

Offline System Analysis of High Frequency Digital Signal

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Abstract - This project highlights the significant of the high frequency (HF) communication system in communication field. With a frequency spectrum between 3 to 30 MHz an ionosphere often reflects the signal frequency very well during transmitting the signal. Hence, the HF communication can be done in long distance transmission. Although, HF communication is applied in radio communication but the HF technology application is still limited because it only involve in certain application. By taking these factors into consideration the idea is generate in order to enhance this application technology. As a result, a research must be conducted to make the HF communication system enhanced in accordance with the development of communication technology. In order to enhance this technology application a system to analysis HF signal should be created to help in developing this communication technology. Concerning to this issues, the system was develop to analyze HF signal. The system is operating in offline mode. The system only capable to read HF signal in form of *.wav file. The system also capable to filter signal so that the process of analyze the signal can be done smoothly. With the periodogram and spectrogram technique the system able to produce a result analysis accurately because it will illustrate the valuable information contain in the signal such as frequency, energy of the signal and the duration of the signal. In addition, the modulation type of the signal and the bit rate also can be determined.

Keywords: HF (high Frequency); GUI (graphic user interface); periodogram; spectrogram.

1. Introduction.

HF communication system has experienced a significant use in our communication system with frequency spectrum from 3MHz to 30MHz. In fact, HF communication system still used in certain organization such as military, marine, aviation and diplomatic interest. This is because HF was implemented by the amateur radio that is still being used until now by the organizations for communication purposes. Moreover HF communication system is a long communication range since an ionosphere often reflects HF radio waves quite well, known as skywave propagation [1]. Hence the HF communication is a low cost communication system compared to others since it requires low power and it only used ionosphere as a transmission medium [2].

HF communication system is only used in certain communication field and cannot be implemented widely such in other wireless application such as cellular phone and television communication system since it has some limitation. The application of HF communication system should be enhanced so that the use of HF communication can be developed in accordance with others. Hence, a system to analyze the HF signal is needed to enhance this communication technology so that the use of HF communication system is more reliable. The system is important to analyze the HF signal so that the data of HF signal can be evaluated automatically and can be improved to receive a good quality signal.

2. Methodology

2.1 Study the m-file of Periodogram and Spectrogram to develop GUI

In this system the technique to analyze the frequency spectrum is periodogram (Power Spectral Estimations). Basic of periodogram is from FFT (fast fourier transform that is obtained by squared the magnitude of FFT divided by the length of series, N . [6].

$$S_{xx} = (1/N)(X(K), X^*(K)) = (1/N) |X(K)|^2 \quad (1).$$

In practice, the periodogram is often computed from a finite-length digital sequence using the fast Fourier transform (FFT). The raw periodogram is not a good spectral estimate because of spectral bias and the fact that the variance at a given frequency does not decrease as the number of samples used in the computation increases. The spectral bias problem arises from a sharp truncation of the sequence, and can be reduced by first multiplying the finite sequence by a window function which truncates the sequence gracefully rather than abruptly [7]. The variance problem can be reduced by smoothing the periodogram. Various techniques to reduce spectral bias and variance are the subject of spectral. One such technique to solve the variance problems is also known as the method of averaged periodograms. The periodogram technique only shows the frequencies at the overall time and not at the particular time. This is one of the limitations of periodogram technique. Hence, the spectrogram technique will be used in order to make this system is efficiently can analyze the signal [3].

Time-frequency is a technique that will be shown a signal in term of power vs time-frequency. This technique is use to determine frequency at the discrete time will measure how the signal frequency will be vary with time. Spectrogram is used in time-frequency technique because it will show more clearly what happen at the particular time. Spectrogram also can determine the modulation type of signal whether it is ASK, FSK, multi FSK, multi-channel ASK or Morse code. [3]

In spectrogram, y-axis display the spectra frequency that illustrated by Fourier transform, whether x-axis display the time for the signal. Red color represents the highest energy in a spectrogram followed by orange, yellow, green, cyan and blue. The mathematical equation for a spectrogram as follows.

For a signal $s(t)$ transforms to the signal as equation below

$$Z(t, f) = \int_{-\infty}^{\infty} h(\lambda) \cdot z(t - \lambda) \cdot e^{-j2\pi f\lambda} \cdot d\lambda \quad (v) \quad (2)$$

$h(\lambda)$ = window function

t_1 = centered on a time of interest ($t-\lambda$)

Power spectrum for a signal is

$$S_z(t, f) = |Z(t, f)| \quad (\text{spectrogram equation}) \quad (3)$$

2.2 Study the m-file of Finite Impulse Response

(FIR) Filter to develop GUI.

