EEE 212

NUMERICAL TECHNIQUES LABORATORY

MATLAB PROJECT SUBMISSION

PROJECT NAME:

"ANALOG SIGNAL PROCESSING USING MATLAB"

GROUP NO: 05

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Introduction:

Signal processing is an Electrical Engineering subfield that focuses on analyzing, modifying and synthesizing signals such as sound, images and scientific measurements. Signal processing techniques can be used to improve transmission, storage efficiency and subjective quality and to also emphasize or detect components of interest in a measured signal. It consists of mapping or transforming information bearing signals into another form of at the output, aiming at some application benefits. This mapping defines a continuous or analog system if it involves functions representing the input and output signals.

Every day in every aspects of our life we have to communicate with each other using different technologies and information. These are nothing but the transmission of some signals. In order to maintain and transmit all the data perfectly, signal processing is a must. In basic signal processing there are two different operations named Modulation and Demodulation. Modulation is the process of encoding information in a transmitted signal while Demodulation is the process of extracting information from the transmitted signal. Many factors influence how faithfully the extracted information replicates the original input information.

In these project, we are basically going to see the Analog Signal Processing using MATLAB. We will see the Modulation & Demodulation of Amplitude, Frequency & Phase of a signal. We will know why those operations are needed, how they are done and what actually the importance of those operations using Graphical User Interface so that we can input as our own requirement and see the respected output graphs thus we can differentiate among those operations and know the exact fact.

Objectives:

1. To know how Amplitude Modulation, Demodulation & Reconstruction works and to see the graphical output for observing the differences among them.

2. To see the differences and working process of Frequency Modulation & Demodulation by interpreting different inputs.

3. To observe the Phase Modulation & Demodulation of a signal also.

4. To create a single platform and environment in which we can perform Modulation & Demodulation process of Amplitude, Frequency & Phase of a signal. We have maintained a user friendly interface to take different inputs and show all of the required graphical figures together using multiple GUI system.

Theory:

Amplitude: Modulation, Demodulation & Reconstruction

Amplitude modulation is a process by which the wave signal is transmitted by modulating the amplitude of the signal. It is often called as AM and is commonly used in transmitting a piece of information through a radio carrier wave. Amplitude modulation is mostly used in the form of electronic communication.

There are two signals-Message Signal & Carrier Signal

Message signal, $\mathbf{m(t) = A_m \cos(\omega_m t + \theta)}$

Carrier signal, $\mathbf{c(t) = A_c \sin(\omega_c t + \theta)}$

-Modulation can be performed by multiplying these two signals.

Modulated signal, $\mathbf{Y_m(t) = m(t) \times c(t)}$

-Demodulation can be performed by multiplying the Carrier signal with the Modulated signal

Demodulated signal, $\mathbf{Y_{dm}(t) = Y_m(t) \times c(t)}$

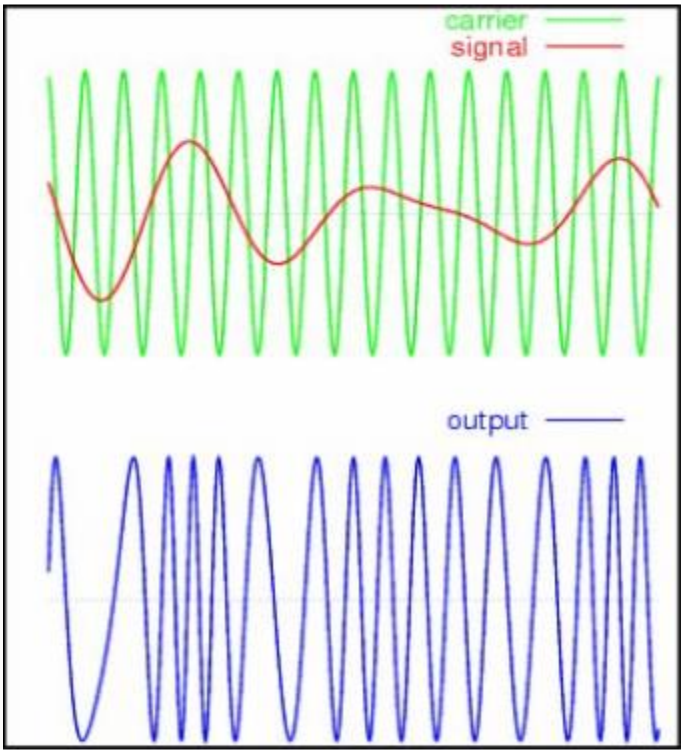
There are some noises in the Demodulated signal. To remove those noises we have to subtract some sinusoidal components from the Demodulated signal, this is called **Reconstruction**. Thus we will get the Reconstructed signal which is exactly as like as the Original Message signal.

Reconstructed signal,
$\mathbf{Y(t) = Y_{dm}(t) – A_m/4 (\cos (2\omega_c + \omega_m)t + \cos (2\omega_c - \omega_m)t)}$

This Y(t) is equal to the m(t).

Frequency: Modulation & Demodulation

Frequency modulation is a form of modulation, which represents information as variations in the instantaneous frequency of a carrier wave. In analog applications, the carrier frequency is varied in direct proportion to changes in the amplitude of an input signal.



The FM-modulated signal has its instantaneous frequency that varies linearly with the amplitude of the message signal. Now we can get the FM-modulation by the following:

$$\varphi(t) = \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau)$$

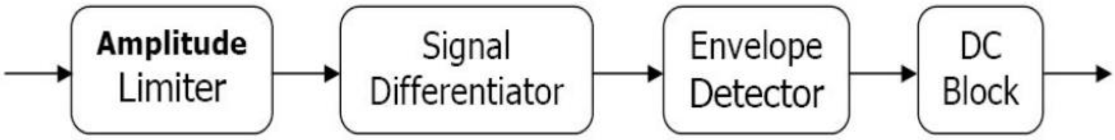
Where K_f is the sensitivity factor, and represents the frequency deviation rate as a result of message amplitude change. The instantaneous frequency is:

$$\omega_i = 2\pi f_c + 2\pi k_f m(t)$$

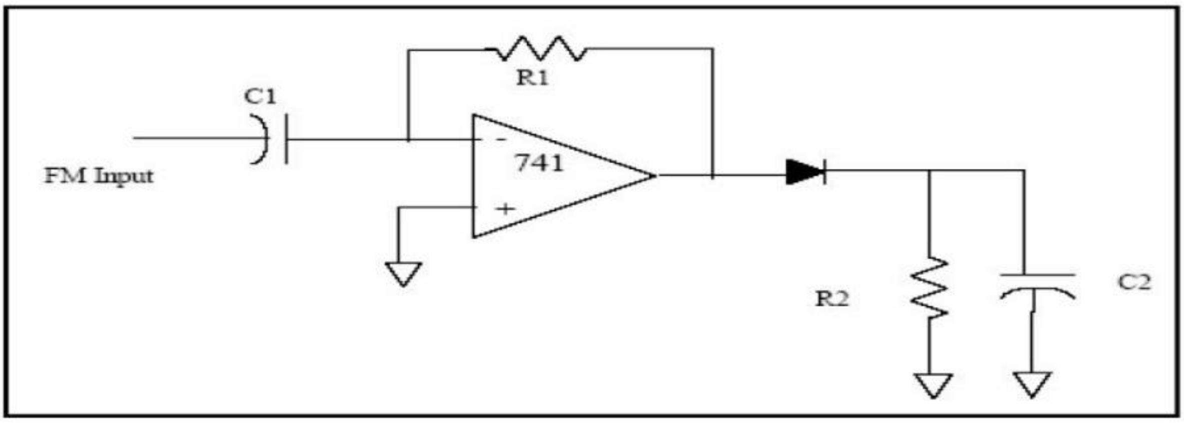
The maximum deviation of Fc (which represents the max. shift away from Fc in one direction) is:

$$\Delta f = k_f m(t)_{\max}$$

Note that The FM-modulation is implemented by controlling the instantaneous frequency of a Voltage Controlled Oscillator (VCO). The amplitude of the input signal controls the oscillation frequency of the VCO output signal. In the FM demodulation what we need to recover is the variation of the instantaneous frequency of the carrier, either above or below the center frequency. The detecting device must be constructed so that its output amplitude will vary linearly according to the instantaneous freq. of the incoming signal. One approach to perform demodulation, is using frequency discrimination:



In this method we differentiate the FM signal to get an AM signal, then we use an envelope detector. The following figure how to implement such a demodulator:



In this case, the output of the differentiator will be an AM modulated signal. The AM modulated signal can be demodulated using an envelope detector.

Phase: Modulation & Demodulation

Phase Modulation is a modulation pattern for conditioning communication signals for transmission. It encodes a message signals as variations in the instantaneous phase of a carrier wave. In phase modulation, the instantaneous amplitude of the baseband signal modifies the phase of the carrier signal keeping its amplitude and frequency constant. The phase of a carrier signal is modulated to follow the changing signal level (amplitude) of the message signal. The peak amplitude and the frequency of the carrier signal are maintained constant, but as the amplitude of the message signal changes, the phase of the carrier changes correspondingly.

