Lab Report - 5

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Note:
The value of α used in this document is given by: $\alpha = 1 + \text{mod}(160; 3) = 2$

Problem 1. (Spectrogram of Chirp Signal)

Generate a chirp signal x(t) = sin(2F(t)t) with F(t) increasing linearly from $2+2\alpha$ Hz to $5 + 5\alpha$ Hz at a sampling rate of 100 samples per second for the duration of 10 seconds.

(1. Plot the signal as a function of time.)

(Solution) $\alpha = 2$

Therefore, F varies from 6 Hz to 15 Hz linearly for 0 to 10 s. Plotting the chirp signal.

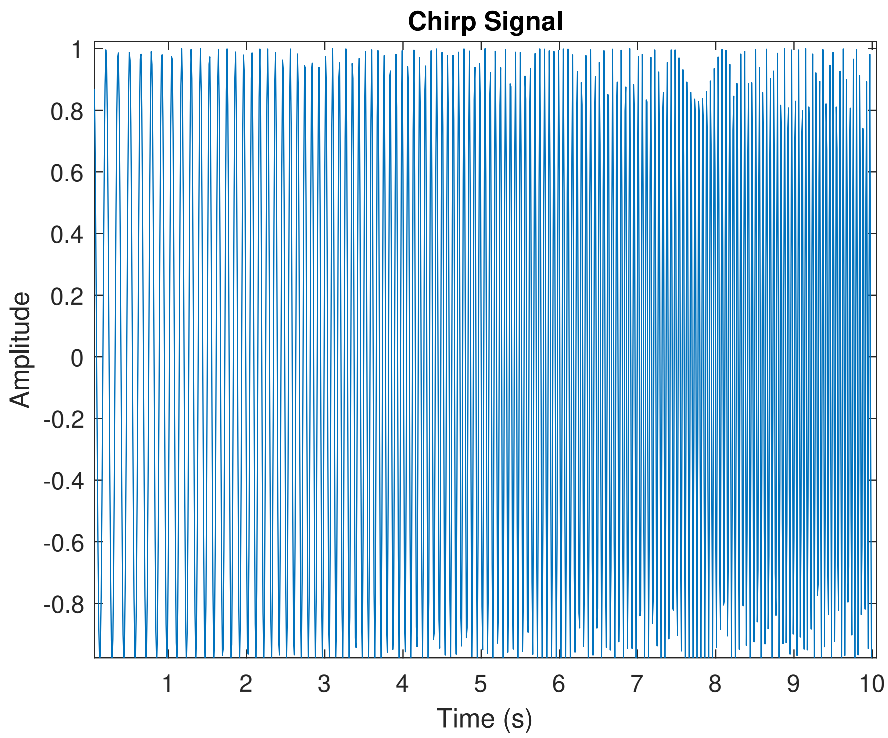

Fig 1: Chirp signal

(2. In a separate figure, plot the frequency spectrum of the signal using FFT. Can you identify the frequency components of the signal?)

(Solution) Plotting the FFT of the chirp signal, we get the following result.

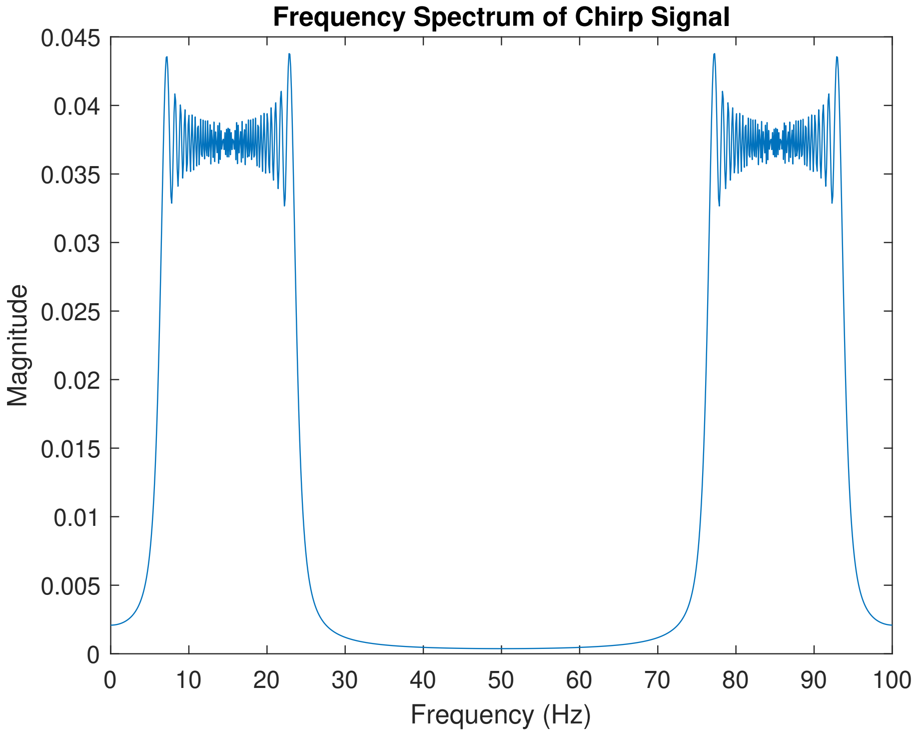

Fig 2: FFT of Chirp signal

From the FFT plot, we can say that the fundamental frequency components of the signal are not fully clear and they span over a range of frequency from 7 Hz to 23 Hz. Also, this gives no information about the temporal variation of the signal.