There are two types of digital filter that are commonly used in digital signal processing which are IIR (infinite impulse response) and FIR (finite impulse response). IIR filter is easily used compares to the FIR filter because the filter size is smaller than FIR filter. But, FIR filter has its own advantage because it has a linear phase that can prevent phase deviation. [8]

The main function of filter is to get wanted signal at certain frequency. It can be classified depends on the frequency response whether it is low pass filter (LPF), High pass filter (HPF), Bandpass filter (BPF) and Bandstop filter.

There are several ways to design FIR filters include Window method, Frequency Sampling method, Parks-McClellan algorithm and least squares method.[9]

Refers to the Gibb phenomenon, Ripples always exist at the frequency response while designing FIR filter. In order to overcome this problem window function must be convolution with the filter frequency. Examples of the window function are: Boxcar, Hamming, Hanning, Triangular, and Blackman. [10]

2.3 Design GUI of the System.

Matlab is a software package for high performance in technical computing, engineering, integrating programming, visualization and computation in a very user friendly environment. Best of all, it also provided extensibility and flexibility with its own high-level programming language. It has two major element that have contribute to it immense popularity; easy to use since data can easily entered especially for algorithms that are adaptable to a table format, and it include high level command for two dimensional visualization and presentation graph [5]. For this project matlab GUIDE is the important part to know. GUIDE propose how to creating GUI by Matlab. Before started with creating GUI the important part that must know is writing m-file and how to relate the m-file with the GUI. A graphical user interface (GUI) is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so forth. The GUI should behave in an understandable and predictable manner, so that a user knows what to expect when he or she performs an action. For example, when a mouse click occurs on a pushbutton, the GUI should initiate the action described on the label of the button. This chapter introduces the basic elements of the MATLAB GUIs. [5]

2.4 Analyze data by using GUI.

When the GUI is completely done the HF signal that was recorded in *.wav file is ready to be analyzed. Analyzed begin when loading the wav file into the system with desired frequency sampling. Users can get the required parameters of the signal as shown in the periodogram and spectrogram. From the periodogram users can determine the frequency spectrums that exist in the HF signal. Since the periodogram has a limitation, hence the spectrogram technique will be used to determine the modulation type and other parameters.

3. Result and discussion

Before using this system, users have to make sure that MATLAB software is running first. Then by typing the command 'entersystem' at the command window, the first GUI as shown in Figure 1 of the system will appear on the screen and it's ready to use by users.

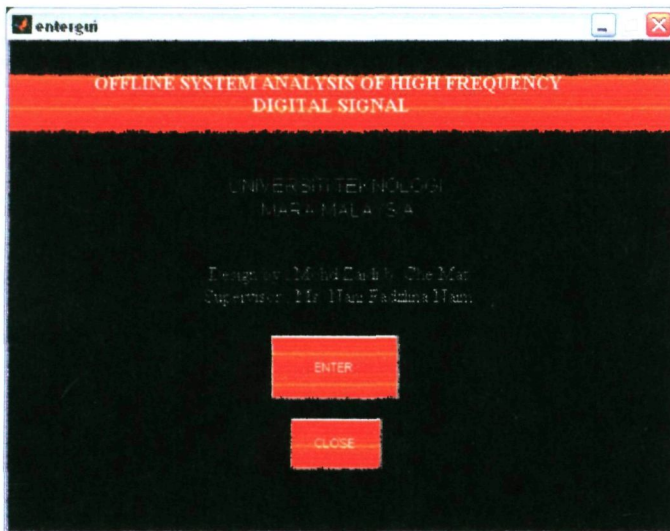


Figure 1: GUI of the system.

To enter the system user must click at the 'ENTER' button so that the next GUI will appear to proceed for the analysis. For the next GUI user must have *.wav file that contain HF signal to do analysis. The next GUI is shown as in Figure 2.

the original waveform will be figure out. Figure 3 shows that the real waveform of the wav file that has been loaded just now. From the figure user can determine the shape and the duration of the signal. For the next analysis user can determine either to playback or filter the signal. The menu GUI will come out together with the waveform figure. The menu is shown as in Figure 4.

