Assignment 3 Output Plots

Simulating Amplitude Modulation and Demodulation

Julia Exercise 6.1 – DSB-SC AM

0.1.1 Julia Exercise 6.1a – DSB-SC Modulation

0.1.2 Simulate double sideband suppressed carrier amplitude modulation (DSB-SC AM) with the following parameters:

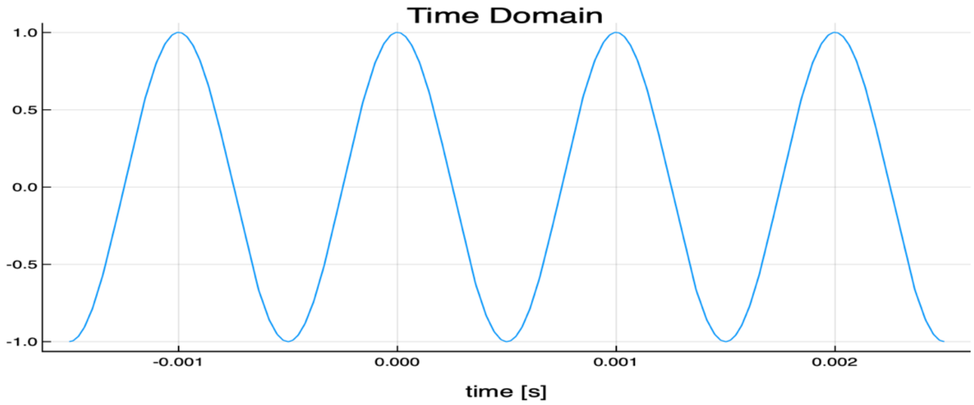
0.1.3 Modulating waveform is an audio signal: f(t) = cos(2 fmt) where fm=1 kHz.

0.1.4 Carrier wave oscillator: cos(2 fct) where fc=20 kHz.

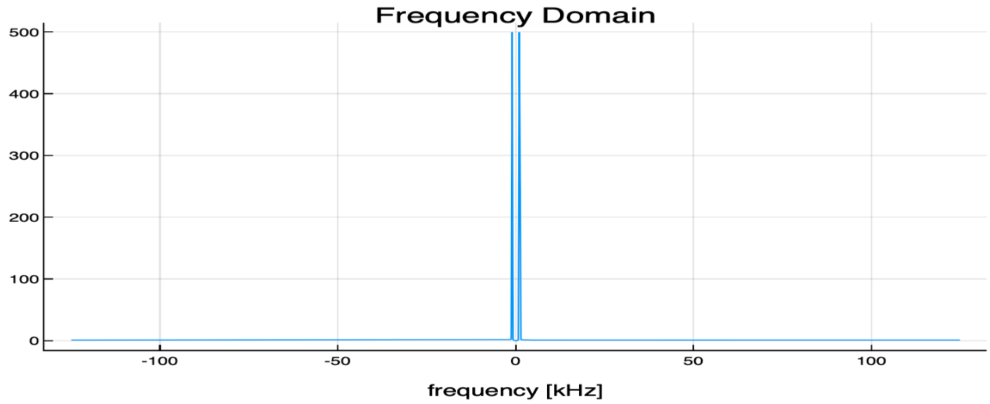
0.1.5 Modulated carrier wave signal: (t) = f(t) cos(2 fct)

0.1.6 (i) Plot the modulating waveform

Out[2]:

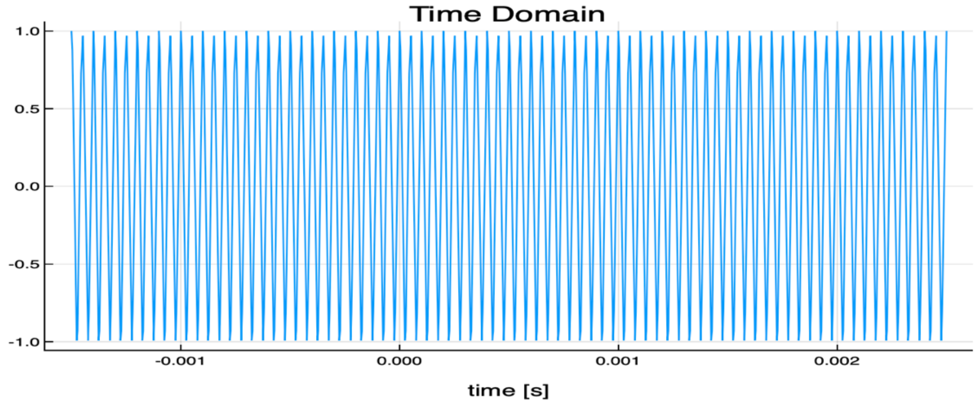


Out[5]:

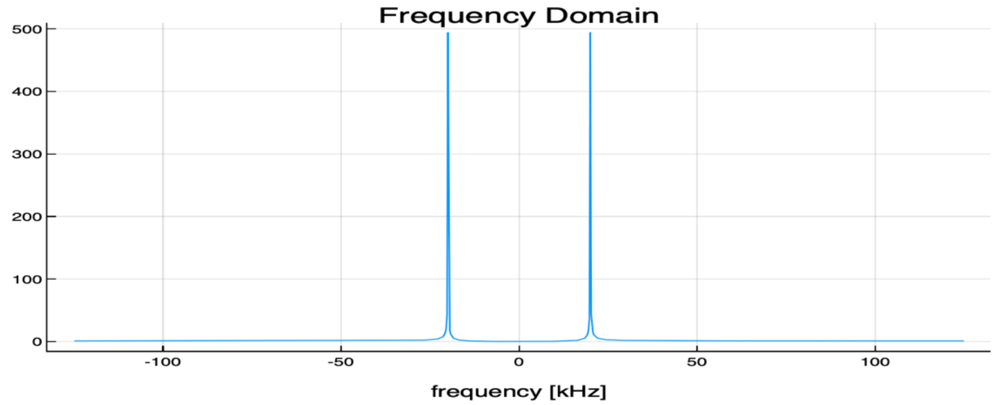


0.1.8 (ii) Plot the carrier sinusoid

Out[6]:

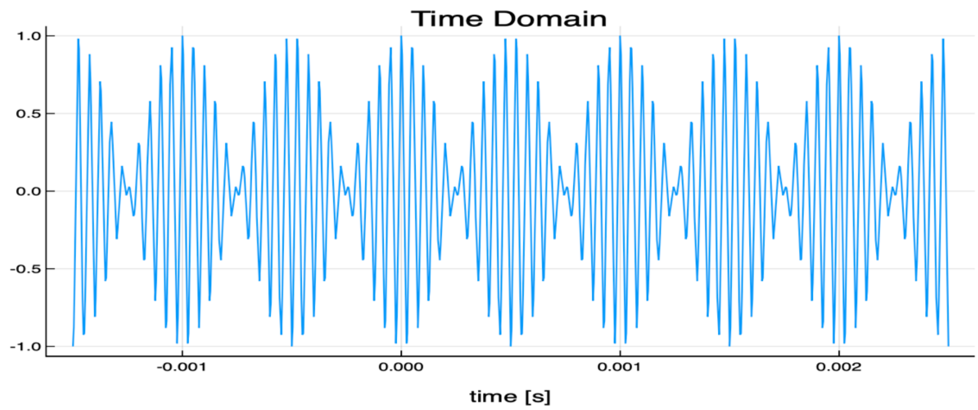


Out[9]:

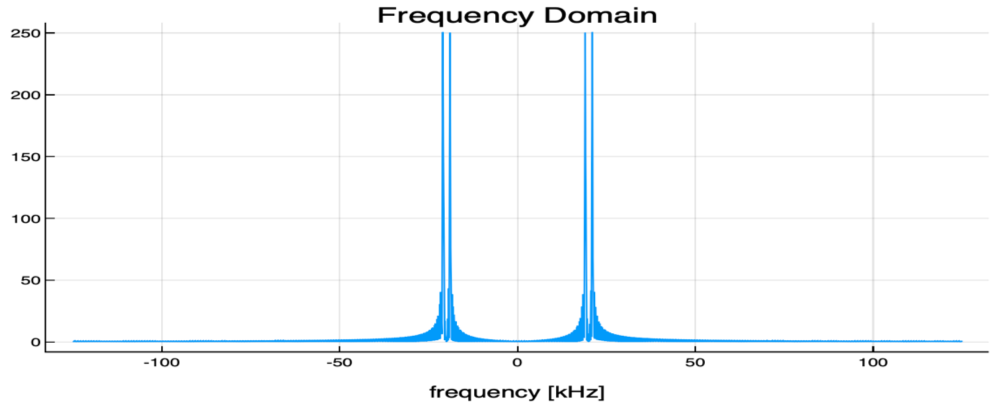


0.1.10 (iii) Plot the amplitude modulated carrier wave

Out[10]:



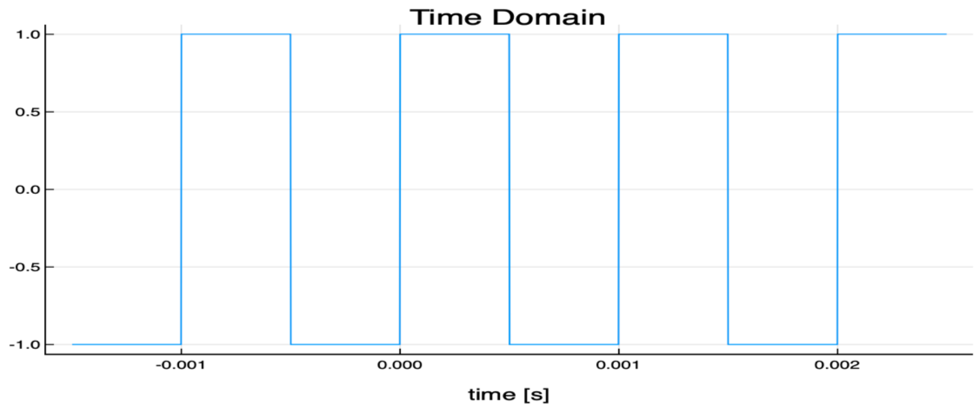
Out[13]:



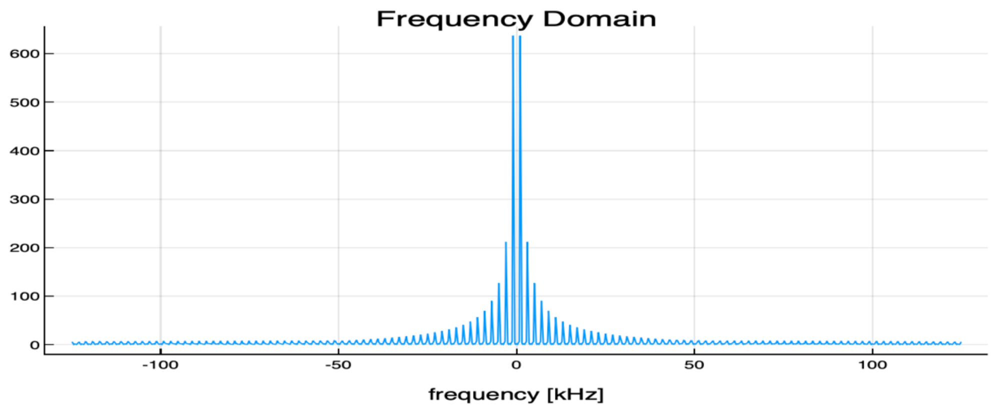
0.1.12 (iv) Using a 1kHz square wave modulating waveform

0.1.13 Plot the modulating waveform

Out[14]:

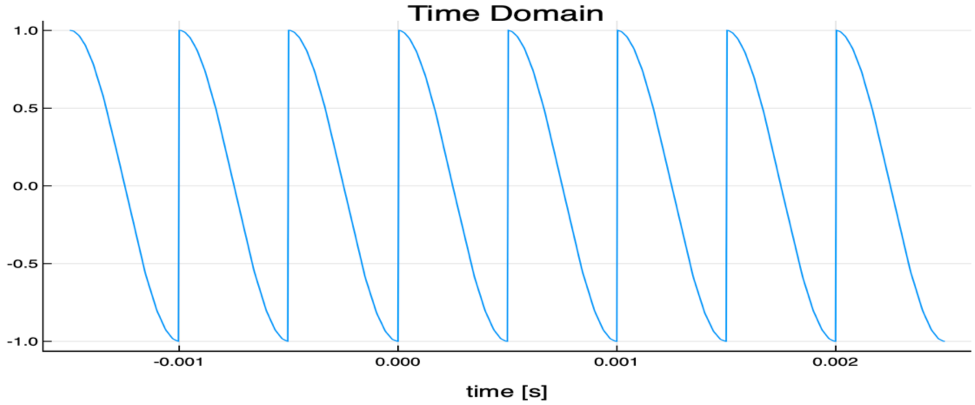


Out[17]:

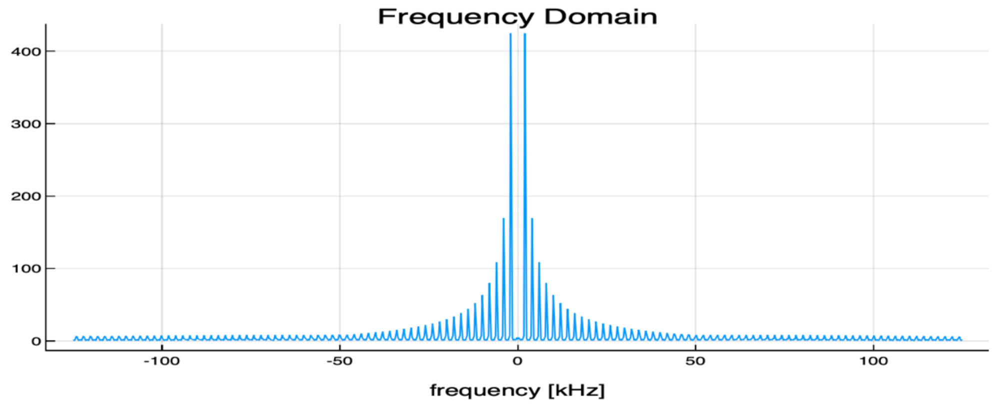


0.1.15 Plot the amplitude modulated carrier wave

Out[18]:



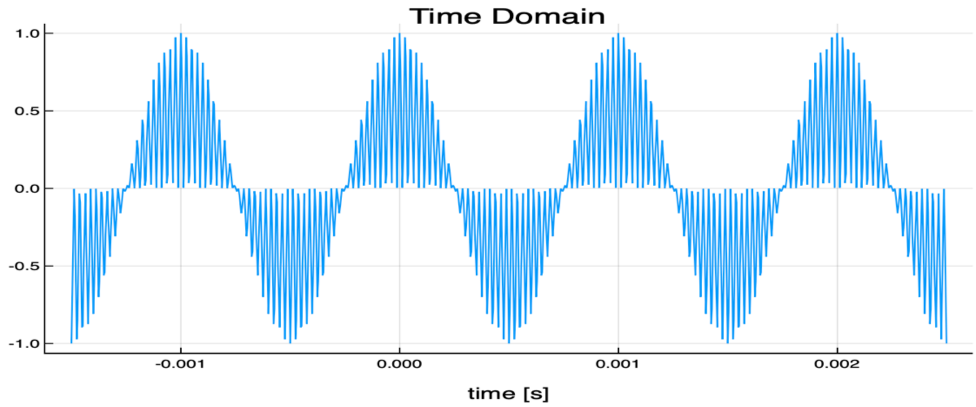
Out[21]:



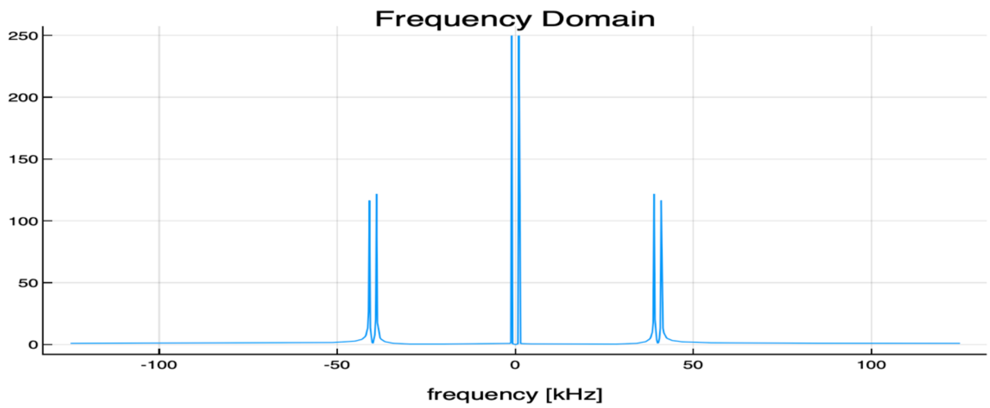
0.1.17 Julia Exercise 6.1b – DSB-SC Demodulation

0.1.18 (i) Plot the DSB-SC Demodulation

Out[22]:



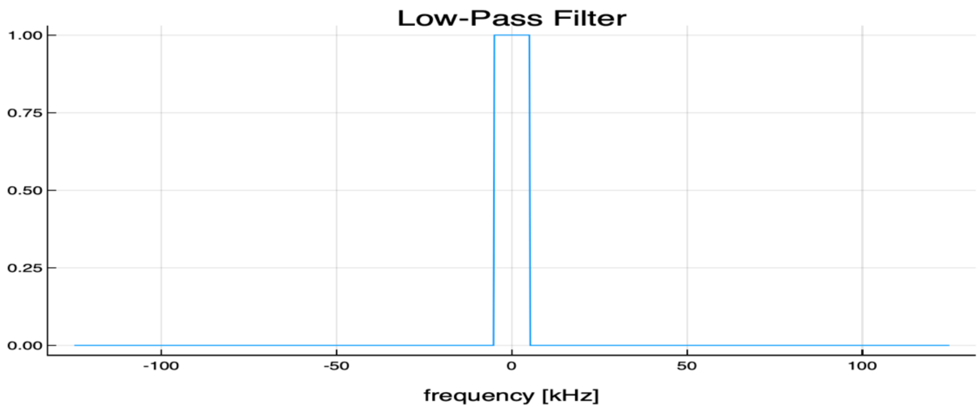
Out[25]:



0.1.20 (ii) Implement an ideal LPF (H) in the frequency domain.

