REAL TIME HIGH FREQUENCY ANALYSIS SYSTEM

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Abstract - A Real Time High Frequency Analysis System provides a program to analyze High Frequency (HF) signal. This paper presents work carried out in developing a user friendly system to observe and analyze HF signal with MATLAB environment. The system consist two main parts; Offline HF analysis and real time (online) HF analysis. The sampling frequency used is 8000Hz and the channel bandwidth is 3 kHz. HF signal is the radio spectrum with frequencies range between 3 to 30 MHz. HF is widely used in long distance communication and very popular among amateur radio operators and military communication [1].

Keyword: High Frequency (HF); Graphic User Interface (GUI); Amplitude Shift Keying (ASK); Finite Impulse Response (FIR); Amplitude Shift Keying (ASK); Frequency Shift Keying (FSK).

1.0 INTRODUCTION

High Frequency is the radio spectrum with frequencies between 3 to 30MHz and combined with the use of the ionosphere (a layer of ionization gases that resides between 100 and 700km above the earth's surface). The ionosphere often reflects HF signal during transmitting [2]. The use of HF communication system is still limited due to multipath fading, attenuation and interference. In recent years concerns have rise, a research to improve HF signal is very crucial. The signals need to be analyzed in order to be improved. HF communication system has a potential to be developed as it is low in cost.

The aim of this project is to enhance the significant of HF by developing a new system to analyze the received HF radio signal. Using this system, signal can be analyzed in offline mode and online mode. In offline mode, it not require to interface with hardware user can analyzes the signal by using HF signal in '*.wav' file form. While in online mode, the system requires HF receiver (YAESU VR 5000) to be connected to personal computer and an online signal will be observed, recorded and analyzed. This system provides a FIR filter to filter the signal in order to observe a smooth result. This system also can determine the modulation type, the frequency containt and the bit rate of the signal by using the periodogram and spectrogram techniques.

2.0 SCOPE OF WORK

MATLAB 7.7 program and GUI were developed in this system to accomplish HF analysis system using MATLAB. This analysis system only capable to read the HF signal data in '*.wav' file (audio file format), in order to access the HF data to be load into the system. For online analysis the HF signal is analyze at the receiving side where the online input system will capture the real HF signal to be record. Since the HF receiver (YAESU VR 5000) is not available, the HF radio or function generator can be used for online analysis.

3.0 METHODOLOGY

The process of developing m-file programming to design a FIR filter, Periodogram, Time-Frequency and Spectrogram Technique with using MATLAB 7.7 is described in this section.

3.1 Filter Design Method Implementation

Fundamentally a filter is a device or process that removes some unwanted component from signal. This means removing some frequencies to suppress interfering signals and reduce noise. In practice, it can be classified into a number of different bandforms describing which frequencies the filter passes (the passband) and which it rejects (the stopband). The filters known as Low-pass filter (LPF), High-pass filter (HPF), Band-pass filter (BPF) and Band-stop filter [3].

For this project, FIR filter has been used, it has useful properties that suitable for phase-sensitive applications, it correspond to equal delay at all frequencies so phase change proportional to frequency

[4]. In addition, MATLAB software packages provide convenient ways to apply these different methods. The window design method, considering as windowed versions of ideal finite filters for implementation because actual signals are finite in time. By truncating or windowing a FIR filter, the frequency response of the FIR filter is convolved with the frequency response of the window. Examples of the window function are; Boxcar, Hamming, Triangular and Blackman.

3.2 Periodogram Technique Implementation

For this analysis system the Periodogram Technique is implemented as a method use in analyzing the frequency spectrum. The Periodogram is an approximation to the Power Spectral Density of a time series. Up to a constant factor, the Periodogram is computed from a finite length digital sequence using the FFT (Fast Fourier Transform) [5]. In this system, Boxcar Window and Hamming Window are been used for the window function. Based on the spectral plot, spectral power function is a smoothed Fourier transform of the autocovariance function. The spectral estimate at a given frequency for a single discrete time series xt is:

$$\bar{C}_{xx}(f) = 2\Delta\left(c_{xx}(0) + 2\sum_{k=1}^{L-1} c_{xx}(k)w(k)\cos(2\pi fk\Delta)\right) \quad (1)$$

From the equation (1), cxx is the autocovariance function evaluated at the lag k, Δ. is the distance between adjacent values, L defines how many lags of the autocovariance function to use, and f is the frequency. The w(k) is the window function which specifies the type of smoothing. The spectral plot consists of Vertical axis equal to power while Horizontal axis equal to frequency. The technique is been used to estimate the spectral density or power spectrum of a random signal from a sequence of time samples of the signal. The spectral density also characterizes the frequency content of the signal [5].