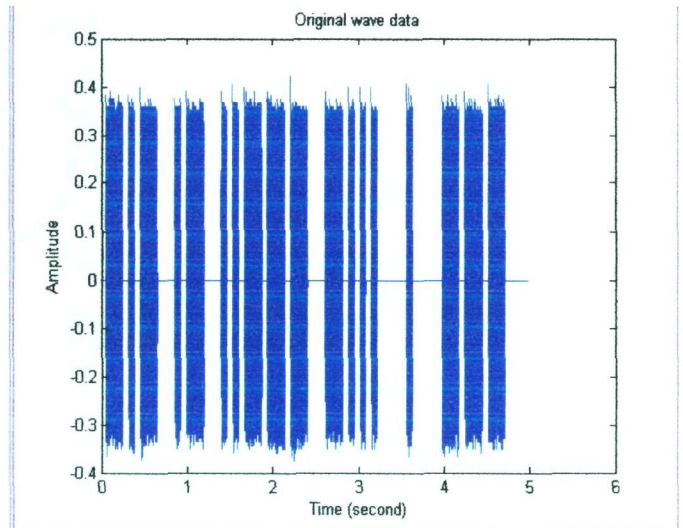


Figure 3: Original waveform

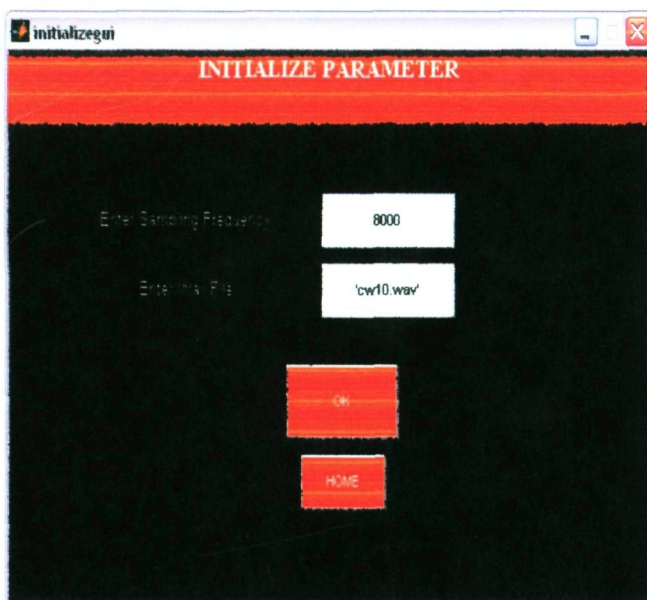


Figure 2: Initialize parameter GUI

Figure 2 shows the second GUI is produced after we click the 'ENTER' button. This GUI is required the user to fill the HF wav file and sampling frequency to proceed the analysis as shown in Figure 2 above. When the required parameter is filled user must be click 'OK' button so that the wav file is loaded into the system. When the file is loaded in the system

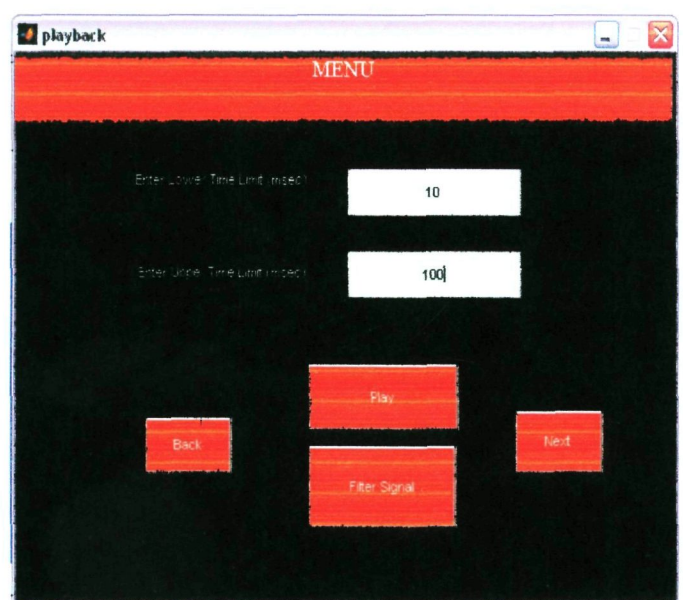


Figure 4: Menu GUI

Refer to the Figure 4, user can choose whether to playback or filter the signal or proceed to the next analysis. If the user wants to playback the signal, user has to fill in the value that are required from the system and click 'Play' button to playback the signal. Users also can proceed to the next analysis by click at the 'Next' button. If user requires

