- Data recording: 'record_audio.m' is used to record the data taken from 'TIMIT_sentences.txt'. sx10 and sx67 are recorded. sx67 is used for the demonstration. The read texts in those audios are as follows:
  - Are your grades higher or lower than Nancy's? (sx10)
  - Last year's gas shortage caused steep price increases. (sx67)

  The data was recorded with 16 bits and 8000 Hz sampling rate.

- Spectrogram Function: 'customSpectrogram.m' is a custom spectrogram generator using a FFT or FSST. The detailed usage of the function is:

```
% Usage: [s, f, t] = customSpectrogram(x, params)
% s is the matrix of returned spectrogram
% f is the vector of frequencies at which spectrogram is computed
% t is the vector of times at which spectrogram is computed
% x is the sample vector
% params is a structure array containing the following parameters:
%     params.Fs: sampling frequency in Hz
%     params.nFFT: number of frequency points to calculate DFT
%     params.window: is a 1x2 row vector where first value specifies the
%         type of window and the second value gives the window length.
%         0 for hanning, 1 for hamming, 2 for rectwin, 3 for
%         kaiser, 4 for chebwin
%     params.nOverlap: number of overlap of samples in adjoining segments
%     params.fsst: 1 to use Fourier synchrosqueezed transform instead of
%         FFT. Default value is 0
%     params.plotType: 1 to view in a tiled layout containing spectrum,
%         time domain waveform, and colorbar. 0 to view only spectrogram.
%     params.zoom: 1 to zoom into the spectrogram. Default value is 0
%     params.zoomTimeRange: start and end of time to be zoomed into. Put
%     the values in a 1x2 row vector. NOTE: params.zoom must be 1
%     params.zoomFreqRange: start and end of frequency to be zoomed into.
```

```
%      Put the values in a 1x2 row vector. NOTE: params.zoom must be 1
%   NOTE: params.Fs, params.nFFT, params.window, and params.nOverlap are
%   reuired. Rest of the parameters will use default values unless
%   otherwise specified.
%
```

There are some helper functions that are used to compute some plots and make the main function neat. They are:

- fftWindowedMatrix.m
- plotSpectrogram.m
- tiledPlot.m

- Example Code: 'main.m' script contains an example code.

```
% This script shows example parameters to use customSpectrogram
%


clear; clc; close all;
[x, fs] = audioread("sx67.wav");


%% get the values and plot only spectrogram
params.Fs = fs;
params.nFFT = 1024;
% need to specify window type
% 0 for hanning, 1 for hamming, 2 for rectwin, 3 for kaiser, 4 for chebwin
params.window = [1, 200];
params.nOverlap = 50;
params.fsst = 0;    % use 1 to use FSST
params.plotType = 1;    % if 0 or not used then plots only spectrogram
params.zoom = 1;    % 1 to zoom into spectrogram with given boundaries
```

```
params.zoomTimeRange = [1.5 2];
params.zoomFreqRange = [500 1500];


[s, f, t] = customSpectrogram(x, params);
```

Here hamming window of length 200 is used with 1024 as the number of fft. The regular plot and the zoomed plots are shown below:

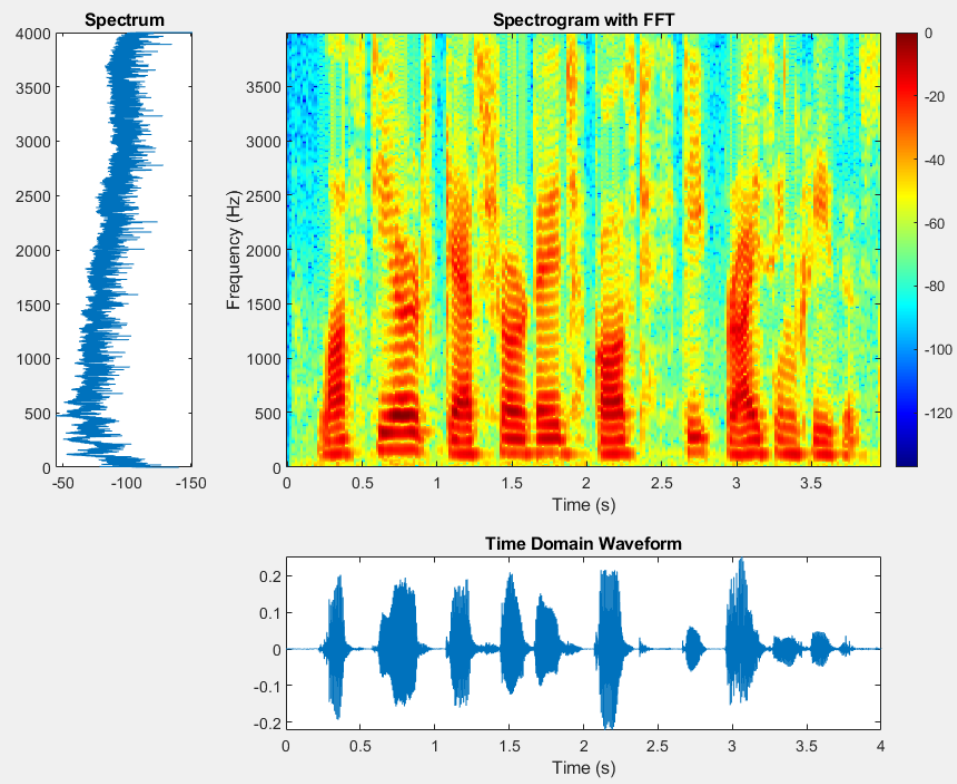

Fig 1

Fig 2 contains the zoomed version of the spectrogram. For this specific audio signal, the time domain and frequency domain boundaries used are [1.5, 2] s, and [500, 1500] Hz.

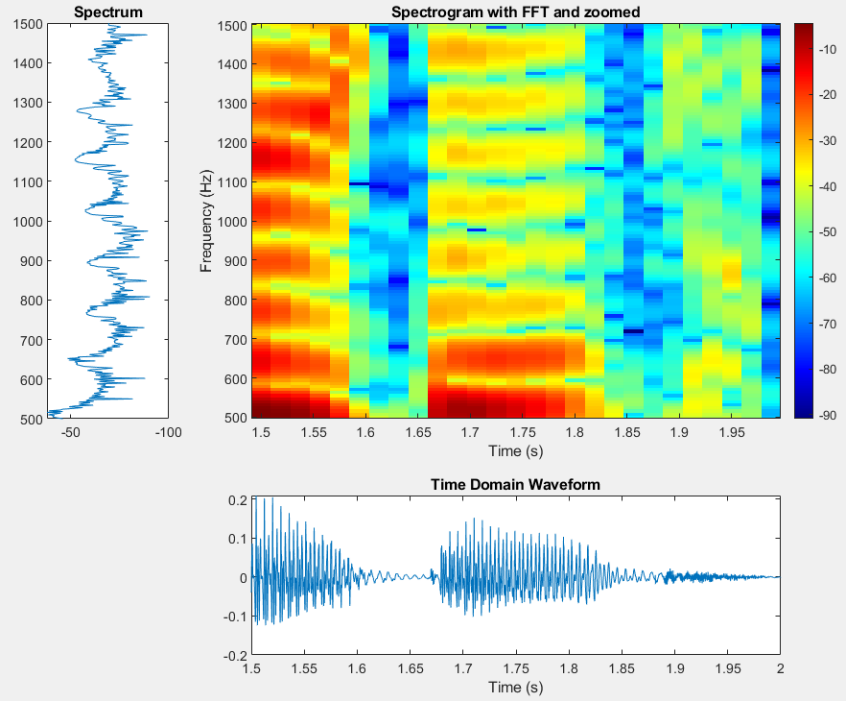

Fig 2

The same results are shown below but computed with FSST. To do that the following code is modifed:

```
params.fsst = 1;
```