(3. Now use the same signal and plot a spectrogram of the signal in a separate plot. Use a hamming window length of 100 samples and an overlap of 10 samples. What do you observe? Compare the DFT and spectrogram representations. Which one do you prefer for such a signal? Try different window lengths (say 100, 150 and 200), and different windowing techniques (say hanning, hamming, blackman) and compare them and comment on them.)

(Solution) Plotting the spectrogram of the chirp signal after windowing with a hamming window length of 100 samples and an overlap of 10 samples, we get the following result.

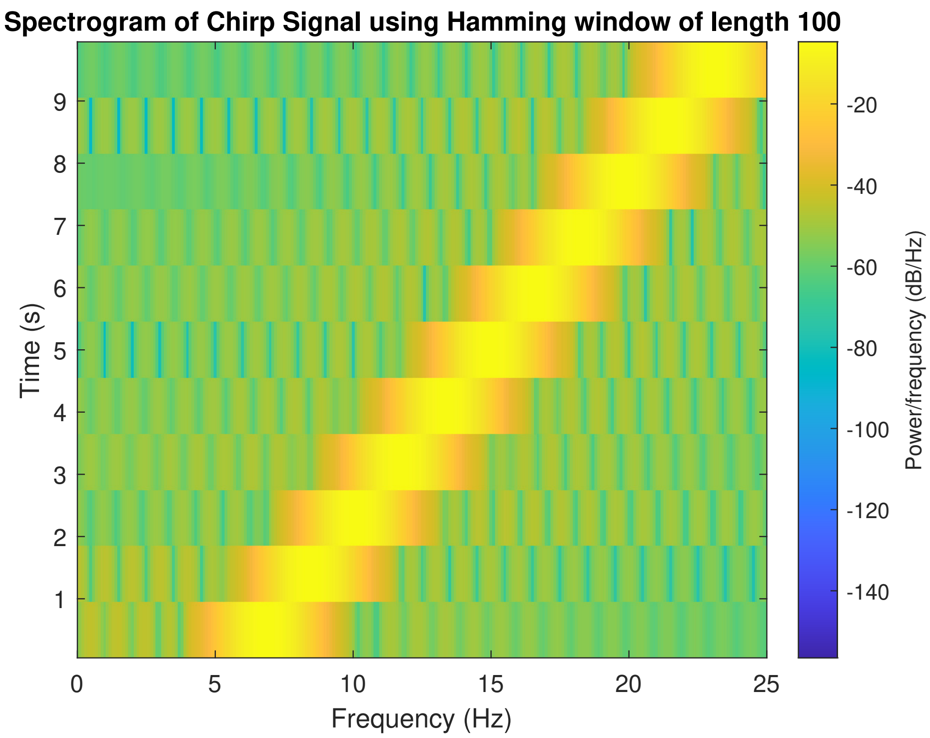

Fig 3: Spectrogram of chirp signal with hamming window of 100 samples

This plot shows us the magnitude of various frequencies at different points in time and how they vary linearly. Since we took a hamming window of 100 samples, and the original signal has 1000 samples, we get 10 bands of frequency each of 1-second duration.