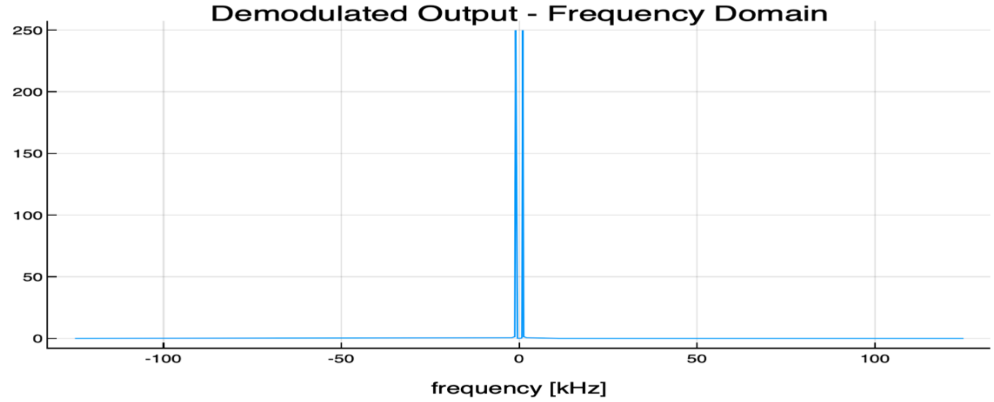
0.1.21 Plot a LPF with a cut-off at 5kHz

Out[26]:

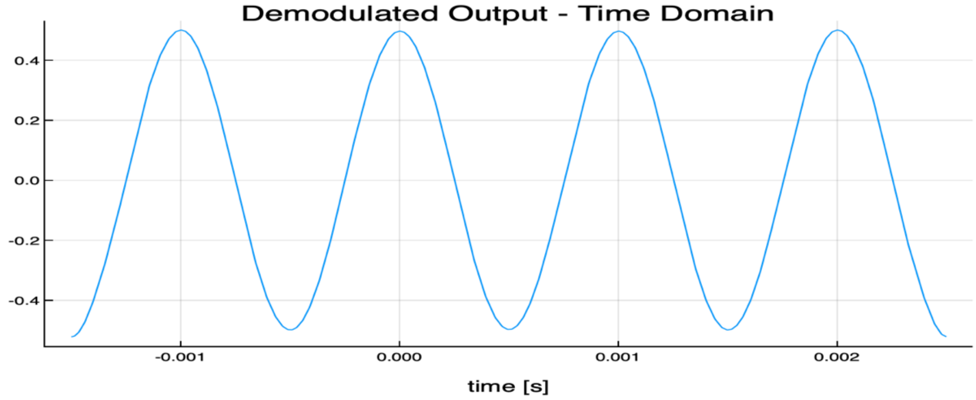


0.1.22 Apply the LPF

Out[27]:



Out[28]:



Does the final output agree with the theory? Do you get out 1⁄2f(t)? 8

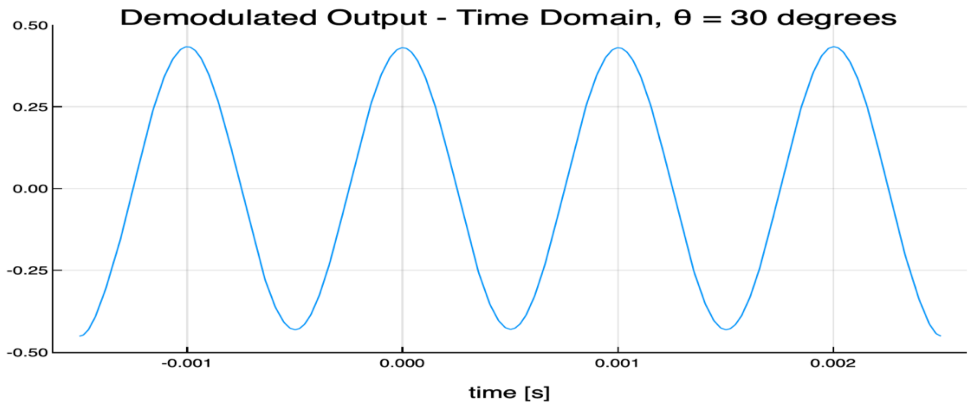
Yes, the final output agrees with the theory. The modulating waveform had a maximum amplitude of 1, while the demodulation output waveform has a maximum amplitude of 0.5.

0.1.23 Julia Exercise 6.1c – Effect of phase error in DSC-SC demodulation

0.1.24 (i) Phase error of 30 degrees

phaseErrori(30)

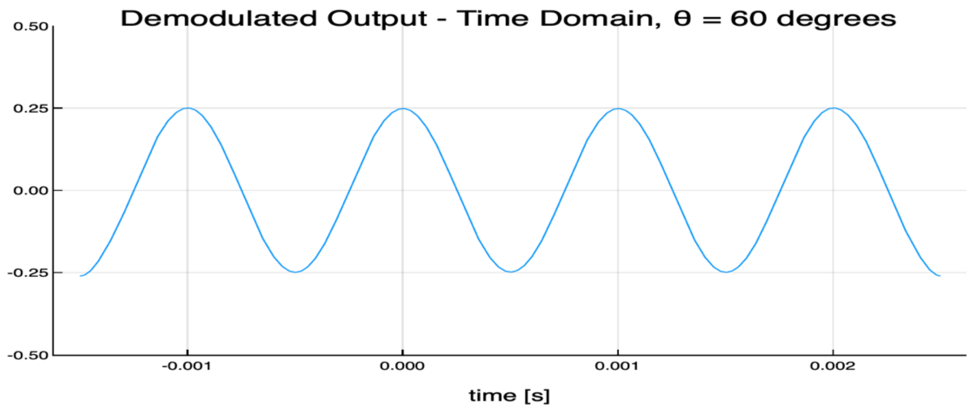
Out[30]:



0.1.25 (ii) Phase error of 60 degrees

phaseErrori(60)

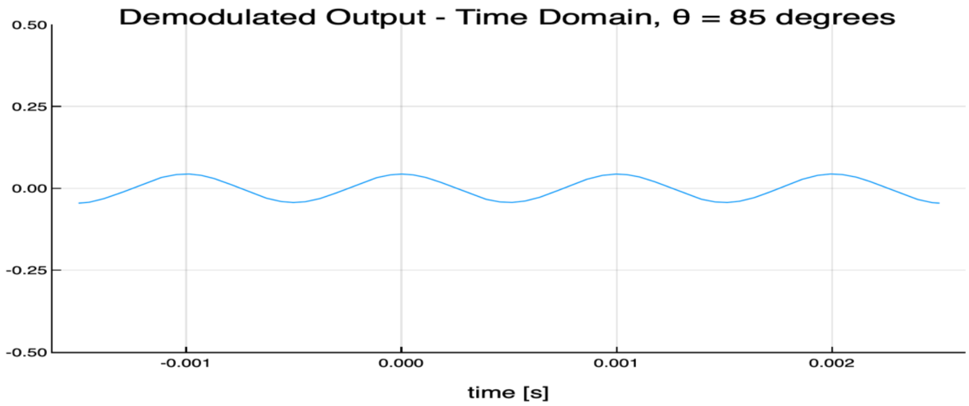
Out[31]:



0.1.26 (iii) Phase error of 85 degrees

phaseErrori(85)

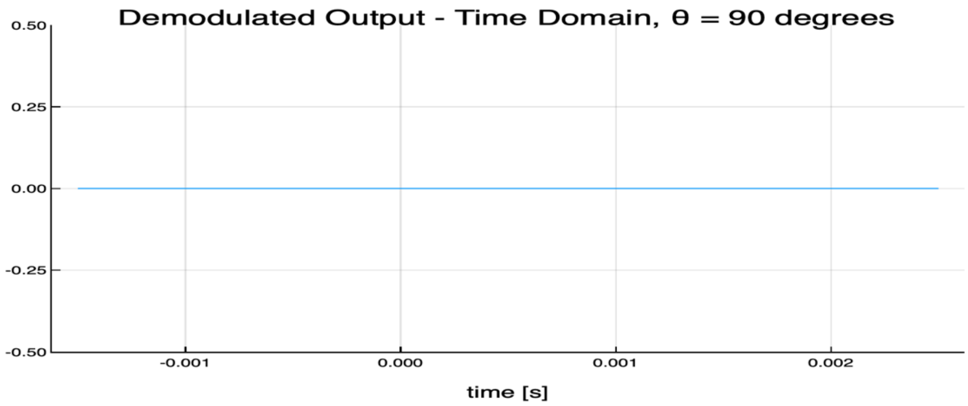
Out[32]:



0.1.27 (iv) Phase error of 90 degrees

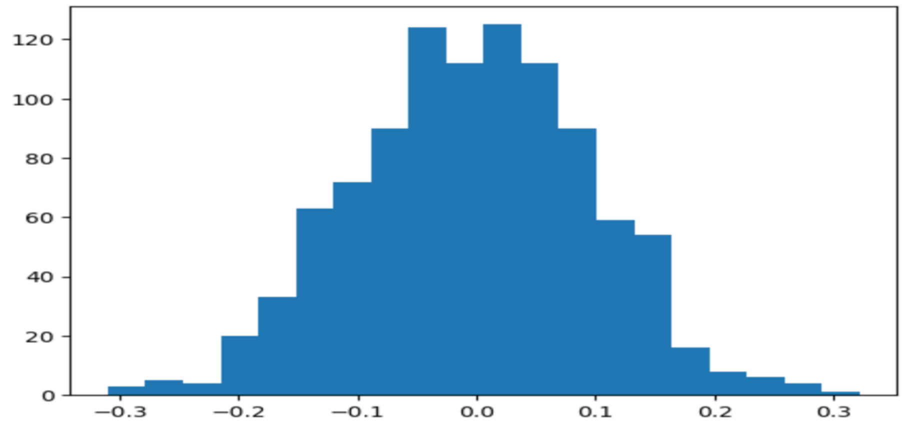
phaseErrori(90)