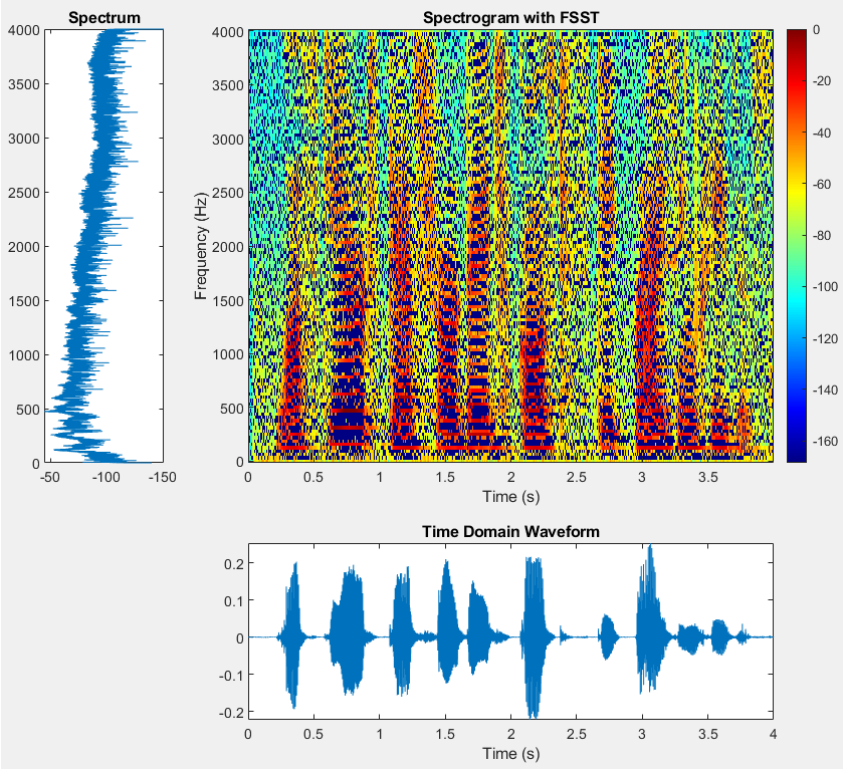

Fig 3

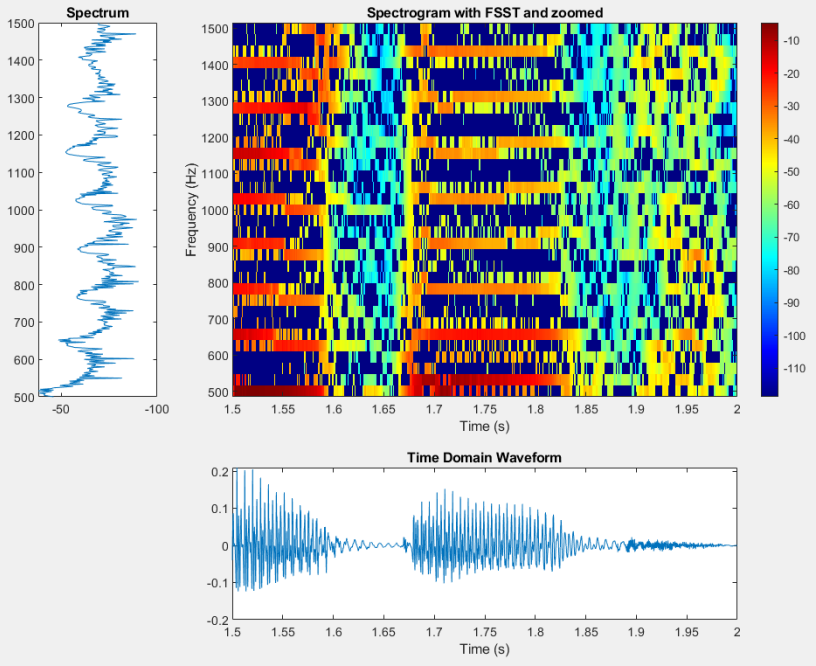

Fig 4

- Comparison with Matlab Functions: According to the homework instructions spectrogram, power spectrum, and Wigner-Ville distribution was supposed to be compared. Unfortunately, wvd did not work out, and ran out of memory. The other two properties were compared and shown below. 'compareWithMatlab.m' script contains the code for this comparison.