Here,

Message signal, $\mathbf{m(t) = A_m \cos (\omega_m t + \theta_m)}$

Carrier signal, $\mathbf{c(t) = A_c \sin (\omega_c t + \theta_c)}$

Then the modulated signal is, $\mathbf{y(t) = A_c \sin (\omega_c t + m(t) + \theta_c)}$

This shows how m(t) modulates the phase - the greater m(t) is at a point in time, the greater the phase shift of the modulated signal at that point. It can also be viewed as a change of the frequency of the carrier signal, and phase modulation can thus be considered a special case of FM in which the carrier frequency modulation is given by the time derivative of the phase modulation.

The phase modulated signal can be simply expressed as,

$$\mathbf{y(t) = A_c \sin [\phi(t)]}$$

Here, $\boldsymbol{\phi(t)}$ is the instantaneous phase that varies according to information signal m(t). A phase modulated signal of form y(t) can be demodulated by forming an analytic signal by applying Hilbert transform and then extracting the instantaneous phase. We note that the instantaneous phase is $\mathbf{\phi(t) = 2\omega_c t + \theta_c + A_m \cos (\omega_m t + \theta_m)}$ is linear in time, that is proportional to $\mathbf{2\omega_c t}$. This linear offset needs to be subtracted from the instantaneous phase to obtain the information bearing modulated signal. If the carrier frequency is known at the receiver, this can be done easily. If not, the carrier frequency term $\mathbf{2\omega_c t}$ needs to be estimated using a linear fit of the unwrapped instantaneous phase.

Process:

Part A: Operation with Amplitude

1. Taking inputs (A_m, F_m, A_c, F_c)
2. Implementing Message & Carrier Signal
3. Modulation
4. Demodulation
5. Reconstruction
6. Showing all of the Graphical Figure

Part B: Operation with Frequency

1. Taking inputs (A_m, F_m, A_c, F_c, Kf)
2. Implementing Message & Carrier Signal
3. Modulation
4. Demodulation
5. Showing all of the Graphical Figure

Part C: Operation with Phase

1. Taking inputs (A_m, F_m, A_c, F_c, Kp)

2. Implementing Message & Carrier Signal

3. Modulation

4. Demodulation

5. Showing all of the Graphical Figure

Here, A_m = Amplitude of Message Signal

F_m = Frequency of Message Signal

A_c = Amplitude of Carrier Signal

F_c = Frequency of Carrier Signal

Kf = Frequency Sensitivity

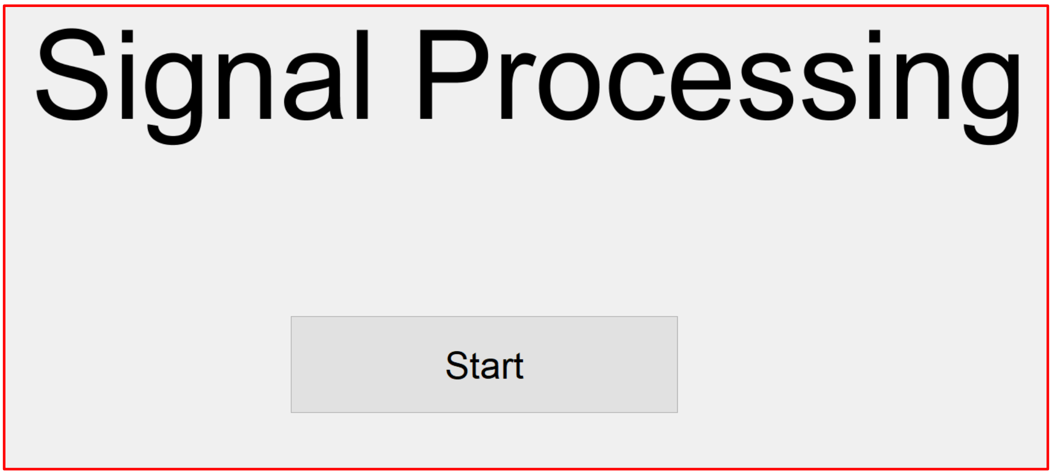
Kp = Phase Sensitivity

Part D: Creating GUI

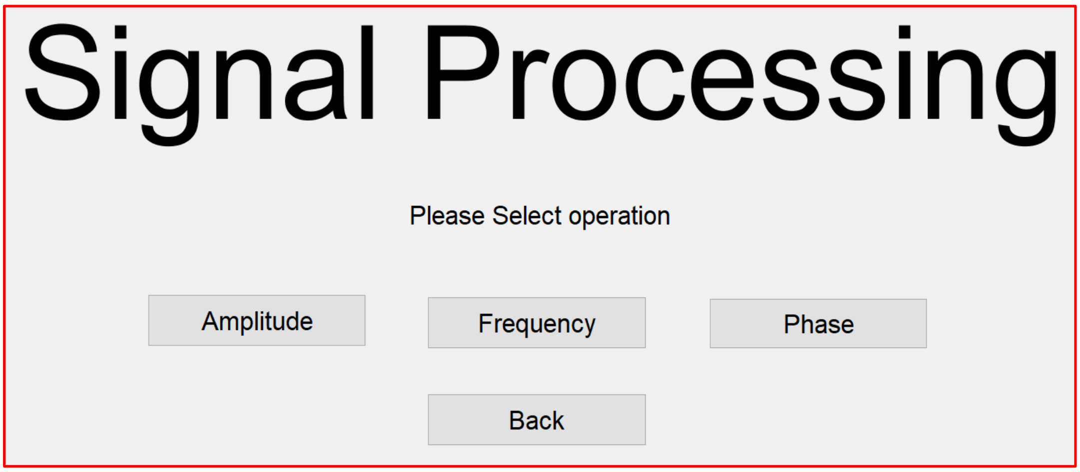
Here, we have internally linked up Part A, B & C through a multiple GUI system so that we can take frequent user input and be able to show the respected output graph.

Output & Results:

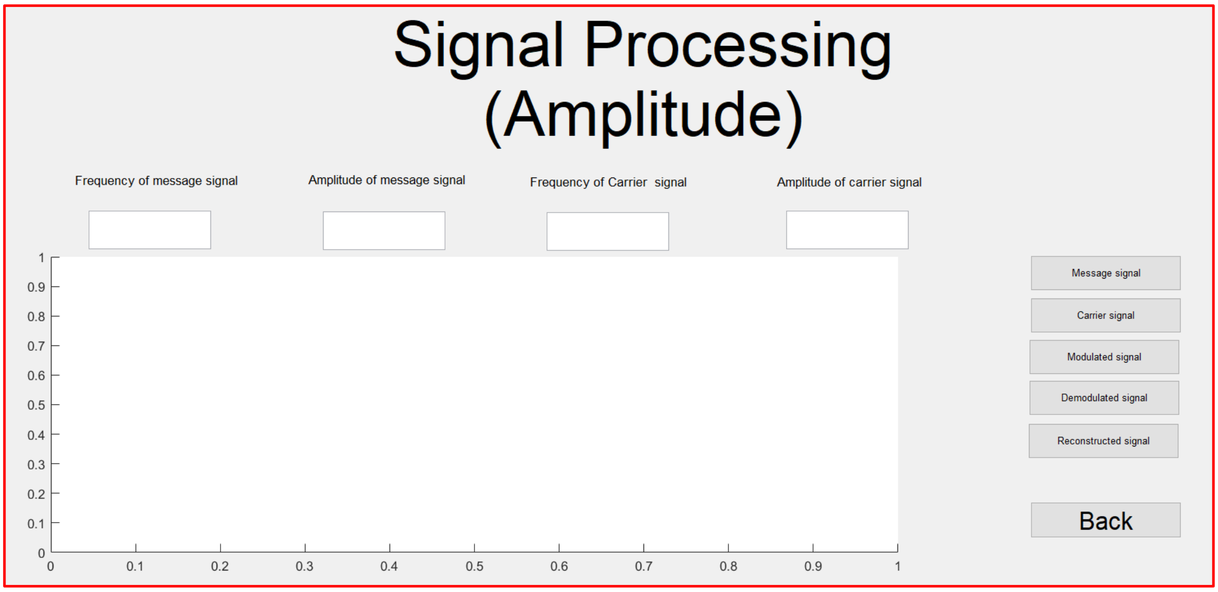
1. At the very first, after run the MATLAB code there will be a window where we can press the **Start** button to proceed.



2. After pressing 'Start' button there will be a window in which we can select three different operations individually named **Amplitude**, **Frequency** & **Phase**.



