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EE430 Term Project Part 1

Spectrograms is a manner of frequency analysis which allow us to investigate the frequency representation of the time signal more precisely. Since most signals are not stationary, investigating them simply by taking their DFT is not accurate. Much more accurate method is to investigate them in small time intervals. Each time interval can be seen on the x-axis of the spectrogram. Therefore, the vertical line at that specific x value is actually a much smaller DFT part of the original signal. This approach helps one to track the frequency components closely at any time. But some parameters of the Spectrogram also important which are window length and window shift.

1.Introduction on Matlab App by using created Matlab App

We have 3 different options on obtained signal which are "Data from Microphone"," Data from the File", "Generate Signal". For "Generate Signal" option, user can specify different parameters of the signals which are signal type, amplitude, frequency, duty cycle, width, initial frequency, phase, stop time, sampling frequency, stop time, window type and length for generating signal, bandwidth, duration and starting time and also for multiple wave option array of amplitude, frequency and phase. These parameters can be open or closed with respect to the chosen signal type. User can use the "Data from Microphone" by selecting the option and can push the buttons "Start Recording" and "Stop Recording" so that the signal from microphone can be derived. Furthermore, user also can add ".wav" file to the App and observe the signal from that ".wav" file. In order to finish the total creating signal user should push the "Generate/Take Signals" button so that the signal has been created and plotted in the figure. For the spectrogram side user have also chance to specify the window type, length and window shift (in terms of samples) size. And by pushing the "Spectrogram" button, app will create a new figure for spectrogram and user will have a chance to observe it (Note: Before pushing the "Spectrogram" button, "Take/Generate Signals" button should be pushed once).

2.Effect of Changing the Window Overlap

The amount of the Window shift is another important parameter that determines the performance of the spectrogram. For a good comparison, spectrogram of "Cough.wav" will be used. And Window Length and Style are same for all three Figures 1.2.3 (Window Length=500, Window Type=" Hamming") but Window shift changes in these 3 different spectrogram and become 10,100,500 respectively. Window shift parameter creates the definition for window overlap, when window shift is small then window overlap will increase. As window shift gets closer to window length window overlap decreases. In our example when window length is equal to 500 and also shift is equal to 500, hence there will be no overlap.

