

EEL 4350 – Principles of Communication

Project 2

Due Tuesday, February 10 at the Beginning of Class

Description

In this project, MATLAB and Simulink are used to construct a system experiment. The experiment contains filter and modulation principles. The Fast Fourier transform used in Project 1 will be used in Project 2 as well. Spectrum analysis for AM double-sideband suppressed carrier (AM DSB-SC) modulation is performed.

Deliverables

Your deliverable will be in the form of a hard-copy report with the following clearly labeled sections:

- Cover sheet including your name, the name and number of the course, and the project number (2).
- Brief Description of Project (1 to 2 paragraphs recommended)
- MATLAB (.m) file and Simulink model diagram. For this project you should create at least a main .m file that performs all operations required along with a Simulink model diagram containing the system construction. You should place comments in the program code that would be helpful to someone reading your program; i.e. at least state where each section of code begins. Use the % sign before placing comments in the .m file.
- Description of results and answers to questions organized as given below with plots included as numbered figures (“Figure 1”, “Figure 2”, etc.). The Figures should be placed at appropriate places within the body of your descriptions.
- Conclusions (likely a 1 paragraph summary)

Failure to adhere to this format will result in deduction of points.

Project Summary:

In this project, you will begin with a message signal that is

$$s(t) = \cos(2\pi \cdot 300t) + \cos(2\pi \cdot 500t) \quad (1)$$

Interference from a 60 Hz power-line source will be included in the simulation. The message signal, including the added interference, is given by

$$m(t) = \cos(2\pi \cdot 300t) + \cos(2\pi \cdot 500t) + 0.2 \cos(2\pi \cdot 60t) \quad (2)$$

A high-pass filter is added to the input to filter out the 60 Hz interference. Next, the signal is multiplied by a 1 kHz carrier signal to provide amplitude modulation. This provides a shift of the spectrum to center it around the carrier frequency and the negative of the carrier frequency, as described in the text. Following this, demodulation is performed. The demodulation in this case is performed by multiplying by a signal with the carrier frequency; this will provide copies of the spectrum (of half the magnitude) to 2 times the carrier frequency and to DC (0 Hz) (you will be asked to show why multiplication by the carrier produces this result). Finally, appropriate filtering is used to separate the 300 Hz and 500 Hz components of the message at the output.

Project Description and Assignment

You will create a system model in Simulink, a subprogram operated within and by MATLAB. To create a new model in Simulink, go to New → Simulink Model in the main MATLAB window (Figure 1). Once in the Simulink window, click on the “Library Browser” button, as shown in Figure 2. This will open a window (Figure 3). From the menu, you can select items to place in your system block diagram.