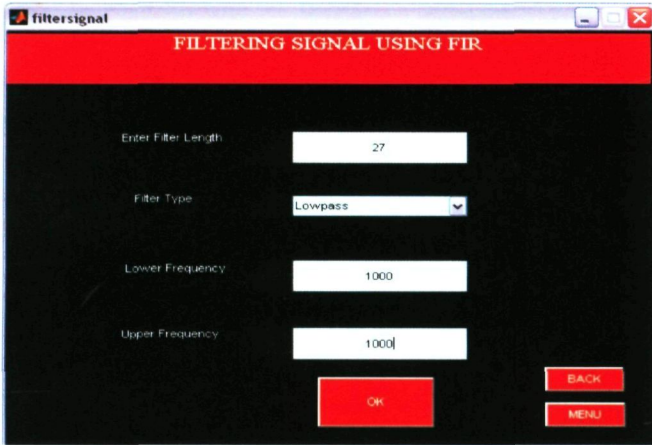


Figure 5: Filter GUI

For this system there are 4 types of FIR filter that can be used including lowpass, high pass, bandpass, and bandstop filter. If the lowpass or highpass filter is used, the upper and lower frequency must be the same value. After the 'OK' button is clicked the filtered waveform will appear. The figure shows that the signal after filtering using FIR filter. The figure is shown as in Figure 6.

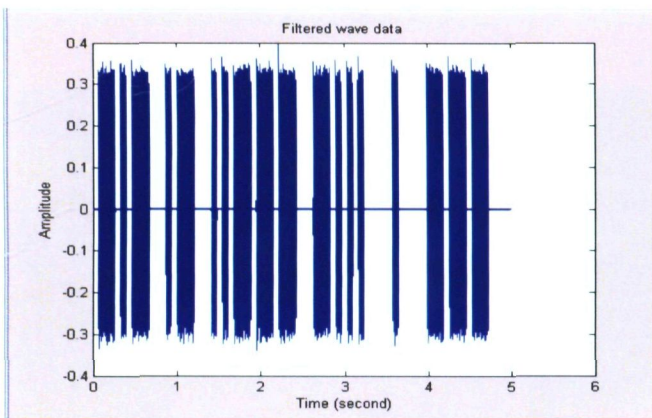


Figure 6: Filtered Waveform

To proceed to the next analysis user must go to the second menu in the system. The next menu is shown as in Figure 7.



Figure 7: Second menu

From the second menu user can determine the analysis required. If user choose to perform the spectrum analysis, the next GUI as in Figure 8 will appear.

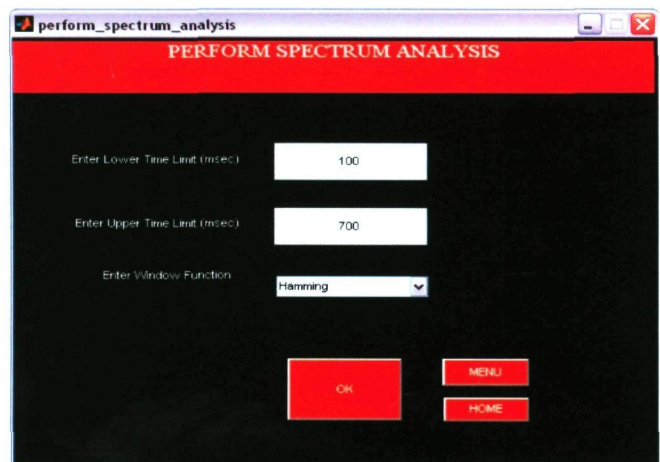


Figure 8: Perform spectrum analysis

To perform spectrum analysis user can choose the window function either boxcar or hamming. After the button 'OK' is clicked the figure of periodogram will appear as shown in Figure 9.