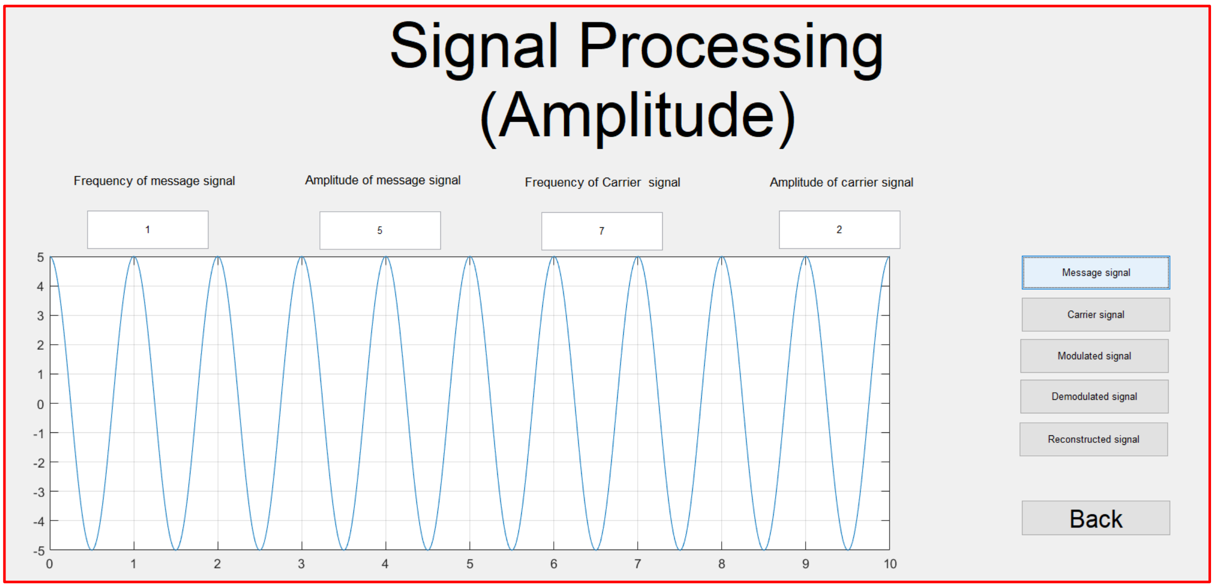
3. Now if we select **Amplitude** then the following window will open.



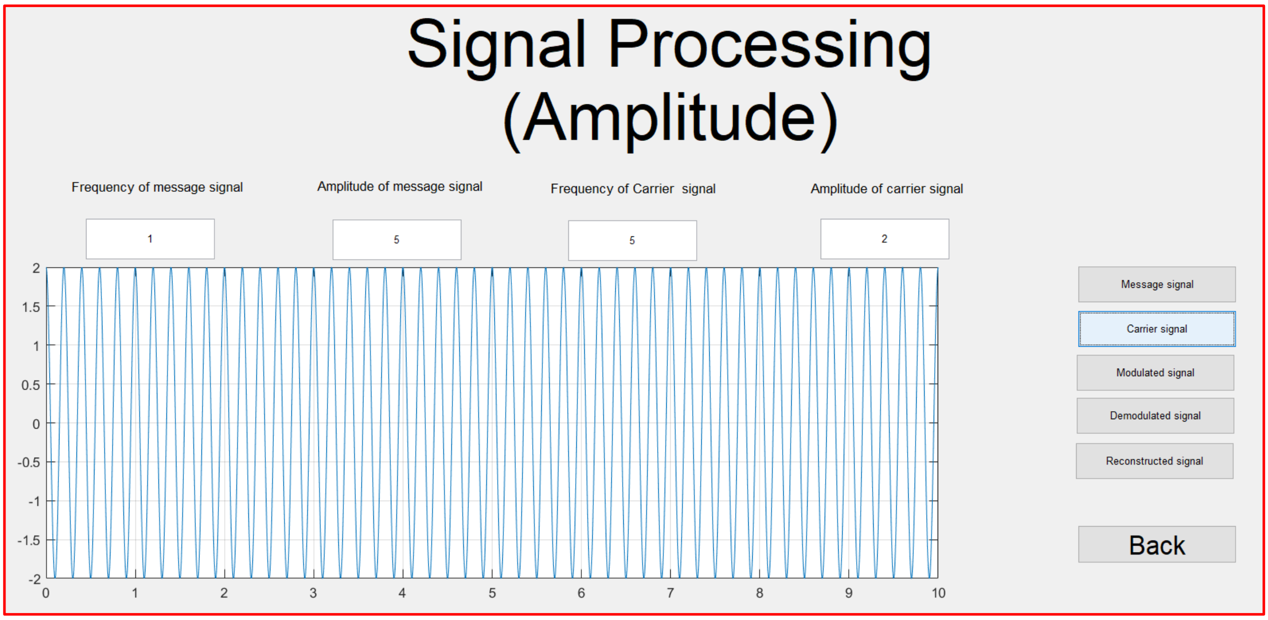
Here we can input the Frequency and Amplitude of the Message signal & the Carrier signal and get the graph of the Message signal, Carrier signal, Modulated signal, Demodulated signal & Reconstructed signal.