On the other hand, the DFT of the signal is as follows,

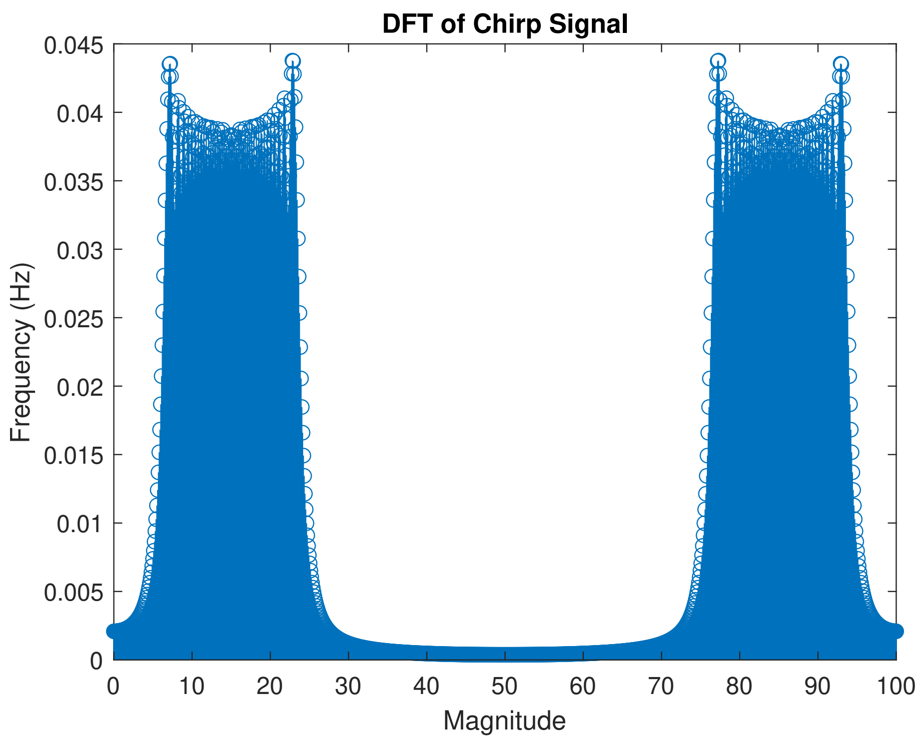

Fig 4: DFT of the chirp signal

As observed, the DFT of the chirp signal provides no information about the temporal variation of the signal and it gives a range of spectral values as the frequency component of the signal.
In such cases where there are temporal variations in the audio signal, we should prefer a spectrogram graph to understand better about the frequency components of the signal.

The following are the spectrogram plots of the chirp signal after applying different windowing techniques of different lengths.