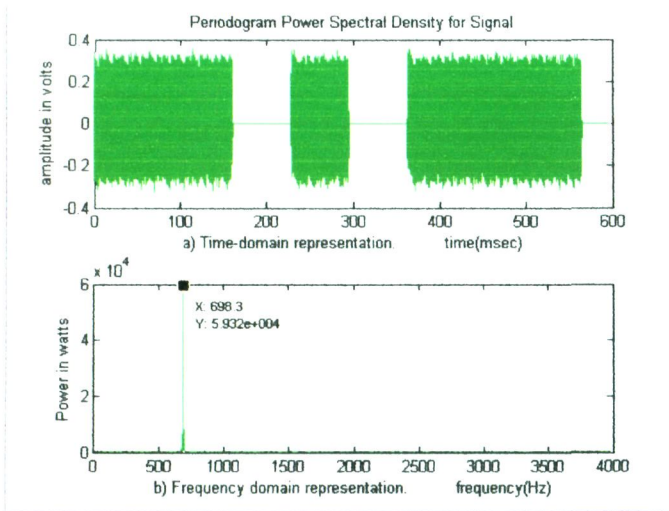


Figure 9: Periodogram

From the example of the periodogram above, it is found that the signal contained frequency which is 698.3 Hz. To assure that the value of the frequency existed in the signal user can click the 'Estimate the Signal Frequency from the spectrum'. Then the GUI as shown in Figure 10 will come out with the frequency value that contain in the signal.

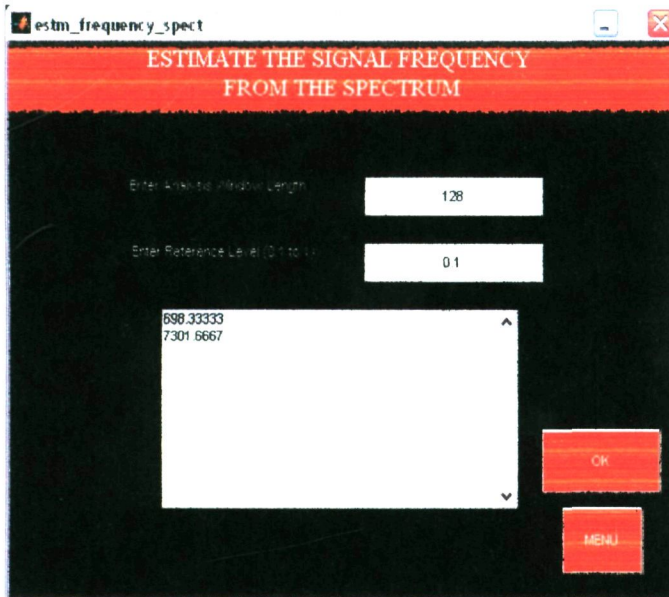


Figure 10: Estimate the Signal Frequency from the Spectrum

From the GUI above, it displays the frequencies that existed in the signal. From the periodogram we observed that the signal exist is may be Morse code or ASK because the signal contain only 1 frequency. Hence, the spectrogram technique is needed to assure the modulation type. To display the spectrogram click the 'perform time-frequency analysis' button. Then the next GUI will appear as shown in Figure 11.

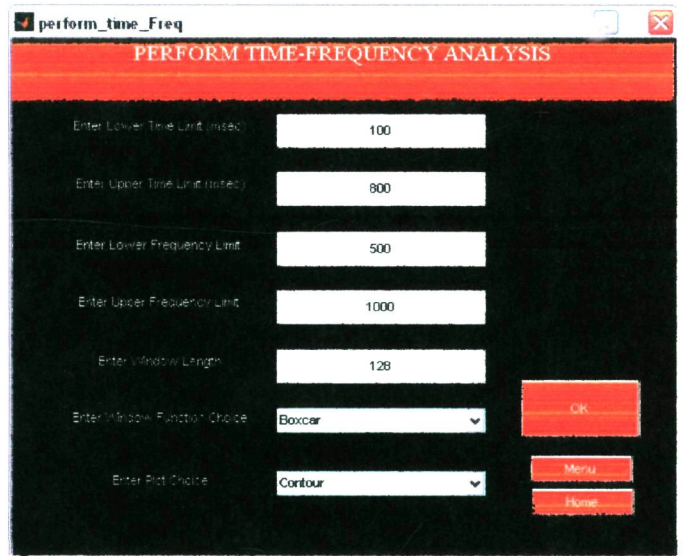


Figure 11: Time-frequency Analysis

From the GUI in Figure 11, user can determine the plot choice of the signal either contour or waterfall by select at the pop-up menu at the GUI. Then by clicked the 'OK' button the spectrogram figure will appear as shown in Figure 12.