For some definite input,

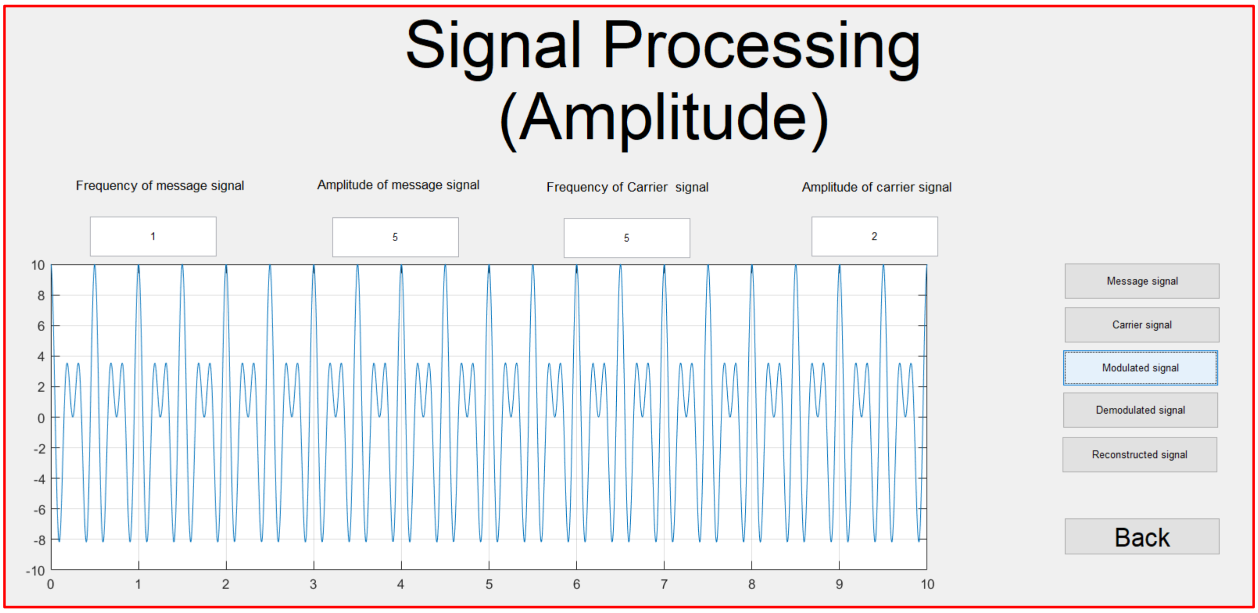
Message Signal



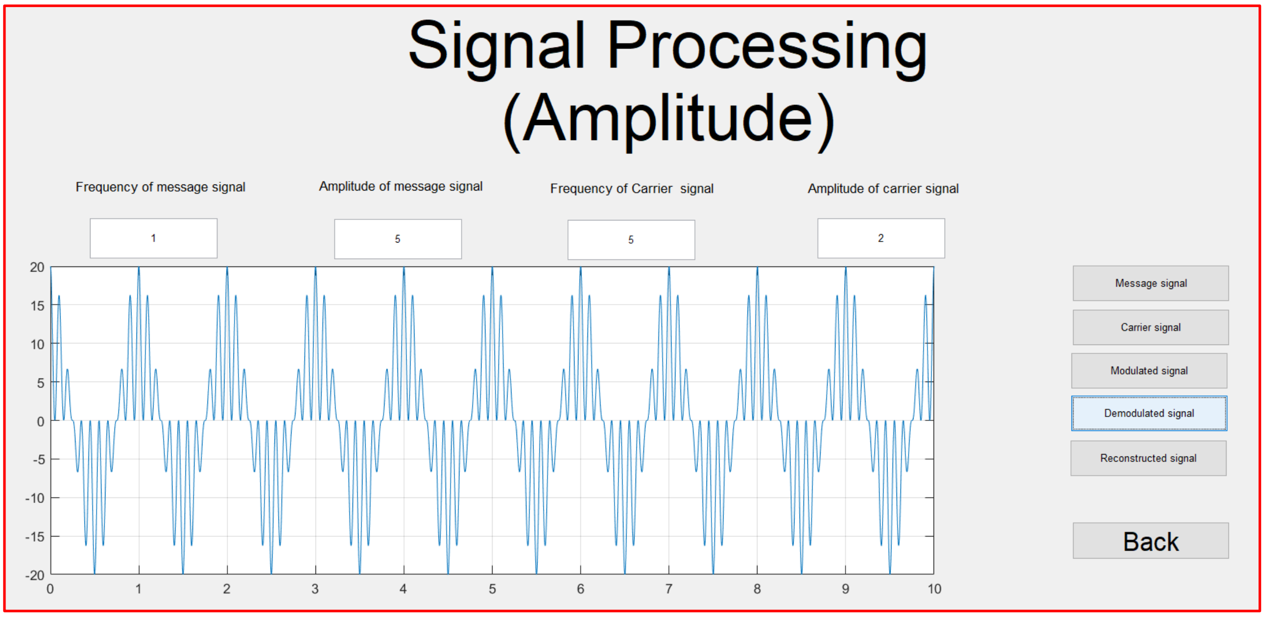
Carrier Signal



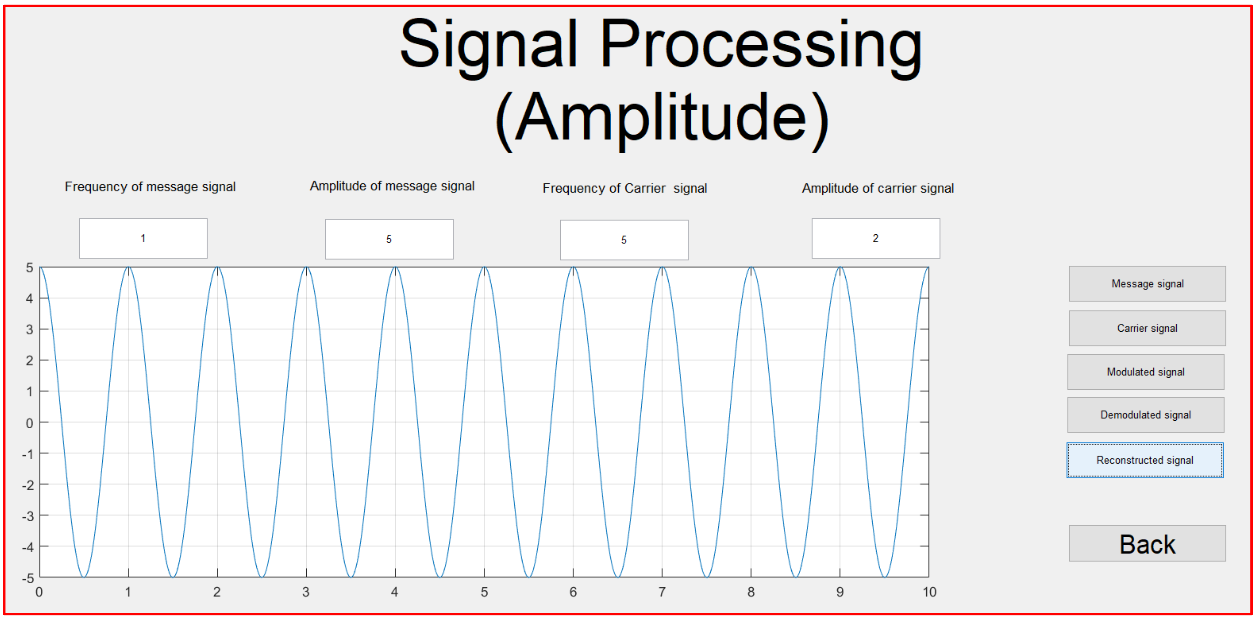
Modulated Signal



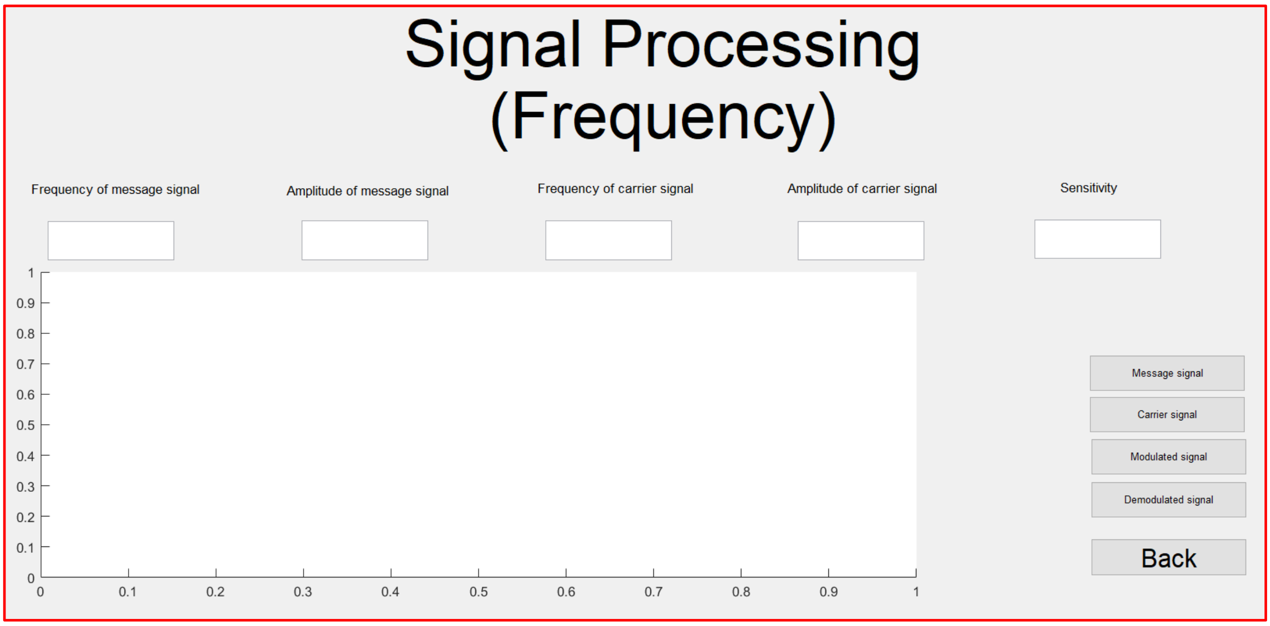
Demodulated Signal



Reconstructed Signal



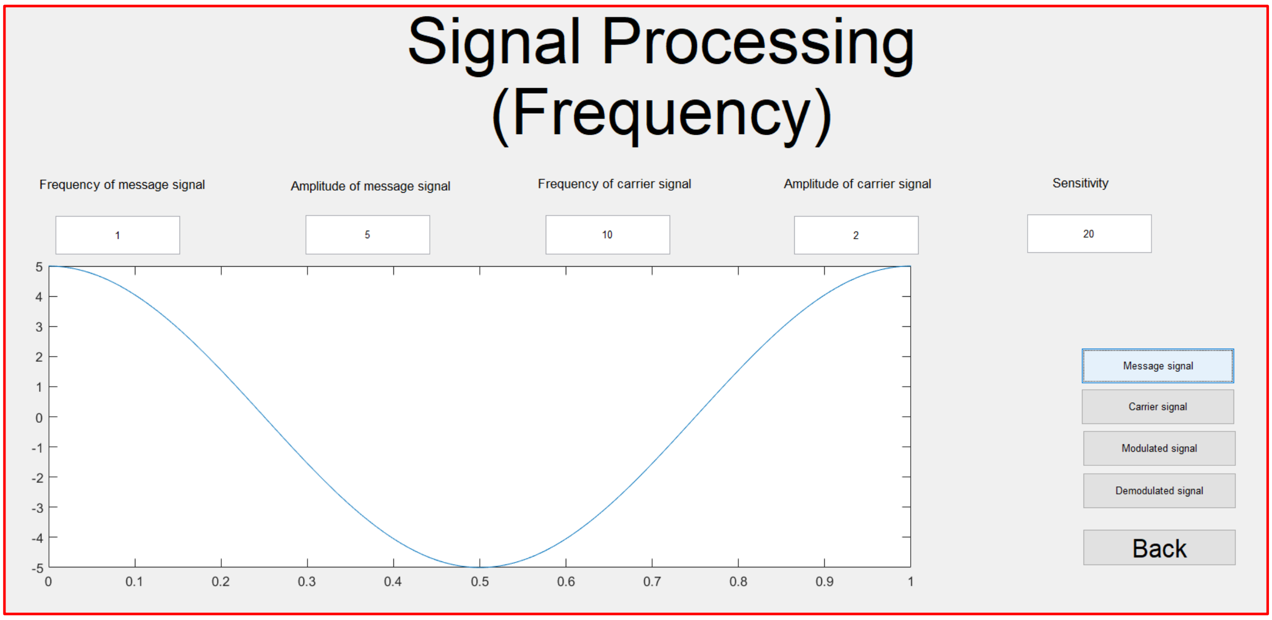
4. Now pressing **Back** button we can get back to the window of step 2 and select **Frequency** or **Phase** button. Here we firstly go for the Frequency operation. So if we select the **Frequency** button then the following window will open.



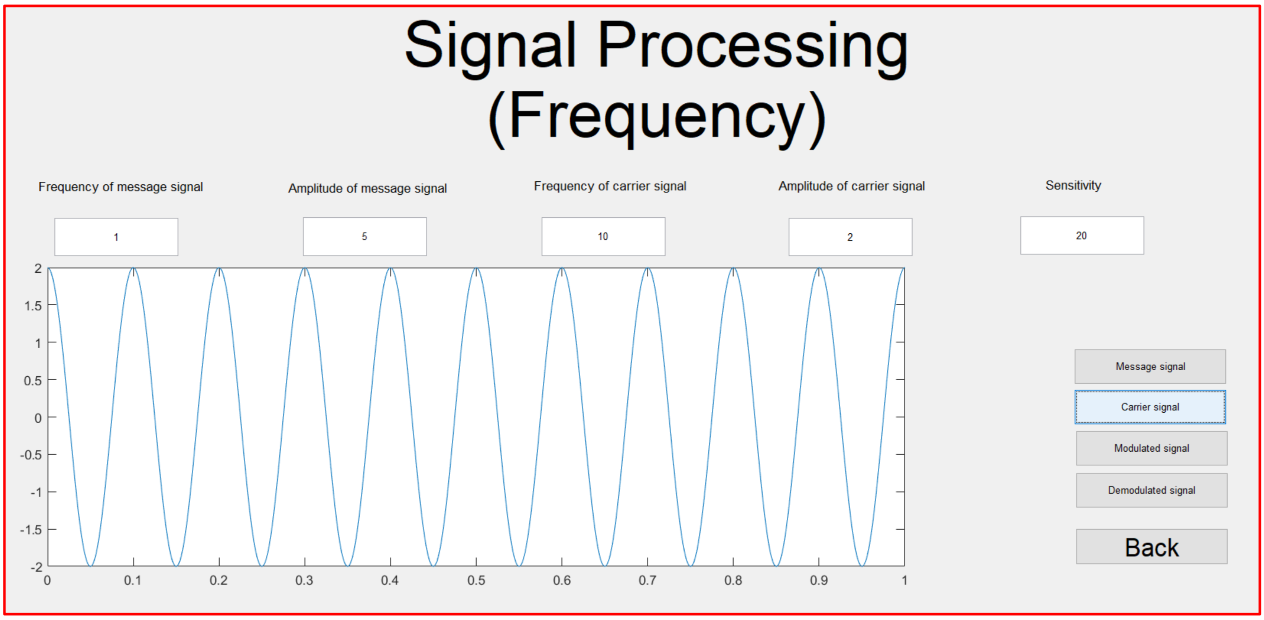
Here we can input the Frequency and Amplitude of the Message signal & the Carrier signal, Frequency sensitivity and get the graph of the Message signal, Carrier signal, Modulated signal & Demodulated signal.