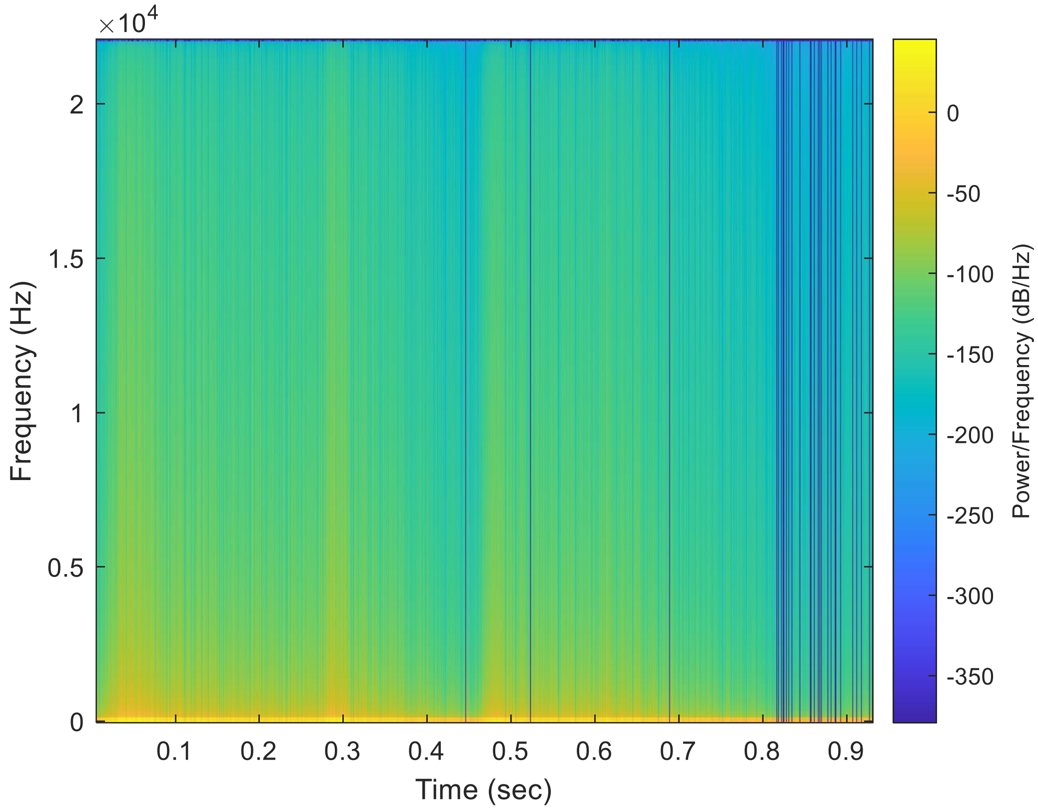

Figure 1-Spectrogram of "Cough.wav" When Window Length=500,Window Shift=10

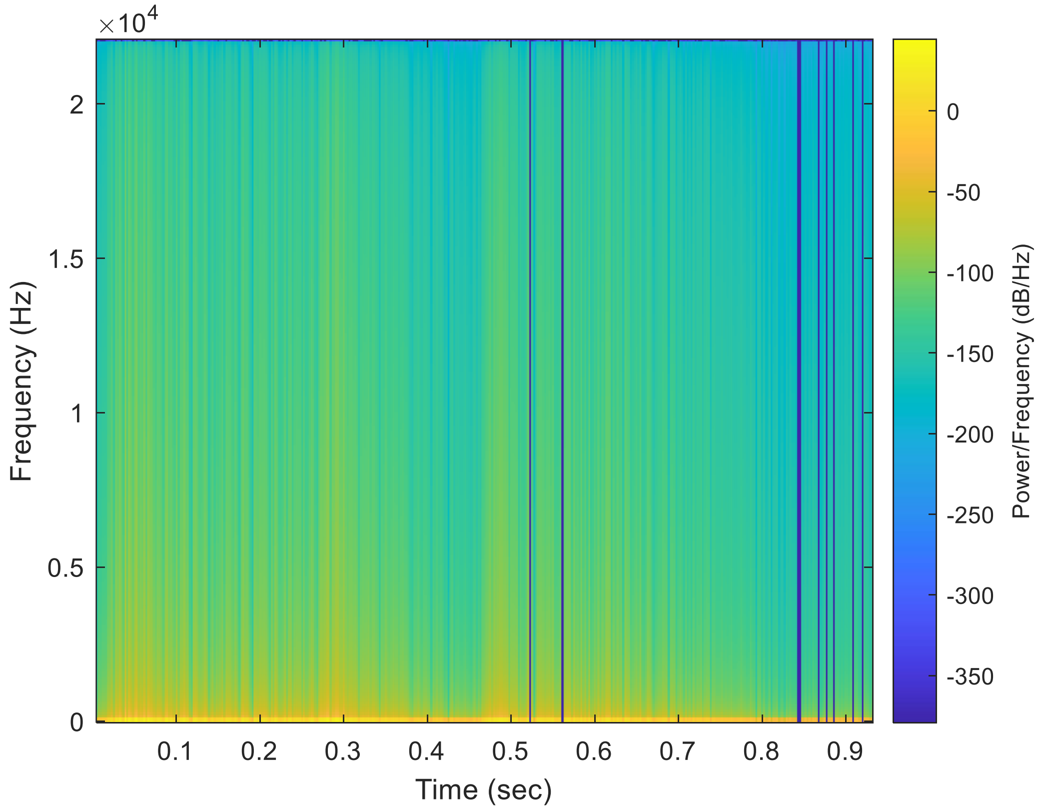

Figure 2-Spectrogram of "Cough.wav" When Window Length=500,Window Shift=100

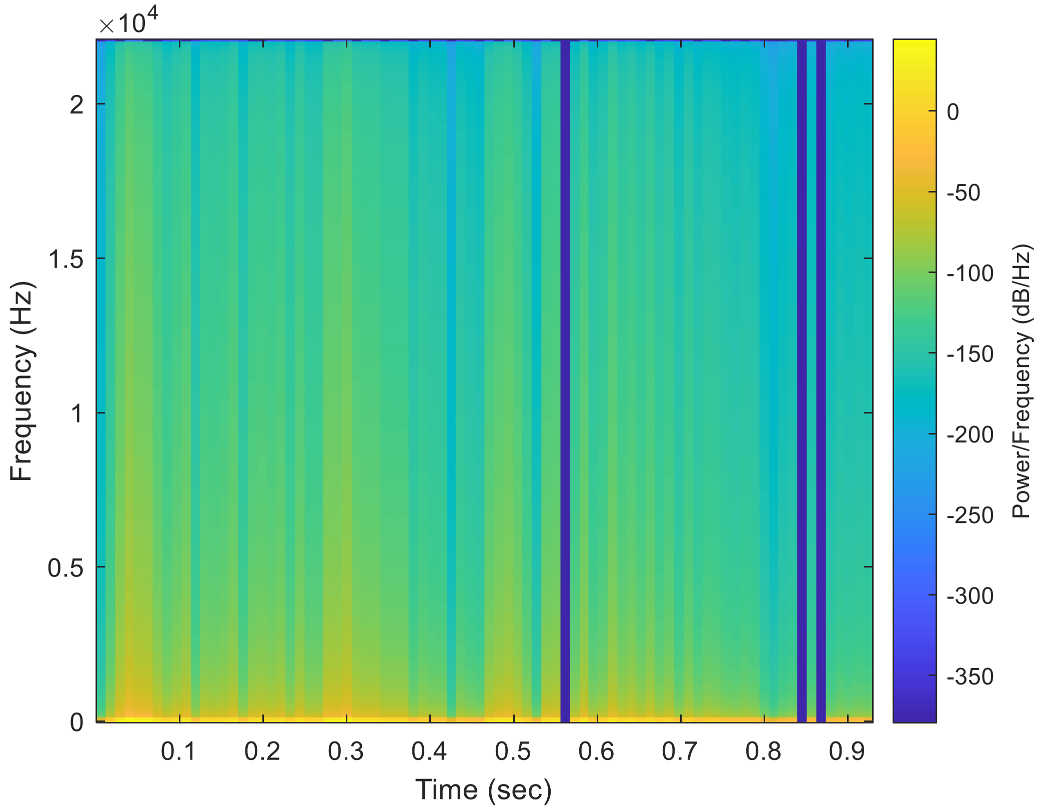

Figure 3-Spectrogram of "Cough.wav" When Window Length=500,Window Shift=500

When the amount of the window shift is small (high window overlap), high frequency components at the ends of the windows whose FFTs are taken becomes more visible as it can be seen from Figure 1,2,3 that yellow parts contain more space and blue part is not visible much. When window shift is large (less window overlap) , these high frequency components are suppressed by low frequency components , as it can be seen that blue parts are more visible at Figure 3.

3.Effect of Changing the Window Length

When a signal is analyzed with different window lengths without changing the window type and amount of shift, the output changes significantly. Outputs for a sample sound file "Cough.Wav" are provided below as an example. Window type is Hamming, amount of shift is 1 and window lengths are 500,100 and 20, in this case.

