# Interactive Learning Software for Communication Engineering Subject

Abdul Hadi Nordin
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail: hadinordin@ymail.com

*Abstract*— As the way of learning become interesting day to day, communication engineering education also goes the same. The project highlights on interactive learning system for electromagnetic and communication subjects using MATLAB program and its graphical user interface (GUI). The system needs the user to enter appropriate parameters into blank boxes in the GUI. Then, the user can obtain the result by clicking the answer button. The program designed offer varieties of engineering problems such as propagation of waves, electric field intensity, plotting electric field, dot and cross product of vectors for electromagnetic part. While for communication part consists of High Frequency (HF) analysis and digital modulation. In digital modulation, user can generate and observe Amplitude-Shift Keying (ASK) signal and Frequency-Shift Keying (FSK) signal. The programs are designed are user-friendly and have interactive tutorials and they can be used as a powerful tool for improving the teaching process. The way of learning will become easier and more interesting.

***Keywords-component: Graphical User Interface (GUI); High Frequency (HF); Amplitude-Shift Keying (ASK); Frequency-Shift Keying (FSK; Electromagnetic.***

## I. INTRODUCTION

In this project, the use of GUI of MATLAB for interactive learning is the fundamental tool for teaching communication engineering problems and concept. Some of the problems are difficult to be understood with oral explanations and simple marker pen drawings on the whiteboard by the lecturer. The way of learning using Matlab GUI becomes widespread use nowadays for example, the interactive module for servo systems learning in Universidad Europea de Madrid, Spain [1]. Another example that almost related to this project system is the teaching of wave propagation phenomenon in open space problems and waveguide devices using Matlab GUI at Universidad Politecnica of Valencia, Spain [2]. In biomedical engineering, Matlab GUI is used for interactive simulation tool for image registration education [3]. School of Electrical and Computer Engineering at the Georgia Institute of technology has used Matlab GUI to design simple FIR along with visualizations of the filter design process [4]. Interactive GUI also has developed for studying animated conic section [5]. Therefore, the use of this stuff should be spread because it will help user especially students to be more understanding in communication engineering education such as in electromagnetic and other communication problems. The way of learning will become easier and minimize the time of explanations by lecturers [6].

## II. SCOPE OF WORK

The interactive learning program was developed using MATLAB R2009b and its GUI to solve and analyzed communication engineering problems. The problems required appropriate input data by the user to obtain the desired result.

## III. METHODOLOGY

In this system, studies are done to develop related m-file programming. The operations of particular engineering education problem are applied and developed in the form of MATLAB codes.

### *A. Study and Develop MATLAB Code of Electric Field Intensity, Dot and Cross Product of Vectors*

The system provides the basic dot and cross product operation of two vectors. The cross of two vectors of a and b can be defined in formal matrix by [7]:

$$\mathbf{a} \times \mathbf{b} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$$

While for dot product:

$$\mathbf{a} \cdot \mathbf{b} = \sum_{i=1}^{n} a_i b_i = a_1 b_1 + a_2 b_2 + \cdots + a_n b_n$$

Both operations are converted to MATLAB command with the two vectors of a and b. Then, this is followed with the command operation code [8].

The electric field intensity $\vec{E}$ is the force per unit charge when placed in an electric field [9]:

$$\vec{E} = \frac{\vec{F}}{Q}$$

Then, the electric field intensity at point of $\vec{r}$ due to a point charge located at point of $\vec{r}'$ is:

$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 R^2}\vec{u}_R = \frac{Q(\vec{r}-\vec{r}')}{4\pi\varepsilon_0|\vec{r}-\vec{r}'|^3}$$

MATLAB code is developed to get the similar answer using the formula above [9].

*B. Simulation of Propagation of Electromagnetic Wave, Plotting Electric Field, Digital Modulation, and High Frequency(HF) Analysis*

In this software, the simulation of electromagnetic wave in freespace and good conducted is demonstrated. In a charge-free medium, the lossy, the wave equation based on Maxwell's equation is of the form [9]:

$$\vec{\nabla}^2\vec{A}_s - \gamma^2\vec{A}_s = 0.$$

Where $\vec{A}_s$ (the phasor form of $\vec{A}$ ) is either $\vec{E}_s$ or $\vec{H}_s$ and $\gamma = \alpha + j\beta$ is the propagation constant. If we assume $\vec{E}_s = E_{xs}(z)\vec{u}_x$, we obtain electromagnetic waves of the form [6]

$$\vec{E}(z,t) = E_0 e^{-az}\cos(\omega t - \beta z)\vec{u}_x$$
$$\vec{H}(z,t) = H_0 e^{-az}\cos(\omega t - \beta z - \theta_\eta)\vec{u}_y$$

Where $\alpha$ = attenuation constant, $\beta = \frac{2\pi}{\lambda}$ = phase constant, $\eta$= intrinsic impedance of the medium; and $\theta_\eta$= phase difference between $\vec{E}$ and $\vec{H}$.

For freespace, if we set $\sigma$ = 0, $\varepsilon = \varepsilon_0, \mu = \mu_0$, we will obtain $\alpha = 0, \beta = \omega/c = \frac{2\pi}{\lambda}$ and $\theta_\eta = 0$. For good conductors, if we set $\sigma \approx \infty$ , $\varepsilon = \varepsilon_0, \mu = \mu_0\mu_r$ , we will obtain $\alpha = \beta = \sqrt{\pi f\mu\sigma} = \frac{2\pi}{\lambda}, \theta_\eta = 45^0$ [9].

To develop plotting the electric field program, a study was made plotting it manually by followed these steps:

1) A starting point was chosen on the field lines.