For some definite input,

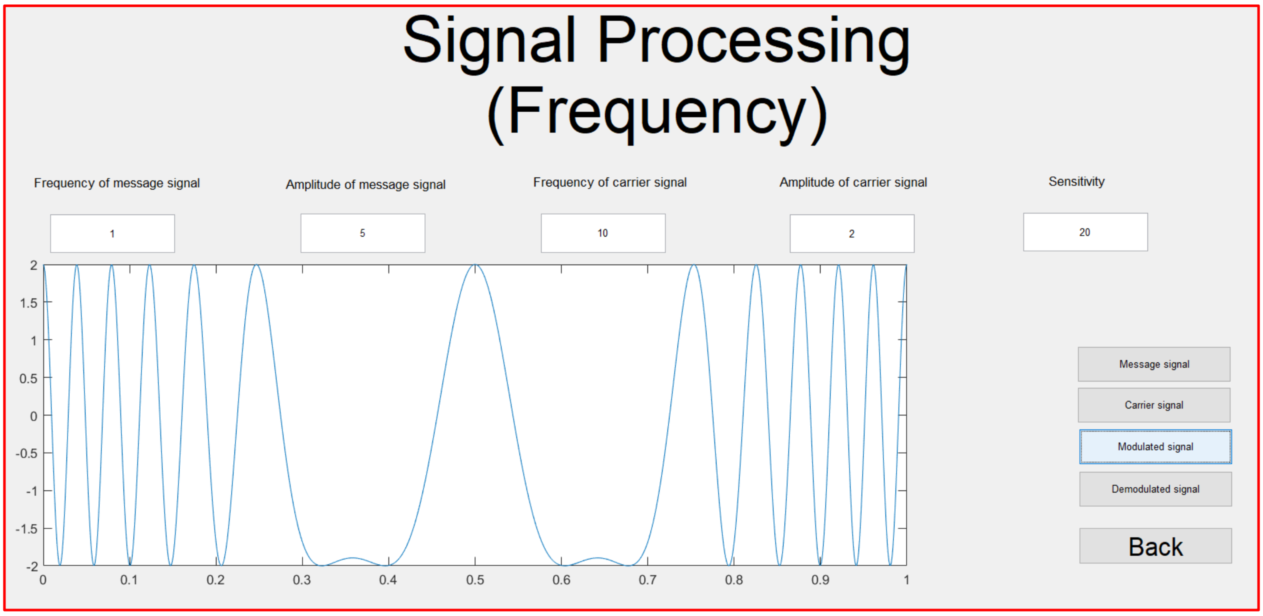
Message Signal



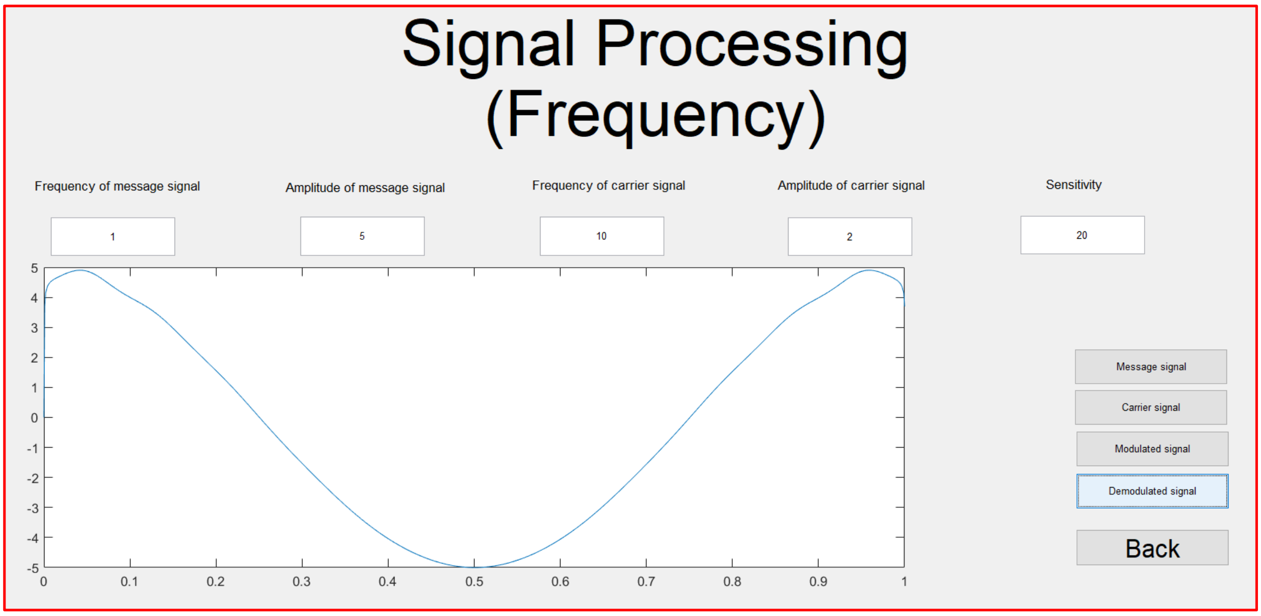
Carrier Signal



Modulated Signal

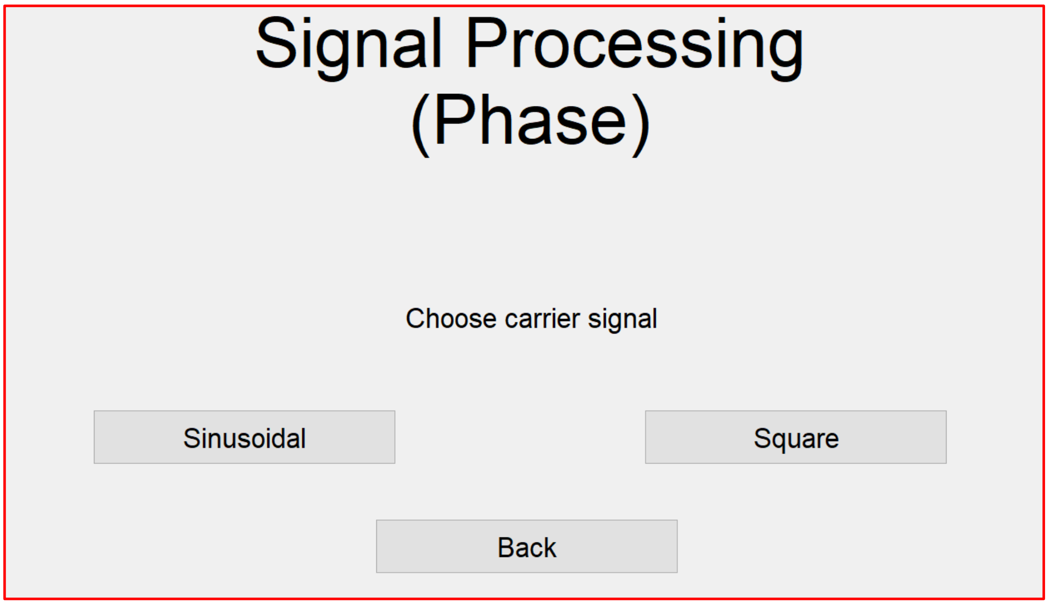


Demodulated Signal



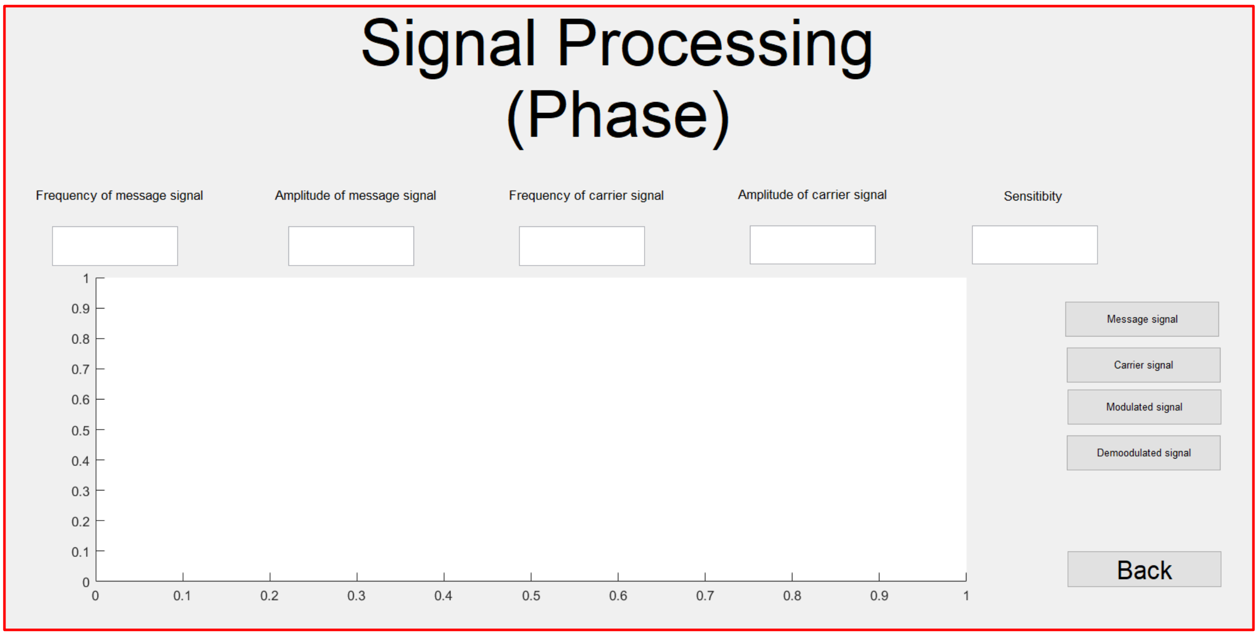
Here in the graph of the Demodulated signal we can see that there is a slight difference from the graph of the Message signal but both of the graphs should be the same. So the slight difference of these two graph is created because we have done this Demodulation operation using a built in function in MATLAB called **fmdemod.** There is also a factor named **Frequency Sensitivity** which we have taken as input from the user interface. For this factor there is also some distraction between the Message signal and the final Demodulated signal.

5. Now pressing **Back** button we can get back to the window of step 2 and select **Phase** button. After selecting the **Phase** button the following window will open.



Here, there are two types of Carrier signal we can select for Phase operation, one is **Sinusoidal** and the other is **Square** signal.

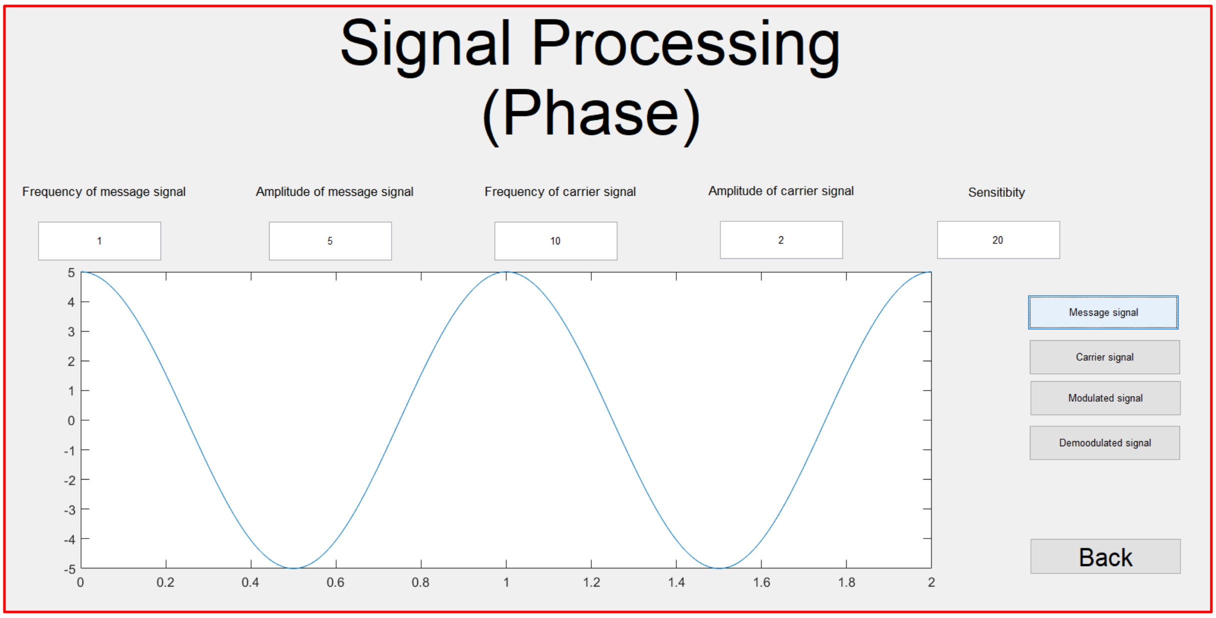
6. If we select **Sinusoidal** then following window will open.



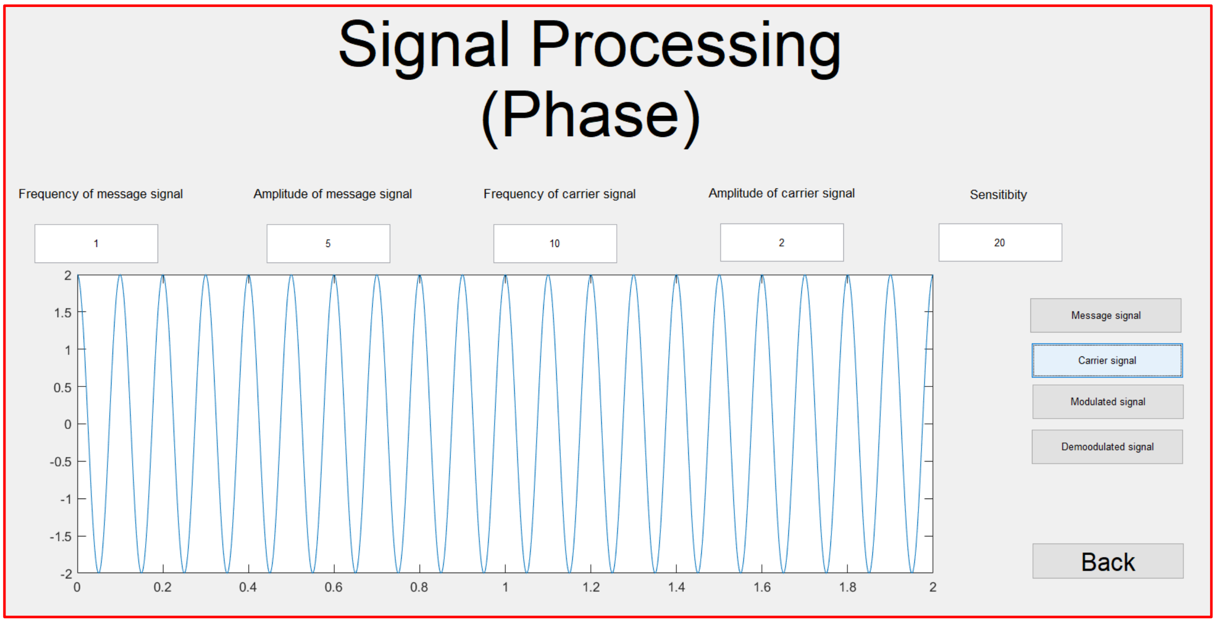
Here we can input the Frequency and Amplitude of the Message signal & the Carrier signal, Phase sensitivity and get the graph of the Message signal, Carrier signal, Modulated signal & Demodulated signal.