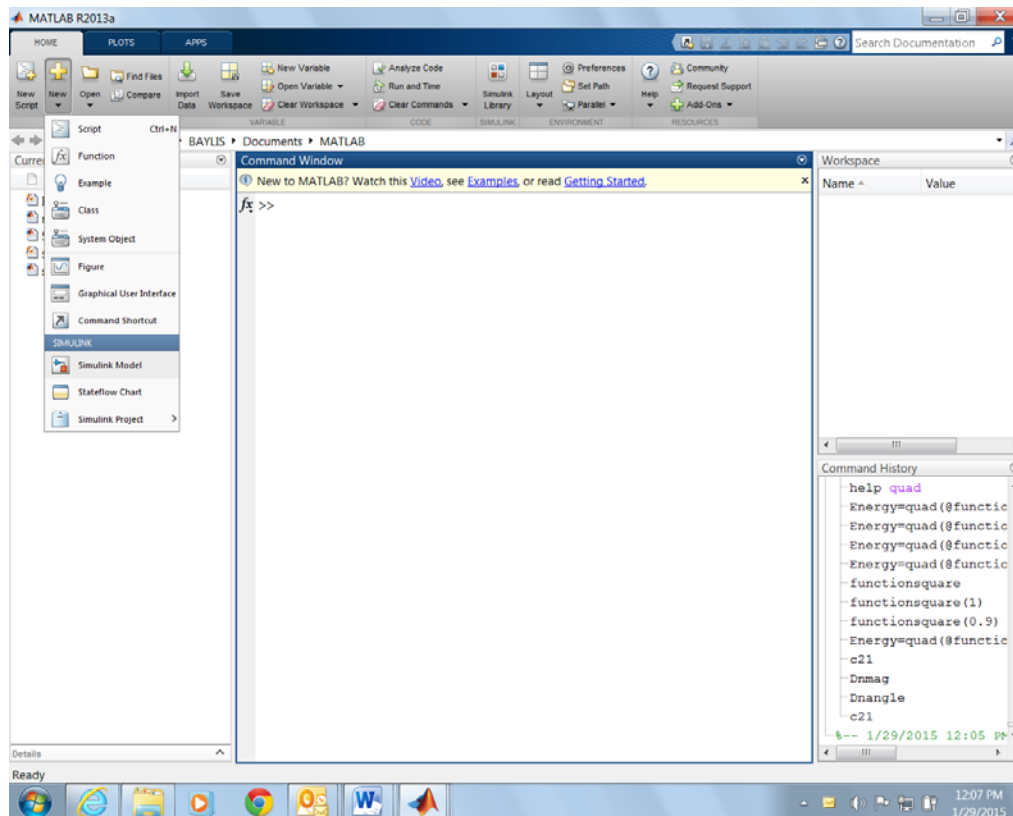


Figure 1. Opening a New Simulink Model

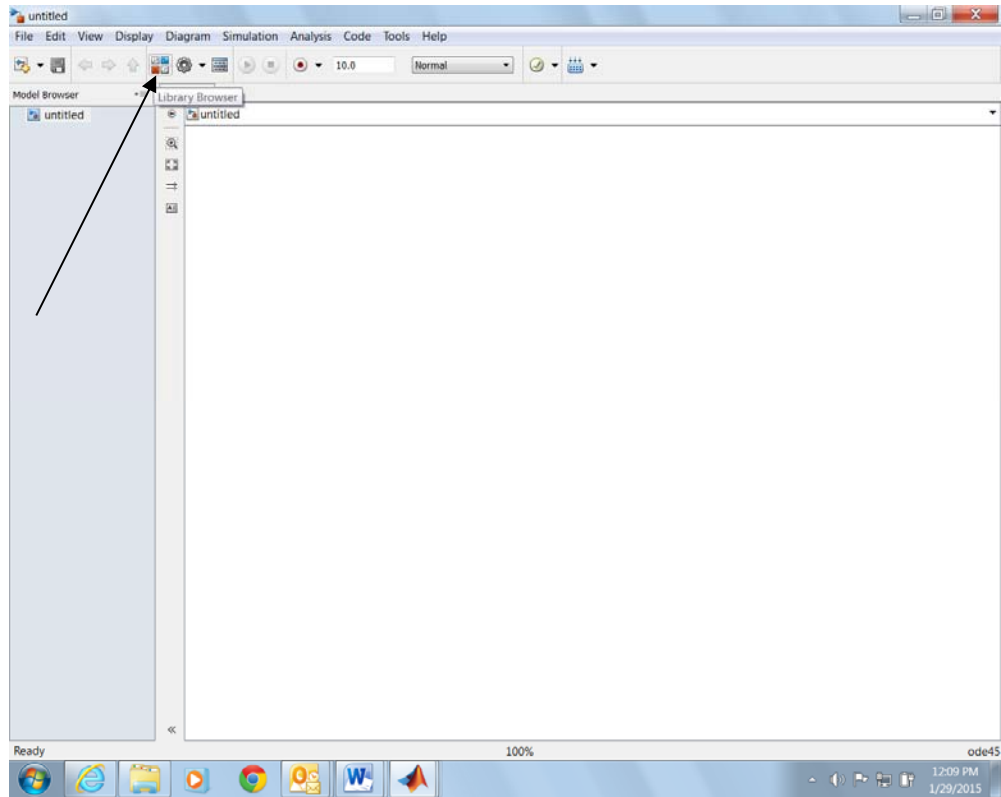


Figure 2. Opening the Library Browser

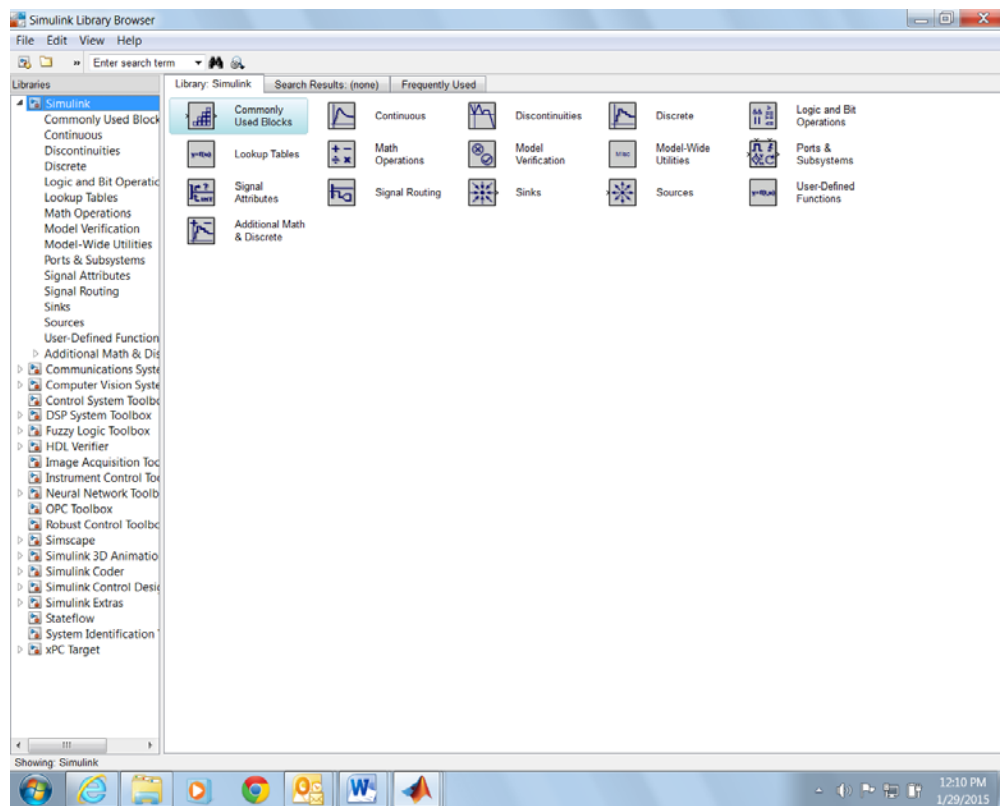


Figure 3. Simulink Library Browser

Figure 4 shows the completed drawing of your diagram. Begin by placing three sinusoidal sources in the drawing. Go to the Sources menu and select “Sine Wave.” Place three copies in the drawing, as shown in Figure 4. To place the Sine Wave sources, go to the Sources menu and select “Sine Wave.” Left click on the Sine Wave icon and hold the mouse button down, dragging it onto the model screen. Release the button to place the component. If you desire to give the component a different name, double click on the text below the icon and type in the desired name. Next, modify the properties of the icon by double clicking on the icon itself. The properties box with the appropriate settings for the 300 Hz cosine wave sources appear as shown in Figure 5. Note that we want to create a cosine, so the phase of the sine will be 90 degrees (a sine function shifted to the left by $\pi/2$ radians is a cosine function). The sample time should be set small enough so that the sine wave can be clearly defined given the frequencies to be used in the problem. Use 0.0001 seconds in this project for all of the sine wave sources (including the carrier for the modulation).