Out[33]:

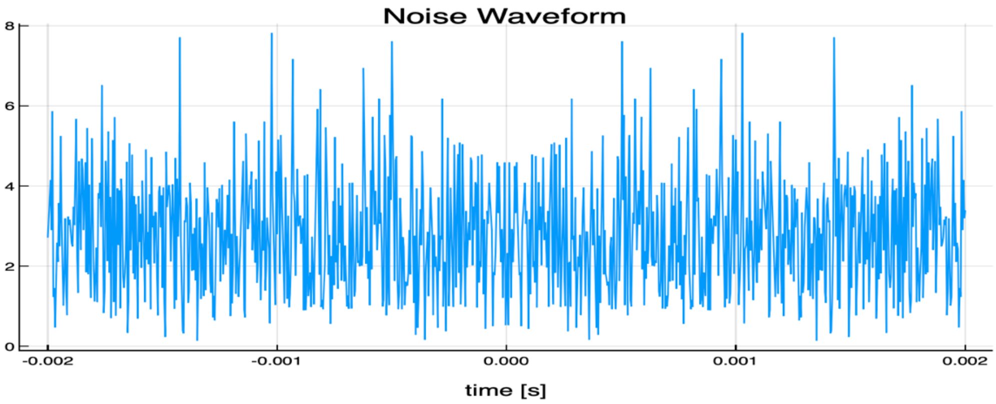


0.1.28 Julia Exercise 6.1d – DSB-SC AM with Gaussian noise

0.1.29 Simulate a noise waveform

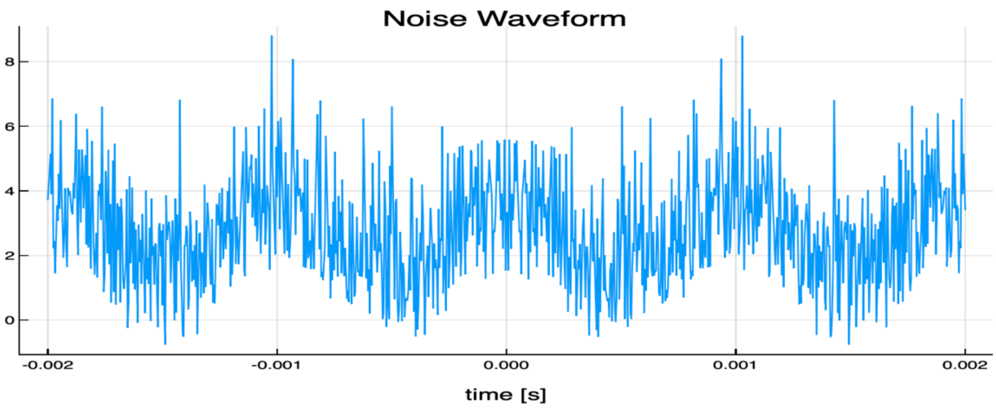


Out[36]:

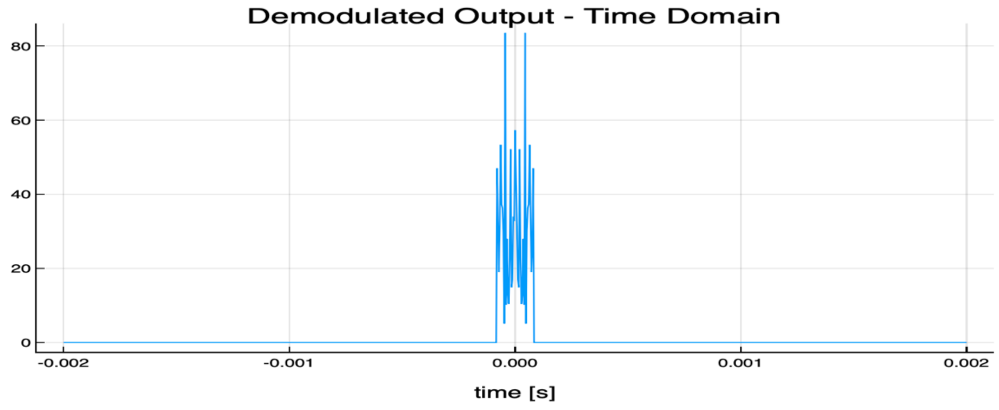


0.1.30 Plot noisy AM signal

Out[37]:



Out[38]:



What effect does a phase shift error have on the output SNR?

No effect to the output SNR. The signal and the noise are both multiplied by the cos , causing its effects to cancel out while calculating the signal to noise ratio.

How would you calculate the SNR at the output of the demodulator?

I would demodulate the noise signal and the DSB-SC signal separately, pass them through a low- pass filter, and finally calculate the ratio of the signal to the noise.

0.2 Julia Exercise 6.2 – DSB-LC AM

0.2.1 Julia Exercise 6.2a – DSB-LC AM Modulation

0.2.2 Simulate double sideband large carrier amplitude modulation (DSB-LC) with the following parameters:

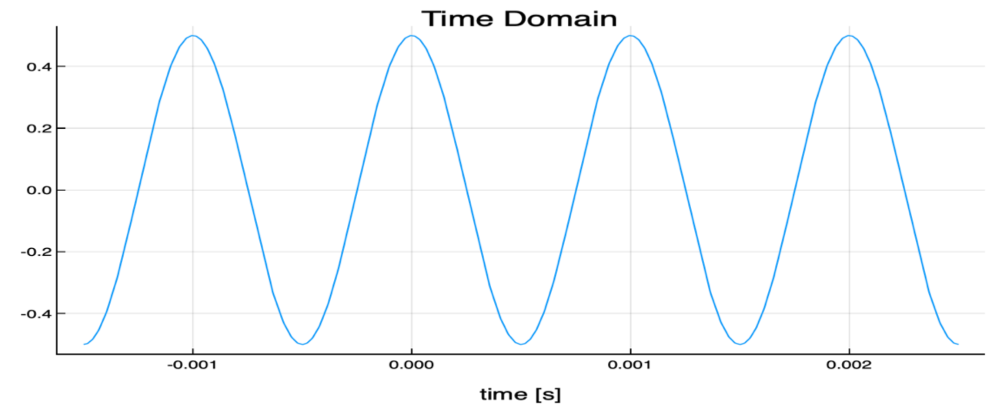
0.2.3 Modulating waveform: f(t) = k cos(2 fmt) where fm=1 kHz and k is a constant (k<A).

0.2.4 Carrier wave oscillator: cos(2 fct) where fc=20 kHz.

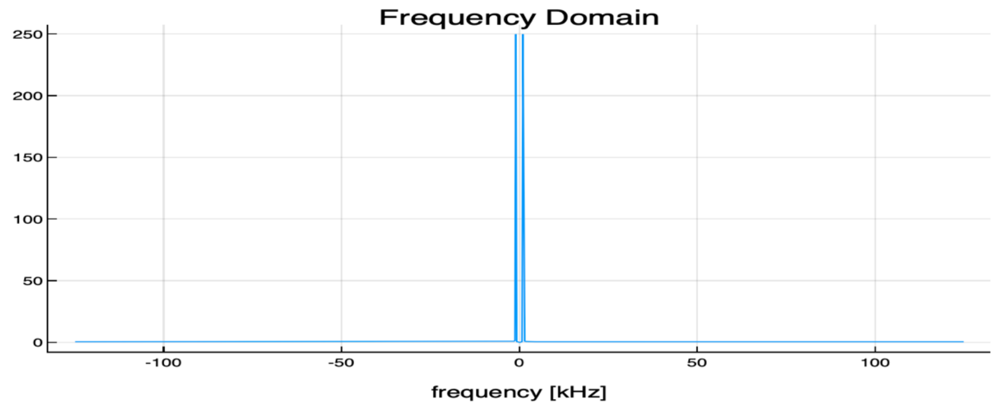
0.2.5 Modulated carrier wave signal: (t) = Acos(2 fct) + f(t) cos(2 fct) where A is a constant. Let A=1 for these simulations. Initially, let k=0.5

0.2.6 (i) Plot the modulating waveform

Out[39]:

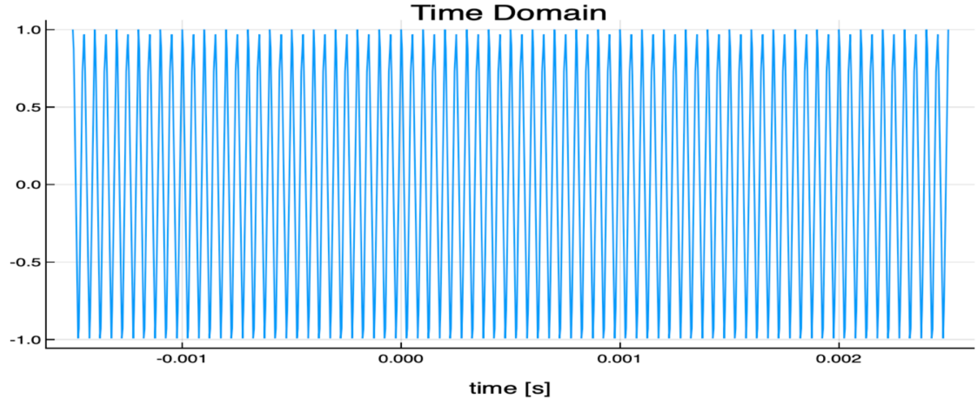


Out[42]:

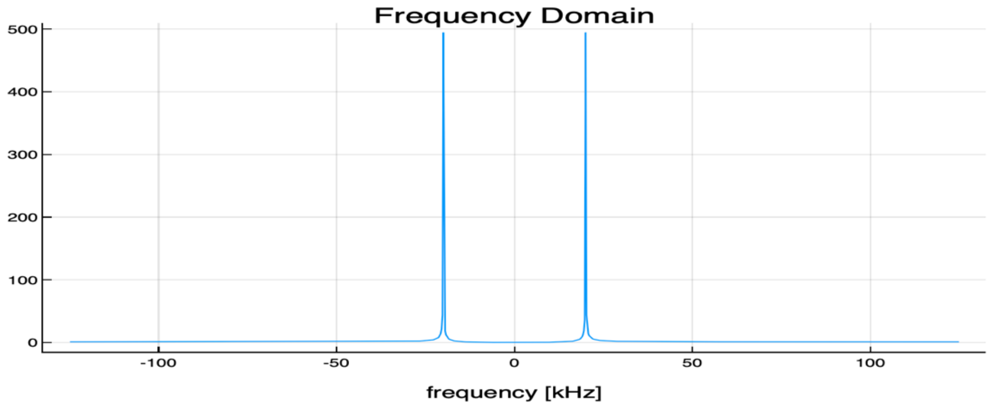


0.2.8 Plot the carrier sinusoid

Out[43]:

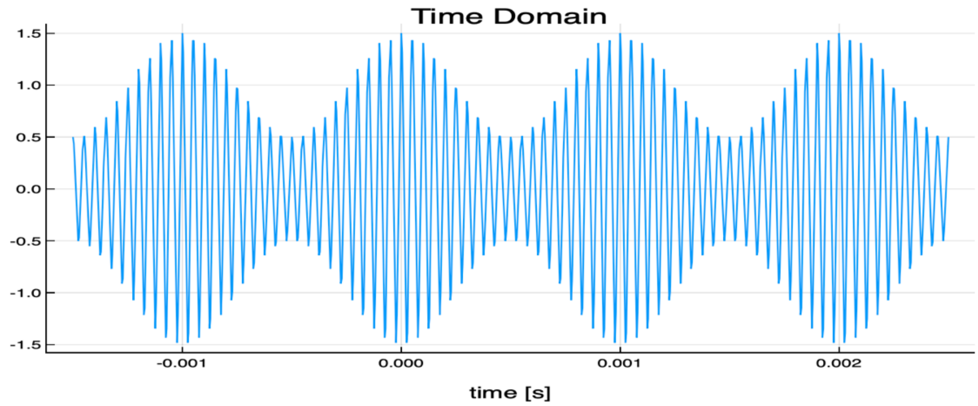


Out[46]:

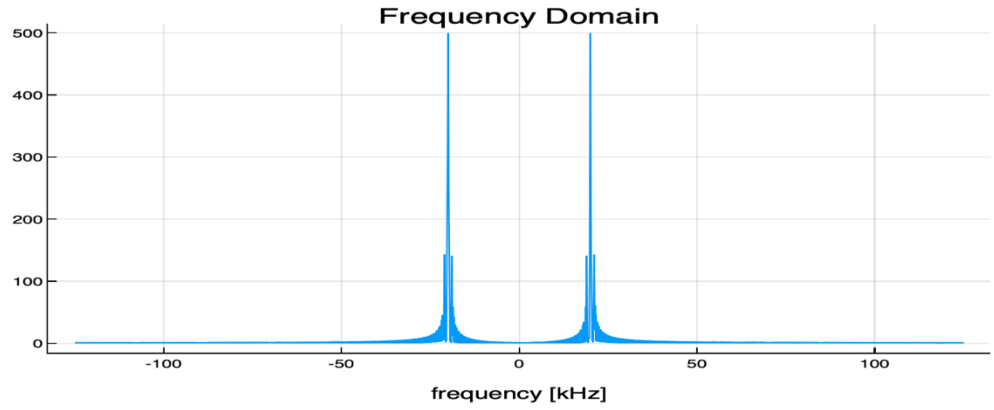


0.2.10 Plot the amplitude modulated carrier wave

Out[47]:



Out[50]:



- lower sideband = +19.20 kHz,-19.20 kHz
- upper sideband = +21.10 kHz,-21.10 kHz
- carrier = +20.14 kHz,-20.14 kHz

What is the modulation index for this case?

Envelope maxima

A(1+m) = 1.5

A = 1.5/(1+m)

Envelope minima

A(1-m) = 0.5

A = 0.5/(1-m)

Therefore:

1.5/(1+m) = 0.5/(1-m)

14

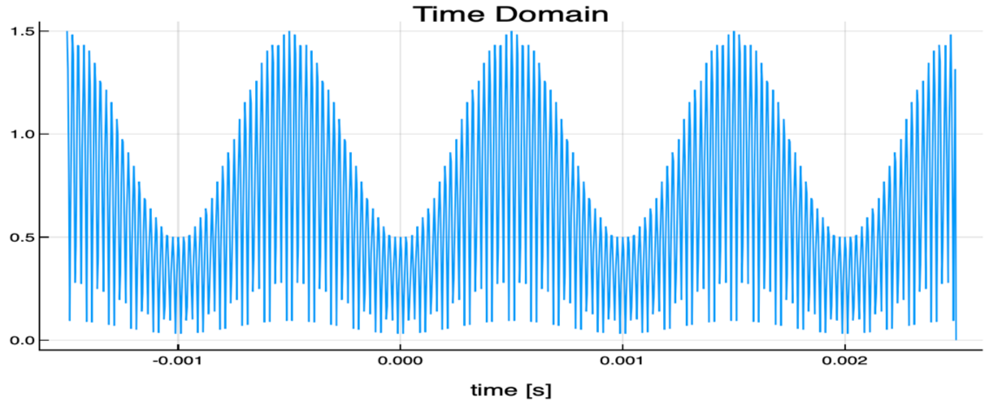
1.5 - 1.5m = 0.5 + 0.5m 2m = 1

m = 0.5

0.2.12 Julia Exercise 6.2b – DSB-LC AM Demodulation

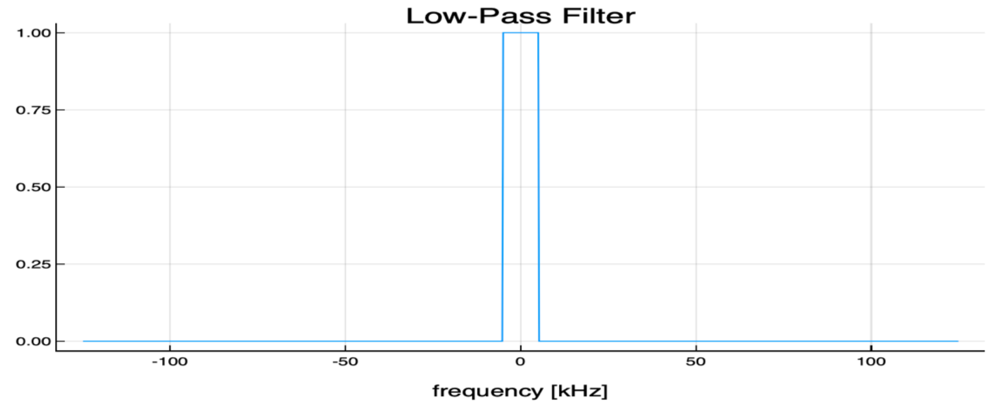
0.2.13 Full-wave rectify the AM signal

Out[51]:



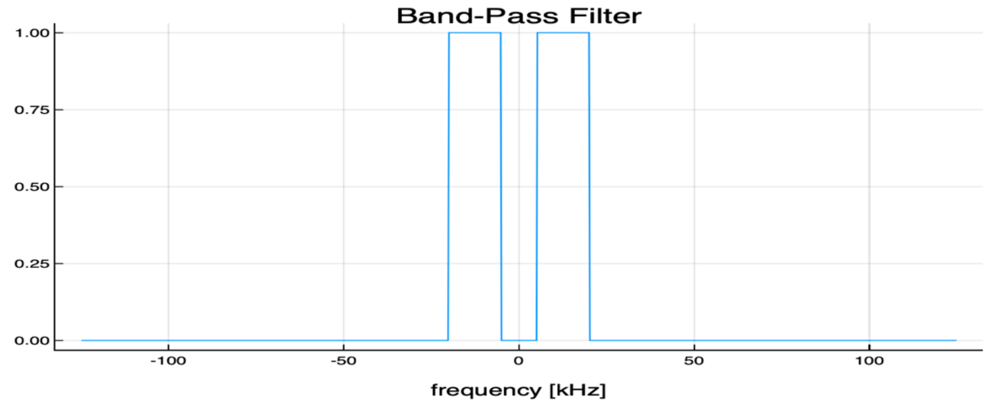
0.2.14 Plot a LPF with a cut-off at 5kHz