2) $E_x$ and $E_y$ at that point were calculated using equation $\vec{E} = \sum_{k=1}^{N}\frac{Q_k\left[(\vec{x}-\vec{x}_k)\vec{u}_x + (\vec{y}-\vec{y}_k)\vec{u}_y\right]}{4\pi\varepsilon\left[(x-x_k)^2+(y-y_k)^2\right]^{3/2}}$

3) A small step along the field line taken to a new point in the plane. A movement $\Delta l$ along the field line corresponds to movements' $\Delta x$ and $\Delta y$ along x- and y-directions respectively. So,

$$\frac{\Delta x}{\Delta l} = \frac{E_x}{E} = \frac{E_x}{\left[E_x{}^2 + E_y{}^2\right]^{1/2}} \quad \text{or}$$

$$\Delta x = \frac{\Delta l \cdot E_x}{\left[E_x{}^2 + E_y{}^2\right]^{1/2}}$$

Similarly, $\Delta y = \frac{\Delta l \cdot E_y}{\left[E_x{}^2 + E_y{}^2\right]^{1/2}}$

4) The field line is moved from the old point (x,y) to a new point x' = x + $\Delta x$ , y' = y + $\Delta y$ . Steps 2 and 3 are repeated. Then, generated new points until a line is completed within a given range of coordinates. On completing the line, step 1 repeated and another starting point chosen. Since there are an infinite number of field lines, any starting point is likely to be on a field line. [9]

Next, for digital modulation and HF analysis sections, the development focused on the graphical user interface (GUI). In digital modulation development, the program is to generate the ASK and FSK signal based on the parameters that appropriate with the modulation. While in HF, the program developed to analyzed the receive HF radio signal in offline mode. Students will be able to determine ASK, FSK, multi ASK, Morse Code or other type of signal modulation by using this program.

*C. GUI Design of The System*

Matlab software is suitable for high performance in technical computing, engineering, integrating programming, visualization and computation in a very user friendly environment especially using its GUI. The software provided extensibility and flexibility with its own high-level programming language. The two major element that have contribute to it immense popularity are easy to use since data can easily entered especially for algorithms that are adaptable to a table format, and it includes high level command for two dimensional visualization and presentation graph. The most important part to know is Matlab GUIDE because it propose how to creating GUI by Matlab. Before starting and create the GUI part, what we need to know is written m-files and how the related m-files with the GUI. A graphical user interface (GUI) is drawing to a program interface. A good GUI can make the program more easily by providing them with a consistent look and intuitive controls such as clickbuttons, list boxes, sliders, menus, and so forth. GUI should behave in a way that is understood and predictable, so the user knows what to expect when they can take an action. For example, if a mouse click occurs on a click button, the GUI should start the action described on the label of a button [10]. In HF analysis, GUI developed into two condition where the *.wav file can be selected either file that is installed from the program or user's file. This included the pop-up menu and click button to load the desired wav file. The analysis is performed in offline mode.

## IV. Result and Discussion

The system is running by MATLAB R2009b. The main menu of the system is as shown in Figure 1 consists of two buttons; which are 'Electromagnetic' and 'Communication'. User can look up for help by clicking the 'Help' button or exit the program by clicking the 'Exit Program' button. User will find more useful button that link to other mode in each window such as 'Help', 'Home', 'Back', link to mode 'Electromagnetic' and 'Communication'. On Electromagnetic mode, there are five operations. There are 'Dot Product', 'Cross Product', 'Electric Field Intensity due to a Charge', 'Plotting Electric Field' and 'Electromagnetic Propagation' mode (Figure 2).

For the second mode, Communication mode, there are two sections; 'Digital Modulation' and 'High Frequency Analysis' as shown in Figure 3. In Figure 4, 'Amplitude-Shift Keying' and 'Frequency-Shift Keying' are under the Digital Modulation mode.

*A. Cross and Dot Product*

For these operations, it only requires two vectors to operate. User needs to enter vector A and B according to the dimensions Ux, Uy and Uz respectively. Then, user can get the answer by clicking the 'Answer' button. Refer to Figure 5 for cross product, the answer appeared are Ux, Uy and Uz direction respectively. Figure 6 shows the result of dot product operation. User also can get an example of question and try on the program by clicking the 'Help' button on the window.

*B. Electric Field Intensity*

In this window as shown in Figure 7, the operation is to determine the electric field intensity at point $\vec{r}$ due to a point charge located at $\vec{r}'$. To perform this operation, firstly the user has to enter the charge value at $\vec{r}'$. Besides the charge box is example how to write the charge value. Then the user should enter the location of point of charge and location of point $\vec{r}$. Click the 'Electric Field Intensity' button to get the answer. An example of question also is provided in 'Help' button.

*C. Plotting Electric Field*

To plot the electric field, user can plot up to eleven point charges and range of axes are between -5 to 5. User needs to enter the points of charge and their appropriate location. The result is shown in Figure 8.

*D. Electromagnetic Wave Propagation*

This window consists of two axes (Figure 9). User can see the differences between wave propagation in freespace and good conductor. The first axes shows electric field wave, magnetic field wave and power density propagate in free space. The simulation is within 10 second. The second figure shows electric field wave, magnetic field wave and power density propagate in a good conductor. The simulation is also within 10 second. Users are allowed to run the one simulation at a time, let one of the simulation stop first and then run the other.