The “Scope” and “To Workspace” boxes come from the “Sinks” menu. The scope allows the time plot of the signal at this point in the diagram to be plotted just by double clicking on the icon. The “To Workspace” creates a vector of values that can be manipulated by a MATLAB script or in the MATLAB command window. We will use this to pass on the vector of values for our “function” “mt”, (or $m(t)$, the message signal). We will write code in our MATLAB script to plot the Fast Fourier Transform of this signal (similar to your first project). After inserting each “To Workspace” diagram, name it by clicking on the box. Also, you must change the “Save Format” of each box to “Structure”, as shown in Figure 6.

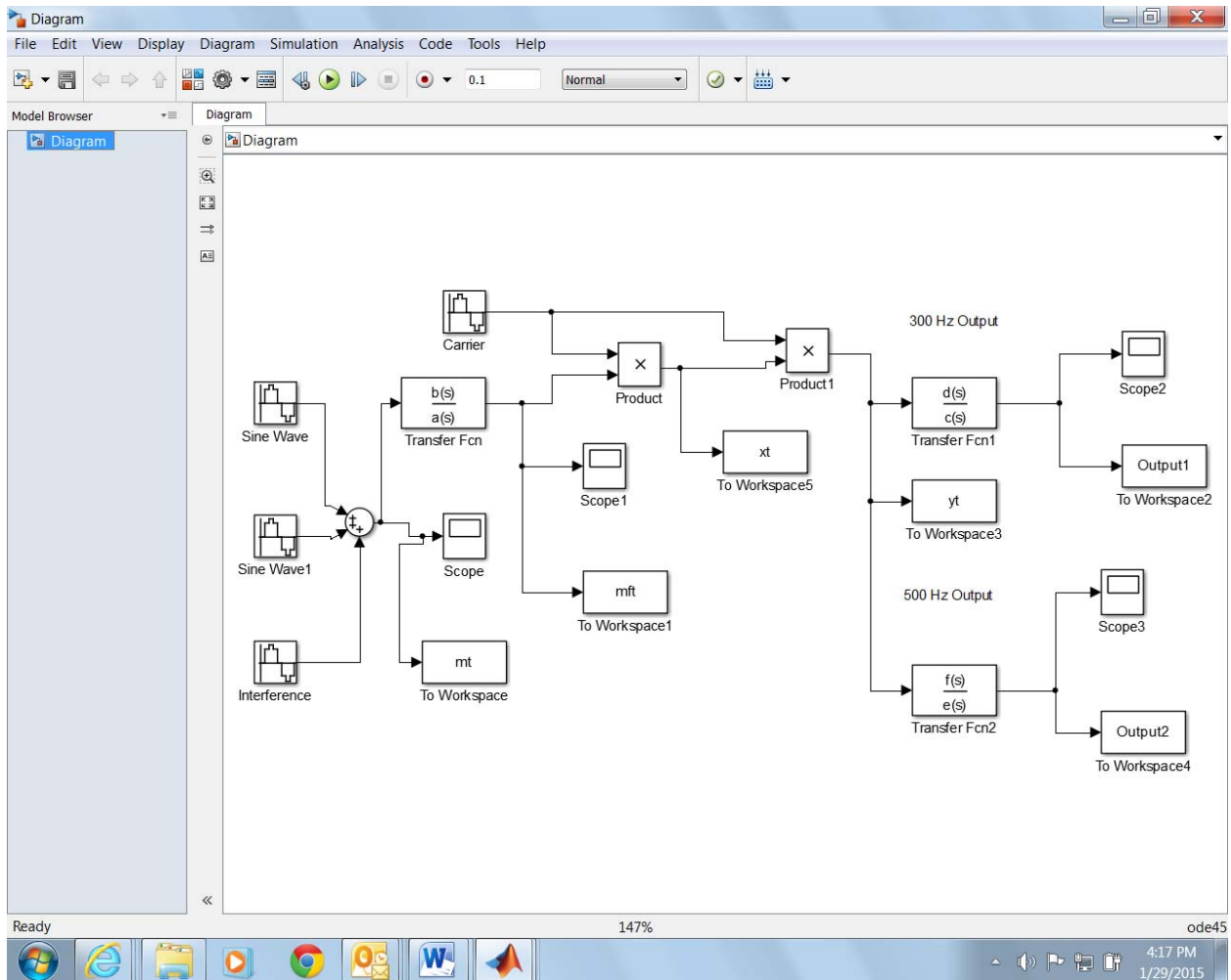


Figure 4. Completed Simulink Model for Experiment

Source Block Parameters: Sine Wave

Sine Wave

Output a sine wave:

$$O(t) = \text{Amp} * \text{Sin}(\text{Freq} * t + \text{Phase}) + \text{Bias}$$

Sine type determines the computational technique used. The parameters in the two types are related through:

$$\text{Samples per period} = 2 * \pi / (\text{Frequency} * \text{Sample time})$$
$$\text{Number of offset samples} = \text{Phase} * \text{Samples per period} / (2 * \pi)$$

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type: Time based

Time (t): Use simulation time

Amplitude: 1

Bias: 0

Frequency (rad/sec): $2 * \pi * 300$

Phase (rad): 0

Sample time: 0.0001

Interpret vector parameters as 1-D

OK Cancel Help Apply

Figure 5. Properties Box for 300 Hz Cosine Wave

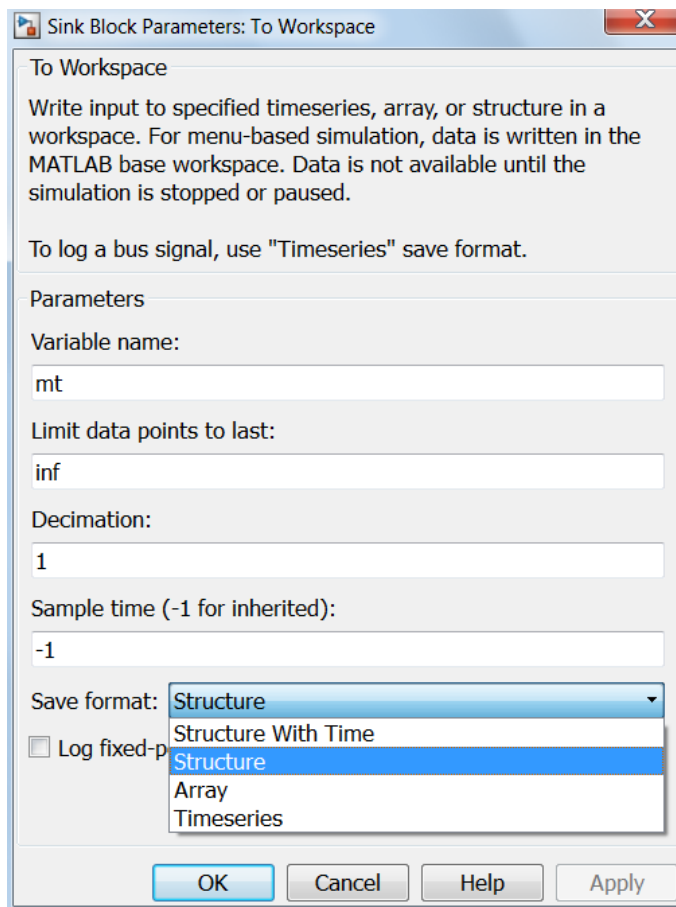


Figure 6. Block Parameter Block for “To Workspace” Blocks: “Structure” must be chosen as the “Save Format”.

Enter a “Transfer Function” icon. This icon will come from the “Continuous” menu. Enter the settings as shown in Figure 7. This transfer function will be set up to describe a high-pass Butterworth filter that will be used to remove the 60 Hz interference from the signal. The entries “b” and “a” will be vectors containing polynomial coefficients defined by the Butterworth filter function to be utilized in your MATLAB program.

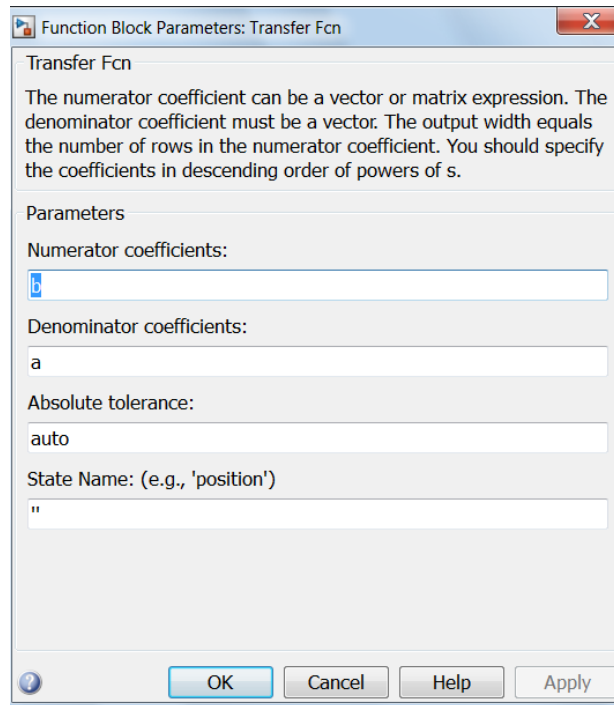


Figure 7. Settings for the Transfer Function Describing the Interference-Removing Filter

The product operator can be found in the Math Operations library and can simply be placed in the window without modification of its settings. A sine wave is added into the system to represent a 1000 Hz carrier for the modulation; its settings should appear as shown in Figure 8. Complete the diagram as shown in Figure 4. For the second transfer function block, enter d as the numerator and c as the denominator, and for the third block, enter f as the numerator and e as the denominator. Finally, go to the pull-down menus in Simulink, select Simulation → Configuration parameters, and set the start time to 0 and the stop time to 0.1, as shown in Figure 9.

Source Block Parameters: Carrier

Sine Wave

Output a sine wave:

$$O(t) = \text{Amp} * \sin(\text{Freq} * t + \text{Phase}) + \text{Bias}$$

Sine type determines the computational technique used. The parameters in the two types are related through:

$$\text{Samples per period} = 2 * \pi / (\text{Frequency} * \text{Sample time})$$
$$\text{Number of offset samples} = \text{Phase} * \text{Samples per period} / (2 * \pi)$$

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type: Time based

Time (t): Use simulation time

Amplitude: 1

Bias: 0

Frequency (rad/sec): $2 * \pi * 1000$

Phase (rad): 90

Sample time: 0.0001

Interpret vector parameters as 1-D

OK Cancel Help Apply

Figure 8. Settings for Carrier Signal

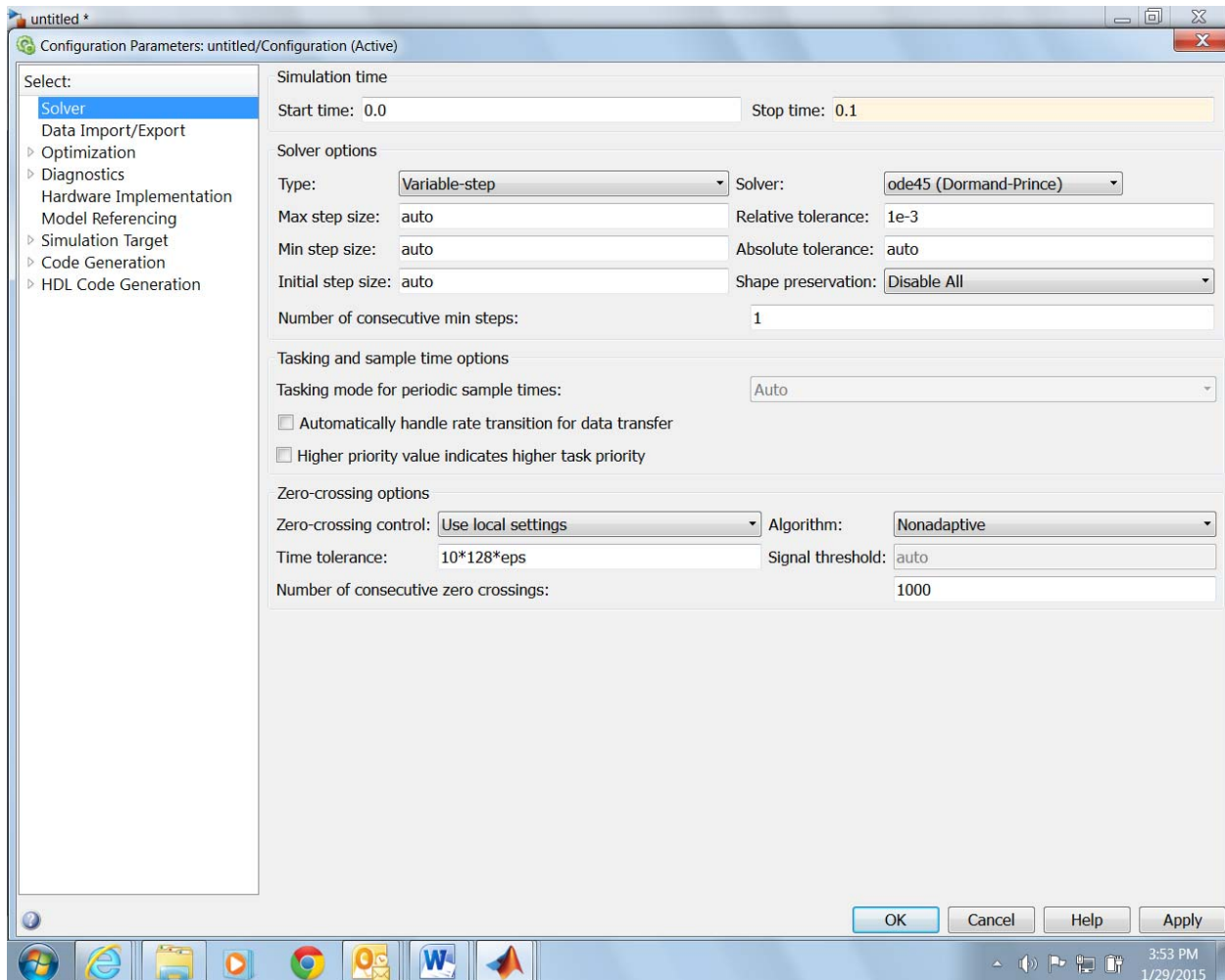


Figure 9. Configuration Parameters Settings

Following the completion of the Simulink diagram, create a new .m file with the following code (or some similar version). The first code defines the three transfer function blocks. Note that the first transfer function is for the interference removal; a high-pass filter with a cutoff frequency of 100 Hz should be sufficient to remove the unwanted 60 Hz component. The second set of coefficients [d,c] selects the 300 Hz component at the output, describing a low-pass filter with a 400 Hz cutoff frequency. Note that the cutoff frequency is somewhat close to the desired signal frequency; this may cause some modification of the amplitude of the signal, since the filter is not an ideal filter. However, this is necessary because the 500 Hz signal must be rejected by this filter. Finally, a bandpass filter is created with [f,e] with a vector describing the two cutoff frequencies: 400 Hz and 600 Hz. We must use a bandpass filter rather than a high-pass filter because there is a spectral component at 2000 Hz due to the demodulation that must also be rejected.

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%ELC 4350 - Principles of Communication
%Project 2
%Dr. Charles Baylis
%This project plots different signals in a simple communication system
%simulated with Simulink.

%Define the filter parameters
[b,a]=butter(9,2*pi*100,'high','s');
[d,c]=butter(9,2*pi*400,'low','s');
[f,e]=butter(9,[2*pi*400 2*pi*600],'s');

%Simulate the model:
sim('Diagram');

%Plot the Fourier Transform of m(t), the message signal:
N0 = length(mt.signals.values);
T0=0.1;
Ts = T0/(N0-1);
m = mt.signals.values;
Dn=fft(mt.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 1000 -1 1])
title('Spectrum of the Message Signal with Interference M(f)')

%Plot the exponential Fourier series of mft, the filtered message signal:
N0 = length(mft.signals.values);
T0=0.1;
Ts = T0/(N0-1);
m = mft.signals.values;
Dn=fft(mft.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 1000 -1 1])
title('Spectrum of the Filtered Message Mf(f)')

%Plot the exponential Fourier series of x(t), the modulated signal:
N0 = length(xt.signals.values);
T0=0.1;
Ts = T0/(N0-1);
m = xt.signals.values;
Dn=fft(xt.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 2000 -1 1])
title('Spectrum of the Modulated Signal X(f)')

%Plot the exponential Fourier series of y(t), the demodulated signal:
N0 = length(yt.signals.values);
T0=0.1;
Ts = T0/(N0-1);

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m = yt.signals.values;
Dn=fft(yt.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 1000 -1 1])
title('Spectrum of the Demodulated Signal Y(f)')

%Plot the exponential Fourier series of Output1, the received 300 MHz
%signal:
N0 = length(Output1.signals.values);
T0=0.1;
Ts = T0/(N0-1);
m = Output1.signals.values;
Dn=fft(Output1.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 1000 -1 1])
title('Spectrum of the Received 300 MHz Signal')

%Plot the exponential Fourier series of Output2, the received 500 MHz
%signal:
N0 = length(Output2.signals.values);
T0=0.1;
Ts = T0/(N0-1);
m = Output2.signals.values;
Dn=fft(Output2.signals.values)/N0;
[Dnangle,Dnmag] = cart2pol(real(Dn),imag(Dn));
k=0:length(Dn)-1;k=k';
f = k/T0;
figure
stem(f,Dnmag);axis([0 1000 -1 1])
title('Spectrum of the Received 500 MHz Signal')

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Report

Run your MATLAB script and provide the following items and discussions in your report.

1. Provide a copy of your MATLAB script (no need to label this as a Figure) and your Simulink diagram (label this as Figure 1).
2. The Input Signal. Double-click on the scope following the input signal including the interference and show a snapshot in time of the scope output (you will need to figure out how to adjust the scope scale appropriately: click on the magnifying glass icon with the “x” on it and drag it over the time interval you would like to show in the plot; a similar operation can be done to modify the y-axis scale). Place the scope output in your report and label it as Figure 2. Comment on the shape of this wave – does it appear like the sum of three sinusoids would be expected to appear? Your MATLAB script has computed the FFT of signal 1 – show this as Figure 3 in your report (MATLAB will label it as “Figure 1”, but do not

worry about this). Note that the script plots the spectrum versus Hz frequency, not radian frequency. Does this spectrum correspond with your expectations?

3. Provide the plot from the scope associated with the signal following interference removal (mft) and show this as Figure 4 in your report. How does this signal appear different from the signal that included the interference? The FFT has been computed for this signal as well; plot this as Figure 5. According to this spectral plot, has the interference been successfully removed?
4. Show the plot of the FFT of x_t (the signal after modulation) and label this as Figure 6. Does this spectral plot correspond with your expectations from the theory developed in the lecture and in the textbook? State appropriate identities. How are the amplitudes of the “copies” of the message spectrum changed? Is this expected from the identities?
5. Show the FFT of the signal after the next multiplication (the demodulation); this is “ y_t ”. Label this as Figure 7. Where are the spectral components? How does this correspond mathematically with your expectations (hint: argue based on $\cos^2 x = \frac{1}{2} + \frac{1}{2} \cos 2x$ and the half-angle identities given on the first day of class)?
6. Examine the time (scope) and FFT plots (from the script) of Output 1; this should be the received 300 MHz signal. Label these as Figures 8 and 9, respectively. Was the filtering successful?
7. Examine the time (scope) and FFT plots (from the script) of Output 2; this should be the received 500 MHz signal. Label these as Figures 10 and 11, respectively. Was the filtering successful?
8. List any conclusions you may have reached concerning the modulation/demodulation/filtering process.

Submit your report with a cover sheet as in Project 1. The format of your answers to the above questions should be a coherent report, answering the questions in order; no numbering for the questions is required; you may choose to subsection the work into reasonable subsections if desired for organization.