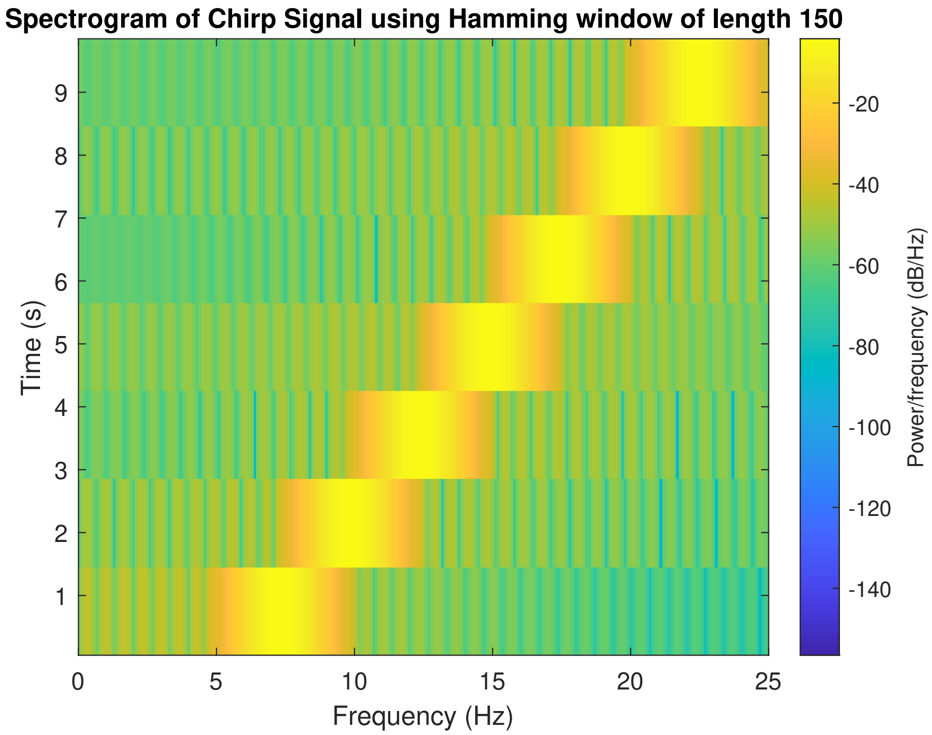

Fig 5: Spectrogram of chirp signal with a Hanning window of 150 samples

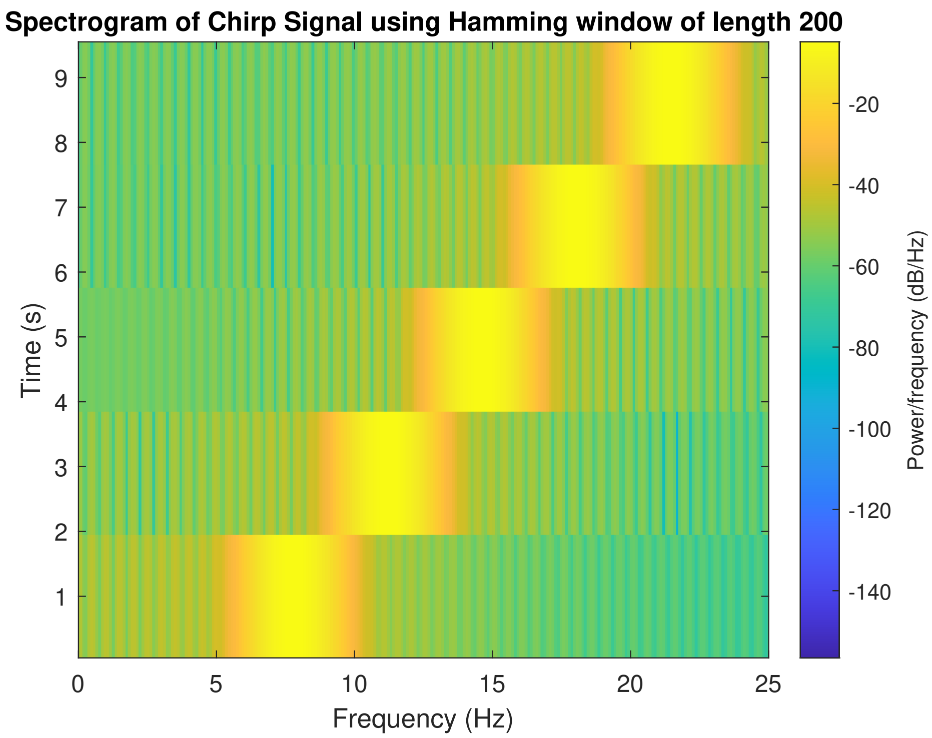

Fig 6: Spectrogram of chirp signal with a Hamming window of 200 samples

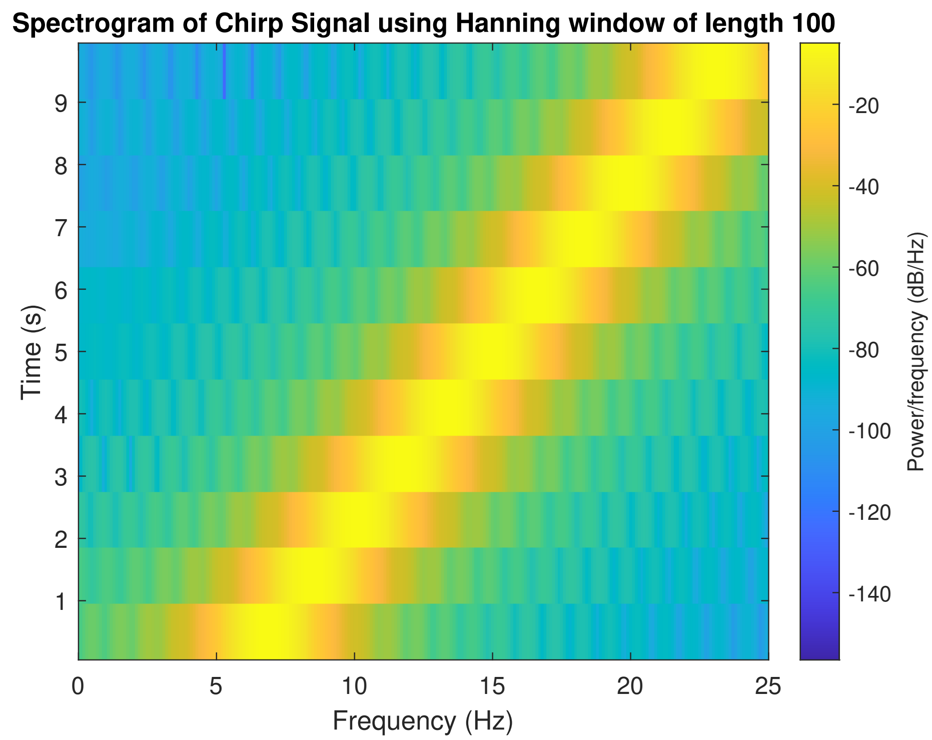

Fig 7: Spectrogram of chirp signal with a Hanning window of 100 samples

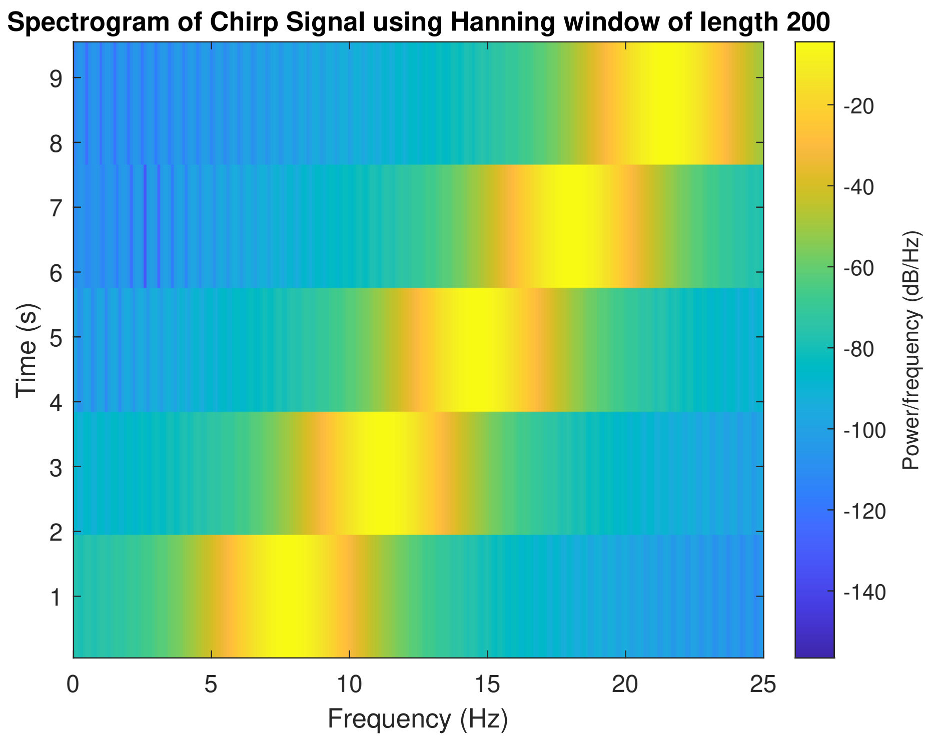

Fig 8: Spectrogram of chirp signal with a Hanning window of 200 samples

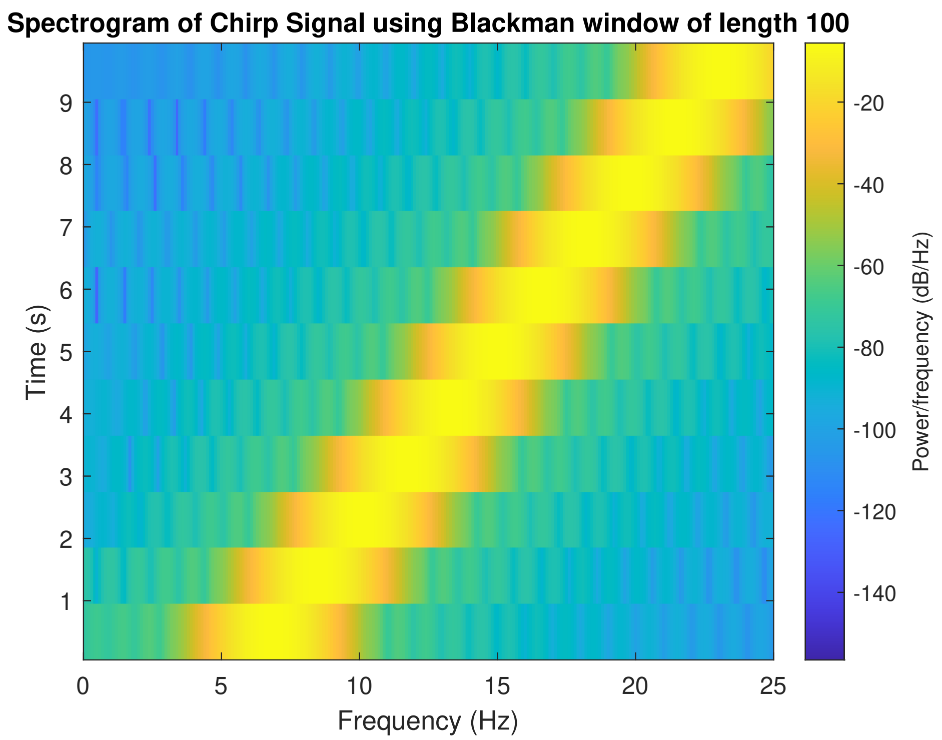

Fig 9: Spectrogram of chirp signal with a Blackman window of 100 samples

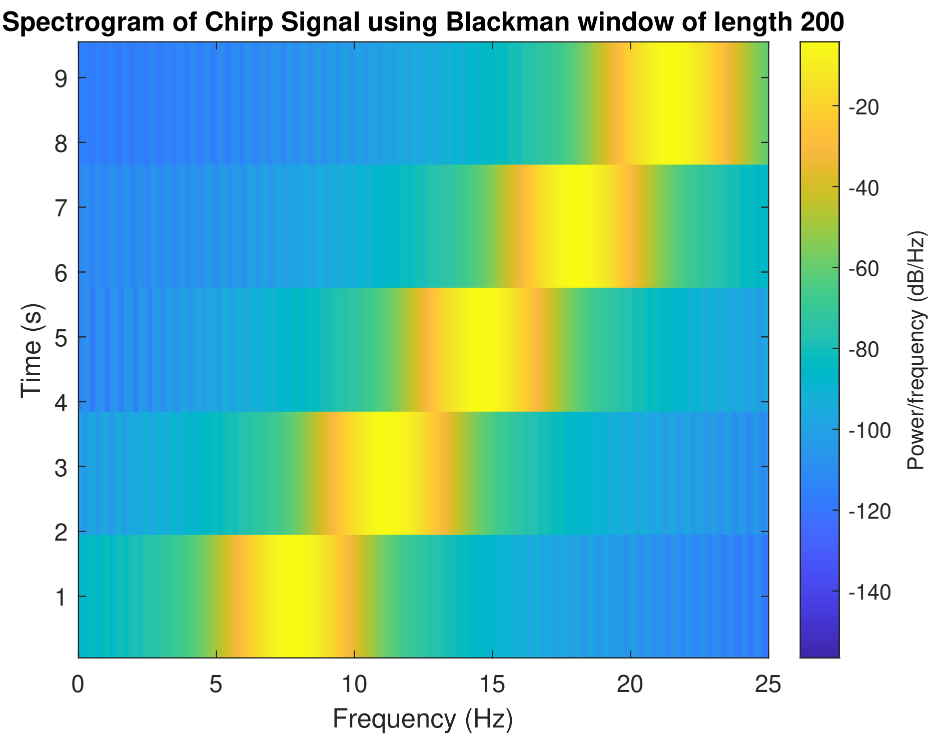

Fig 10: Spectrogram of chirp signal with a Blackman window of 200 samples

As observed from the graphs, the Hanning and Blackman windowing technique provides better results than the Hamming window as it gives accurate information about the magnitude of the frequency components. As we increase the number of samples of these windows, we get more and more accurate frequency components, but we have to compromise the number of samples in the time domain, basically a trade-off.

But irrespective of the window used, they all bring us to the same conclusion that the frequency increases from around 7 Hz to 23 Hz in a linear fashion.