Wave propagation in other types of media can be derived from that for lossy media as special cases. For free space, if we set $\sigma = 0$, $\varepsilon = \varepsilon_0, \mu = \mu_0$, we will obtain $\alpha = 0, \beta = \omega/c = \frac{2\pi}{\lambda}$ and $\theta_\eta = 0$. For good conductors, if we set $\sigma \approx \infty$, $\varepsilon = \varepsilon_0, \mu = \mu_0\mu_r$, we will obtain $\alpha = \beta = \sqrt{\pi f \mu \sigma} = \frac{2\pi}{\lambda}, \theta_\eta = 45^0$ [4].

*E. Digital Modulation of ASK and FSK*

This system will generate ASK and FSK signal. In ASK, user has to enter the parameter such as the frequency sampling. User also has to enter appropriate values of frequency signal (carrier) and the signal bit rate. Then, this is followed by the sequence of the signal. By clicking the 'Generate!' button, the signal of ASK will be generated as in shown in Figure 10. While to generate FSK signal as shown in Figure 11, the parameters that are needed to be fulfill is the frequency sampling, low signal frequency, high signal frequency, bit rate and sequence of the signal. All frequencies parameters are in Hertz (Hz) unit and bit rate in bits per second (bps). 'Generate!' button is clicked to generate the FSK signal.

*F. High FrequencyAnalysis*

In this section (Figure 12), user can either load their own wave file or load from the menu which has already exist in the system. Then, user should follow the arrangement from step 1 to 6. Step 1 is to initialize analysis parameter, user required to enter the sampling frequency, for example (8000Hz) and load the wave file. Then, click the 'OK' button (For user mode, the waveform will automatically generated after load the file). Then, the original waveform of the signal will appear and it indicates that the signal has been loaded into the system. The example of image of the original waveform is shown in Figure 13.

To playback the signal that has been loaded, user has to enter lower and upper time limit. Then click button 'OK' to playback the signal and user can hear the signal.

Step 3 which is Filter Signal needs user to select the type of filter in the pop-up menu consists of lowpass, highpass, bandstop and bandpass filter. User is required to complete the appropriate value that is suitable for the file then to run the filtering process by clicking the 'OK' button. The filtered waveform will appear as shown in Figure 14.

To perform spectrum analysis, user has to choose the window function either to use Boxcar or Hamming by selecting at the pop-up menu provided. Then click button 'OK', periodogram of spectrum analysis will appear as shown in Figure 15. It shows that the frequency exists at 963.6Hz. User can click data cursor at figure toolbar to get the value on the peak of frequency. It illustrates that there is only one frequency exists in the signal, it can be concluded that the signal is ASK or Morse code.

Next part is Perform Time-Frequency Analysis which is to display the spectrogram. User should select the plot choice of the signal at the pop-up menu either Contour or Waterfall. Click 'OK' button then spectrogram of the signal will appear as shown in Figure 16. From the figure it seems that there is only one frequency exists with a constant time, so as the conclusion 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)

<u>Bit rate ≈ 1/ 300ms = 3.3bps</u>

The last step is to estimate the value of frequency contained in the signal through the spectrum analysis and the signal frequency from the time-frequency presentation. By entering the reference level and then click 'OK' button, both results will come out simultaneously on the screen as shown in Figure 17 and Figure 18. Figure 17 come out with the estimate frequency contained in the signal. From figure 18, it shows the signal frequency at the highest normalized energy.

*1) Result for Frequency Shift Keying (FSK)*

Figure 19 shows the periodogram of the signals that has two signal frequencies and exist at 1866 Hz and 4466 Hz. The spectrogram in Figure 20 gives that the signal is FSK since it has two signal frequencies that exist at different time.

<u>Bit rate ≈ 1/ 500ms = 2bps</u>

*2) Result for Multi Frequency Shift Keying (multi-FSK)*

From Figure 21, the periodogram illustrates that the first signal exist at 254.3 Hz. Since more than one frequency exists in the signal, so that the signal is multi-FSK. Result for time-frequency analysis is shown in Figure 22. From the figure it illustrates that the signal is multi-FSK since the time is overlapped between two frequencies with a constant time.

<u>Bit rate ≈ 1/ 300ms = 3.33 bps</u>

*3) Result for Morse code*

Periodogram in Figure 23 illustrates that the frequency exists at 788 Hz signal might be Morse code or ASK because the signal contain only one frequency. Result from time frequency analysis displayed in Figure 24 and convinced that the signal is Morse code since the signal frequency exists at a different time that represent dot and dash.