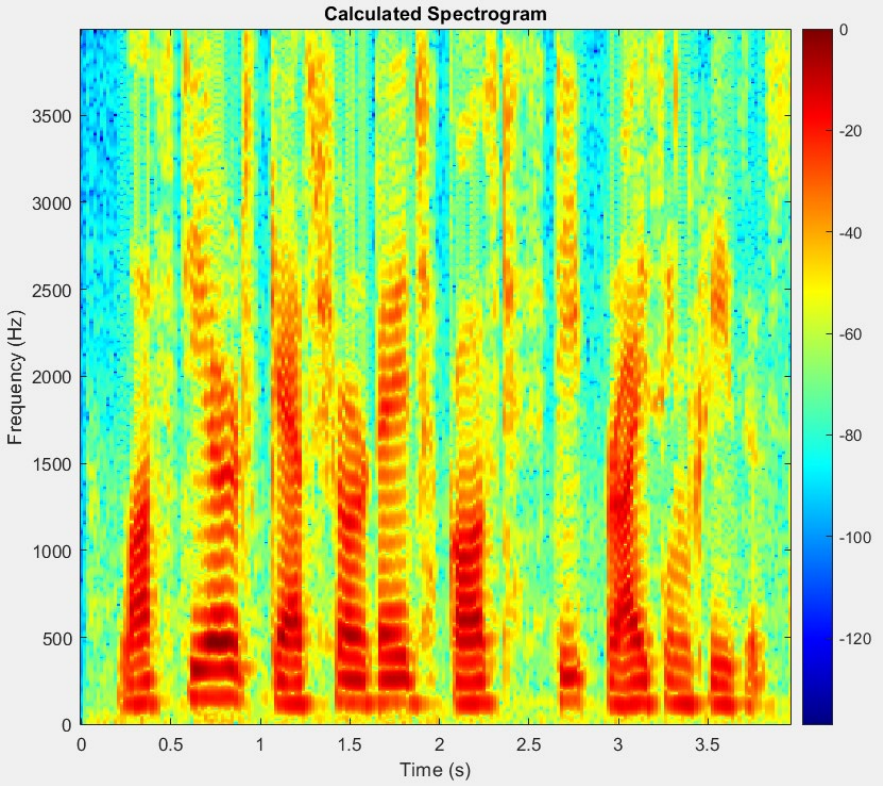

Fig 5

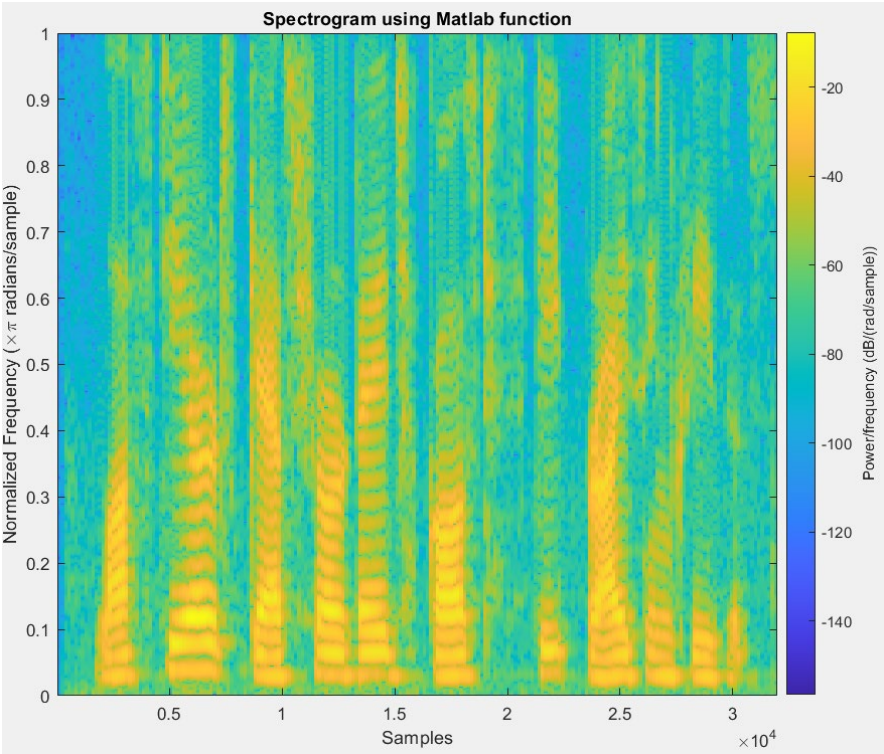

Fig 6

Fig 5 and 6 are identical but with different color mapping.