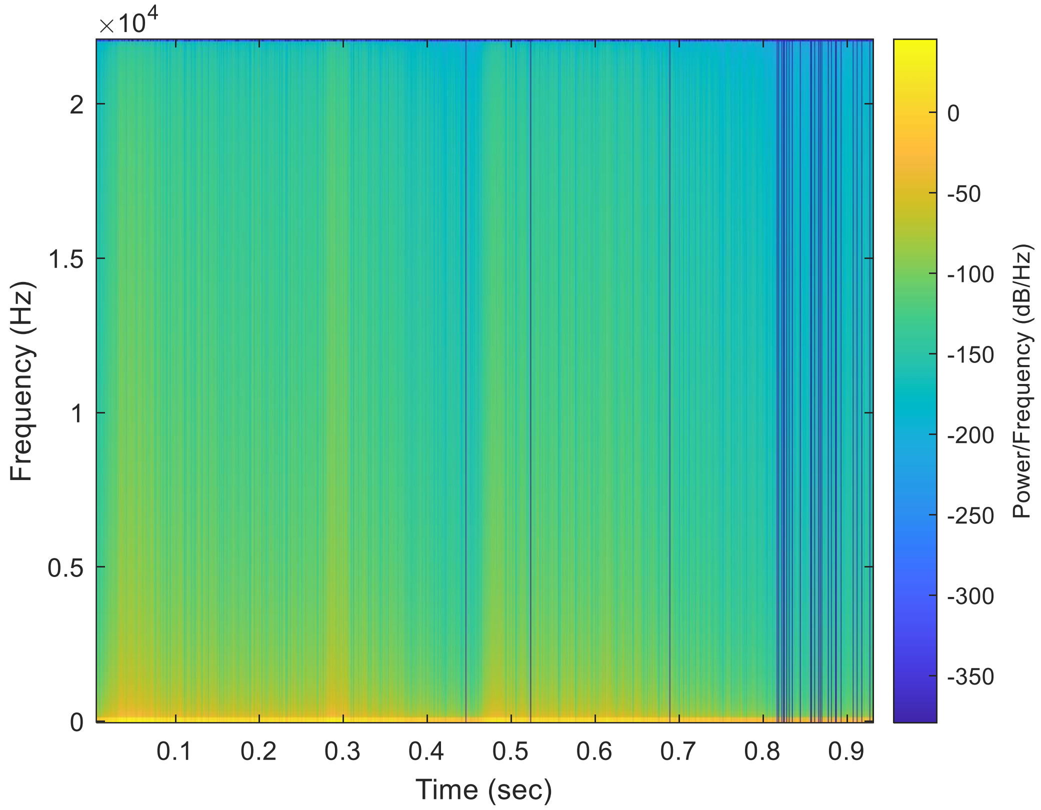

Figure 4-Spectrogram of "Cough.wav" When Window Length=500,Window Shift=1

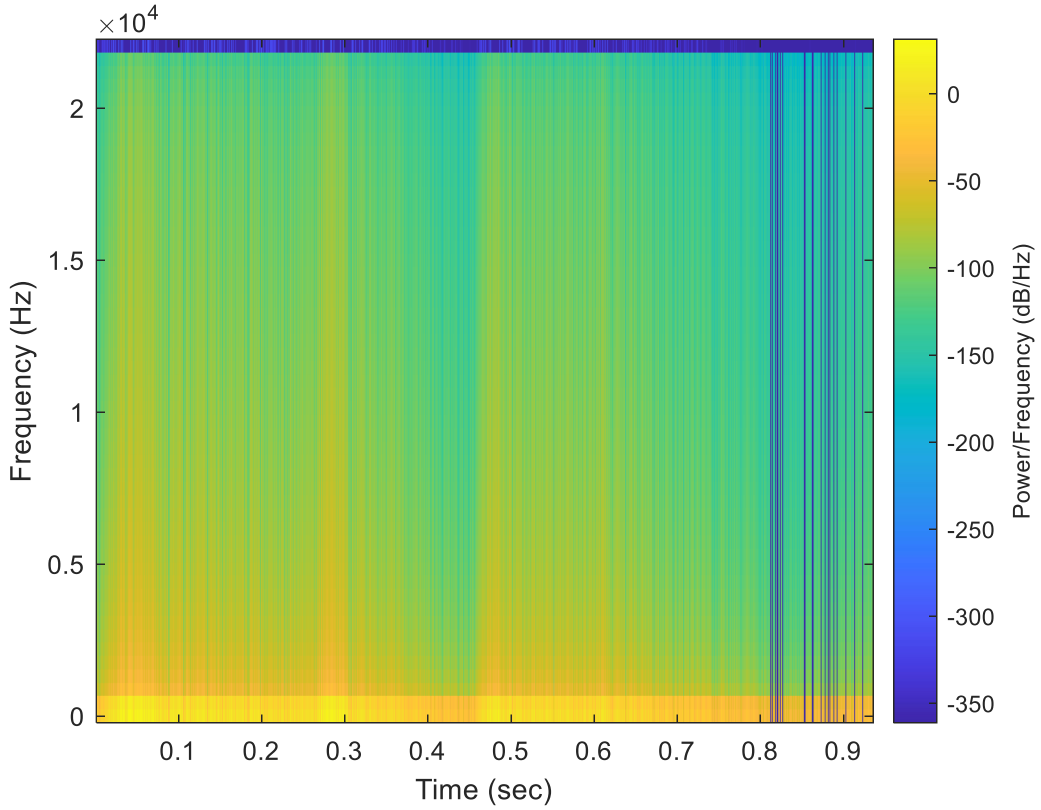

Figure 5--Spectrogram of "Cough.wav" When Window Length=100,Window Shift=1

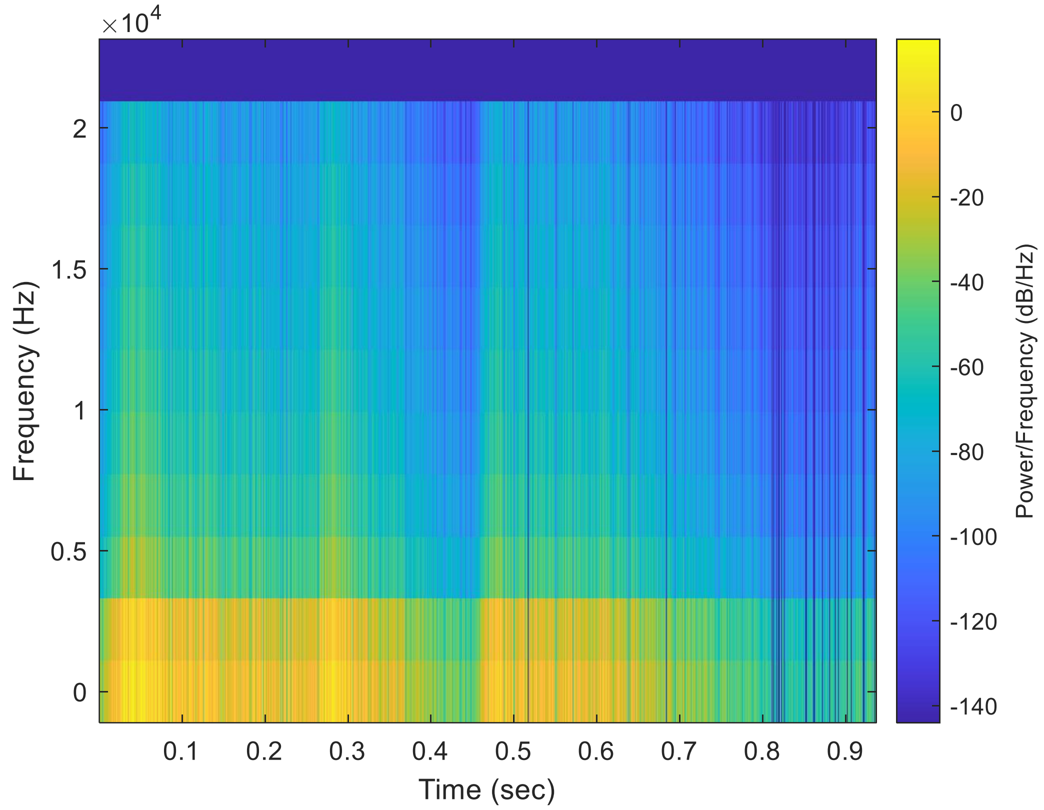

Figure 6--Spectrogram of "Cough.wav" When Window Length=20,Window Shift=1

As seen from the above Figures 4,5,6 when the length of the window is increased, the resolution on the time axis decreases dramatically. If the length of the window is equal to the length of the input signal, the spectrogram gives the FFT the complete input signal. As the window length reduces, the input signal becomes more fractional and the precision of the instantaneous frequency analysis is increased.