<u>Bit rate ≈ 1/ 250ms = 4 bps</u>

*Figure 1: Home of the system menu*

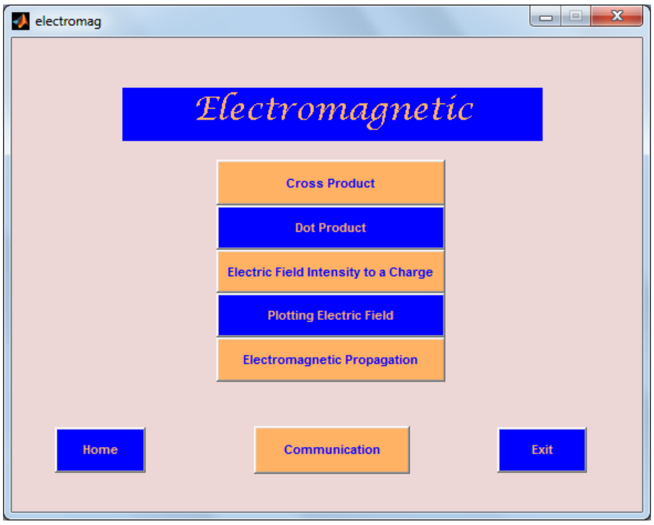

*Figure 2: Electromagnetic mode*

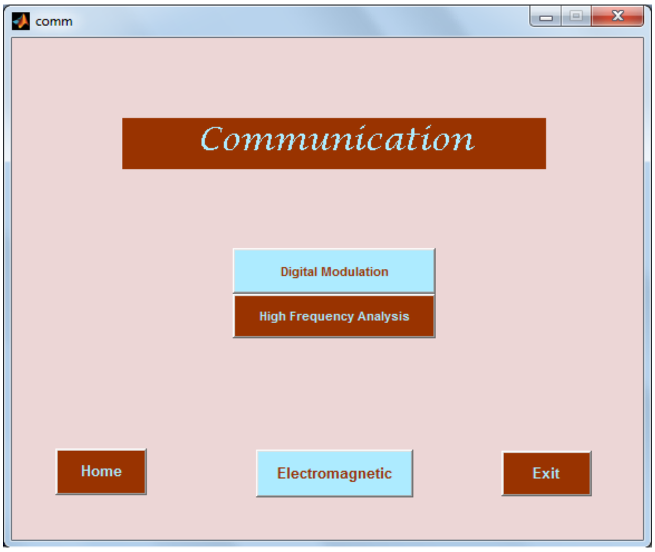

*Figure 3: Communication mode*

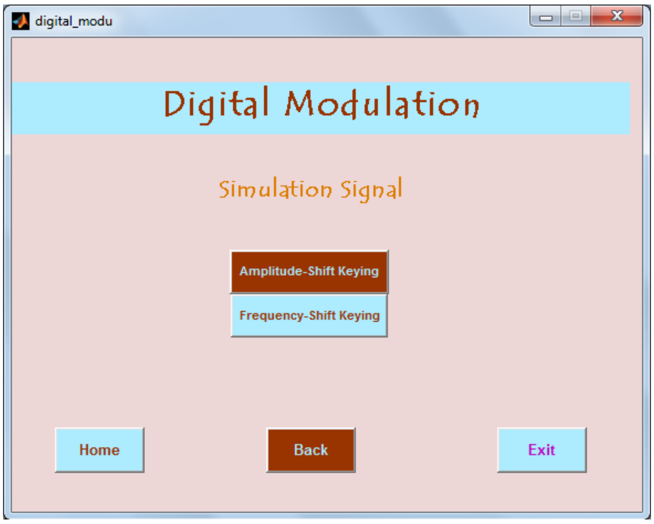

*Figure 4: Digital modulation mode*

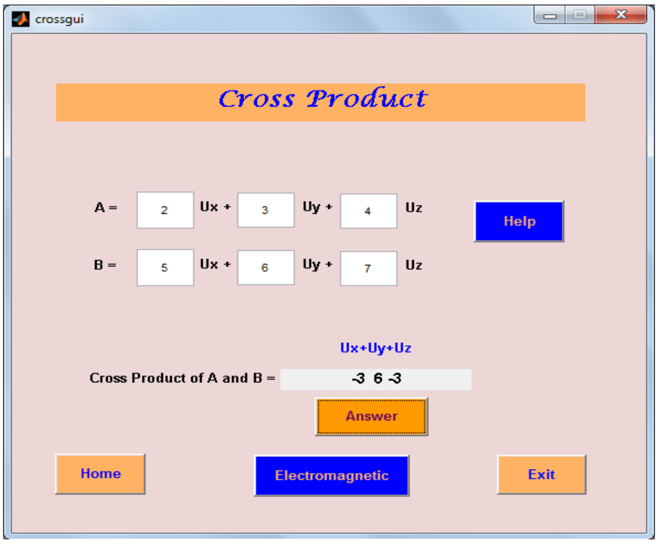


Figure 5: Cross product calculator

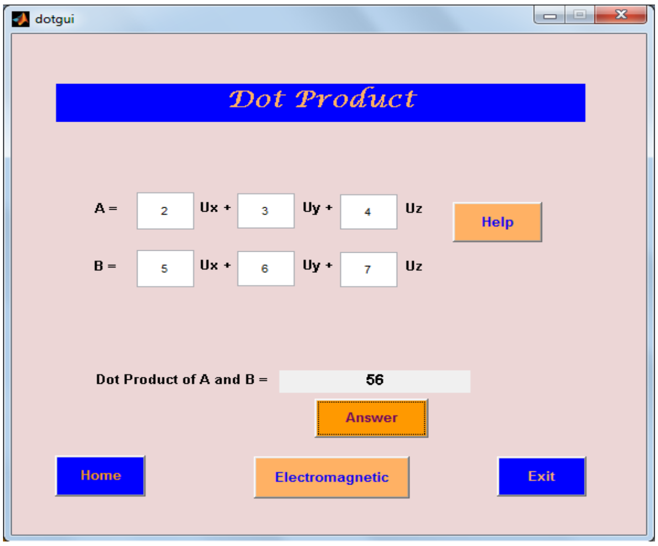


Figure 6: Dot product calculator

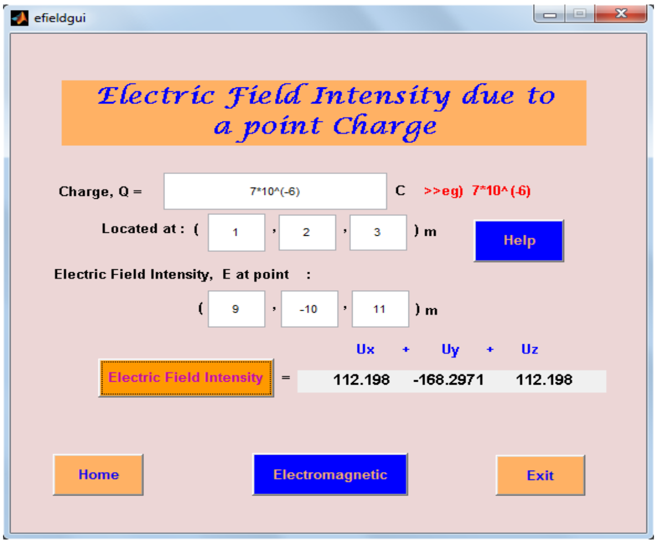


Figure 7: Electric field Intensity due to a point charge

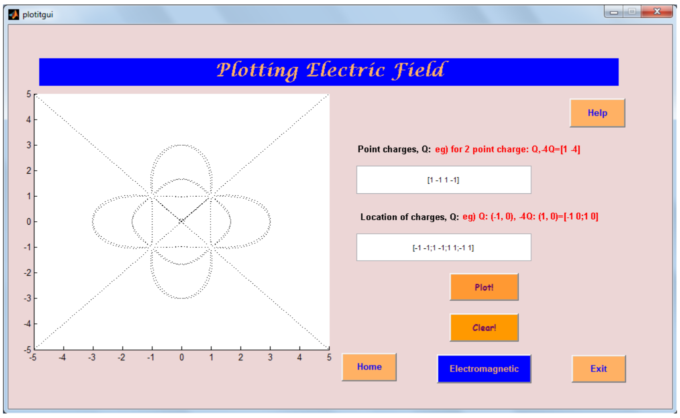


Figure 8: Plotting electric field

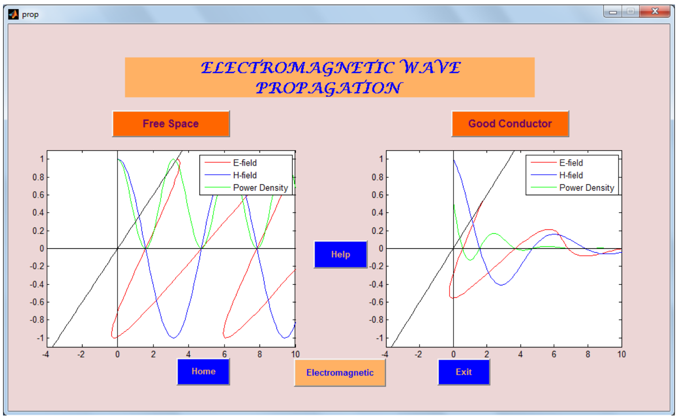


Figure 9: Electromagnetic wave propagation

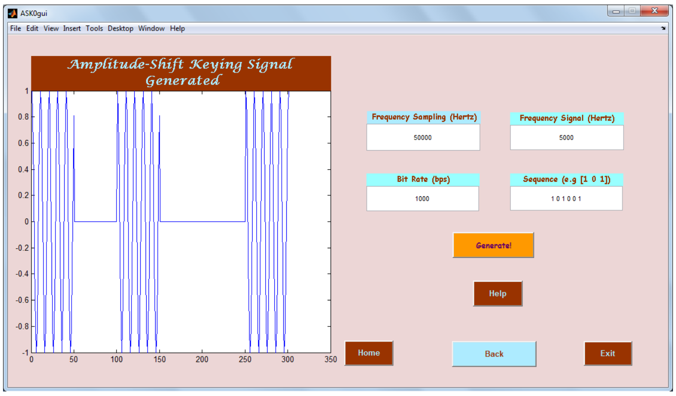


Figure10: Amplitude-Shift Keying generated signal

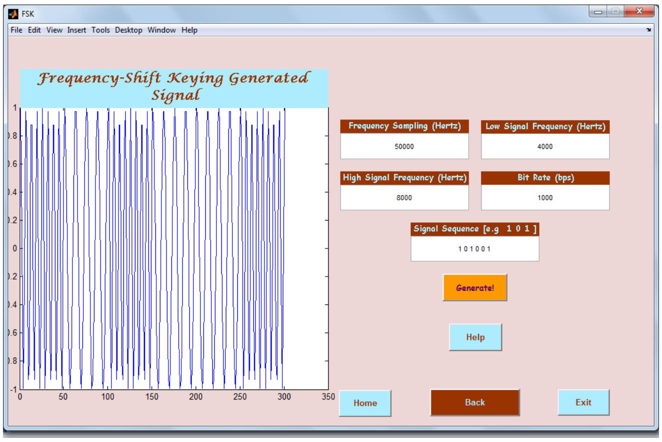


Figure 11: Frequency-Shift Keying generated signal

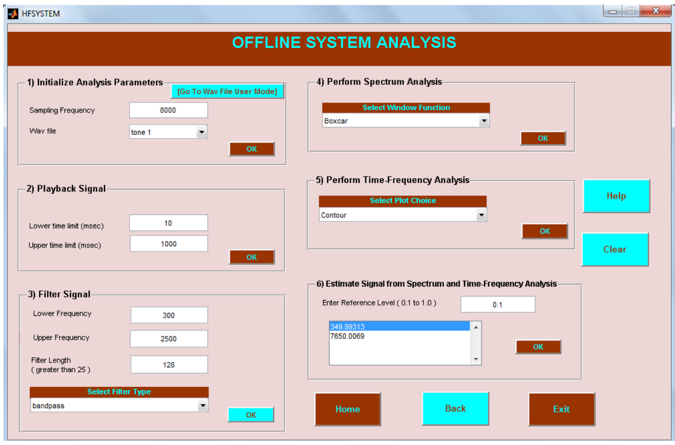


Figure 12: HF Analysis

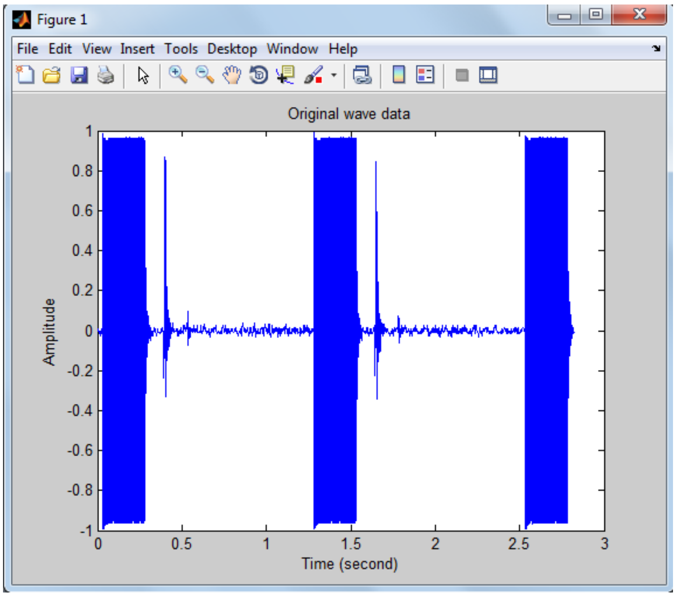