(Pitch Extraction)

(1. Plot the spectrogram of the instruα.wav. You may use any window of your choice and sample duration for the window. Can you now locate the fundamental pitch? Now plot the spectrum in the conventional way. Locate the fundamental pitch. Was our definition of the pitch correct in Experiment 3? Read upon the pitch of an instrument and discuss it briefly in your report.)

The spectrogram of the instrα.wav is as follows,

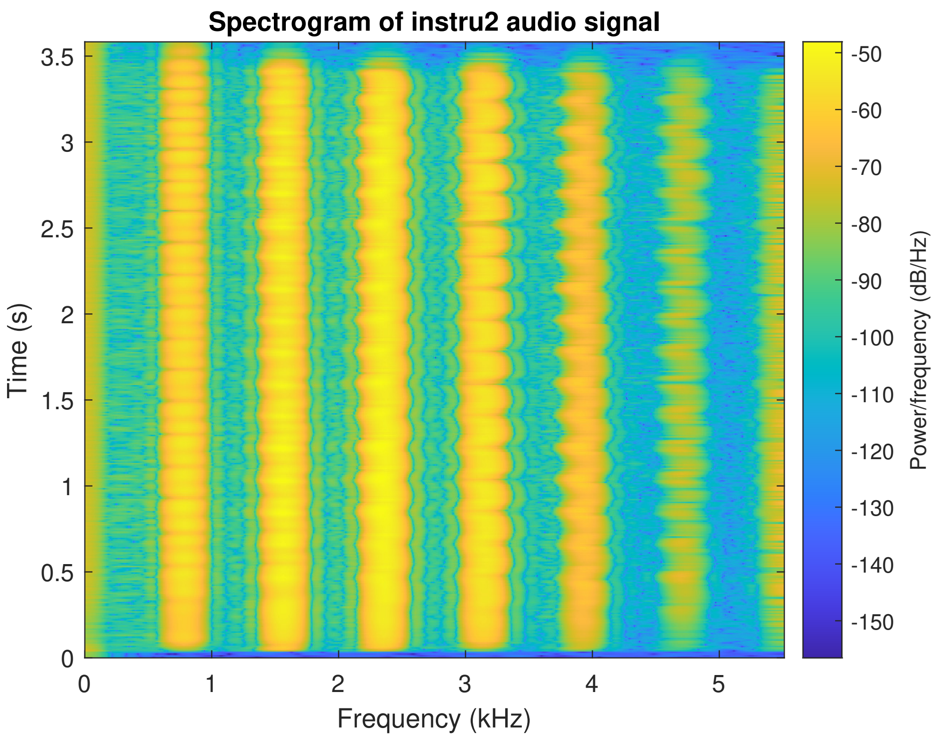

Fig 11: Spectrogram of instru2.wav audio signal with a hanning window

As observed from the graph, we can see multiple frequency components, most of which are harmonics, the first frequency component being around 700 Hz - 900 Hz and the most dominant frequency being around 2100 Hz - 2500 Hz.

The fundamental pitch of the audio signal is the lowest frequency component, in this case around 700 - 900 Hz The frequency spectrum of the same audio signal by plotting FFT is as follows,

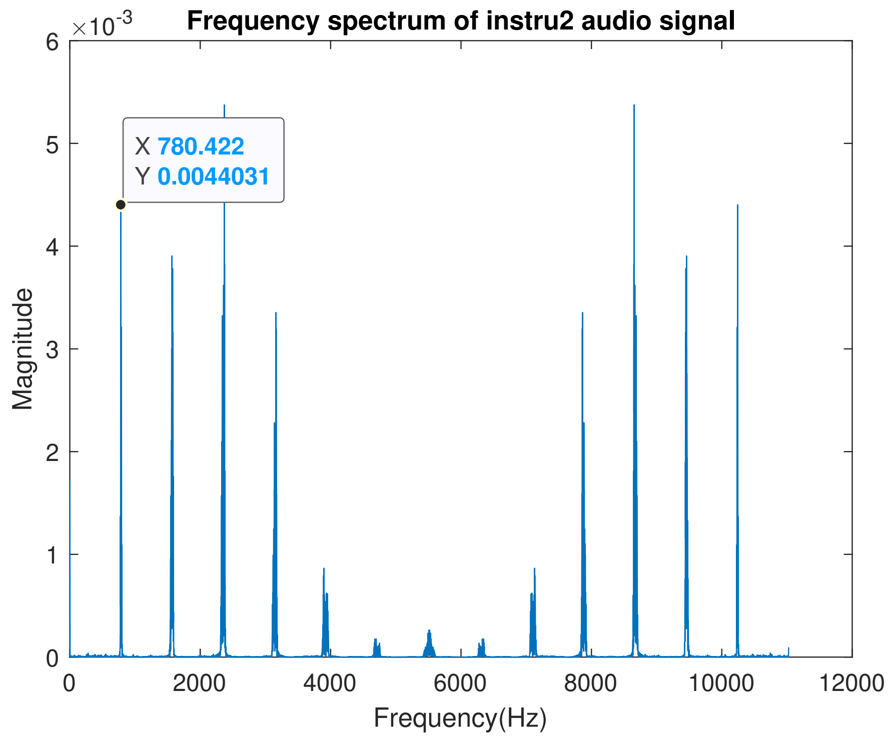

Fig 12: FFT of Instru2.wav audio signal with a hanning window

As observed, the fundamental frequency is clearly distinguishable and it is 780 Hz and the most dominant frequency component is 2300 Hz.