3.3 Time-Frequency and Spectrogram Technique Implementation

Time-Frequency (TF) technique is been used for this system in order to determine frequency at the discrete time and to measure how the signal will vary in time. It was a tool for analysis and processing of 'nonstationary' signal. As additional function, the spectrogram technique has been used. Spectrogram is an image that shows how the spectral density of a signal varies with time. Spectrogram also can determine the type of modulation in the signal; ASK, FSK, multi-FSK or Morse code. The spectrogram plot that been used is Waterfall plot and Contour plot. In spectrogram plot, the y-axis display the spectra frequency that illustrate by Fourier transform while x-axis display the time of signal. Red color represents the highest energy in a spectrogram followed by orange, yellow, green, cyan and blue [6]. The mathematical equation for a spectrogram as follows;

Using Fourier series transform concept to transform signal s(t) to the signal, as equation shown below;

$$f(x) = \sum_{n=-\infty}^{\infty} \hat{f}(n/T)e^{2\pi i x\xi_n}\Delta\xi. \quad (2)$$

$\hat{f}$= window function

$\chi = (t,f)$

s(t)=centered on time of interest (t- $\hat{f}$)

Power spectrum equation for a signal is;

$Sz(t,f) = |f(t,f)|$ (spectrogram equation) (3)

3.4 MATLAB GUI Design

MATLAB software consist graphics, it include function that customize the appearance of graphics to build a complete graphical user interfaces (GUI) in MATLAB applications. To develop an user friendly program MATLAB GUI has been used. GUI is a pictorial interface to a program and it easier to adjust parameters and visualize a program. In developing GUI for this system, it began with layout the basic control for the program. The basic controls are static text, edit box and button. The properties of the controls need to be define in Property Inspector by double-click on a controls. It bring up a window listing all properties of control such a tag, string, font and etc. In writing callback, it creates two files _gui.fig and _gui.m. It contains codes that define callback function for each controls so it need to locate the function for the button. The callback runs when the GUI user clicks a button. Similarly, each menu item usually performs a different function [7].

4.0 RESULT AND DISCUSSION

The performance of the proposed method is tested on a personal computer with Centrino Duo 1.6 GHz processor and 512 MB of RAM. This system is running by MATLAB version 7.7 (R2008b) Software. To open this system is user has to type a 'realtime' at the MATLAB common window and a first GUI will appear on the screen as shown in Figure 1. Hence the system is ready to be used by the user. There are three buttons as shown in Figure 1. This system provides two modes system analysis 'Offline System Analysis' and 'Online System Analysis'. User is able to choose the required button. Click button 'EXIT PROGRAM' to end the system.

4.1 Result for Offline System Analysis

In offline mode analysis, user has to click 'Offline System Analysis' button as shown in figure 1 and the offline analysis program menu will appears as shown in Figure 2. In offline mode analysis, it not binds to interface with hardware. For this system, user has to follow the procedure in arrangement from step 1 to step 6. For step 1; to initialize analysis parameter, user require to enter the sampling frequency and filename.wav. The button 'OK' indicate that the system will do the operation after the button was clicked. Then the original waveform of the signal will appears and it indicates that the signal has been loaded into the system. The image of the original waveform is shown in Figure 3.

The following analysis user can playback the signal. User has to fill the lower time and upper time value. Then click button 'OK' to playback the signal.

For step 3 is 'Filter Signal', user has to select the type of filter at the pop-up menu, there are lowpass, highpass, bandstop and bandpass filter. Users require completing the required value then to run the filtering process is by click 'OK' button. The filtered waveform will approach as shown in Figure 4.

For the following analysis is to perform spectrum analysis. In this section, user can determine the window function either to use Boxcar or Hamming by selecting at the pop-up menu provided. Then by click button 'OK' the periodogram of spectrum analysis will appear as shown in Figure 5. From the figure seems that the signal contained frequency which is 2456 Hz, user can click data cursor at figure toolbar to get the value. It illustrates that there are only one frequency exists in the signal, it can be concluded that the signal is ASK or Morse code.

Hence the spectrogram technique was added in order to assure the modulation type of the signal. To display the spectrogram, go to the next part 'Perform Time-Frequency Analysis'. In this part user has to select the plot choice of the signal at the pop-up menu either Contour or Waterfall. Then by click 'OK' button the spectrogram of the signal will appear as shown in Figure 6. Refer to the figure it seems that there only exist one frequency with a constant time, it can briefly concluded that the signal is ASK modulation. The bit-rate of the signal can be calculated by this equation;

Bit rate of the signal≈ 1/ (duration bit) **(4)**

Bit rate ≈ 1/ 400ms = 2.5bps

For last analysis user can estimate the value of frequency contained in the signal through the spectrum analysis and the signal frequency from the time-frequency presentation. User has to enter the reference level. Hence by click 'OK' button the both result will appear simultaneously on the screen as shown in Figure 7 and Figure 8. The Figure 7 come out with the estimate frequency contain in the signal. From figure 8, it showed the signal frequency at the highest normalized energy.

4.1.1 Result for Frequency Shift Keying (FSK)

The periodogram of Figure 9 shows the signal has two frequencies and exists at 1360 Hz. The spectrogram in Figure 10 illustrates that the signal is FSK since the frequencies exist at different time.

Bit rate ≈ 1/ 600ms = 1.67bps

4.1.2 Result for Multi Amplitude Shift Keying (multi-ASK)

Periodogram in Figure 11 illustrates that the frequency exists at 350 Hz. Since more than one frequency exists in the signal it can concluded that the signal is multi-ASK. Result for time-frequency analysis is shown in Figure 12. From the figure it illustrates that the signal is multi-ASK since the time is overlapped between two frequencies.

Bit rate ≈ 1/ 300ms = 3.33 bps

4.1.3 Result for Morse code

Periodogram in Figure 13 illustrates that the frequency exists at 698.3 Hz and accepted that the signal exist is may be Morse code or ASK because the signal contain only one frequency. Result from time frequency analysis displayed in Figure 14 and convinced that the signal is Morse code since the signal frequency exists at a different time.

Bit rate ≈ 1/ 250ms = 4 bps

4.2 Result for Online System Analysis

User has to click 'online system analysis' button as show in Figure 1 and the online analysis program menu will appear as shown in Figure 15. For online mode analysis, this system requires interfacing with hardware where user has to connect the HF radio to the PC. For this system, user has to follow the procedure in arrangement from step 1 to step 7. For step 1; require user to fill the required sampling frequency. By click button 'OK' the online input system appears as shown in Figure 17. The connection between HF radio and PC must been setup as shown in Figure 16 and when the radio is connected, the online input system will capture the signal directly. It will show the waveform of the signal moving, click button 'stop' to stop the signal and record the signal by using the sound recorder provided in the PC as shown in the Figure 18. The recorded signal is save in .wav file. Click button 'analyzed signal manually' to continue the following analysis.

For step 2; User must fill sampling frequency and filename.wav (recorded signal). By clicked button 'OK' it will indicate that the signal has been loaded into the system. The next analysis is to playback the signal, user has to fill the desired value for lower and upper time. Then click 'OK' button to playback the signal.

For step 4, is ' Filter Signal', user requires filling the required value then to run the filtering process is click 'OK' button. The filtered waveform will approached as appeared in figure 19.

For the following analysis is to perform spectrum analysis. In this section, user has to select the window function either to Boxcar or Hamming by select at the pop-up menu provided. Then by clicked button 'OK' and the periodogram of spectrum analysis will appear as shown in Figure 20. From the figure seems that the signal contained frequency which is 2017 Hz.

For step 6; user has to select the plot-choice type from the pop-up menu either 'Contour' plot or 'Waterfall' plot. The spectrogram will appears by clicking 'OK' button as shown in Figure 21.

For final analysis user can estimate the value of frequency contained in the signal through the spectrum analysis and the signal frequency from the time-frequency presentation. User has to enter the reference level. Hence by click 'OK' button the both result will appear simultaneously on the screen as shown in Figure 22 and Figure 23. The Figure 22 come out with the estimate frequency contains in the signal. From Figure 23, it showed the signal frequency at the highest normalized energy.

As a result, the modulation type of online analysis cannot be examined since the signal is contains too much noise. This is due to of HF receiver (YAESU VR 5000) is not obtainable whereas with this receiver, it can achieved a smooth signal to be analyze.

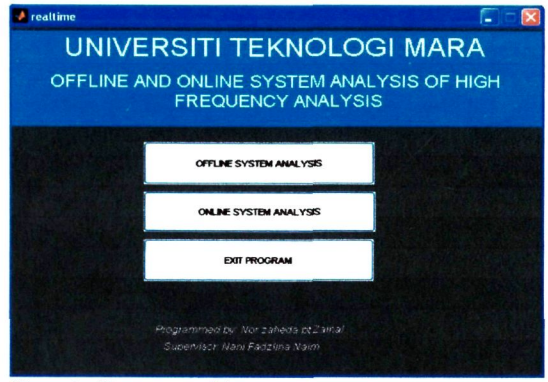

Figure 1: Home menu of the system

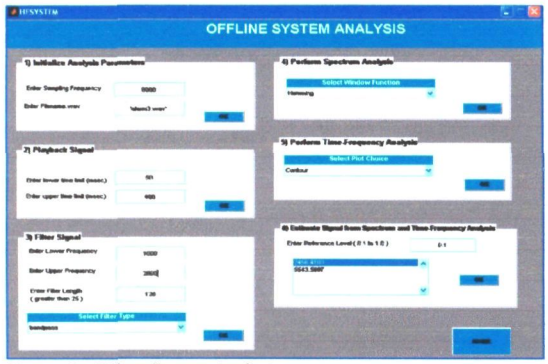

Figure 2: Offline System Analysis menu

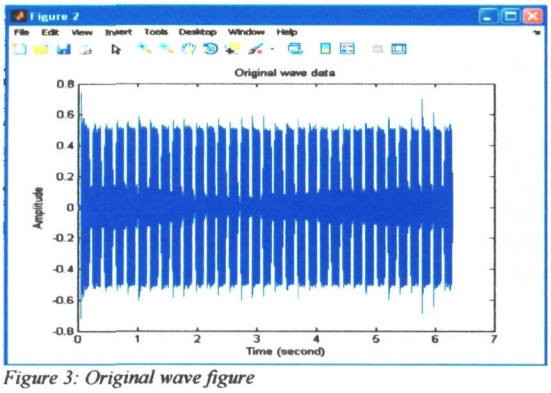

Figure 3: Original wave figure

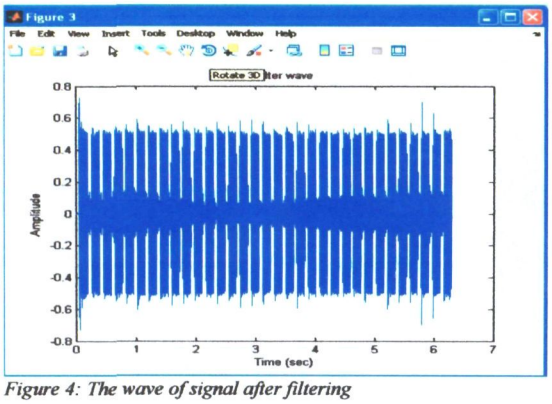

Figure 4: The wave of signal after filtering

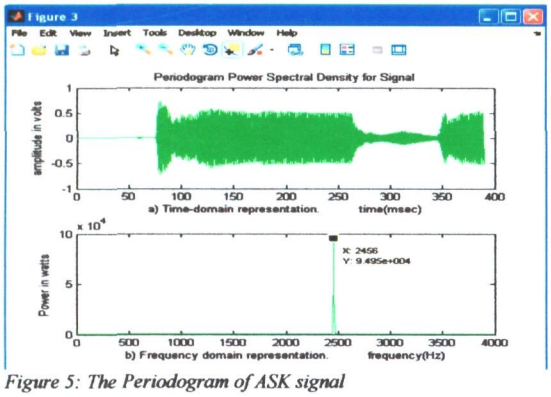

Figure 5: The Periodogram of ASK signal

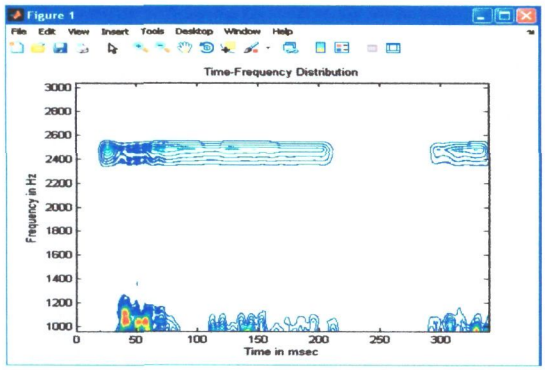

Figure 6: The Spectrogram of ASK signal

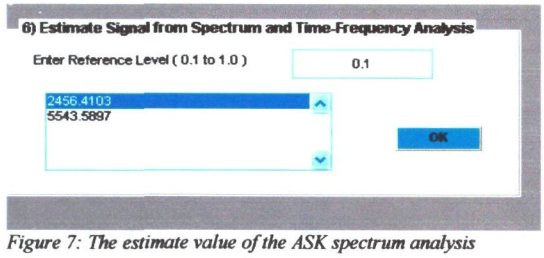

Figure 7: The estimate value of the ASK spectrum analysis

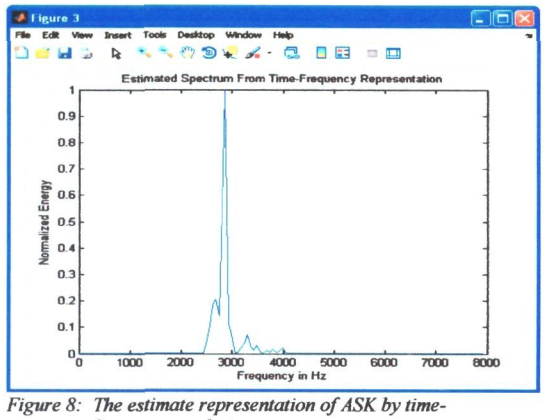

Figure 8: The estimate representation of ASK by time-frequency analysis