For some definite input,

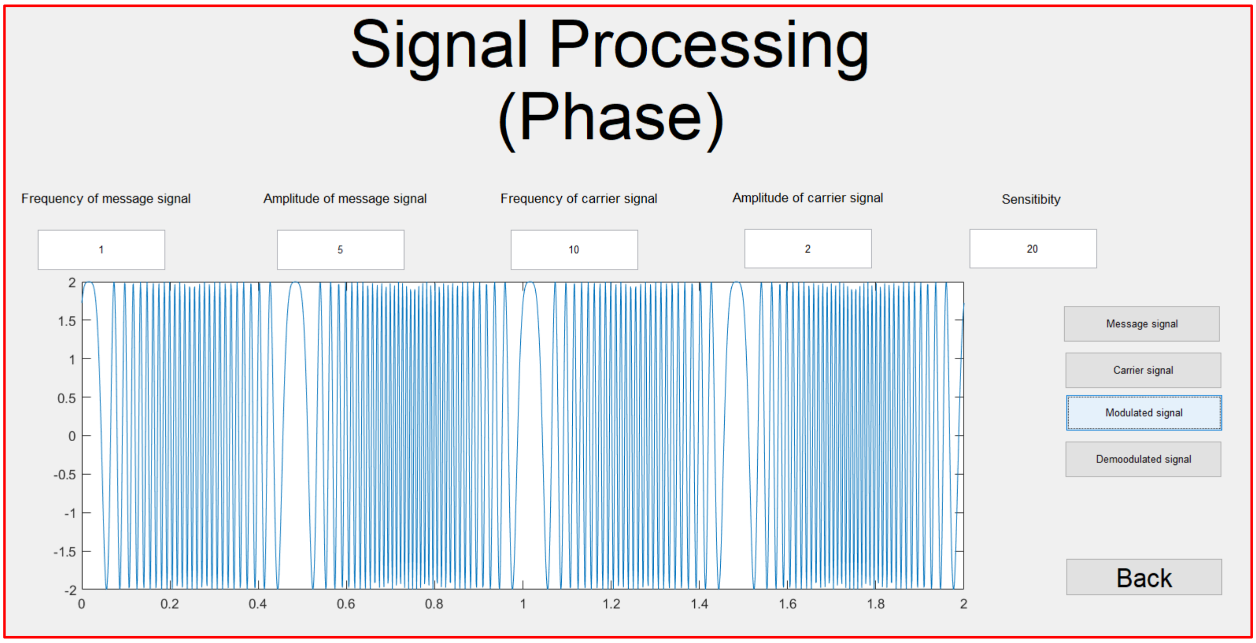
Message Signal



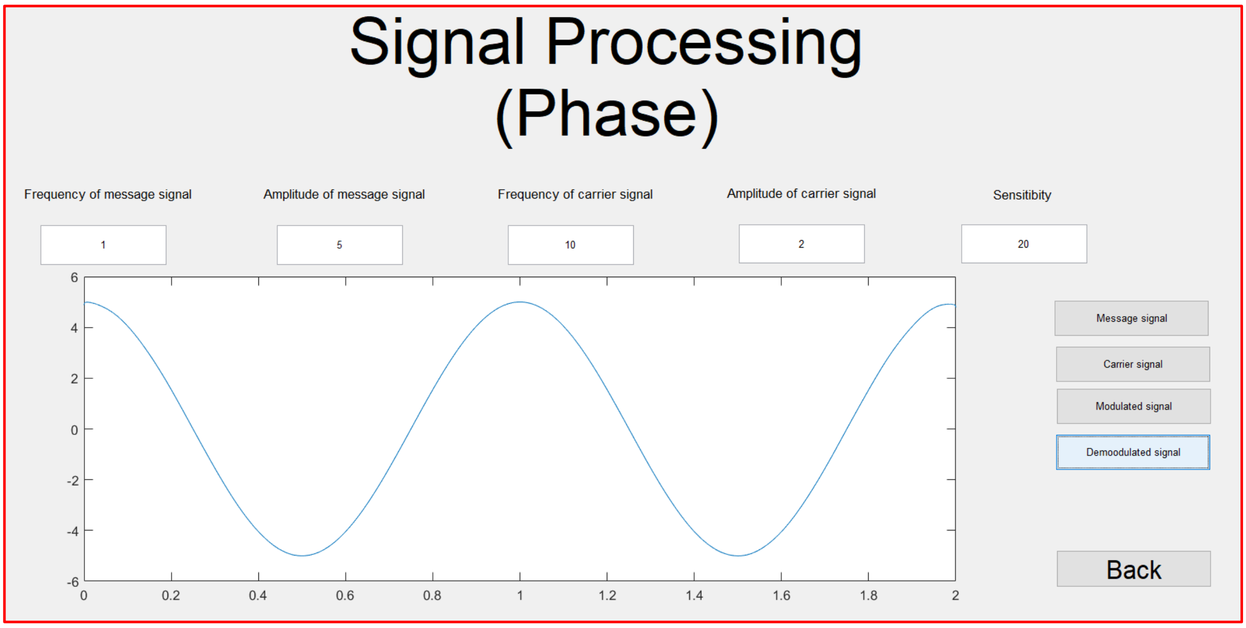
Carrier Signal



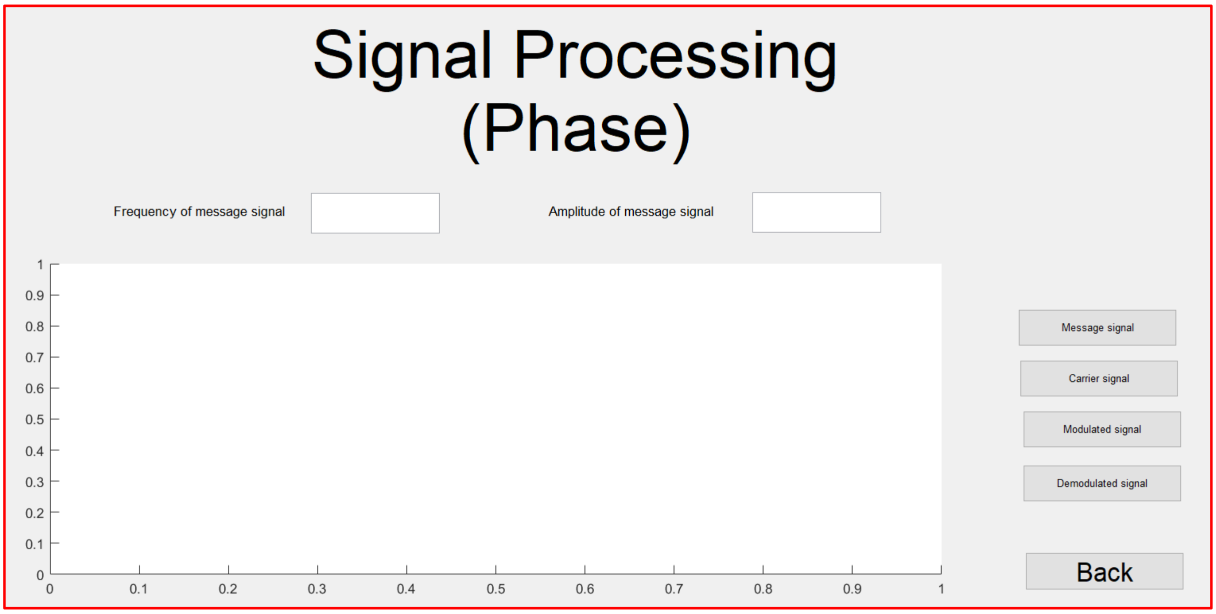
Modulated Signal



Demodulated Signal



7. Now pressing **Back** button we can get back to the window of step 5 and select **Square** button. After selecting the **Square** button the following window will open.

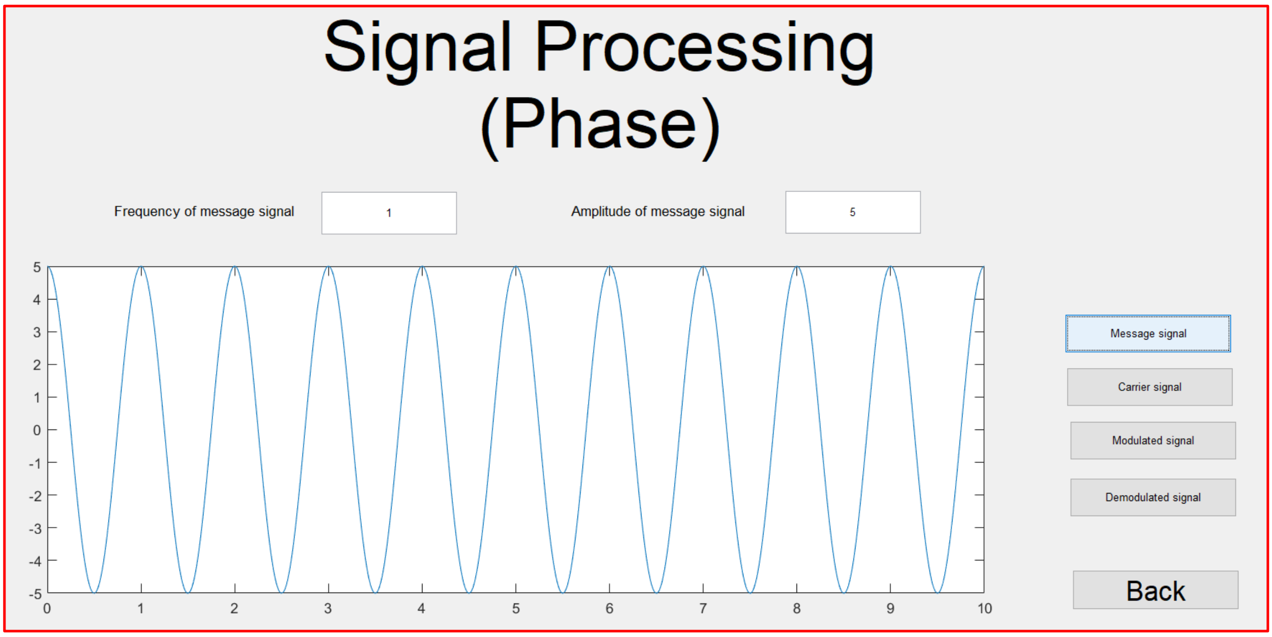


Here, we can input the Amplitude & Frequency of the Message signal and get the graph of the Message signal, Carrier signal, Modulated signal & Demodulated signal.

