EE/TE 4385

Lab 4: AM (De)Modulation

Lab Report Due: 9/27/06, 2PM,

Amplitude (De)Modulation: LabVIEW Implementation

Introduction:

Modulation is a process by which characteristics of a high-frequency carrier signal are altered to convey information contained in a lower-frequency message. Though it is theoretically possible to transmit baseband signals (or information) without modulating the data, it is far more efficient to send messages by modulating the information onto a carrier wave. High frequency waveforms require smaller antennae for reception, efficiently use available bandwidth, and are flexible enough to carry different types of data. There are a variety of modulation schemes available for both analog and digital modulation.

Background:

Amplitude Modulation (AM) is an analog modulation scheme where the amplitude (A) of a fixed-frequency carrier signal is continuously modified to represent data in a message. The carrier signal is generally a high frequency sine wave used to "carry" the information on the *envelope* of the message. The result is a double-sideband signal, centered on the carrier frequency, with twice the bandwidth of the original signal.

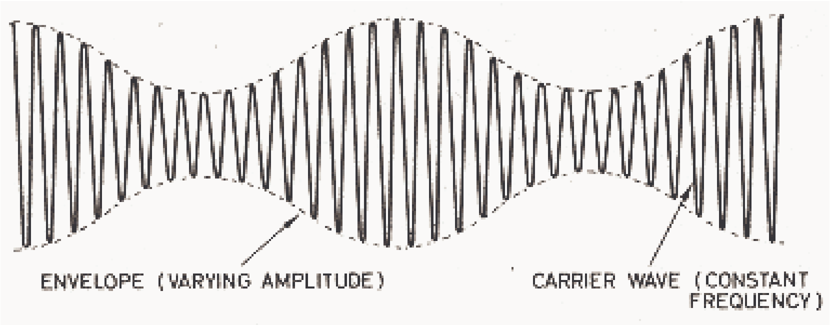


Figure 1 - Time domain of an AM signal

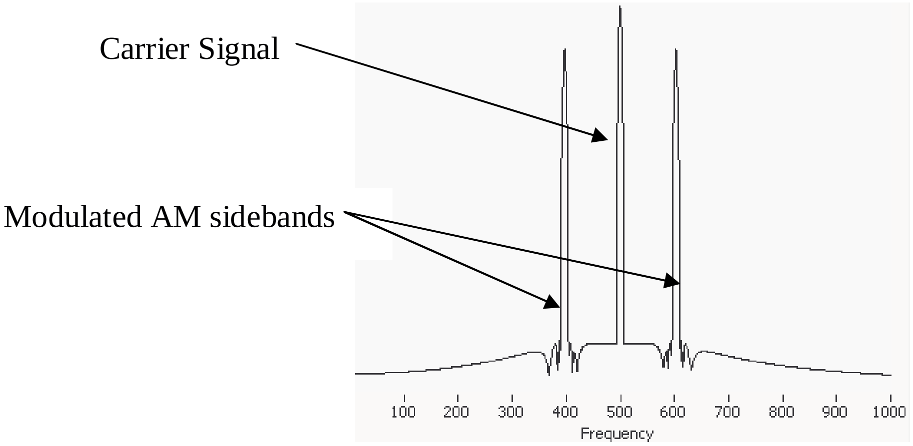


Figure 2 – Frequency domain of an AM signal

The following algorithm is commonly used to represent amplitude modulation:

$$y(t) = C\sin(\omega_c t) + M\frac{\cos(\phi - (\omega_m - \omega_c)t)}{2} - M\frac{\cos(\phi + (\omega_m + \omega_c)t)}{2}$$

Gathering like terms and simplifying the equation leaves:

$$y(f) = A(1 + k\sin(\omega_m t + \varphi))\sin(\omega_c t)$$

The main advantage of using AM modulation is that it has a very simple circuit implementation (especially for reception), creating widespread adoption quickly. AM modulation however wastes power and bandwidth in a signal. The carrier requires the majority of the signal power, but actually does not hold any information. AM uses twice the required bandwidth by transmitting redundant information in both the upper and lower sidebands.

Programming:

The following steps describe how to build a VI which implements the last of the two equations shown above for Amplitude Modulation. Download AM-ModulationTemplate.vi from the course website. Inspect the front panel and block diagram that has already been created for you. When this VI is completed, you will be able to select the amplitude and frequency of both the carrier and data signals as well as see the time and frequency domain representation of the signals. The graphs display the behavior of the carrier and sideband signals as modulation parameters (amplitude and frequency) change. The following front panel represents the operation of a completed VI:

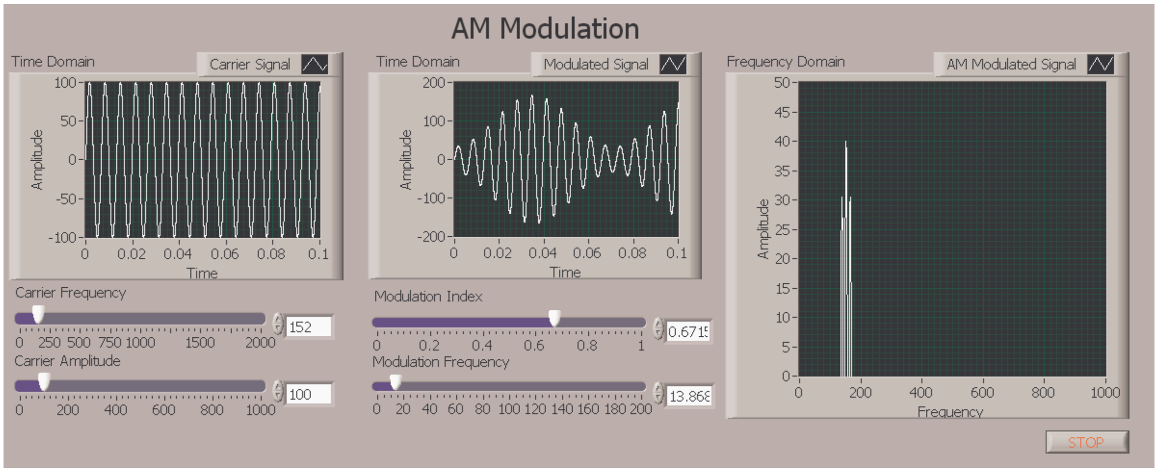


Figure 3 – Completed AM modulation VI

The block diagram consists of a while loop which contains various controls and graphs to display and control the AM signal component information.

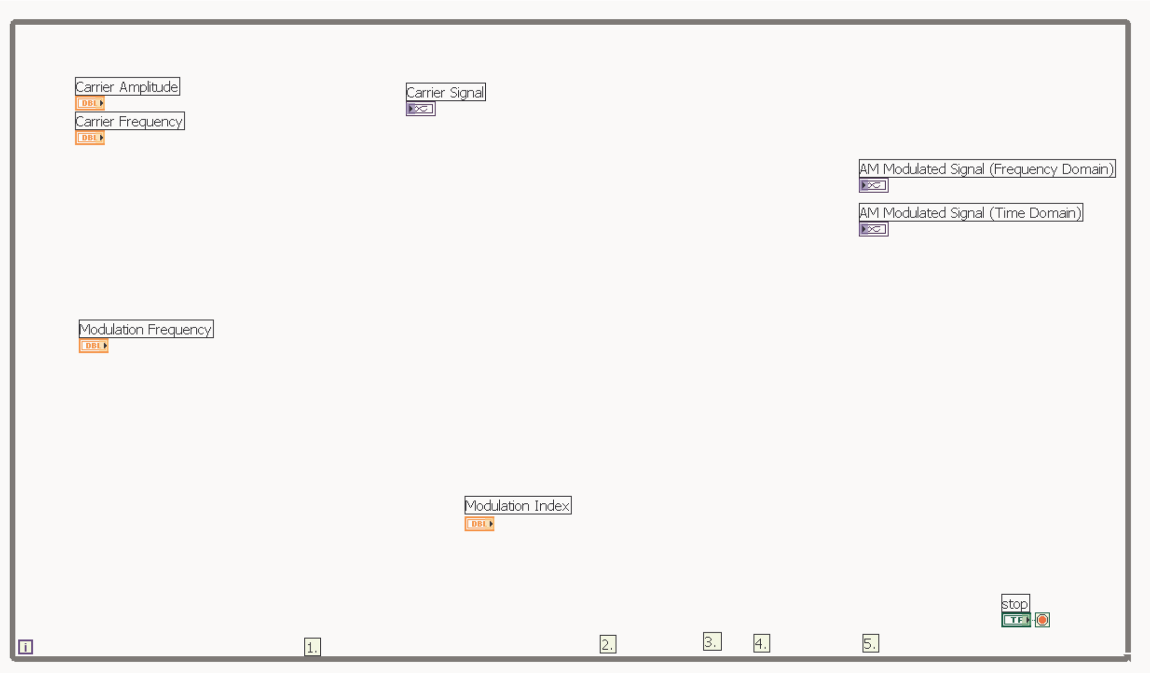
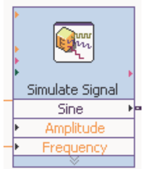
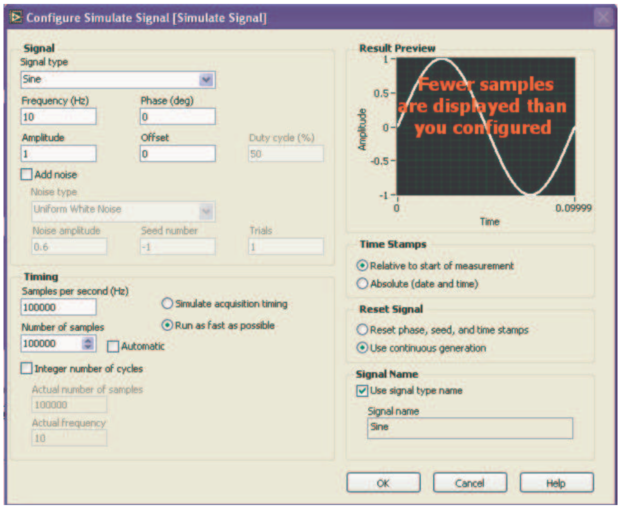


Figure 4 – AM modulation example block diagram



1) Place a “Simulate Signal” Express VI on the bock diagram. A dialog box will open to configure the function. Select the signal type to be a sine wave, set the frequency to 10 Hz, and the amplitude to 1 volt. Increase the samples per second to be 100000. Deselect the option to automatically select the number of samples, and set the value to also be 100000. Once you have finished, the dialog box should resemble the image below:



Signal
Signal type: Sine
Frequency (Hz): 10
Phase (deg): 0
Amplitude: 1
Offset: 0
Duty cycle (%): 50
☐ Add noise
Noise type: Uniform White Noise
Noise amplitude: 0.6
Seed number: -1
Trials: 1

Timing
Samples per second (Hz): 100000
○ Simulate acquisition timing
● Run as fast as possible
Number of samples: 100000
☐ Automatic
☐ Integer number of cycles
Actual number of samples: 100000
Actual frequency: 10

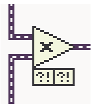
Time Stamps
● Relative to start of measurement
○ Absolute (date and time)

Reset Signal
○ Reset phase, seed, and time stamps
● Use continuous generation

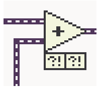
Signal Name
☑ Use signal type name
Signal name: Sine

Figure 5 – Final dialog box options for the Simulate Signal Express VI

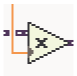
Select the "OK" button. LabVIEW will now generate all of the code required for this function. Make another copy of the function by selecting the VI on the block diagram and drag the copy to an open area. For the first Simulate Signal VI, wire the Carrier Amplitude into amplitude input and Carrier Frequency into frequency input. For the second Simulate Signal VI, wire the output of the Modulation Frequency slider control into the frequency input. Wire a constant value of 1 into the amplitude input by right-clicking on the connector and selecting "Create>>Constant".



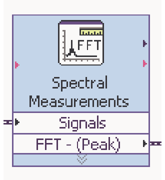
2) Place a "Multiply" VI on the block diagram. Wire the sine wave output of the second Simulate Signal VI into the multiply function. Wire the output of the Modulation Index slider control into the other input of the multiply function. Also, wire the output of the first Simulate Signal VI into the Carrier Signal graph.



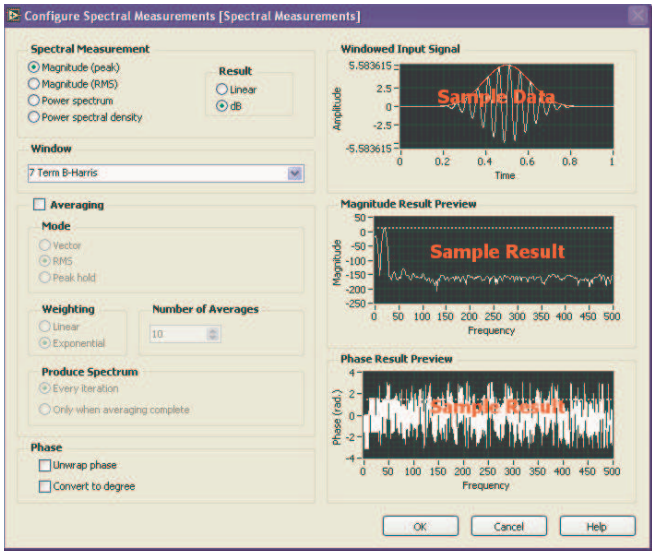
3) Place an "Add" VI on the block diagram and wire the output of the Multiply function from the last step into the function. Also wire a constant value of 1 into the Add function.



4) Place a "Multiply" VI on the block diagram. Wire the output of the Add function into the first input of multiply function. Wire the output of the first Simulate Signal VI (carrier Signal) into the second input of the Multiply function.



5) Place a "Spectral Measurements" Express VI on the block diagram. A dialog box will open to configure the function. Select the spectral measurement to be magnitude (peak) in dB. Set the Window to be "7 Term B-Harris" (do not enable averaging). Once you have finished, the dialog box should resemble the image below:



Configure Spectral Measurements [Spectral Measurements]

Spectral Measurement
- ● Magnitude (peak)
- ○ Magnitude (RMS)
- ○ Power spectrum
- ○ Power spectral density

Result
- ○ Linear
- ● dB

Window
7 Term B-Harris

☐ **Averaging**

Mode
- ○ Vector
- ● RMS
- ○ Peak hold

Weighting
- ○ Linear
- ● Exponential

Number of Averages
10

Produce Spectrum
- ● Every iteration
- ○ Only when averaging complete

Phase
- ☐ Unwrap phase
- ☐ Convert to degree

Figure 6 – Final dialog box options for the Spectral Measurements Express VI

Select the OK button. LabVIEW will now generate the code for the function. Wire the output of the add function from the previous step in the signals input connector. Also wire the output of the add function to the AM Modulated Signal (Time Domain) graph. Finally wire the output of the Spectral Measurements Express VI to the AM Modulated Signal (Frequency Domain) graph.

Your VI is now complete. The block diagram of the completed program should resemble the image below. Press the run icon to execute your VI. Vary the values for the carrier and modulation amplitude and frequency to see the effect it has on the signal.

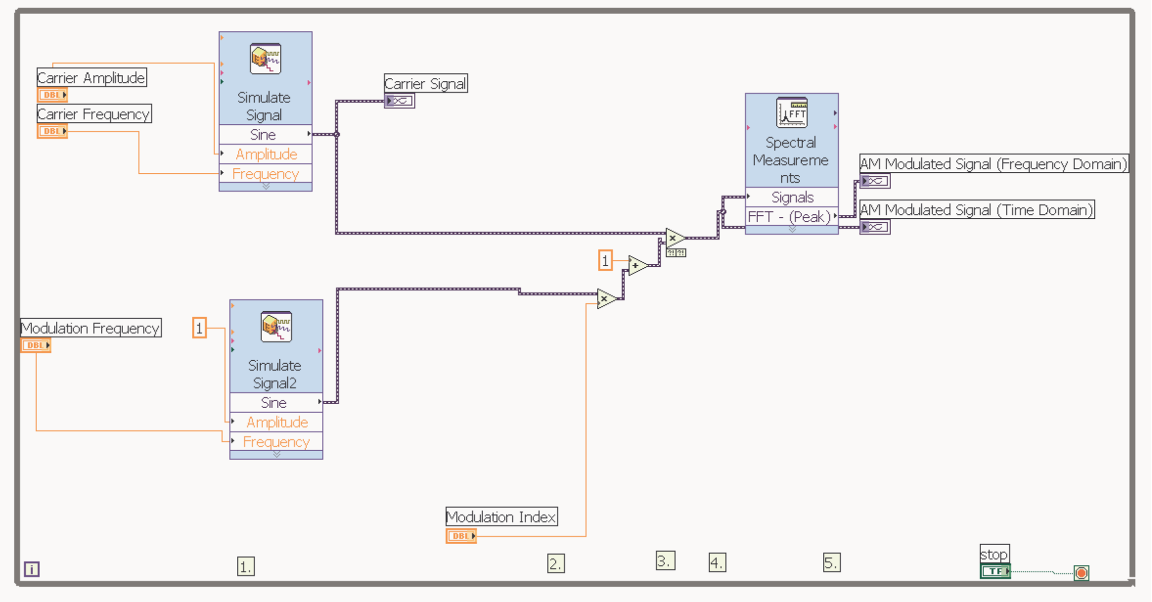


Figure 6 – Completed AM modulation block diagram

AM Demodulation Using LabVIEW:

We will use the basic demodulation approach with full rectification and low pass filter followed by a DC removal. Using the absolute value, Filter, and AC-DC estimator VI functions, implement the demodulation of AM signal to on the same modulation block diagram as shown below.