4. Signals with Multiple Sinusoidal Components

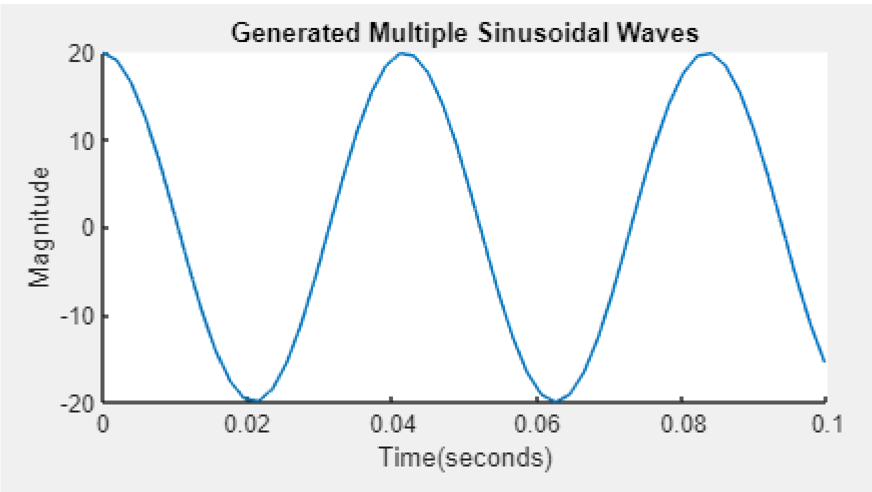

*Figure 7: Plot of 10*cos(1000*2pi*t) + 10*cos(1000*2pi*t) vs time*

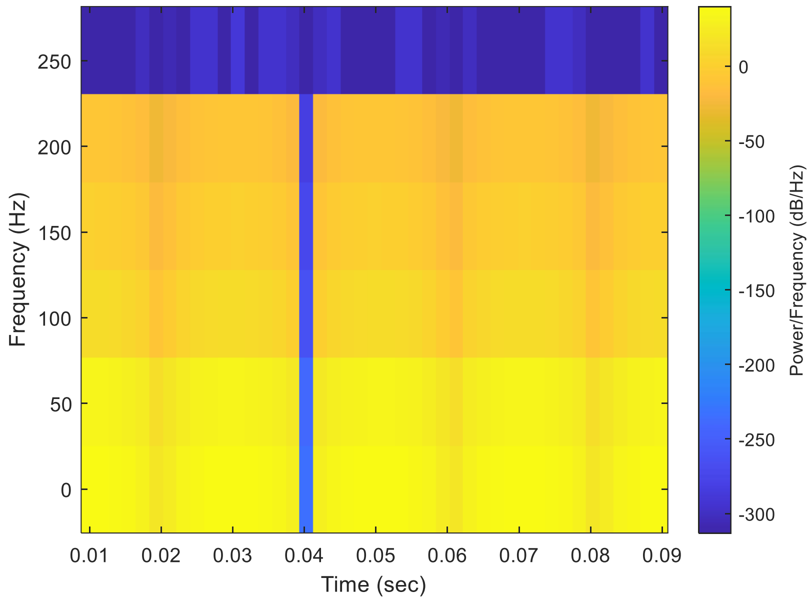

*Figure 8: Spectrogram of 20*cos(1000*2pi*t) Sinusoidal*

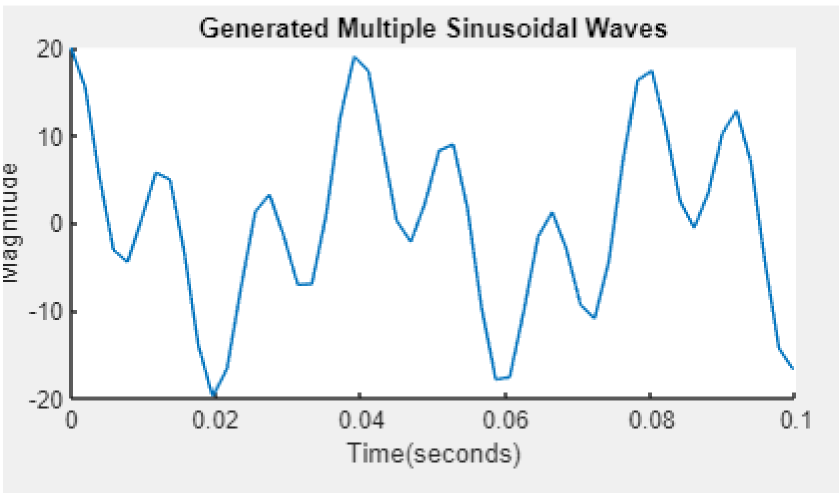

*Figure 9: Plot of 10*cos(1000*2pi*t) + 10*cos(1100*2pi*t) vs time*

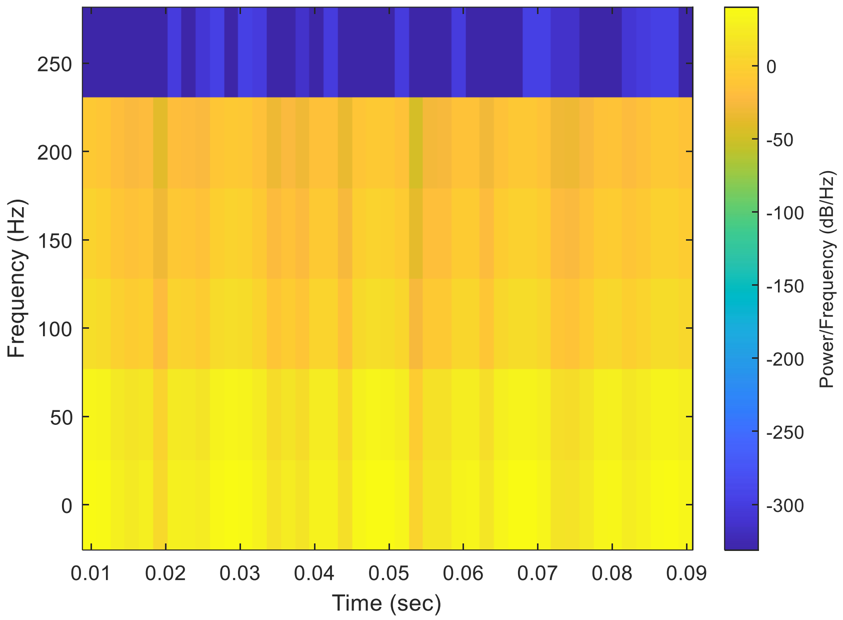

*Figure 10: Spectrogram of 10*cos(1000*2pi*t) + 10*cos(1100*2pi*t) Sinusoidal with window length 10*