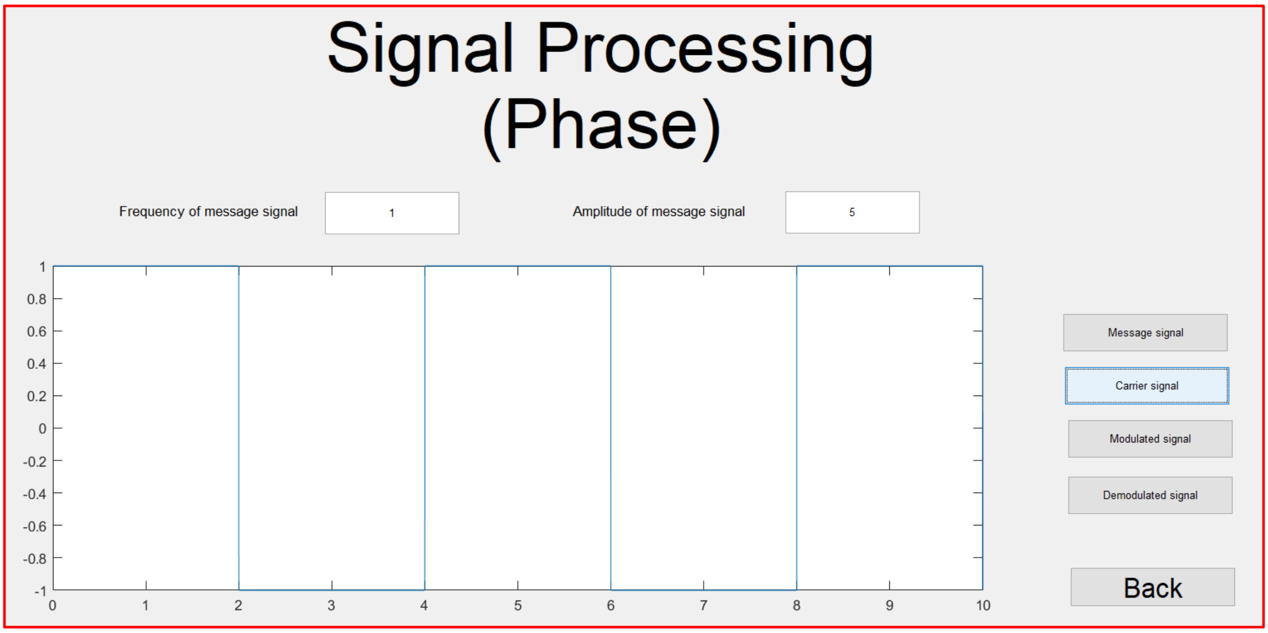
In this part we do not take any input for the Carrier signal because we have used a fixed Square signal as the Carrier signal. As the Phase Modulation-Demodulation through a square signal do not depend on the frequency or time period or amplitude of the square signal that's why we have used a built in square signal. Again we also do not take phase sensitivity as input because if we using square signal as the carrier signal then there is no need of Phase sensitivity.

For some definite input,

Message Signal

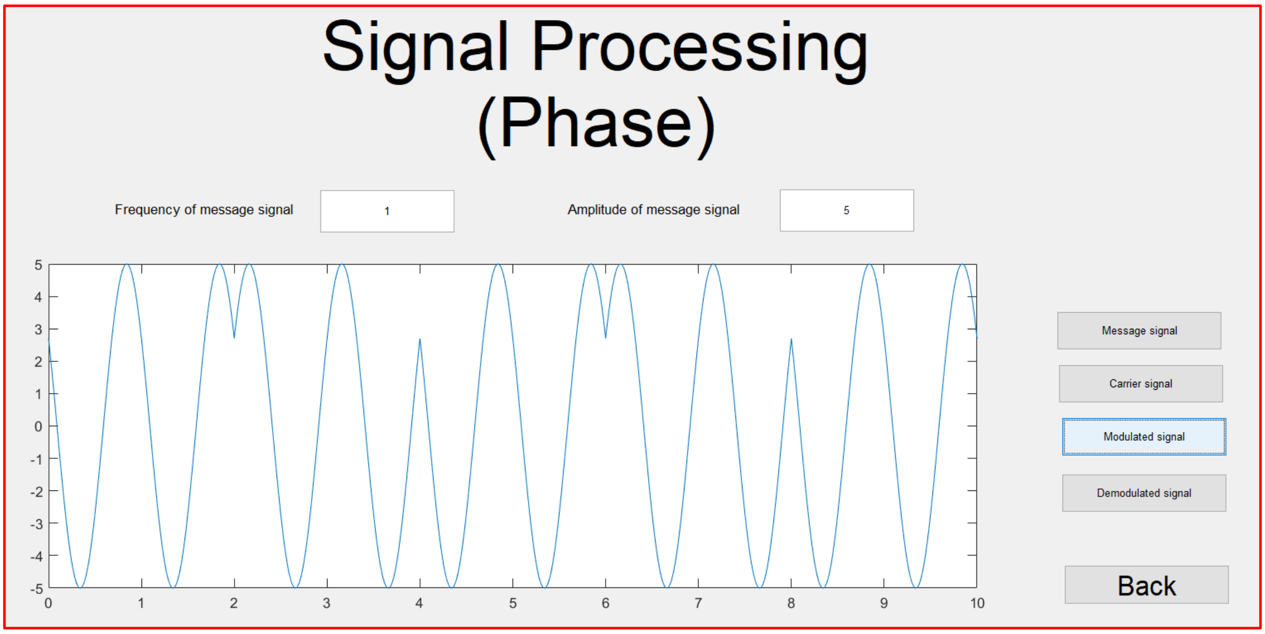


Carrier Signal

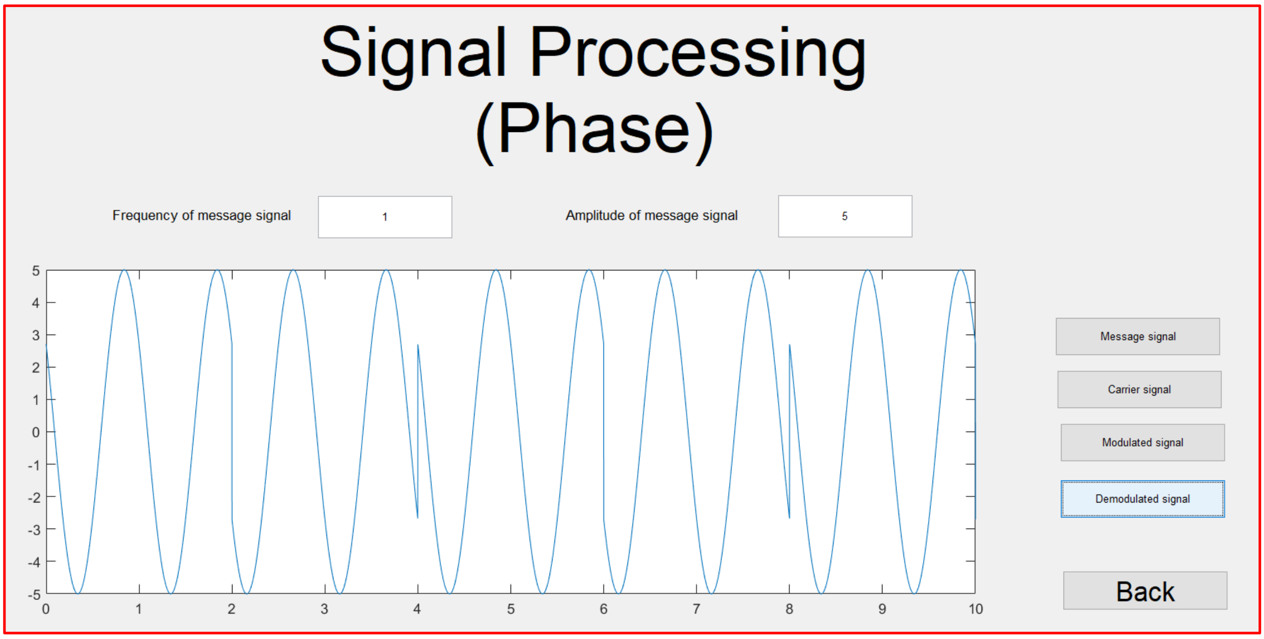


Here it is the pre-determined Square signal which we have used as the Carrier signal.

Modulated Signal



Demodulated Signal



Here in the graph of the Demodulated signal we can see that there is a slight difference from the graph of the Message signal but both of the graphs should be the same. This difference is created because of having some extra component after doing the Modulation process which we cannot be able to remove.

Limitations:

1. After doing Frequency Demodulation we can see a slight difference in the graph of the Demodulated signal than that of the Message signal. But these two graphs should be the same. We cannot be able to do the exact and proper demodulation to match this with the Message signal.

2. In the Phase demodulation using the square signal there is also a slight difference in the graph of the Demodulated signal and Message signal. This is because there is some extra components are associated with the modulated signal after doing Modulation. And after doing demodulation we cannot be able to remove all of the unnecessary components and have failed to extract the perfect original signal.

3. If we input bigger frequency of the Message & Carrier signal then we may get all of the required graphs but then the graphs will be so much scribbled. That’s why we cannot properly differentiate and perfectly understand the differences among the particular graphs.

4. There are no zoom in or zoom out system to see our output graphs with more perfection and in a broader angle.

Conclusion:

Our target was to build up a platform and a system where we can perform and observe the Modulation & Demodulation process graphically. We wanted to create a system where we can input just the amplitude and frequency of the message & carrier signal and get the detailed output such that we can easily be able to see the basic difference of modulation & demodulation process. Further we also wanted to make such a user friendly environment in where we can be able to input frequently as per our need and get the perfect result. In spite of having a little bit limitations we think we are able to establish the project with a significant amount of perfection that completes all of our objectives perfectly.