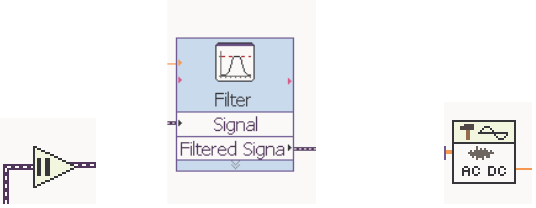


Figure 7 – LabVIEW VIs that you need to complete the AM modulation and Demodulation block diagram below

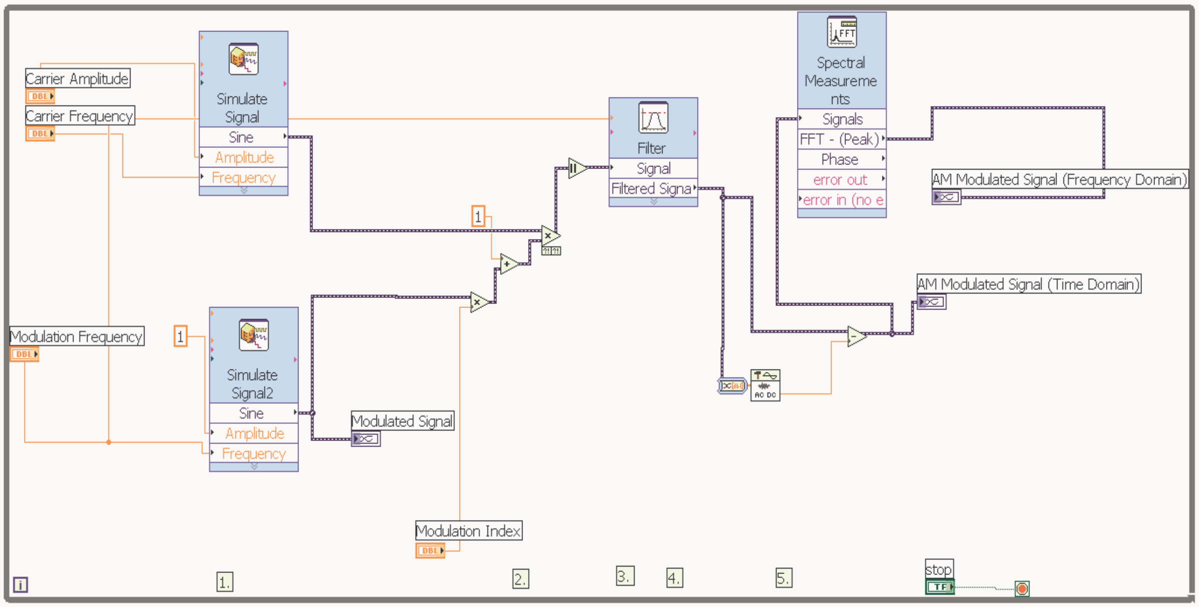


Figure 8 – Completed AM modulation and Demodulation block diagram

AM Demodulation: C6713 DSK Implementation Using CC

For this part of the lab, you will demodulate the AM signal generated by the arbitrary waveform generator on your lab bench.

- Use your project files from the previous FIR laboratory. We will add additional functions to build the AM demodulator.
- Create a lab4 project directory under myprojects subdirectory in c:\ti folder.
- Copy your FIR project files into this directory. Make sure that your program still compiles without any problem. Keep the sampling rate 8 KHz.
- Change the arbitrary waveform generator setting to Mod. You can adjust the modulation index using AM Depth and modulated signal frequency using AM Freq. Carrier Signal's properties can be adjusted pushing Sine button. Adjust Sine's frequency to 4 KHz. Modulated Signal frequency to 100 Hz.

- Inside the interrupt handler use abs function to generate fully rectified signal. Feed the rectified signal into FIR subroutine. Note that you need to redesign your filter coefficients to reduce your cutoff frequencies for passband and stopband to 300 Hz and 600 Hz using fdatool in MATLAB (look at the previous lab manual). Update your filter coefficients array and length of the filter N in your program based on your new FIR filter design
- As a last step you need to remove DC component from the demodulated signal. In order to estimate the DC component of the demodulated signal, you can use recursive exponential averaging as follows:

```
DC=rho*FIRoutput+(1-rho)*DC;
```

- You select as a low value such as 0.005 to adjust how fast your estimate reaches the DC. Use this DC value to subtract from every sample FIRoutput . Here, DC will calculated for every generated FIR filter output where FIRoutput represent your FIR output samples.
- Observe the output of C6713 DSK and compare it to the AM modulation input veify that your signal has been demodulated. Collect the results for your lab report.