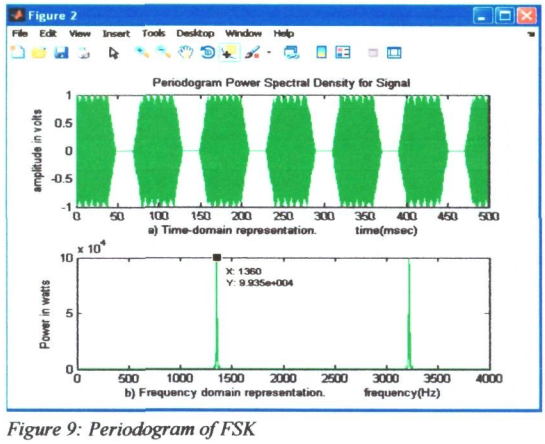

Figure 9: Periodogram of FSK

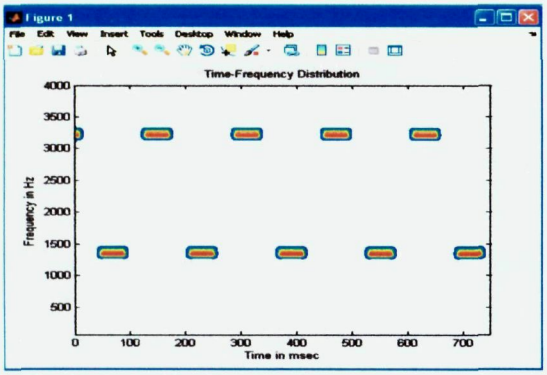

Figure 10: Spectrogram of FSK

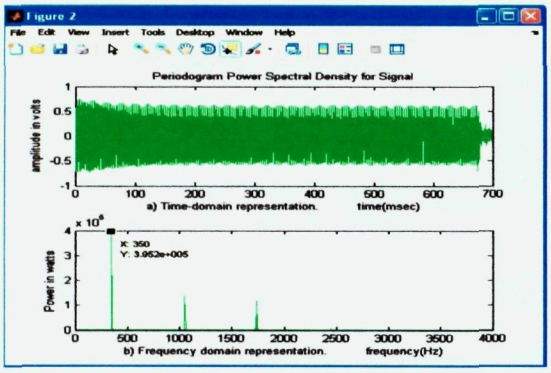

Figure 11: Periodogram of Multi-ASK

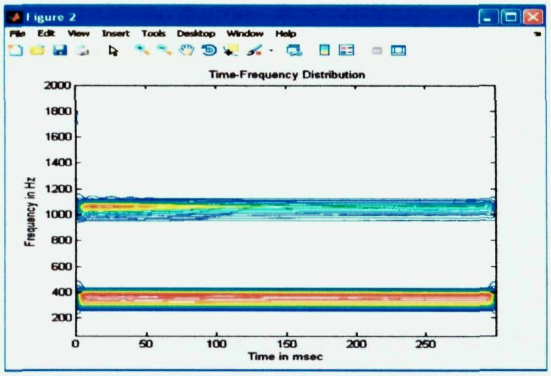

Figure 12: Spectrogram of Multi-ASK

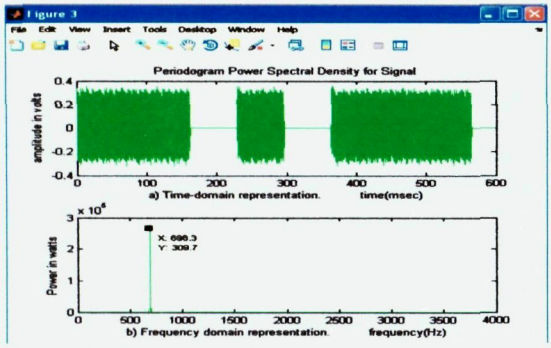

Figure 13: Periodogram of Morse code

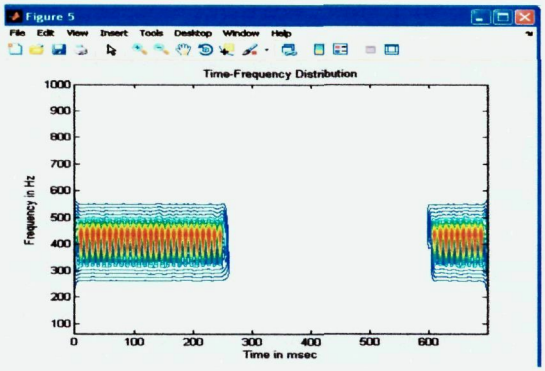

Figure 14: Spectrogram of Morse code

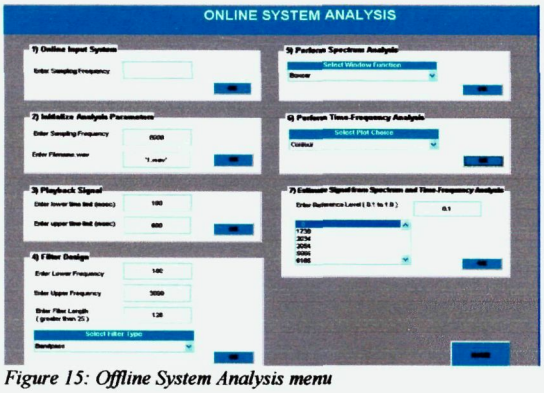

Figure 15: Offline System Analysis menu

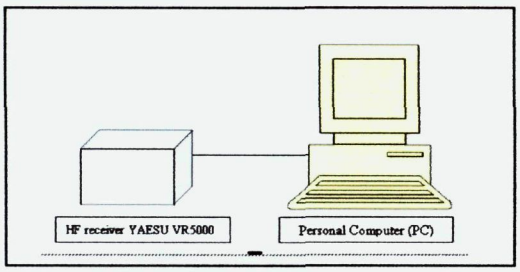

Figure 16: Connection between HF radio and PC

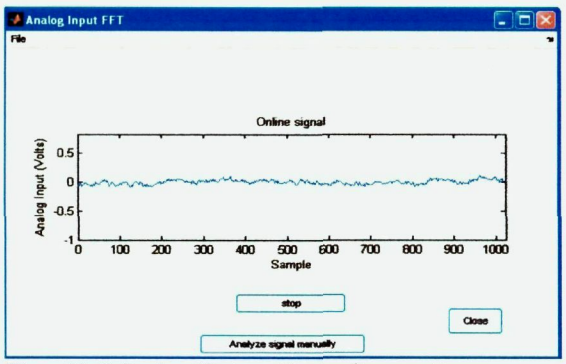

Figure 17: Online Input System without radio connection

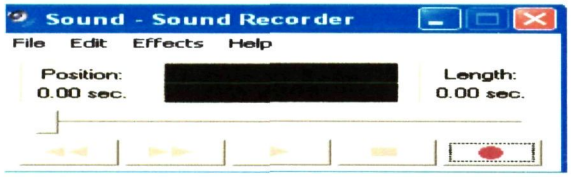

Figure 18: Sound recorder

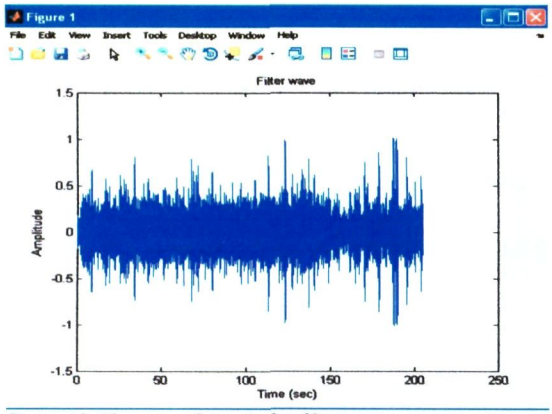

Figure 19: The wave of signal after filtering

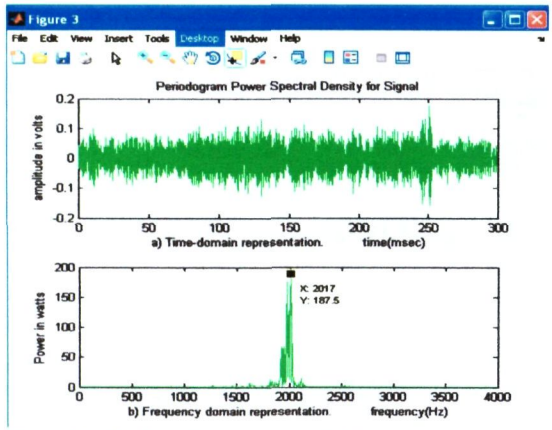

Figure 20: The Periodogram of recorded signal

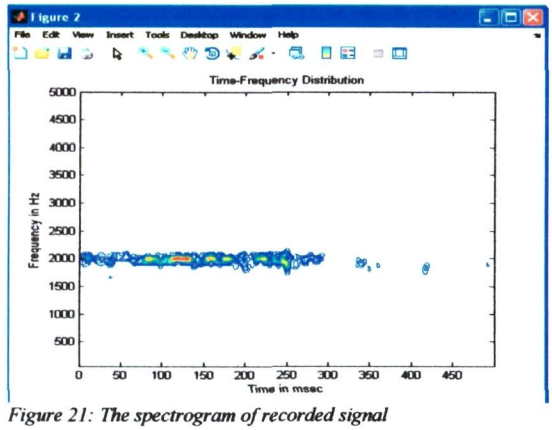

Figure 21: The spectrogram of recorded signal

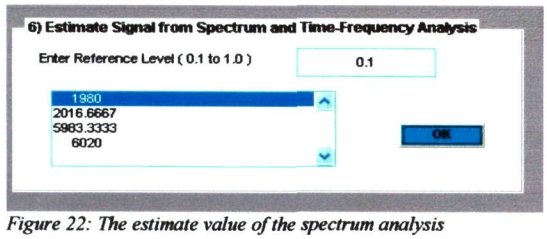

Figure 22: The estimate value of the spectrum analysis

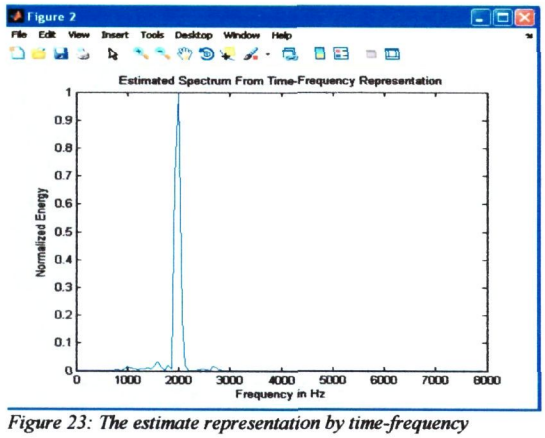

Figure 23: The estimate representation by time-frequency

5.0 CONCLUSION

As a conclusion, this project has achieved the objective with the success of this system. Beside, this system also provides a user friendly interface. This system is very useful for user who is interested to learn and explore on high frequency signal not only for the beginner but also for other HF communication user.

6.0 FUTURE WORK

For future development, this system can be improved to become an Advance High Frequency Analysis System hence can be commercial as a new tool measurement in electronic communication technology. For online mode analysis, it should be implement with adding more function where the HF signal can be analyzed directly without recording it. This system should be carried out a new technique that can determines the result automatically.

7.0 AKCNOWLEDGEMENT

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