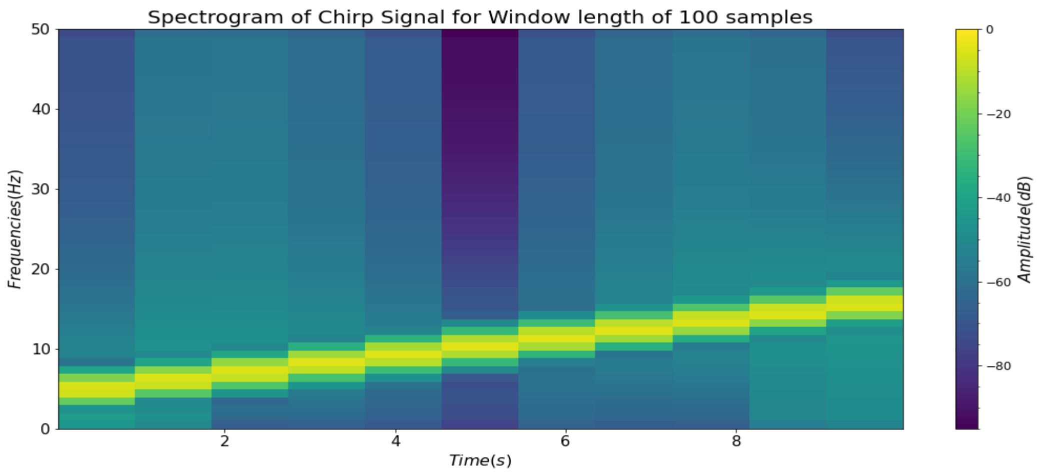

Figure 4: Spectrogram of the Signal with 100 sample window length

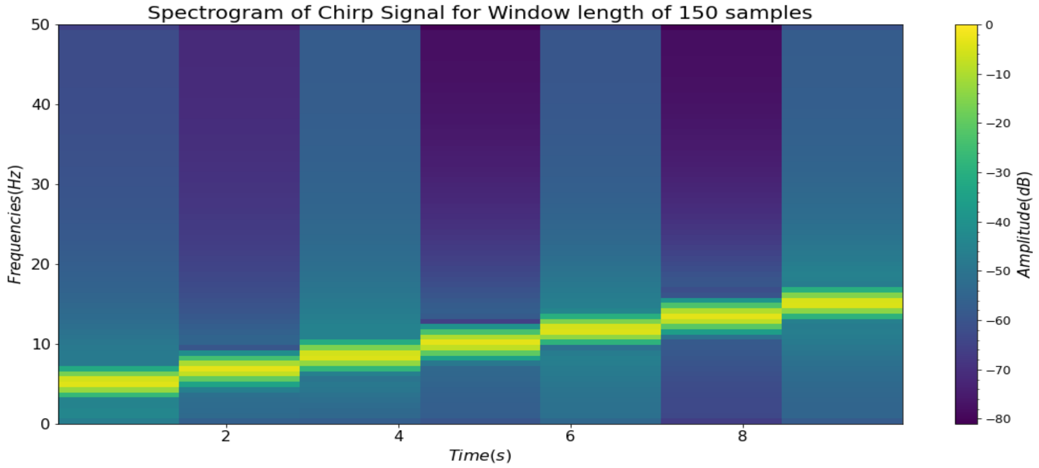

Figure 5: Spectrogram of the Signal with 150 sample window length

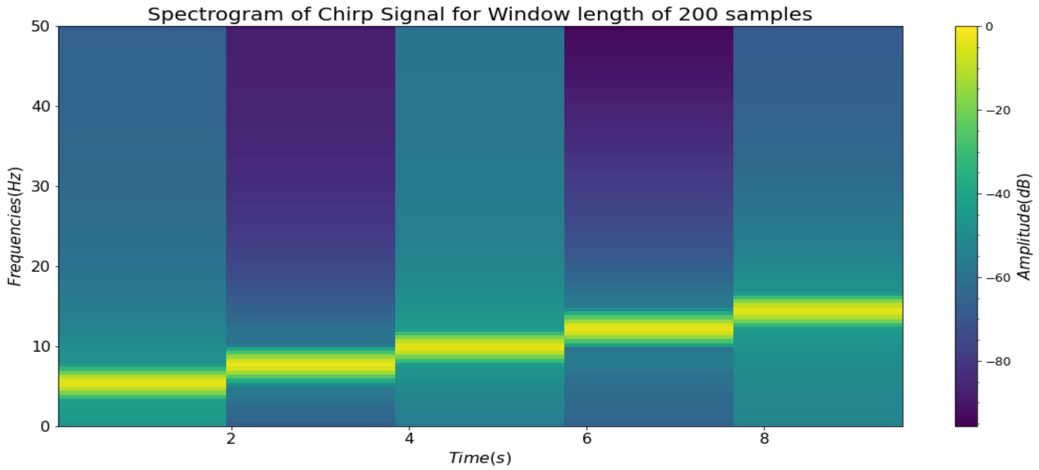

Figure 6: Spectrogram of the Signal with 200 sample window length

The spectrogram is plotted for different windowing lengths, i.e, 100, 150 and 200 samples. On increasing the windowing length it can be seen the spectrum for the frequency is more smooth and refined. The peaks can be clearly distinguished. But another observation on inceasing the window length is that the number of frames for time decreases. Hence the frequency resolution increases but the time resolution decreases.

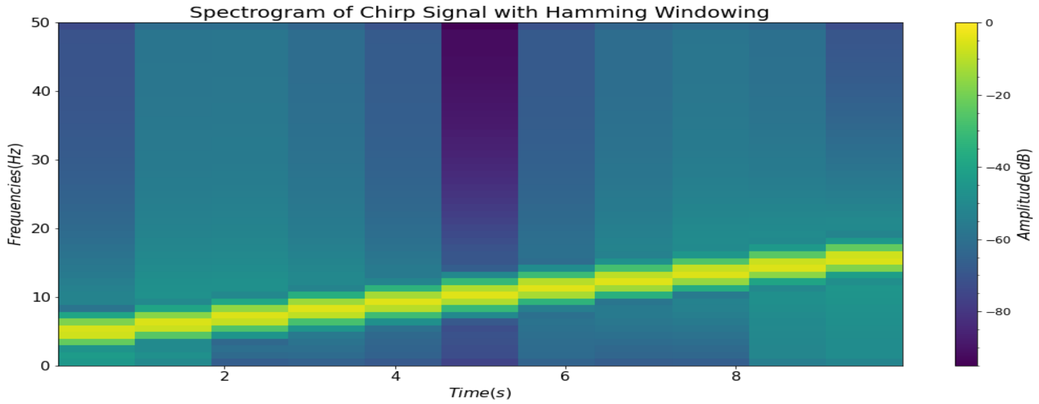

Figure 7: Spectrogram of the Signal with Hamming Window

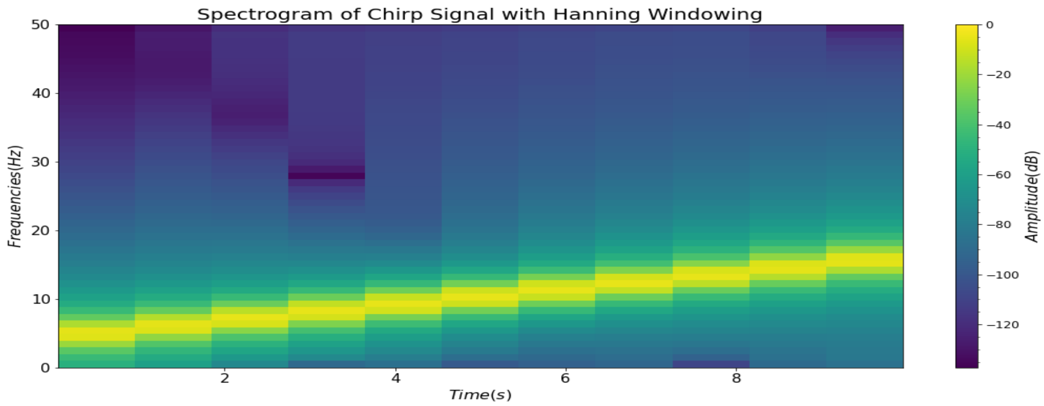

Figure 8: Spectrogram of the Signal with Hanning Window

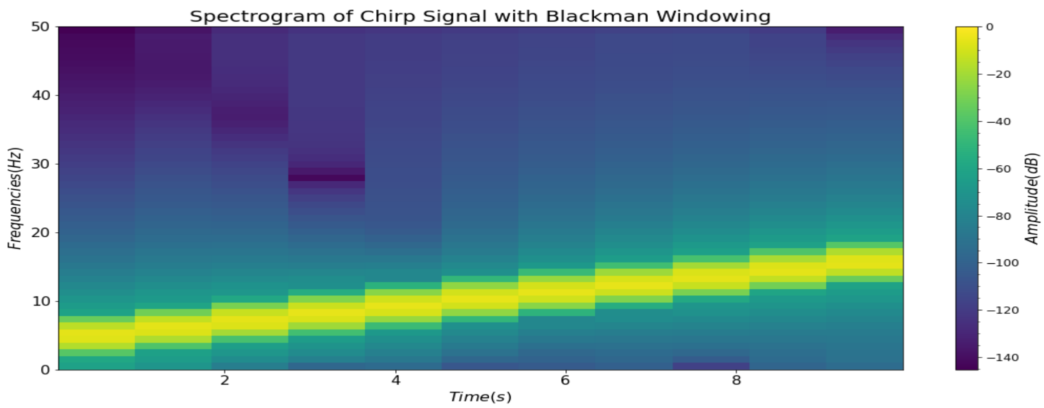

Figure 9: Spectrogram of the Signal with Blackman Window

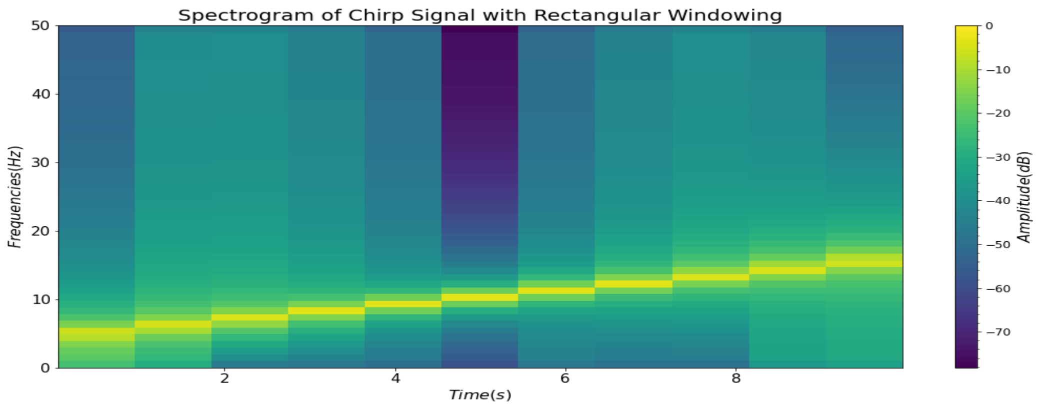

Figure 10: Spectrogram of the Signal with Rectangular Window

The spectrogram is plotted for different techniques, i.e., Hamming, Hanning, Blackman and Rectangular Window. The Hamming window and Hanning window have approximately the same frequency bands, but there is a slightly higher spectral leakage. This is because Hamming window has smaller side lobes than Hanning window. The blackman window has a wider frequency band than previous techniques due to wider main lobes. The rectangular windowing has high spectral leakage, because of minimal side lobe attenuation.

Problem 2

(Pitch Extraction)

(Instrument Audio Signal)

(Solution)

The audio signal is read from the file 'instru1.wav'. The spectrogram of the given audio signal is plotted.