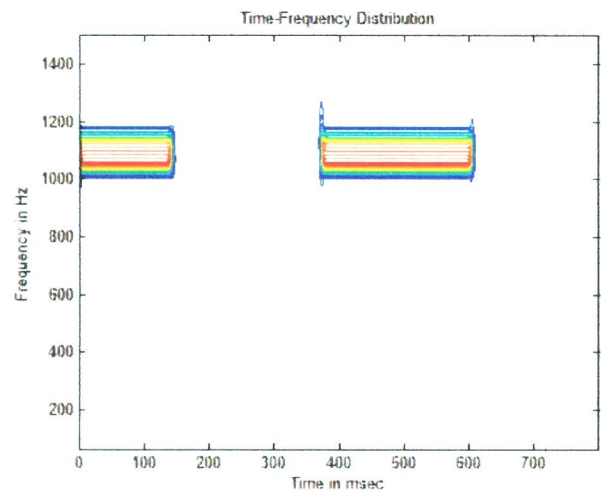


Figure 12: Spectrogram

From the spectrogram in Figure 12, the signal frequency exists at a different time. The dot and dash is represented as in the spectrogram in Figure 12. Hence, the signal is a Morse code signal. From the time-frequency analysis the signal frequency also can be estimated by clicking the 'Estimate the signal Frequency from the time-frequency presentation' button at the menu. Then the GUI as in Figure 13 will be shown. From the spectrogram above the bit rate of the signal can determine by this equation, Bit rate = $1 / (\text{duration bit})$ (5).

Bit rate of the signal $\approx 1/90m = 11.11$ bps.

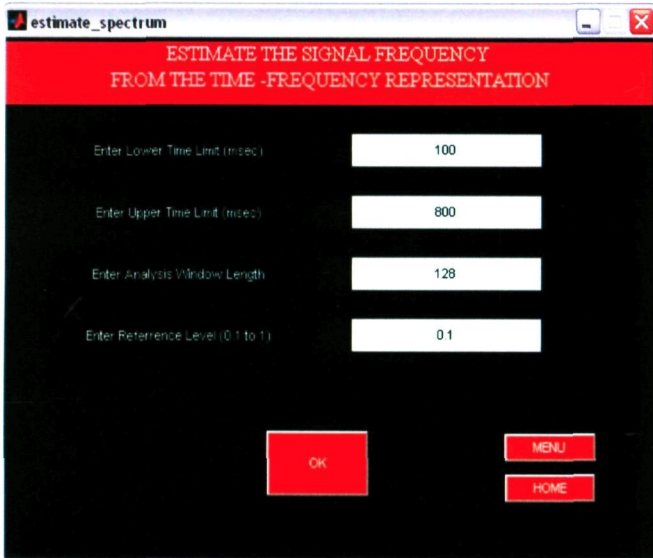


Figure 13: Estimate the signal frequency from time frequency representation.

When the 'OK' button is clicked the figure estimated frequency from the time-frequency representation is shown as in Figure 14.

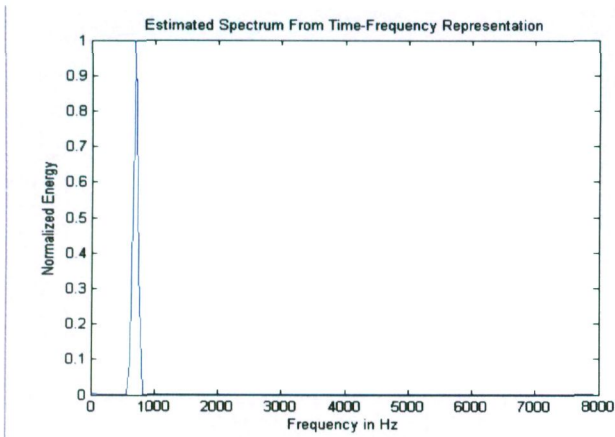


Figure 14: Estimated Spectrum from the Time-frequency representation.

From the Figure 14 it showed clearly the signal frequency at the highest normalized energy.