In our previous experiment, we defined that the fundamnetal frequency was the most dominant frequency, which is wrong in the context of music theory. The lowest frequency component is called the fundamental frequency, in this case it is 780 Hz.

(2. Plot the spectrogram of the opera.wav. Are you able to now track the variations in the fundamental pitch better compared to Experiment 3? Comment on it.)

The spectrogram and the FFT plot of the opera.wav file is as follows,

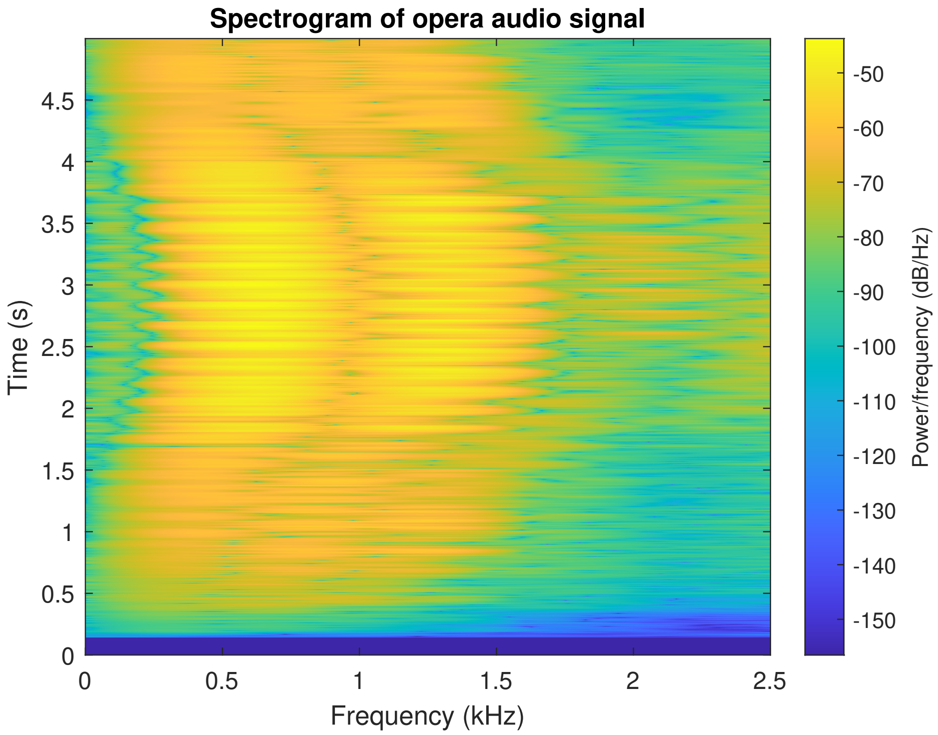

Fig 13: Spectrogram of opera.wav audio signal

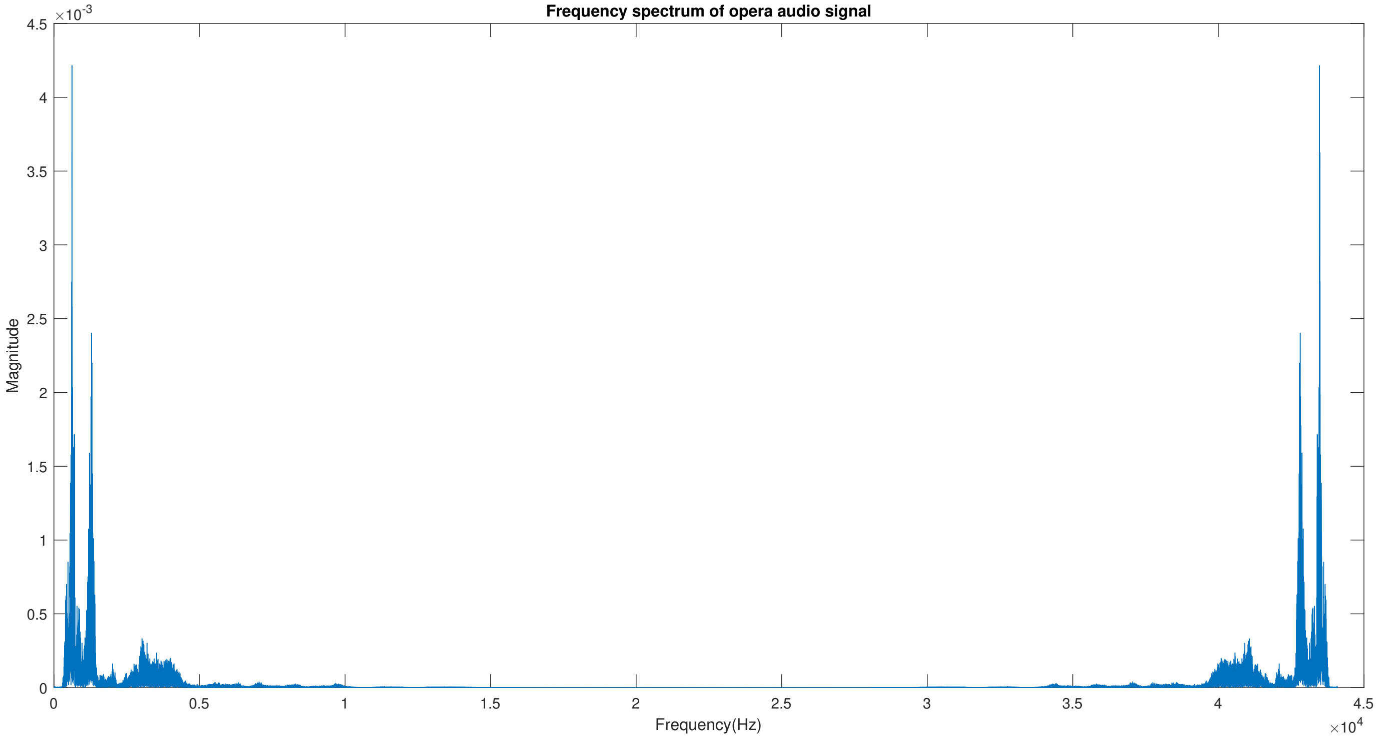

Fig 14: FFT of opera.wav audio signal

As observed from the spectrogram, the temporal variation of the frequency is clearly visible as the frequency of the audio signal reaches a peak and reduces. This temporal variation is much more clear when plotted in a spectrogram.

Problem 3. (Spectro-Temporal Analysis of Speech) Record saying your name (preferably .v

These are the various plots of my name recorded,

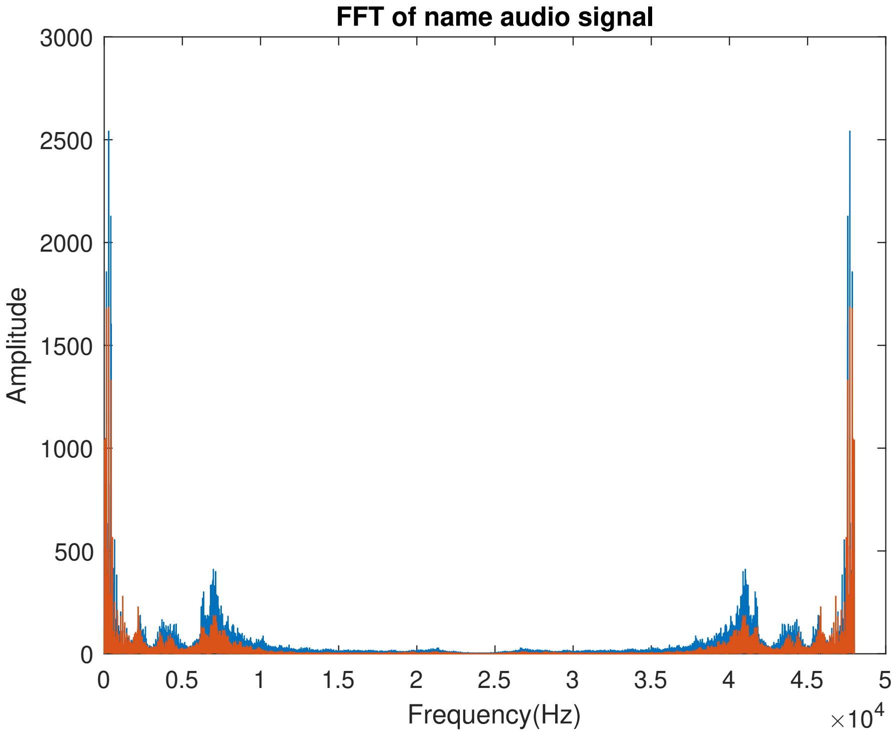

Fig 15: FFT of opera.wav audio signal

Images/e51_fft-eps-converted-to.pdf

Fig 16: FFT of opera.wav audio signal

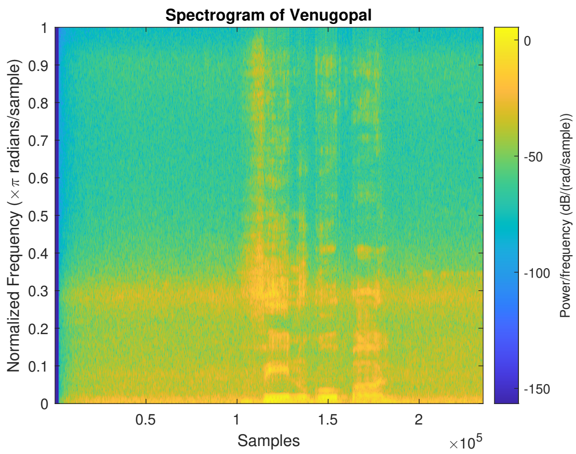

Fig 17: FFT of opera.wav audio signal

These plots tell the frequency spectrum of my name and it shows the dominant peaks in places of vowels and lesser peaks in places of consonants.

A Code Repositories

`https://github.com/VenugopalRadhakrishnan/DSP-Lab`.