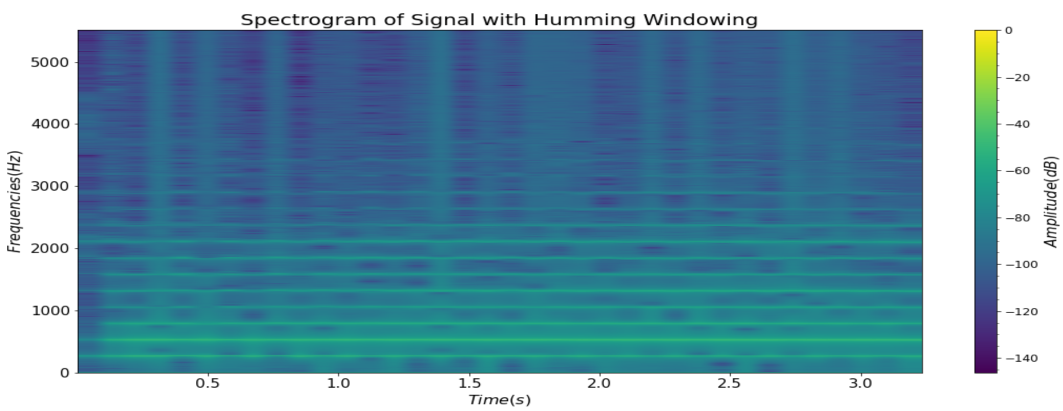

Figure 11: Spectrogram of the Signal

The fundamental pitch is the fundamental frequency which can be located from the plotted spectrogram. It is the first peak for along frequency axis. In the plot, the bottom most horizontal yellow line corresponds to fundamental pitch or frequency, which is at around 250 Hz.

The Magnitude Spectrum of the Fourier Transform is plotted against frequency.

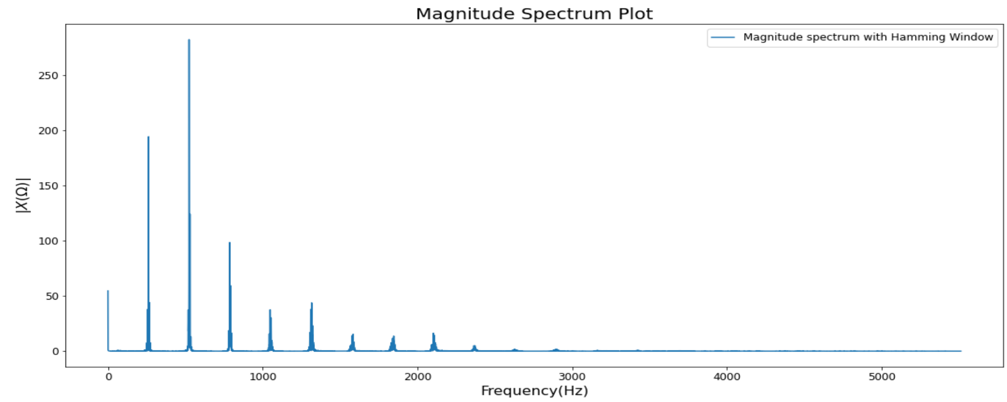

Figure 12: Magnitude Spectrum of the signal

The fundamental frequency is the first peak in the magnitude spectrum with a certain threshold. It is calculated using the find_peaks() function in *scipy* library. It is found to be at 256.69 Hz.

Pitch is an auditory sensation in which a listener assigns musical tones to relative positions on a musical scale based primarily on their perception of the frequency of vibration. Pitch is a major auditory attribute of musical tones, along with duration, loudness, and timbre. Pitch may be quantified as a frequency, but pitch is not a purely objective physical property; it is a subjective psycho acoustical attribute of sound. A sound generated on any instrument produces many modes of vibration that occur simultaneously. A listener hears numerous frequencies at once. The vibration with the lowest frequency is called the fundamental frequency; the other frequencies are overtones. This is also called fundamental pitch.

(Opera Audio Signal)
(Solution)

The audio signal is read from the file 'opera.wav'. The spectrogram of the given opera signal is plotted.

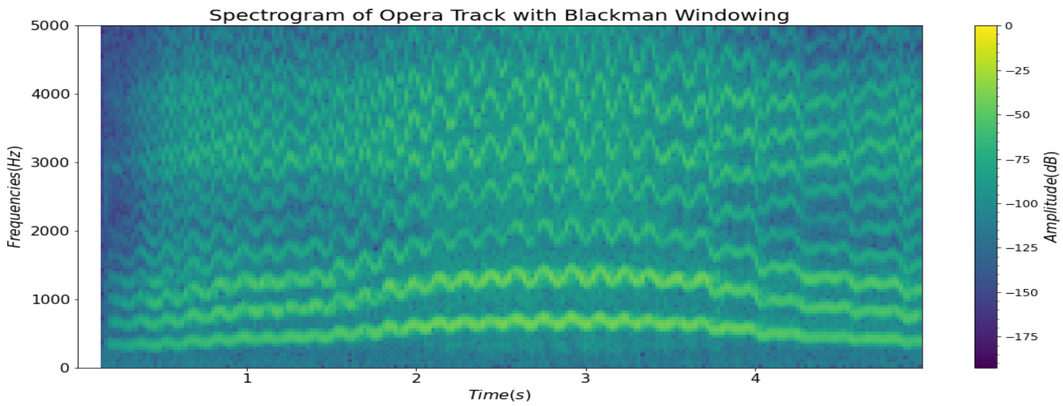

Figure 13: Spectrogram of the Audio Signal

In the 3^{rd} Experiment, we had calculated the first frequency peaks at each time interval. We found out that it increases from beginning to middle of the signal as the voice becomes more shrill and then there is a decrease in the peaks. This is evident in the plotted spectrogram. We can see the bottom most line increases till 3s and then there is a decrease. We are able to analyze the given opera signal better which has varying fundamental pitch with time.

Problem 3

(Spectro-Temporal Analysis of Speech)

(Solution)

The audio signal of the name is recorded with a sampling rate 4000 Hz using the *record* function which is defined in the notebook file. It is plotted using the *specgram()* function as shown in the Figure 14.

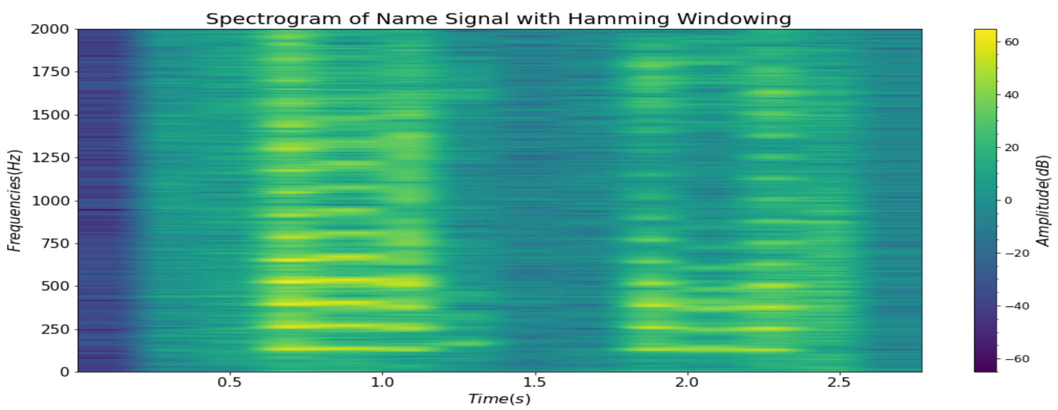

Figure 14: Spectrogram of the Name Signal

The *phonemes* can be observed at :

- 'Ka' at 0.6s
- 'Ra' at 0.9s
- 'N' at 1s
- 'Te' at 1.9s
- 'Ja' at 2.1s
- 'S' at 2.25s

Code Repository

The code, input and output of all the problems is in the following repository :
`https://github.com/KaranTejas/DSP-Lab/tree/main/Experiment5`.