3.1 Result for Dual Tone Multiple Frequency (DTMF) or Multi FSK.

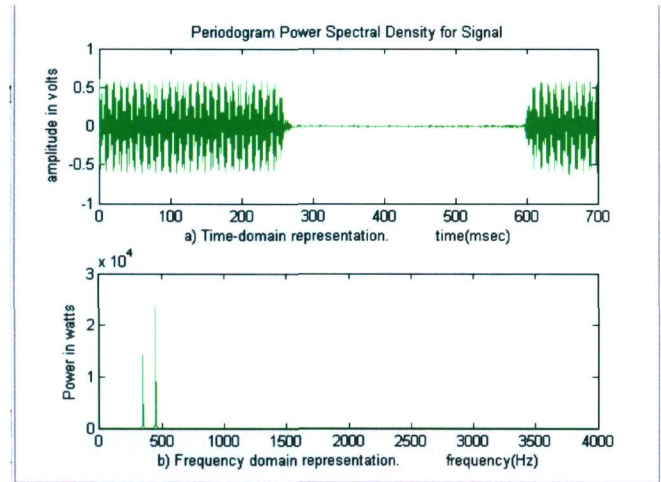


Figure15: Periodogram

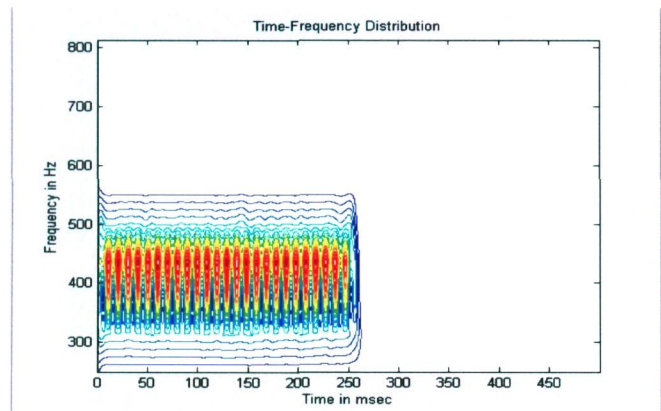


Figure 16: Spectrogram

From the periodogram in Figure 15 there are 2 frequencies existed in the signal. The signal is may be the FSK or multi FSK which is known as DTMF. To assure the modulation type hence, the time-frequency analysis technique is used. From the spectrogram in Figure 16 shows that the signal is DTMF or multi FSK since it has a combination with two frequencies and suddenly stop.

$$\text{Bit rate} \approx 1/250\text{m} = 4 \text{ bps}$$

3.2 Result for Frequency Shift Keying (FSK)

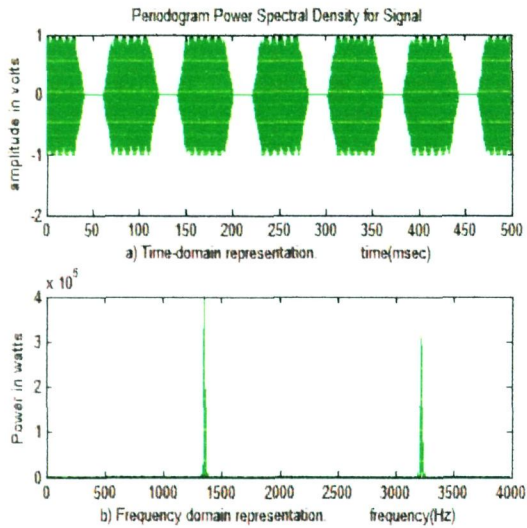


Figure 17: Periodogram

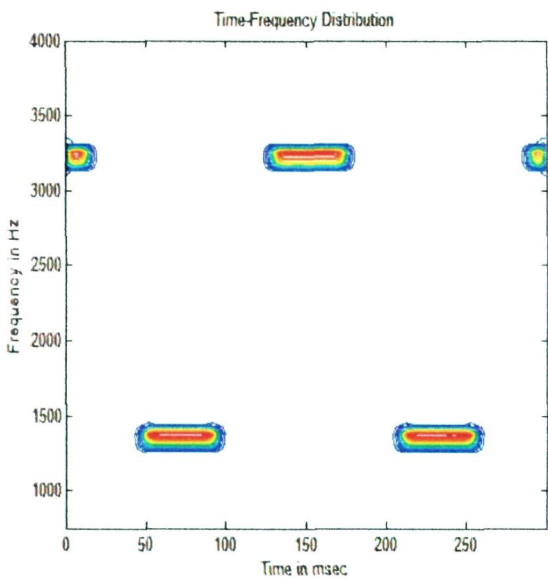


Figure 18: Spectrogram

The periodogram of Figure 17 the signal has two frequencies same as Figure 16. But to illustrate the signal the time frequency must be done to assure the type modulation of the signal has. Refer to the Figure 18 it shows that the signal is FSK since the frequencies exists at a different time.