Out[52]:



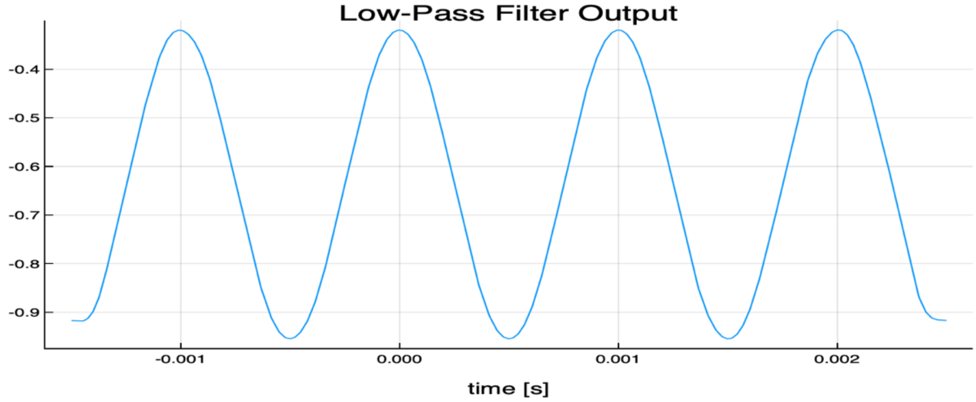
0.2.15 Plot a BPF with a passband of 20Hz to 5kHz

Out[53]:



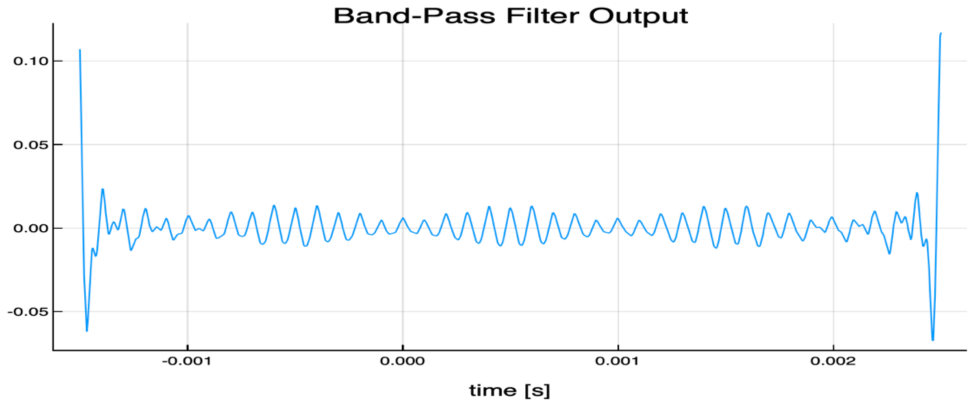
0.2.16 Plot the output of the low-pass filter

Out[54]:



0.2.17 Plot the output of the band-pass filter

Out[55]:

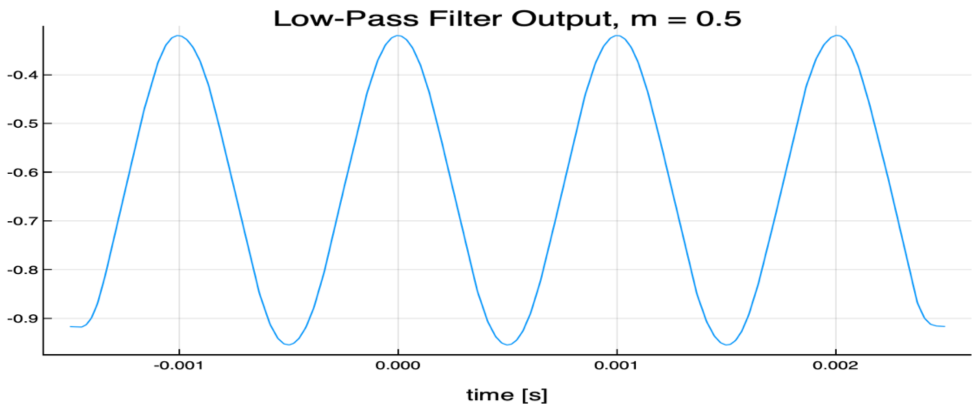


0.2.18 Julia Exercise 6.2c – DSB-LC AM modulation index

0.2.19 Fine modulation

modulationIndex(0.5)

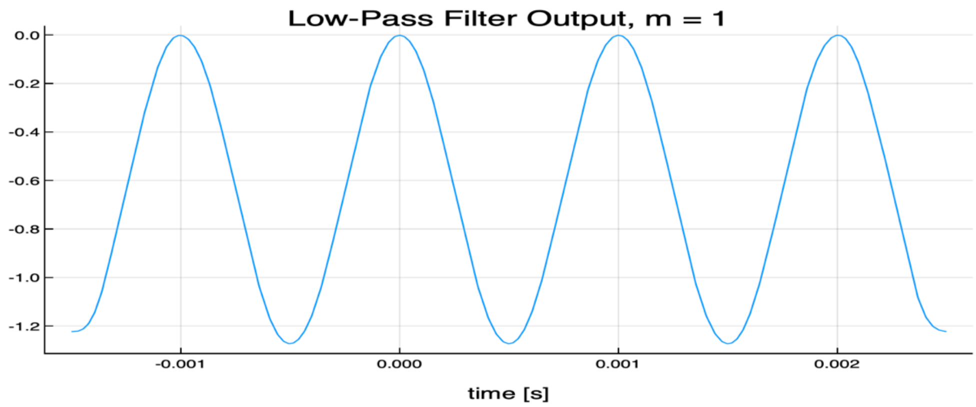
Out[57]:



0.2.20 Critically modulated

modulationIndex(1)

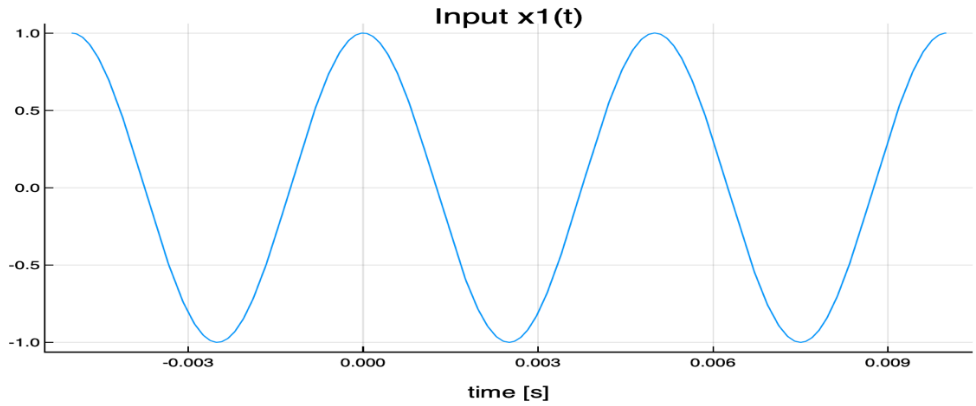
Out[58]:



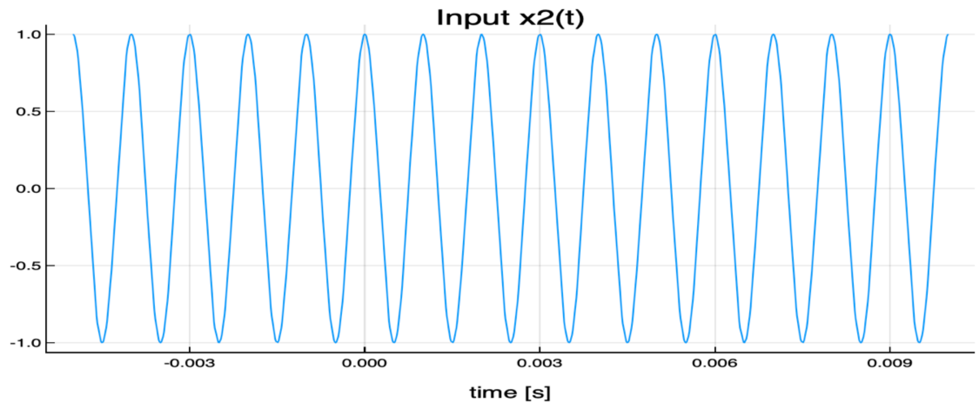
Julia Exercise 6.3 – Quadrature Multiplexing

0.3.1 Plot all inputs signals

Out[60]:

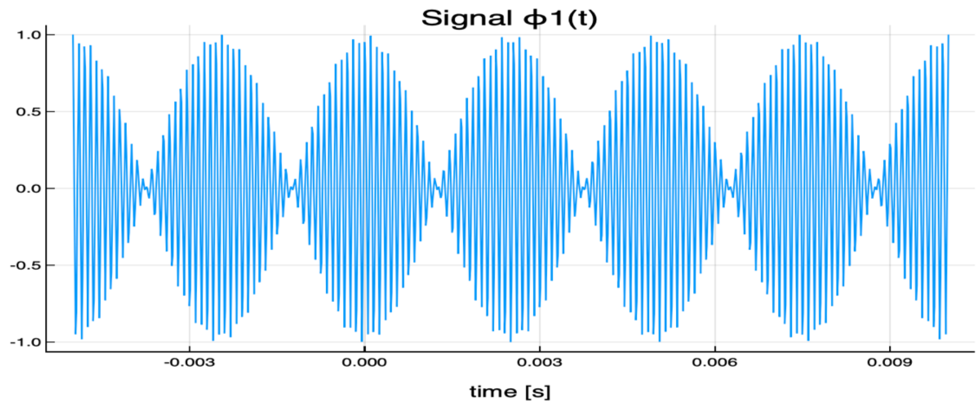


Out[61]:

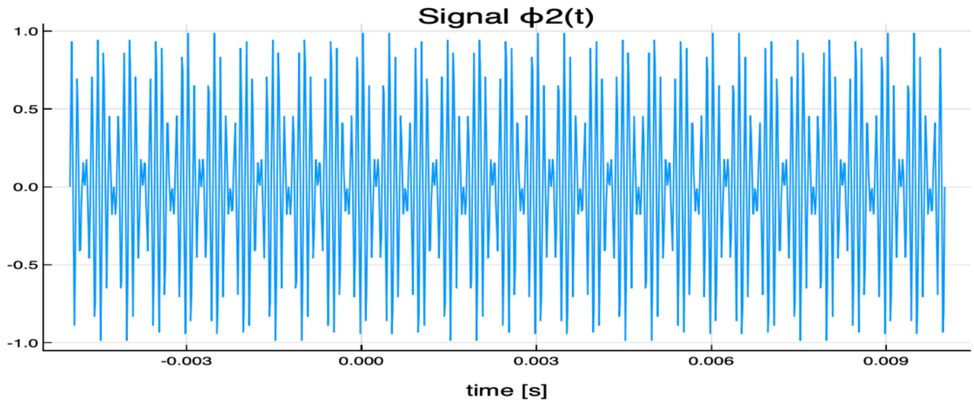


0.3.2 Plot all modulated signals prior to addition

Out[62]:



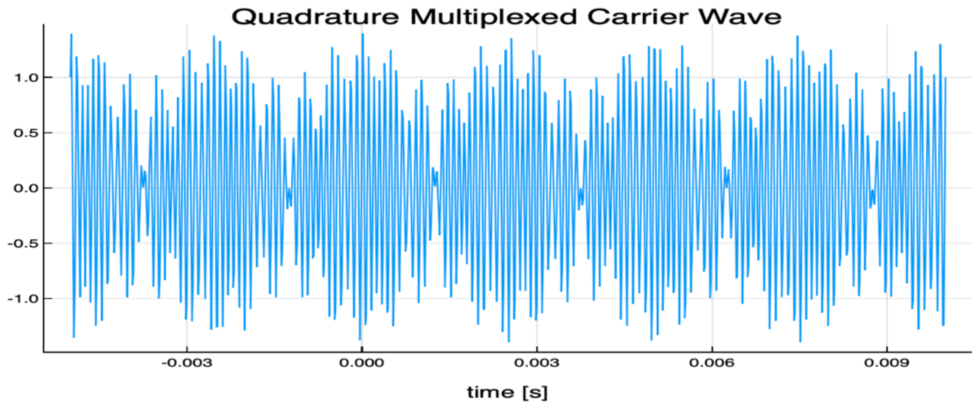
Out[63]:



0.3.4 Plot the quadrature multiplexed carrier wave:

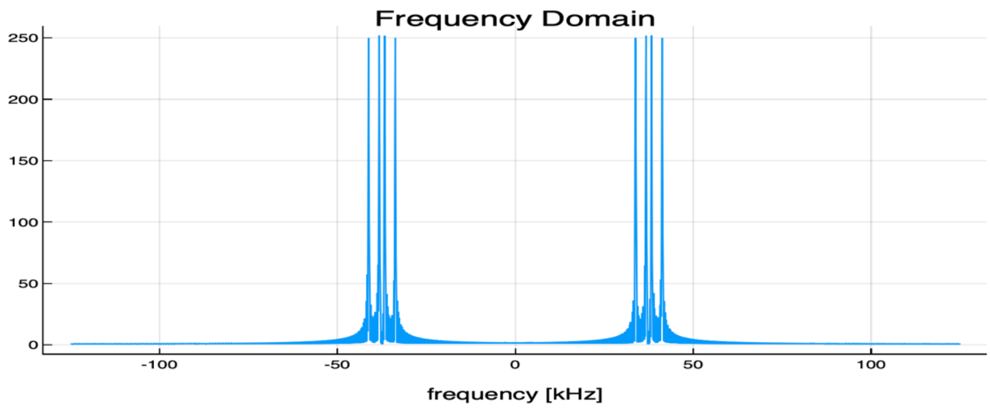
Time Domain

Out[64]:



0.3.5 Frequency Domain

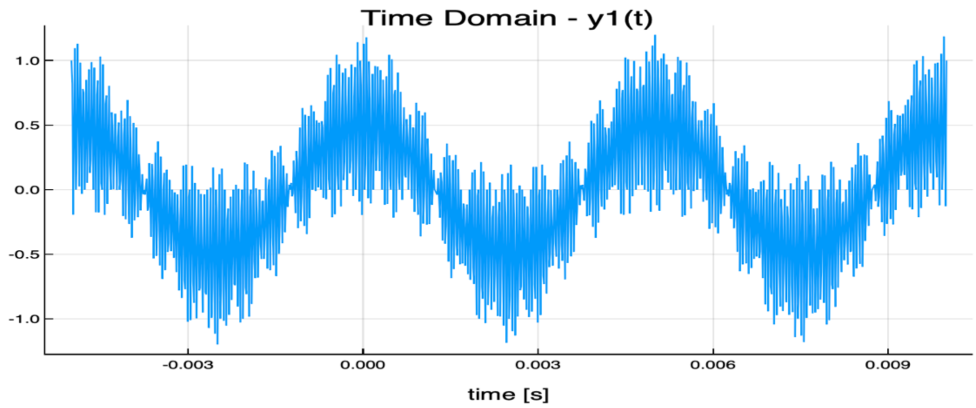
Out[67]:



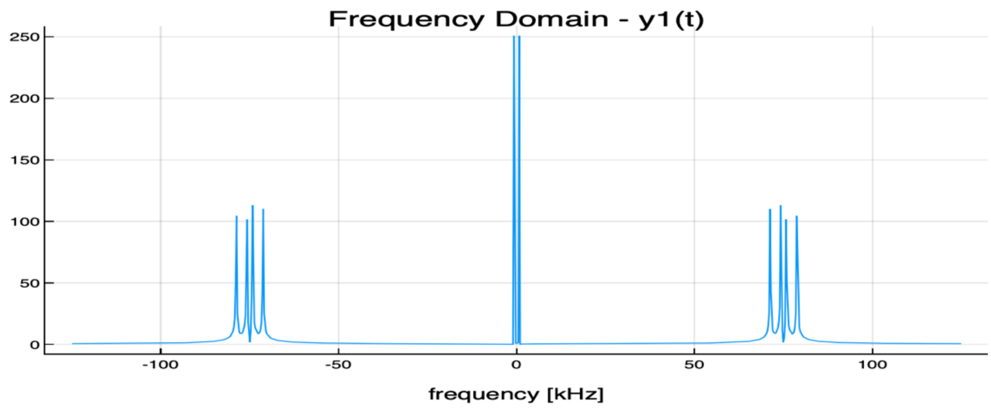
0.3.7 Plot all demodulated signals prior to filtering

0.3.8 Signal y1(t)

Out[68]:

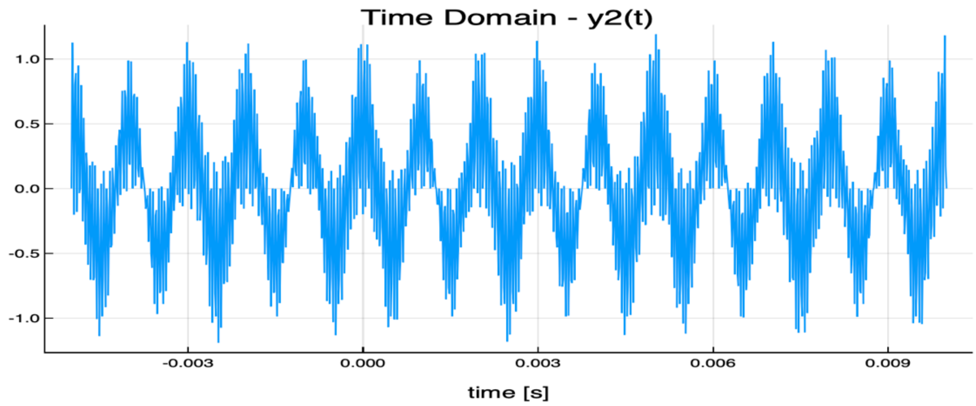


Out[71]:

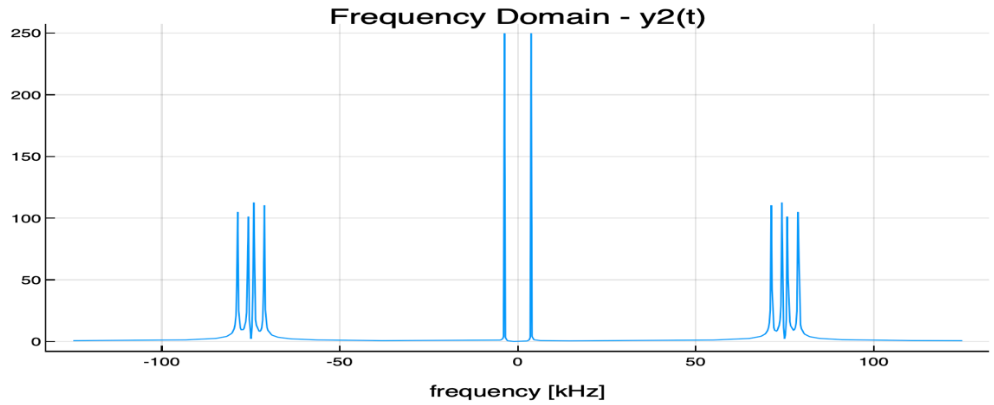


0.3.10 Signal y2(t)

Out[72]:

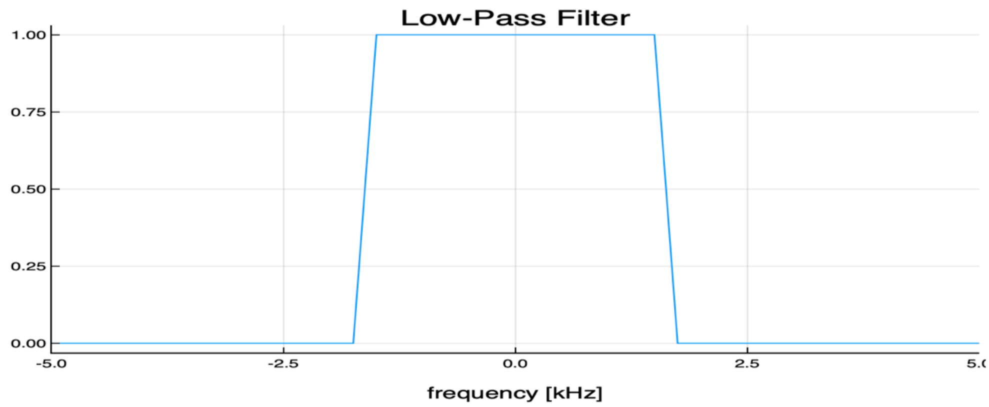


Out[75]:



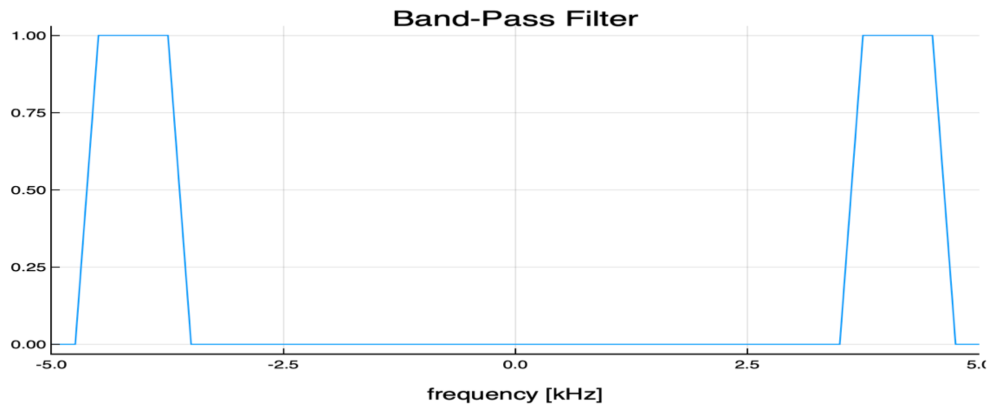
0.3.12 Plot the Low-Pass Filter

Out[76]:



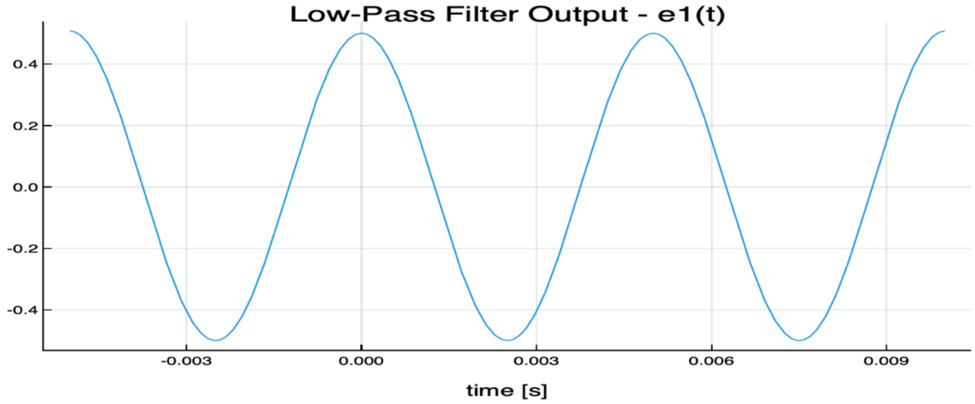
0.3.13 Plot the Band-Pass Filter

Out[77]:

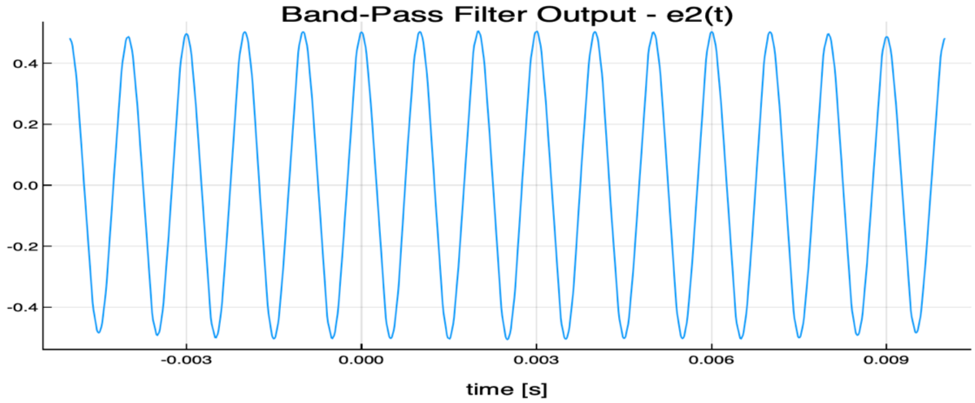


0.3.14 Plot all final outputs

Out[78]:



Out[79]:

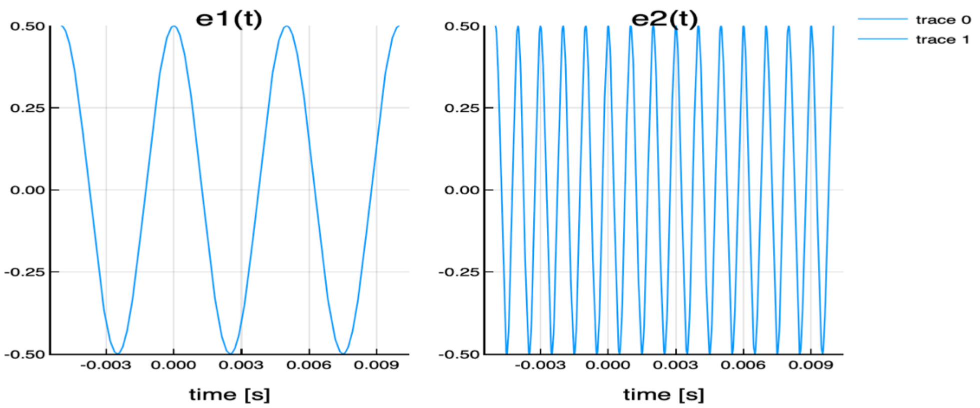


0.3.15 Case of Imperfect quadrature - sin and cos oscillators

0.3.16 Case = 0 deg

imperfectQuadrature(0)

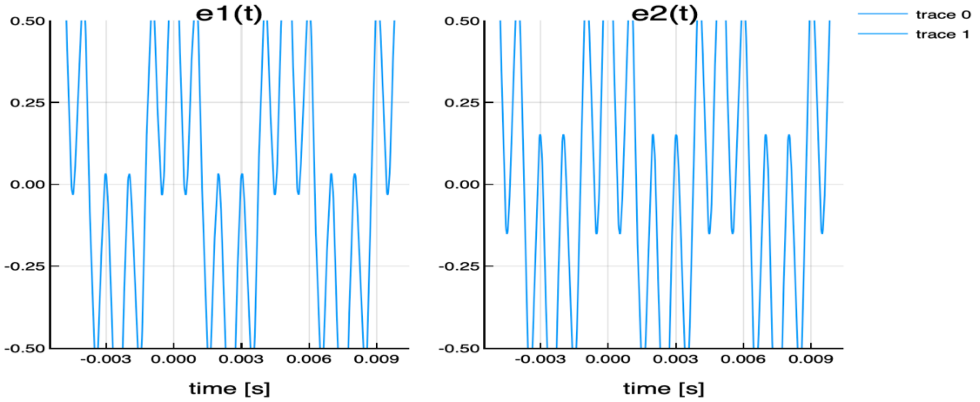
Out[81]:



0.3.17 Case = 60 deg

imperfectQuadrature(60)

Out[82]:



0.3.18 Case = 90 deg

imperfectQuadrature(90)

Out[83]: