Laboratory 2 Preparation using Simulink

1. **Single Sideband Suppressed Carrier (SSB-SC) Modulation and Demodulation Techniques**

You are required to build an SSB modulator based on the phase shift method (read the attached Lab2 instruction sheet, and familiarize yourself with the SSB modulator theory in the notes). Figure 1 below shows a Simulink simulation of lower sideband SSB (the upper sideband has been suppressed at the output of the adder). This can be checked in the analysis window using the sink calculator to view the real spectra of the relevant sinks.

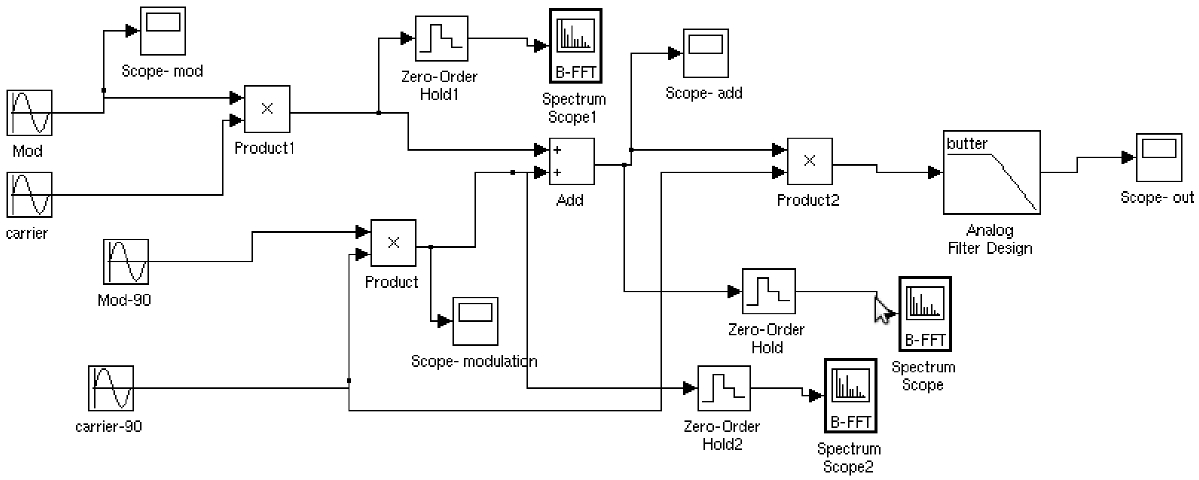

Figure.1

Upper sideband SSB can be achieved by swapping sine and cosine outputs of the carrier in Simulink. We are actually changing the phase from 90 to -90 degrees or vice versa, because the outputs are sines and cosines. In the hardware lab, you will have to build a phase shift circuit.

First set up the circuit as seen in Figure 1. The parameters are as follows:

- Modulating signal: frequency 1kHz, amplitude of 1V. (The signal fed into the lower multiplier is $\hat{f}(t)$, which is be pi/2 phase shifted – labelled “Mod-09” in Figure 1.)
- Carrier signal: frequency 20kHz, amplitude of 1V. (The carrier signal fed into the lower multiplier is must also be pi/2 phase shifted)
- Set the system sample rate need to satisfy the Nyquist criteria. The highest frequency component in the simulation is 41kHz, which occurs at the output of the demodulator. A system sample rate of 150kHz is sufficient (you can experiment on this and see how the output changes by using 200kHz and 250kHz). Note that the entered simulation parameter is the sample spacing in seconds (the sample time), so you need to convert the sampling frequency to sampling time. (e.g. for 200kHz, dt = 1/200e3=0.000005 seconds)
- Check the output of the two multipliers. You should obtain typical double sideband suppressed carrier signals (as you got in Laboratory 1).
- Simulate from 0 to 10ms. This should show 10 cycles of the modulating waveform.

Check the magnitude spectrum at the output of both multipliers (this is done by adding zero-order hold and spectrum scope). Remember to initialise the zero-order hold block and click the buffer input. The number of samples in the buffer should be set to a power of two (1024 should be fine). The frequency resolution depends on the length of time T' that is Fourier transformed.
Recall frequency resolution = 1/T' where T' = (buffer samples * sample spacing). What frequency

resolution does this buffer length of 1024 correspond to?

To view the negative part of the spectrum, double click on **spectrum scope, axis properties** and select **frequency range** to be **-Fs/2 to Fs/2 (this sample rate is the zero-order hold sample rate)**. You should change the axis to range from -50 to 50kHz. Figure 2 shows the typical DSB-SC frequency spectrum at the output of one of the multipliers. The SSB-SC signal comes from the adder. The adder sums the modulated signals (original and phase shifted versions). After running the system, check the frequency spectrum of the output of the adder. Figure 3 shows the frequency spectrum at the output of the adder.

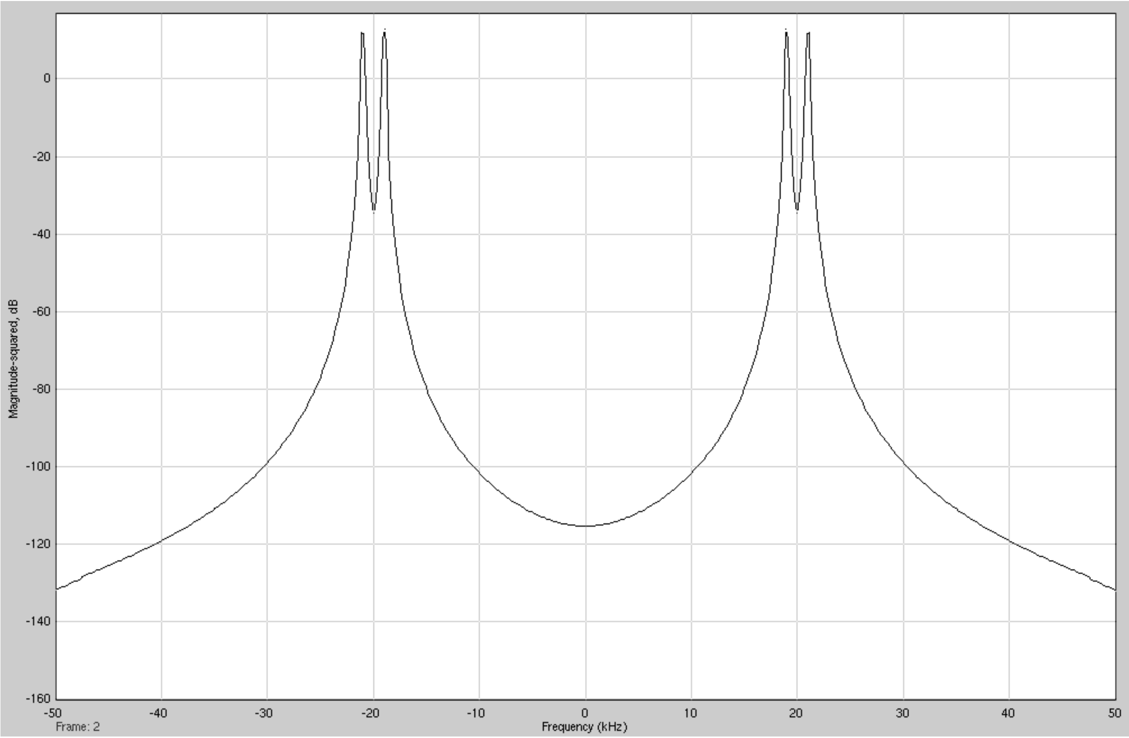

Figure 2

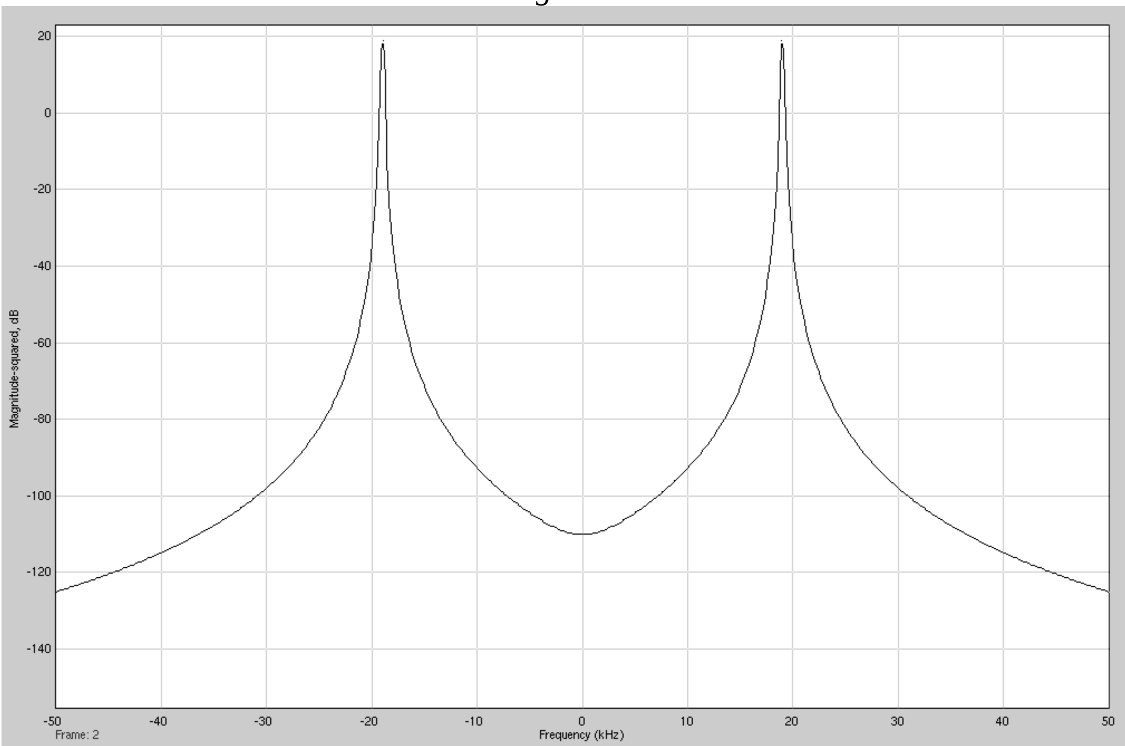

Figure 3

Demodulation of SSB

The demodulation of the SSB-SC signal is similar to the DSB-SC synchronous demodulation discussed in laboratory 1. The modulated SSB signal is multiplied by a signal with the same phase as the original carrier signal and then passed through a low pass filter. Use an analog filter, like you did in Prelab 1. The simulated outputs will look similar to the waveforms that you will obtain in the hardware practicals.

2. Quadrature Multiplexing

Generate two signals $f_1(t)$ and $f_2(t)$, one with frequency at 50Hz and the other with frequency 1kHz. Multiply one with a sine wave of frequency 20kHz and the other with a cosine of the same frequency as shown above in Figure 4.

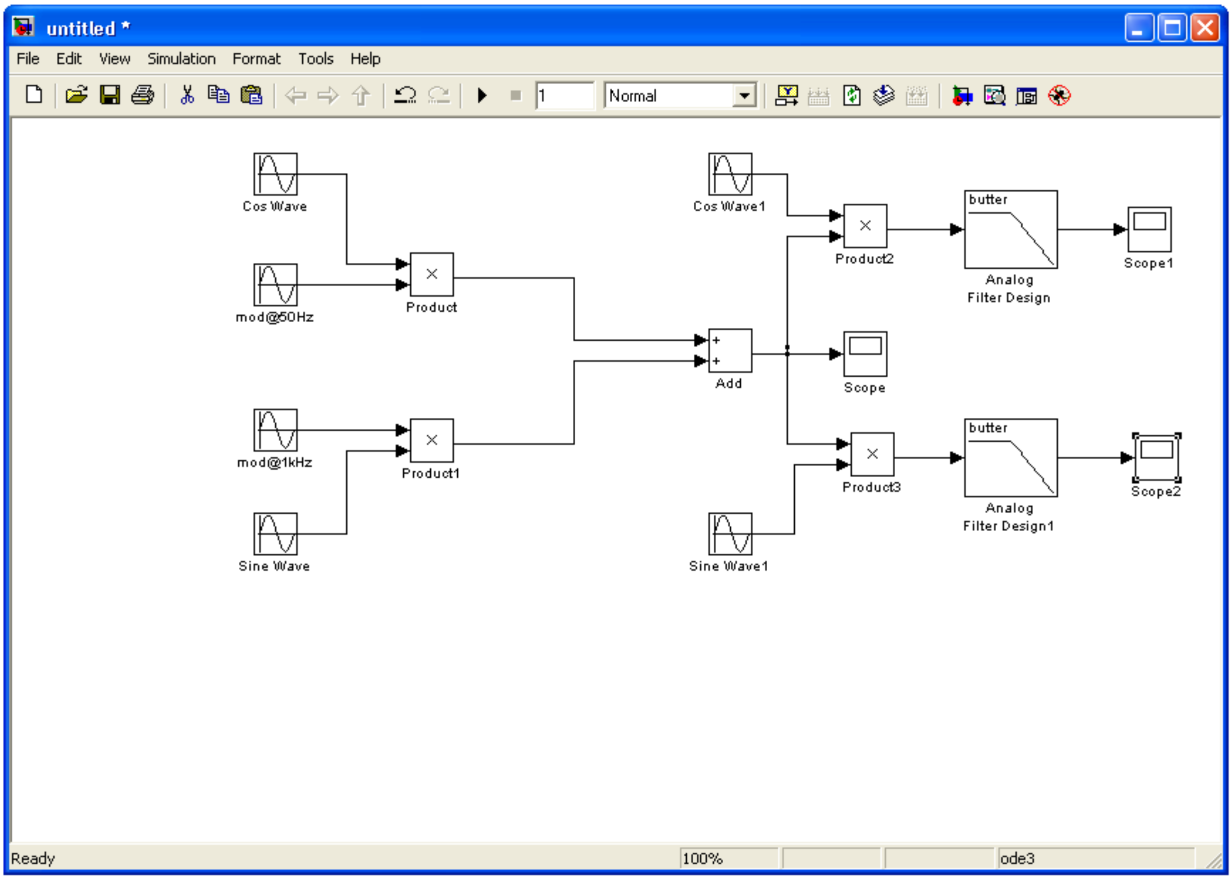

Figure 4

Sum the two modulated signals to obtain the multiplexed modulated carrier signal. Demodulate by multiplying by either a cosine wave followed by a low pass filter to recover $f_1(t)$, or by multiplying by a sine wave to recover $f_2(t)$ (create two additional signal generator). Check that the correctly demodulated signals appear at the two outputs. Note that these output signals have half the amplitude of the modulating waveforms $f_1(t)$ and $f_2(t)$ – this factor of a half is consistent with the mathematical analysis.

Now introduce a phase error into one (or both) of the demodulating carrier signals. What happens as you increase the phase error from 0 to 90 degrees? You should also observe increasing inter-channel coupling or “cross-talk”. Also inspect this in the frequency spectrum.

Figure 5 shows the output of the adder. Figure 6 and Figure 7 show the final demodulated outputs. These plots are without demodulator phase errors i.e. no inter-channel coupling present (the amplitudes of the two output signals are different because $f_1(t)$ and $f_2(t)$ had different amplitudes).

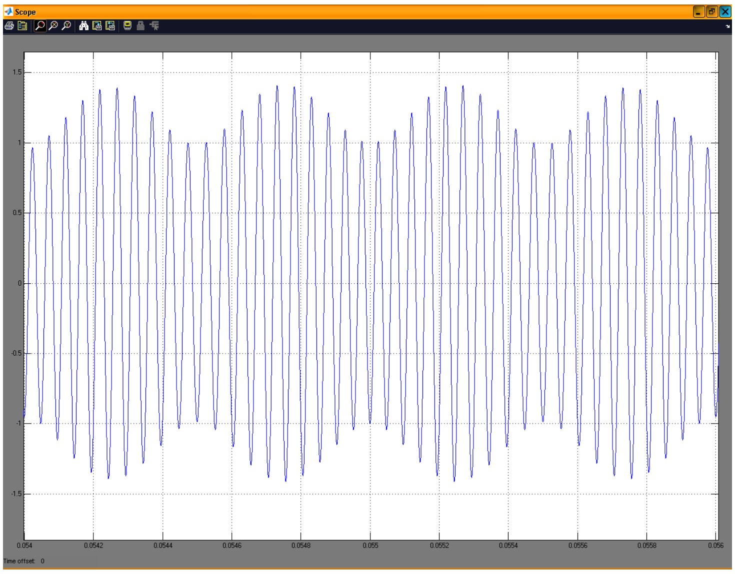

Figure 5

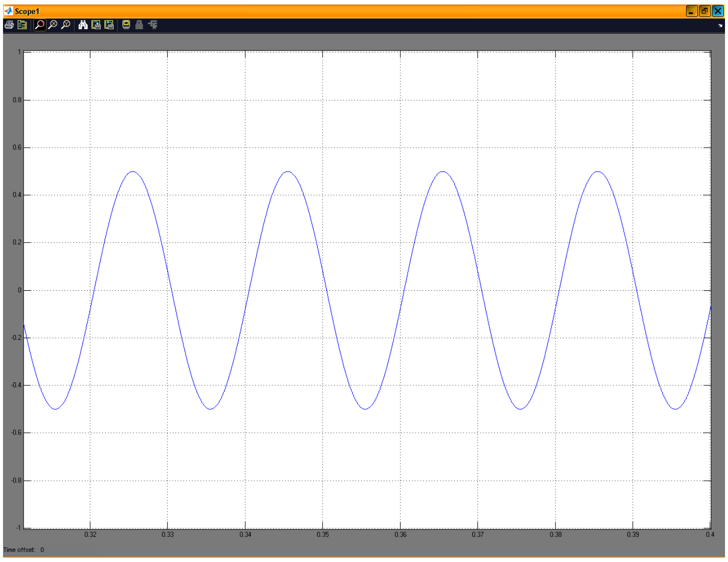

Figure 6

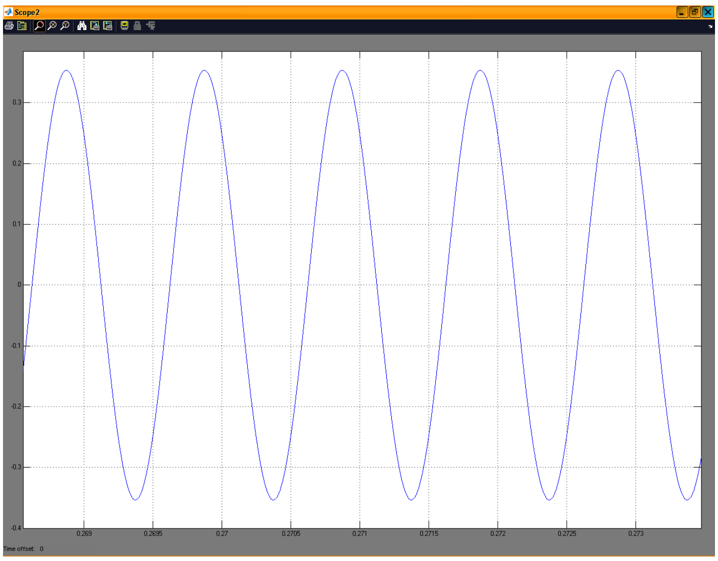

Figure 7