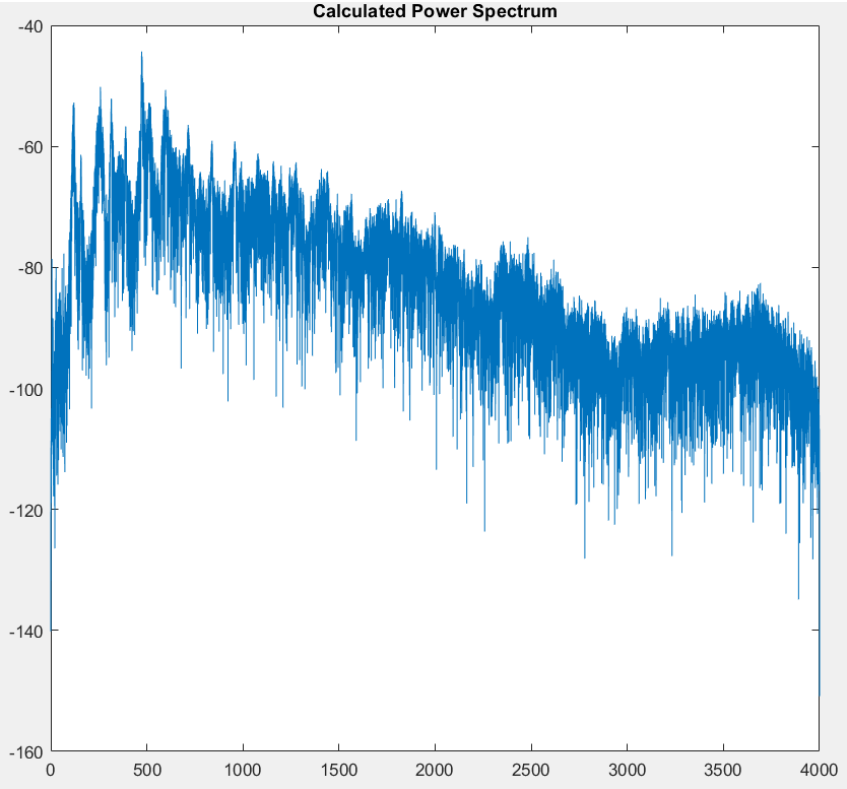
Calculated Power Spectrum
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
3500
4000

Fig 7

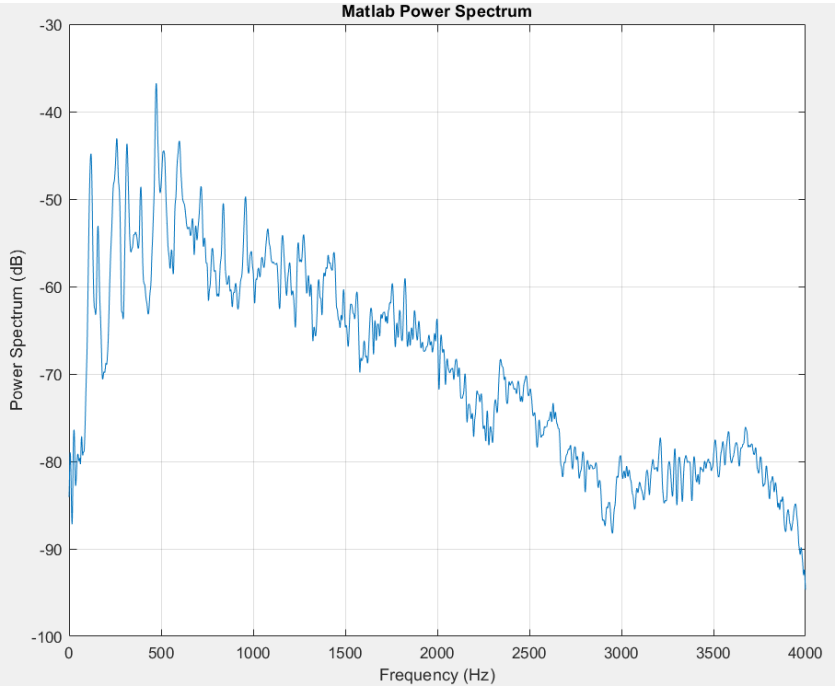
Matlab Power Spectrum
Power Spectrum (dB)
-30
-40
-50
-60
-70
-80
-90
-100
0
500
1000
1500
2000
2500
3000
3500
4000
Frequency (Hz)

Fig 8

Fig 7 and 8 have similar structure, while the Matlab computed power spectrum is much more smoother and the manually computed one is quite noisy. Also, there are other unknown variables like window type, fft length, etc used in the default matlab function which is responsible as well.

- Wide band and Narrow band examples: Fig 1 and 2 are representations of a narrow band example. Lines 12 and 13 of 'main.m' are modified as follows to get the wide band plots. The modifications and the respective plots are given below.

  params.window = [1, 10];

  params.nOverlap = 2;

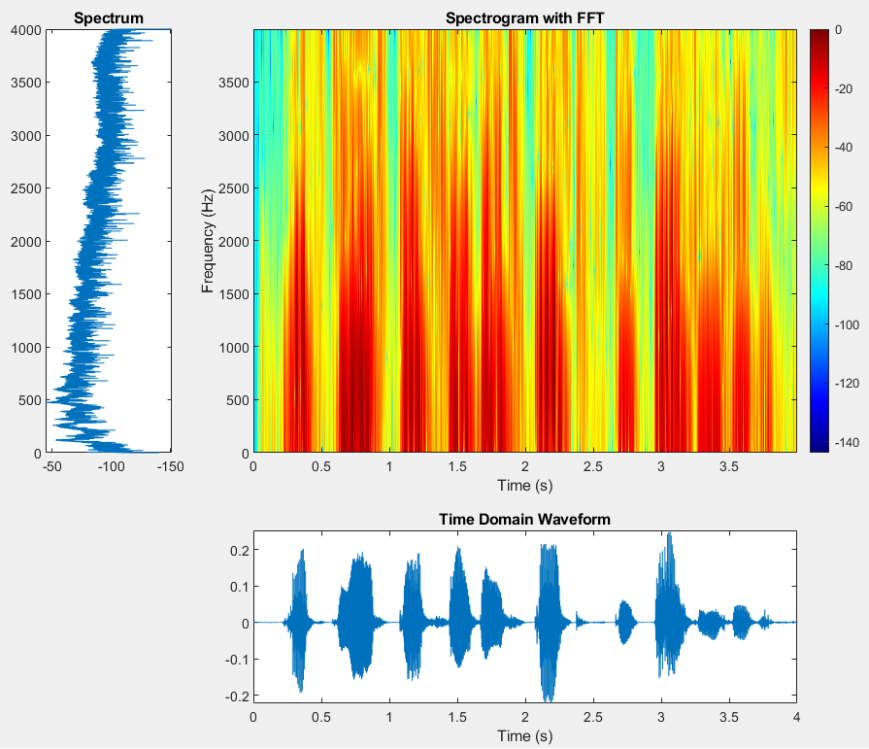

Fig 9

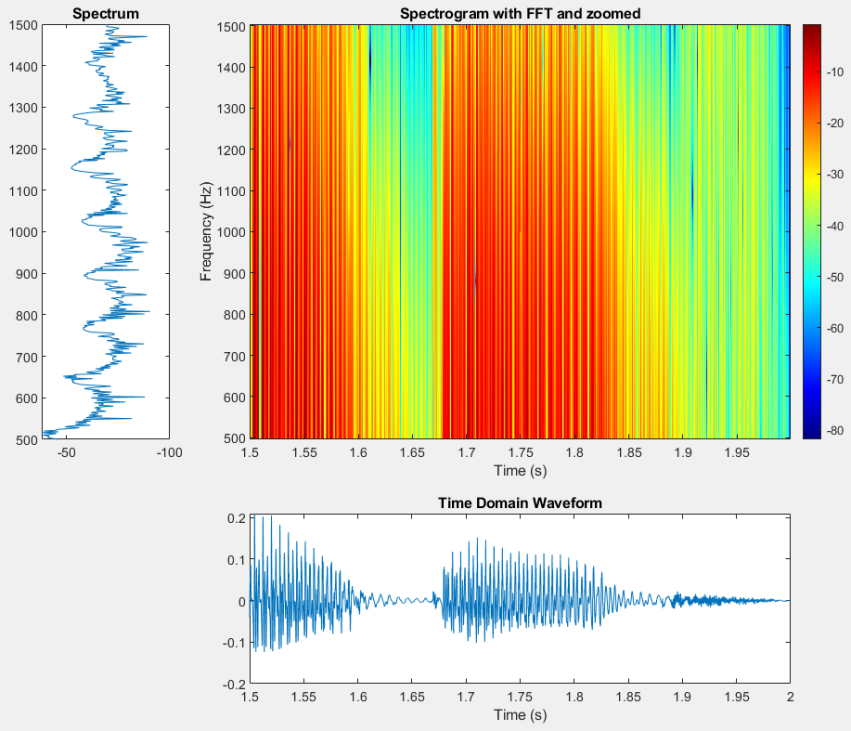
Spectrum
Spectrogram with FFT and zoomed
Frequency (Hz)
Time (s)
Time Domain Waveform
Time (s)

Fig 10