Figure 13: Original wave

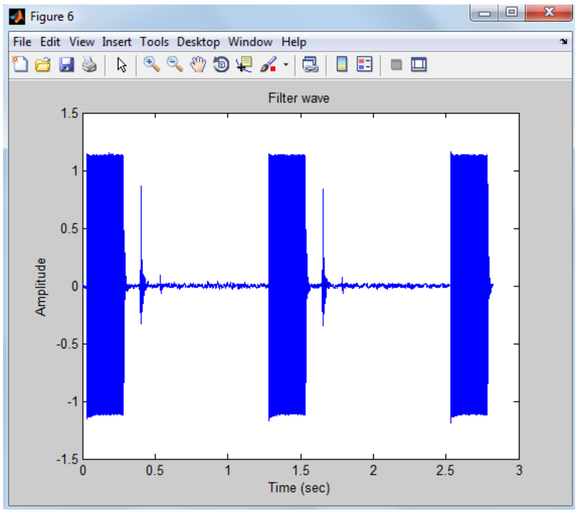


Figure 14: Filtered signal

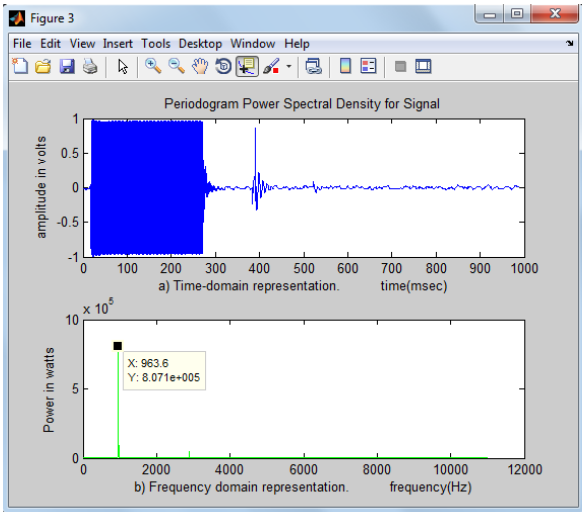


Figure 15: Periodogram of ASK signal

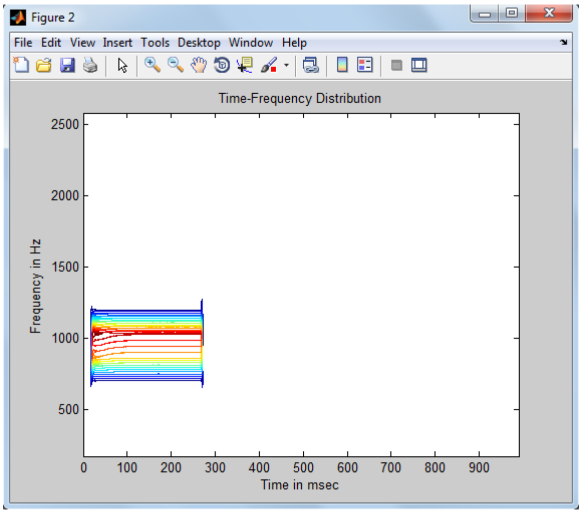


Figure 16: Spectrogram of ASK signal

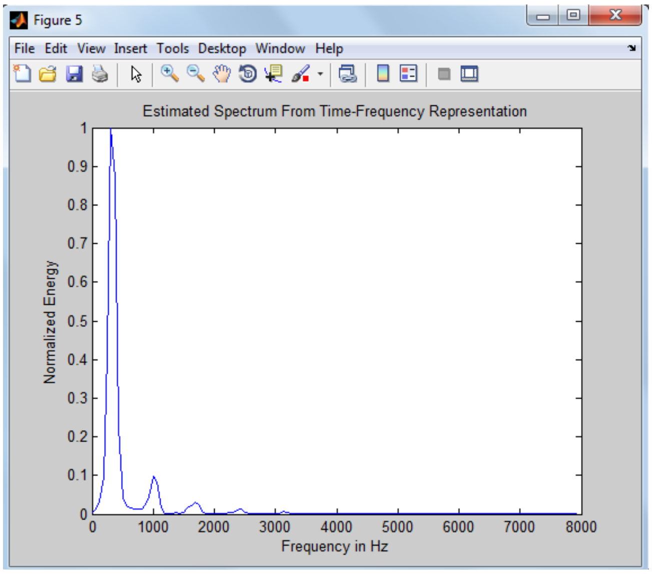


*Figure 17: The representation of ASK by time-frequency analysis*

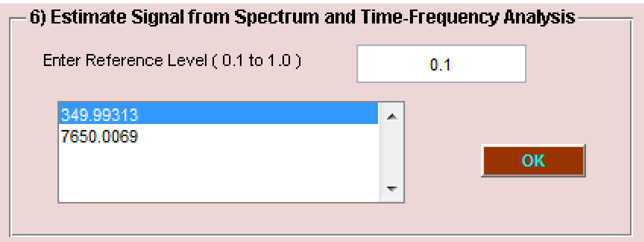


*Figure 18: The estimate value of ASK by spectrum analysis*

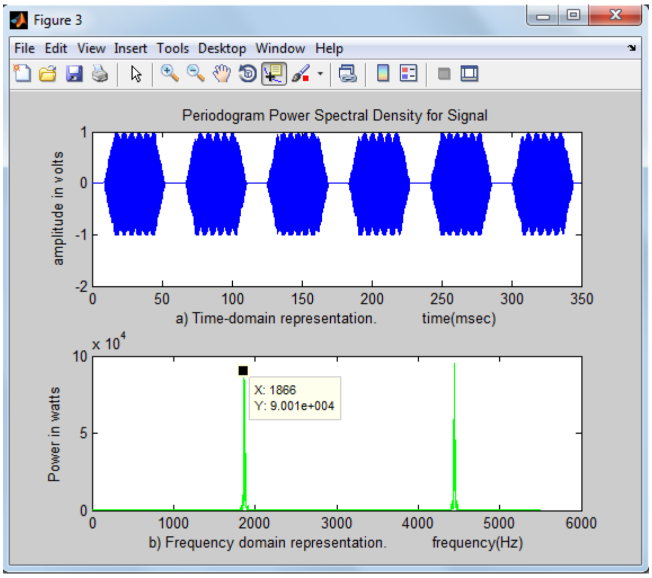


*Figure 19: Periodogram of FSK*

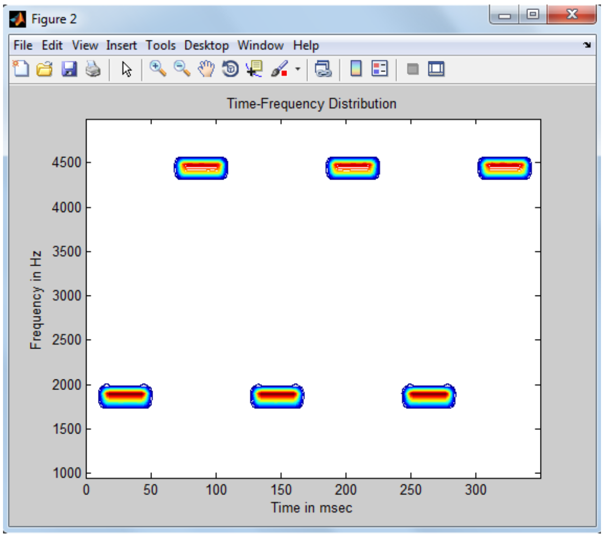


*Figure 20: Spectrogram of FSK*

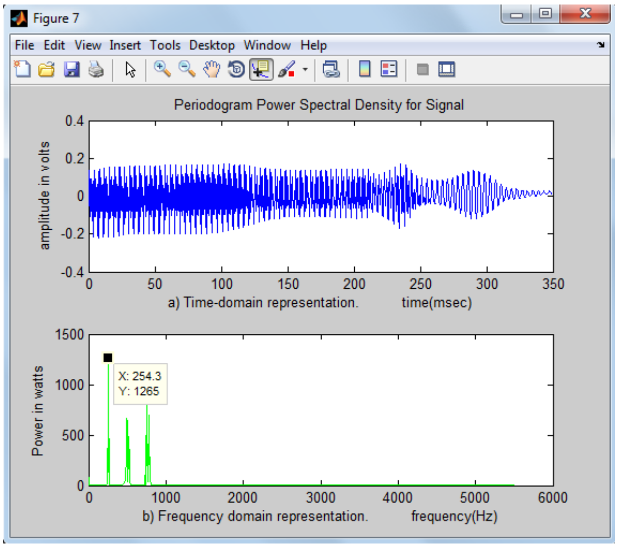


*Figure 21: Periodogram of Multi-FSK*

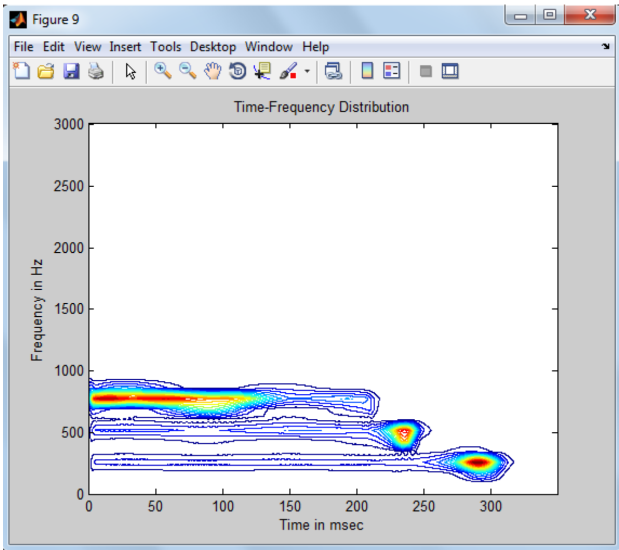


*Figure 22: Spectrogram of Multi-FSK*

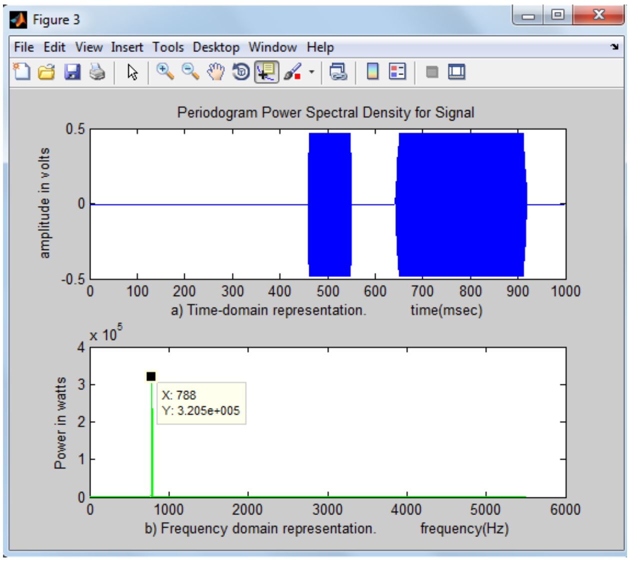


*Figure 23: Periodogram of Morse code*

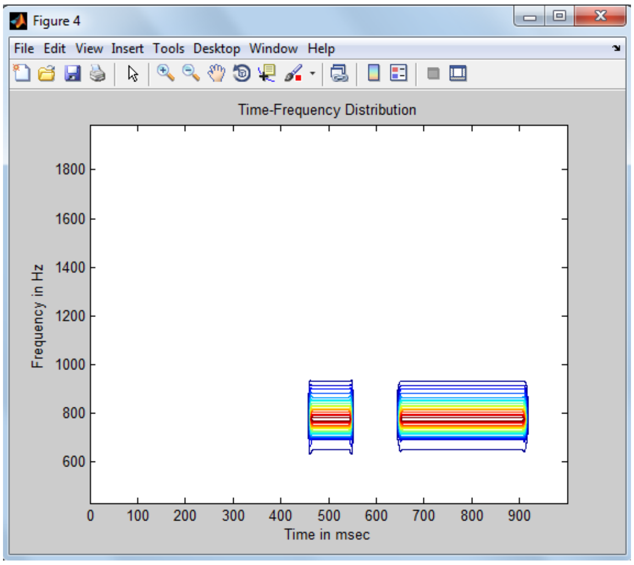


*Figure 24: Spectrogram of Morse code*