Bit rate $\approx 1/400m = 2.5bps$.

3.3 Result for Amplitude Shift Keying (ASK)

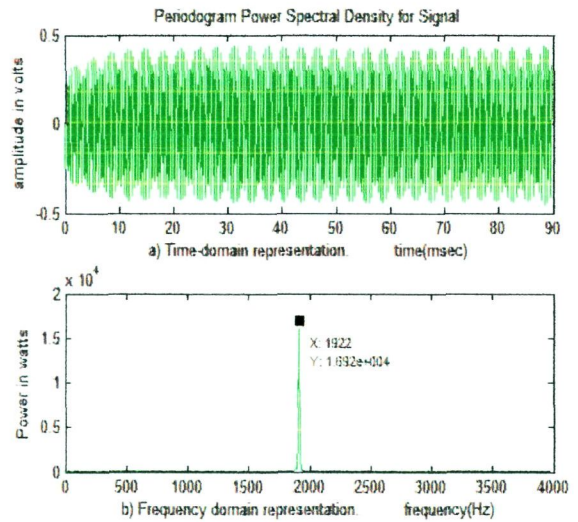


Figure 19: Periodogram

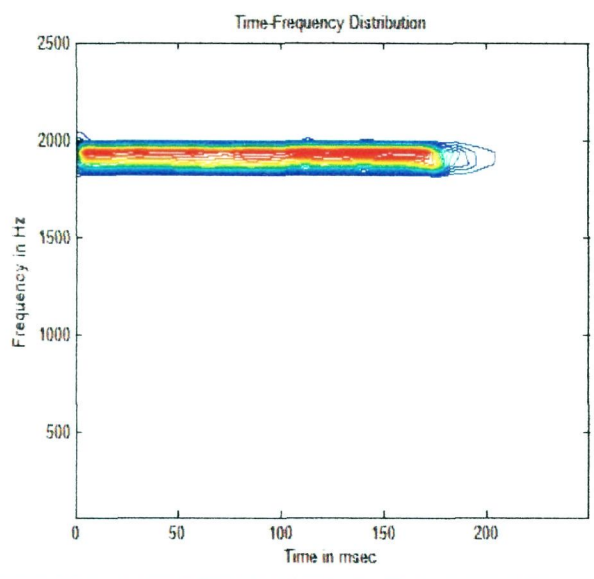


Figure 20: Spectrogram

Refer to the periodogram in figure 19, illustrate that the frequency is 1922 Hz. since there are only frequency exist in the signal is may be ASK or morse code.

Result from time- frequency analysis has been shown in figure 20. From the analysis it indicates that the signal is ASK. The estimation bit rate is

Bit rate $\approx 1/170m = 5.88bp$

4. Conclusion

The main Objective of this project is to enhance the application of technology based on HF communication system. The idea was generate since the HF communication systems is very quite important in certain organization. Eventhough the system communication is not as popular as other system communication but the system is still having a commercial value since it can transmit signal in long distance. Besides that it is well known with low cost communication system since it is only used an ionosphere as a transmission medium. Taking all factors into consideration, a system is needed so that it can analyze the signal with easily and accurately.

Overall the objective of this project has successfully achieved with existing of this system that can analyze the HF signal in communication system. With this system user can analyze the HF signal easily since it is used a spectrum analysis and time frequency technique. With this system user can determine the required signal's parameters such as, modulation type and etc.

Besides that, with this project it indicates that the ionosphere also important in communication systems. An ionosphere is a good transmission medium since the ionosphere often refracts HF radio waves quite well (a phenomenon known as skywave propagation), this range is extensively used for medium and long range radio communication.

5. Future work

In the future, this project can be improved to become a commercial technology. This improvement will radically improve the HF communication system in the future. There are a few things should be improved to enhance this system in the future. For the improvement this system should add more function such as user can determine automatically the signal modulation and the bit rate so that the process to analyze of the signal can be done faster than usual. Besides that this system also can be built as a stand-alone program so that it can run by itself. Hence matlab software is not necessary in order to run this system.

For other mechanism improvement, this system should be able to translate the content of the morse code signal received so that user are able understand clearly the meaning of the message received. Hence, the process of translation is become more faster than usual.

References

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