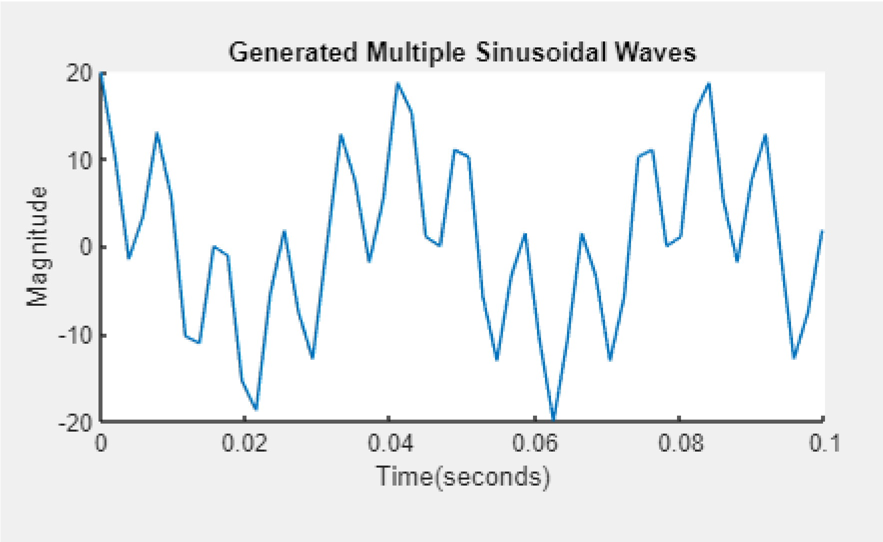

*Figure 11: Plot of 10*cos(1000*2pi*t) + 10*cos(5000*2pi*t) vs time*

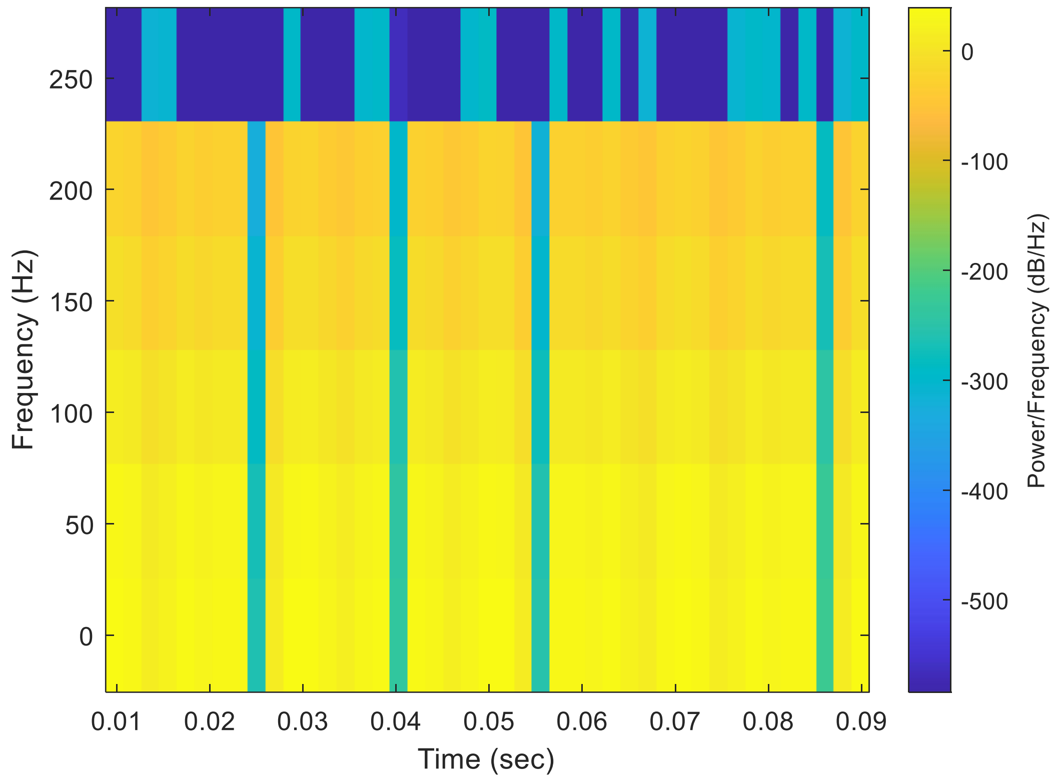

*Figure 12: : Spectrogram of 10*cos(1000*2pi*t) + 10*cos(5000*2pi*t) Sinusoidal with window length 30*

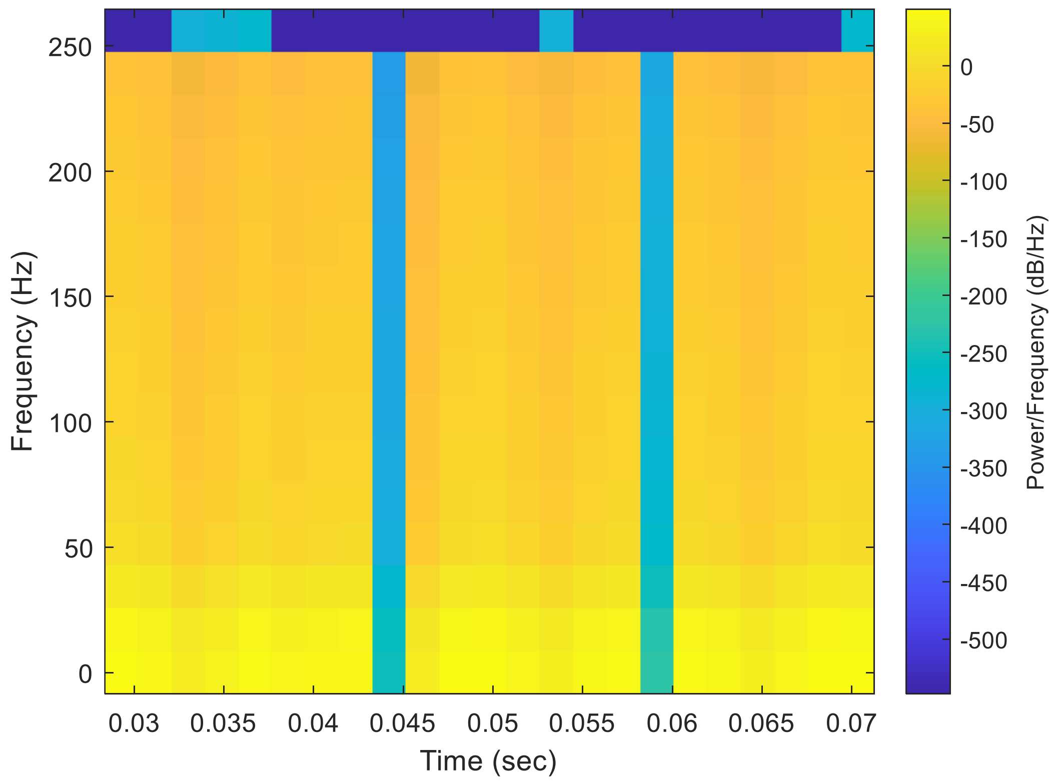

*Figure 13: Spectrogram of 10*cos(1000*2pi*t) + 10*cos(5000*2pi*t) Sinusoidal with window length 10*

Fourier's theorem states that any waveform in the time domain can be represented by the weighted sum of sines and cosines. Frequency analysis shows the difference between these two sine waves in our example. Different frequency values will show the distinction more so when frequencies are 1000 Hz and 5000 Hz their spectrogram have different negative peaks.

To show the effect of the window length and frequency difference, as you can see from the Figures 12 and 13 as the window length increases the division of the spectrum is more prominent whereas the window length decreases the division of the spectrum is more uncertain. Furthermore, as the frequency difference between the sinusoidal components of the overall signal the distinction of the spectrogram will be inherently visible. As a note, the distinction of the spectrums could be derived from the negative peak (color turns to blue) number and the distinction could be created by increasing the frequency difference between the participant sinusoidals or increasing the window length.

5.Analyzing the Effect of the Window Type

Choice of the window type during the windowing operation is significant especially in some cases. For example, if the undesirable high frequency noise is aimed to be removed from the spectrum of the signal, Gaussian Window should be used.

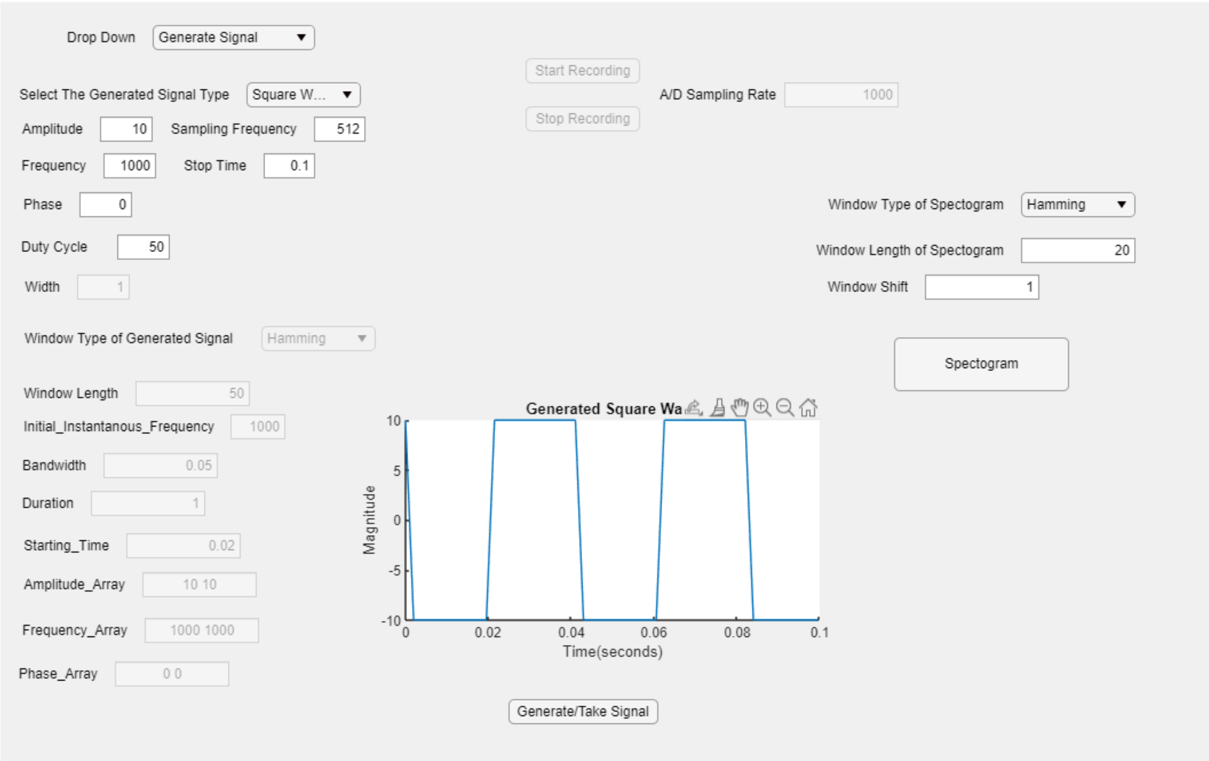

Figure 14: Square Wave generated to analyze the effect of window type

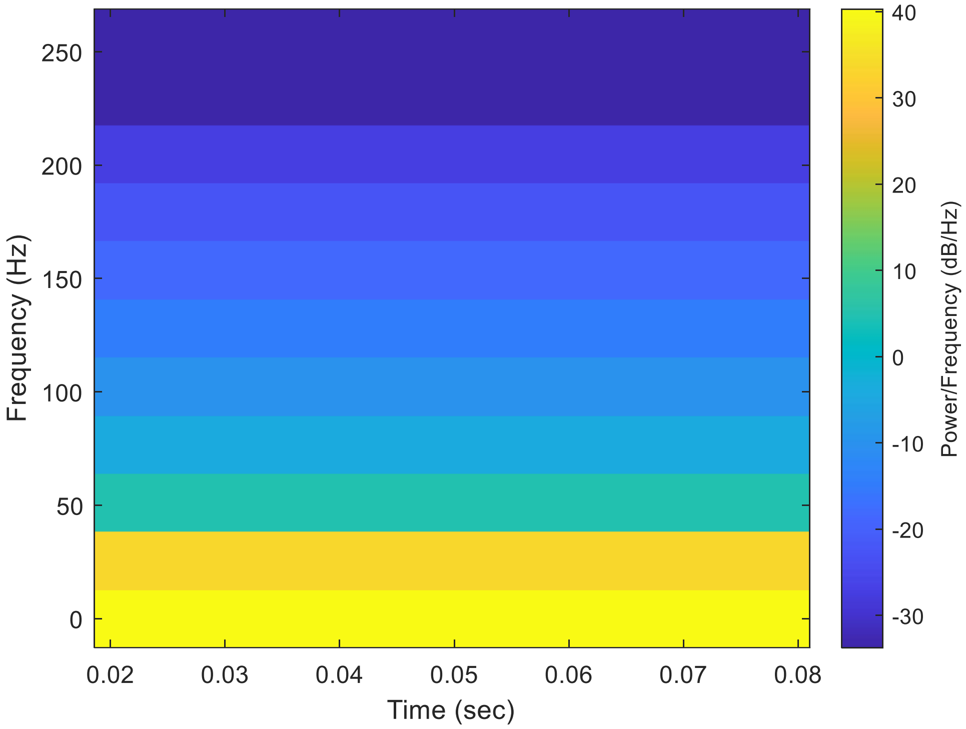

Figure 15: Spectrogram of the Computer Generated Square Wave with Window Type Hamming

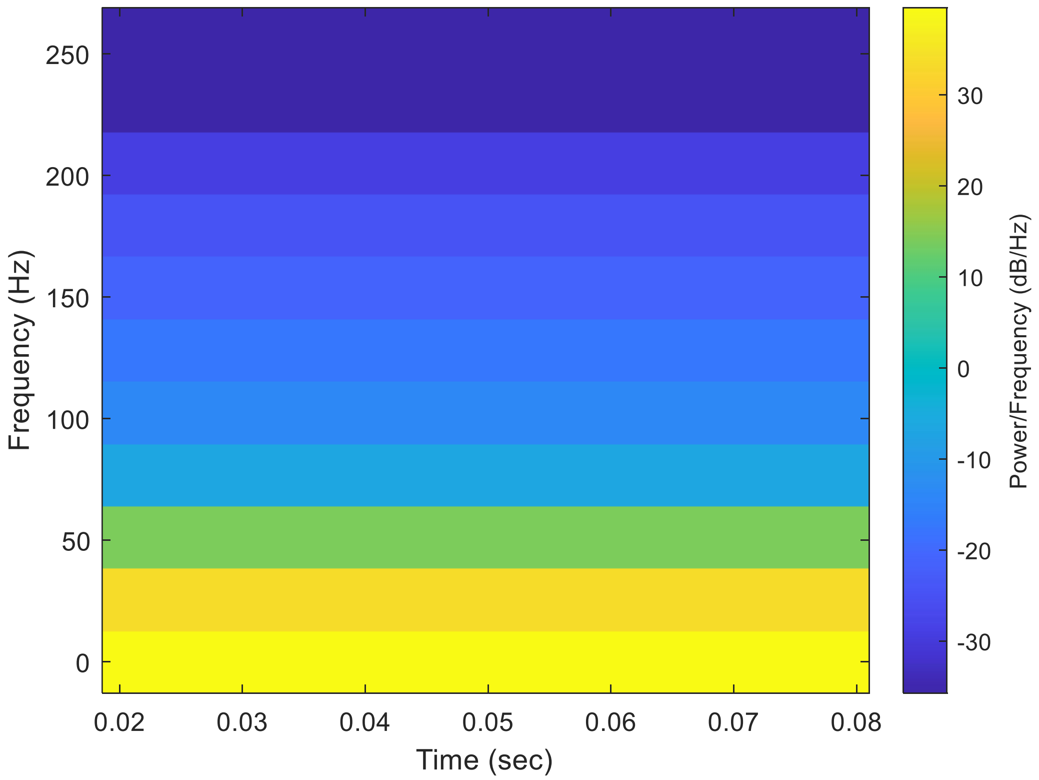

Figure 16: Spectrogram of the Computer Generated Square Wave with Window Type Gaussian

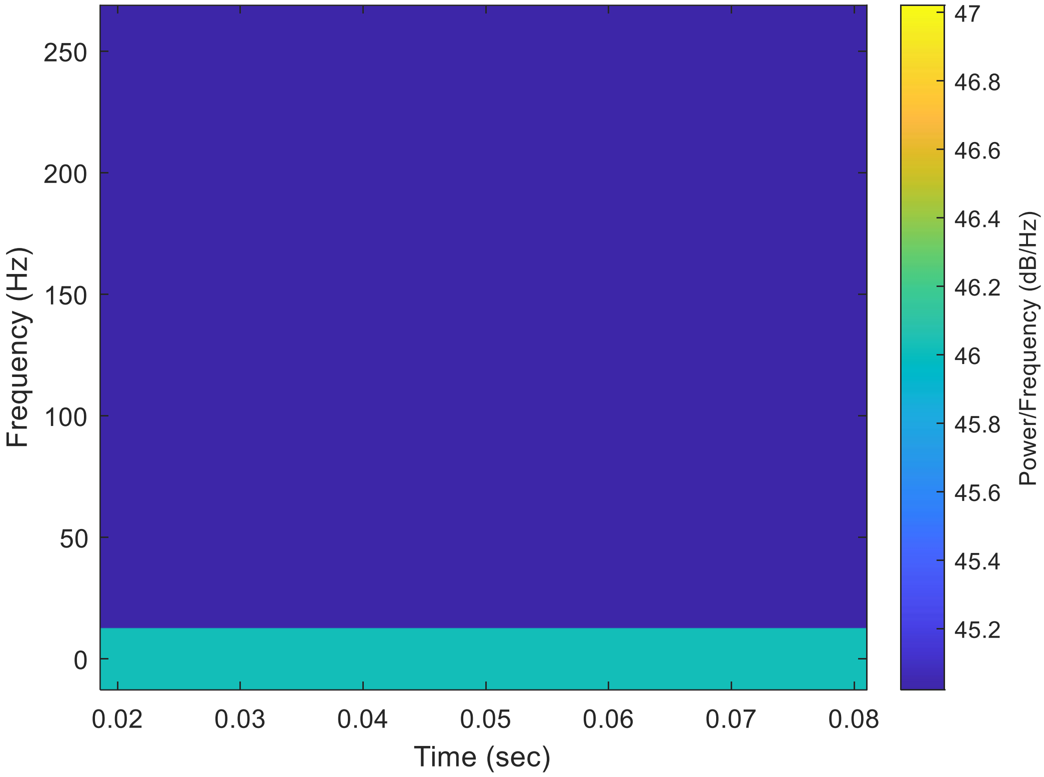

Figure 17: Spectrogram of the Computer Generated Square Wave with Window Type Rectangular

As you can see from the Figures 15, 16 and 17 the spectrogram of the square wave signal varies according to the window type of the signal. One can derive that the rectangular window type for the square wave signal will terminates the diversity of the Power/frequency ratio of the different frequency bands. Hence, usage of the rectangular window type for this case may result with an undesirable result in the spectrogram of the square signal. Furthermore, if Figure 15 and Figure 16 are compared with each other, in the spectrogram of the window type Hamming (Figure 15), the power of the high frequency bands are larger than the Gaussian type as it is stated in the head of the section. This is because that the Gaussian window type suppresses the high frequency components of the FFT of the signal, whereas the Hamming window type passes the high frequency bands more than the Gaussian type.