## CONCLUSION

Overall the objectives of the project have been successfully achieved. GUI has been developed which is suitable for learning purposes. The system developed is useful for the students to understand more on electromagnetic and solve some communication engineering problems.

## FUTURE WORK

In the future, the system absolutely can be improved to be more dynamic and user-friendly. Problems such as electric field intensity to a charge, dot and product of vector can be improved by modifying the program to make the operation involved with more point charges and number of vectors respectively. The wave propagation GUI also can be improved further using 3D plot. There are other digital modulation that can be developed such as Quaternary Phase-Shift Keying (QPSK), 8-Phase-Shift Keying (PSK), 8-Quadrature-Amplitude Modulation (QAM) and so on. Other problems and analysis that relates to communication engineering problems can be developed with this program to make the program more interesting for future learning purposes using this platform.


## ACKNOWLEDGMENT

I want to express my appreciation to my supervisor Miss Nani Fadzlina Naim for guidance and motivation during the development of the program. Thanks to my friends and everyone who have involved and their pray for my success for the completion of this project either directly or indirectly.


## REFERENCES


[1] Aliane, N. (2010). "A Matlab/Simulink-Based Interactive Module for Servo Systems Learning " Education, IEEE Transactions 53(2): 265.

[2] Bachiller, C. E., H. Belenguer, A. Morro, J.V. Vidal, A. Boria, V.E. (2006). "Teaching of advanced wave-propagation phenomena in open-space problems and waveguide devices using MATLAB GUIs." Antennas and Propagation Magazine, IEEE 48(2): 128.

[3] Gharaibeh, K. M. (2009). "Computer Applications in Engineering Education." An interactive simulation tool for image registration education **18**(2): 255-237.

[4] McClellan, J. (2008). "Educational Matlab GUIs " Filter Design Demo from http://users.ece.gatech.edu/mcclella/matlabGUIs/.

[5] Kleder, M. (2006). "Interactive GUI: Animated conic section through five points." from http://www.mathworks.com/matlabcentral/fileexchange/12981-interactive-gui-animated-conic-section-through-five-points.

[6] J. M. Rodrguez, *et al.*, "Development of educational software for the teaching of telecommunication engineering by using MATLAB," *European Journal of Engineering Education,* vol. 26, pp. 361-374, December 2001 2001.

[7] (6 April 2011). "Cross Product." from http://en.wikipedia.org/wiki/Cross_product.(20 March 2011). "Dot Product." from http://en.wikipedia.org/wiki/Dot_product.

[8] (20 March 2011). "Dot Product." from http://en.wikipedia.org/wiki/Dot_product.

[9] H. A. Rahman, "Electrical Engineering Laboratory III EEE430," Universiti Teknologi Mara, Report2008.

[10] Refaat Yousef Al Ashi,Ahmed Al Ameri "*Introduction to Matlab GUI*",uae University College of Engineering, Electrical engineering department, ieee uaeu student branch,1996.