Experiment 7

SSB Modulation and Demodulation

Objectives :

By the end of this experiment, the student should be able to:

1. Demonstrate the modulation and demodulation process of SSB.
2. Deal with phase shift splitter (QPS).

Introduction:

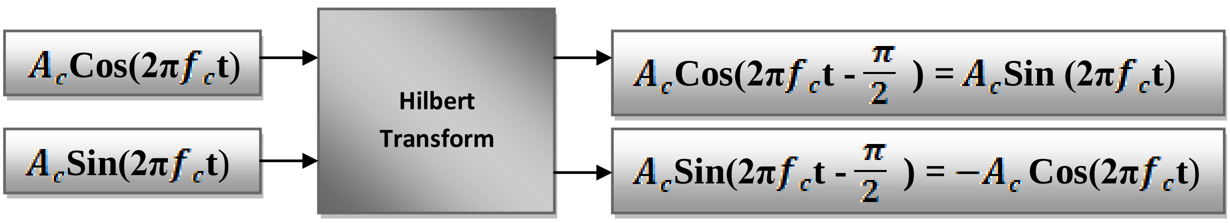
Single sideband (SSB) is a common analog modulation scheme for voice communications. With SSB only one sideband(either the upper USB or the lower LSB) is present in the modulated carrier. That is acceptable because the two sidebands contain the same information, so the elimination of one sideband does not cause a loss of information. SSB uses radio spectrum efficiently: for a given message signal, only half as much bandwidth is occupied by the modulated carrier (compared with DSB or AM). SSB is used for amateur (ham) radio, citizens' band (CB) radio, and short-wave broadcasting.

There is more than one way to generate SSB carriers. One method is to use a DSB modulator and then eliminate one sideband (either the lower or the upper) with a filter. That method is conceptually simple but has a significant drawback. The filter can be challenging to design: it must have a quite sharp roll-off that will pass the one sideband but reject the other sideband that is just the other side of the carrier frequency. In the present experiments SSB carriers will be generated by a different method. The method employed here is known as the phasing method, and it incorporates a Hilbert transform.

Hilbert Transform

In general, a signal **m(t)** has a Hilbert transform $m(t)_h$,in a Hilbert transform, both the input and the output are in the time domain. This is unlike the Fourier transform, for which the input is in the time domain and the output is the frequency domain description of the input. The Hilbert transform is a linear, time-invariant system. If the input is a sinusoid, the output is also a sinusoid of the same frequency. For a sinusoidal input, the output has a phase that is less than that of the input by $\frac{\pi}{2}$ radians.

The amplitude is unchanged between input and output Here is an examples:



Quadrature Phase Splitter (QPS)
The Hilbert transform that will be used in these experiments is incorporated into a module called the Quadrature Phase Splitter.

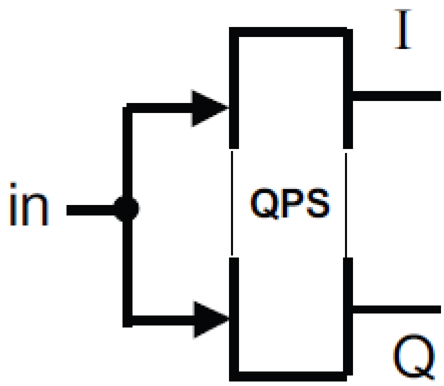


Figure 1. QPS Module

This module has two inputs and two outputs. If the two inputs are connected together (as they will be in the SSB modulator) then the difference in phase between the second and first outputs is $\frac{\pi}{2}$ radians. That is to say, with the two inputs of the Quadrature Phase Splitter connected together, the second output is the Hilbert transform of the first output.

<u>Single Sideband Generation Using Phasing model :</u>
The phasing method of SSB generation is based on the addition of two DSBSC signals, so phased that their upper sidebands (say) are identical in phase and amplitude, whilst their lower sidebands are of similar amplitude but opposite phase. The two out-of-phase sidebands will cancel if added; alternatively the in-phase sidebands will cancel if subtracted.
The principle of the SSB phasing generator in illustrated in Figure 1. Notice that there are two 90^{o} phase changers**.**

The SSB modulated signal is defined as:

S(t)= m(t).Cos(2πf$_c$t) ± m(t)$_h$.Sin(2πf$_c$)……………………………………………….(1)

Where:
f_c is the Carrier frequency parameter.
$m(t)_h$ is the Hilbert transform of the message signal ***m(t)***.
The **minus sign** indicates the upper sideband and the **plus sign** indicates the lower sideband.

If we consider the message signal m(t) is equal to **Cos(2πf$_m$t)** then equation 1 will be defined as:

S(t)= Cos(2π f$_m$t) . Cos(2πf$_c$t) ± Sin(2πf$_m$*t*) . Sin(2πf$_c$*t*)………………………..….(2)

SSB Generation Block diagram :

A block diagram, showing how equation (2) could be modelled with hardware, is shown in Figure 2 below.

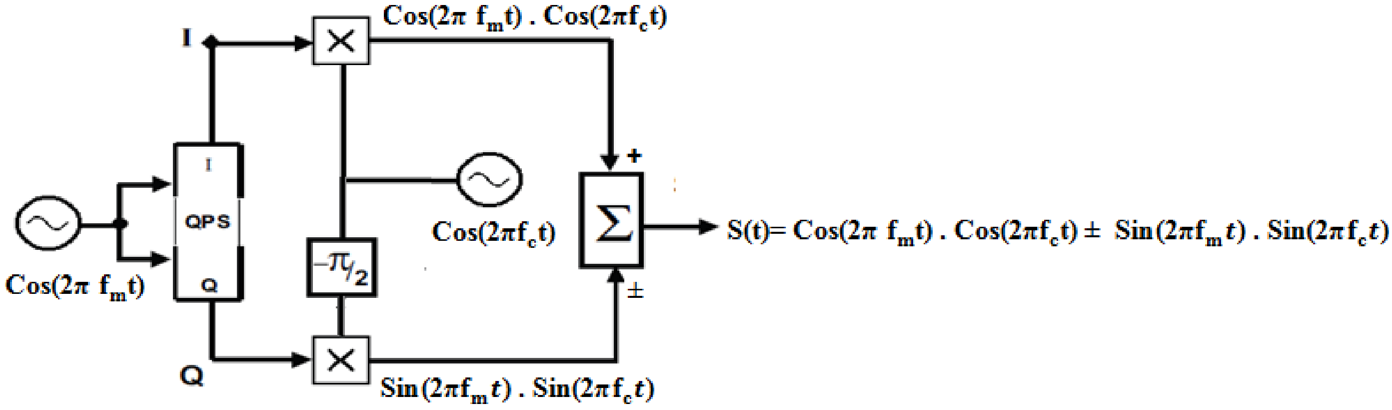


Figure 2. SSB Generator Block Diagram

The wideband phase splitter consists of two complementary networks - say I (In phase) and Q (Quadrature). When each network is fed from the same input signal the phase difference between the two outputs is maintained at 90^{o} . Note that the phase difference between the common input and either of the outputs is not specified; it is not independent of frequency.

SSB Demodulation using phasing method:

We will use the phasing type demodulator, block diagrams of which are shown in Figure 3 The 90 degree phase shifter in the lower - Q - arm of the structure (left block) needs to introduce a 90 degree phase shift over all frequencies of interest. In this case these are those of the message. Such a 'filter' is difficult to realize. A practical solution is the Quadrature phase splitter - QPS - shown in the right block.

This maintains a 90 degree shift between its outputs, although the phase difference between one input and either output varies with frequency. This variation is acceptable when the message is speech. Note that ideally there should be identical low pass filters in each multiplier output. In practice a single low pass filter is inserted in the summing output.

The practical advantage of this is a saving of components (modules). One disadvantage of this is that the QPS will be presented with larger-than-necessary signals at its inputs - the unwanted sum frequency components as well as the wanted difference frequency components. Unwanted components increase the risk of overload.

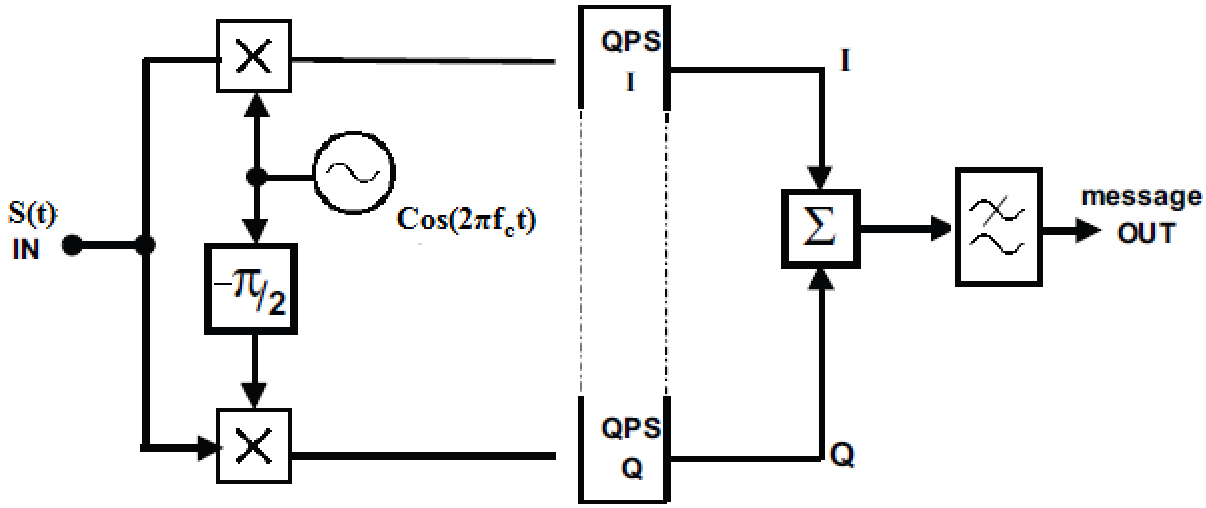


Figure 3. SSB Demodulator Block Diagram

Spectral Analysis :

Based on equation 2 the spectrum of USB and LSB modulated signals will be as shown in figure 4.

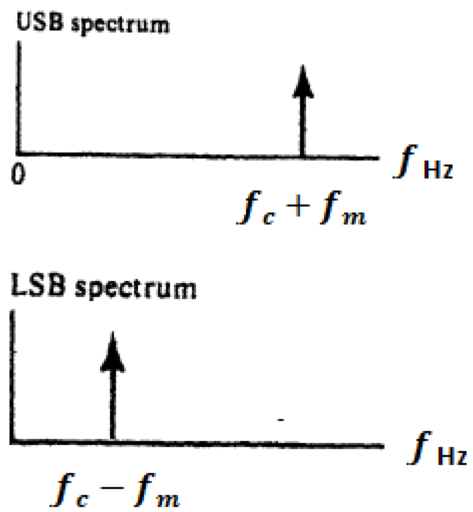


Figure 4. The spectrum of USB and LSB modulated signals

Lab Work:

This experiment consists of two parts. In Part I we generate the SSB signal using single-tone message signal. In Part II we demodulate the signal.

Modules :

The following plug-in modules will be needed to run this experiment: Audio Oscillator, Multiplier, QPS ,Tunable LPF, Phase Shifter.

Part l: SSB Generation

Procedure:

1. Construct The block diagram of Figure 2, which models the SSB generation block diagram, by using TIMS as shown in figure 5.

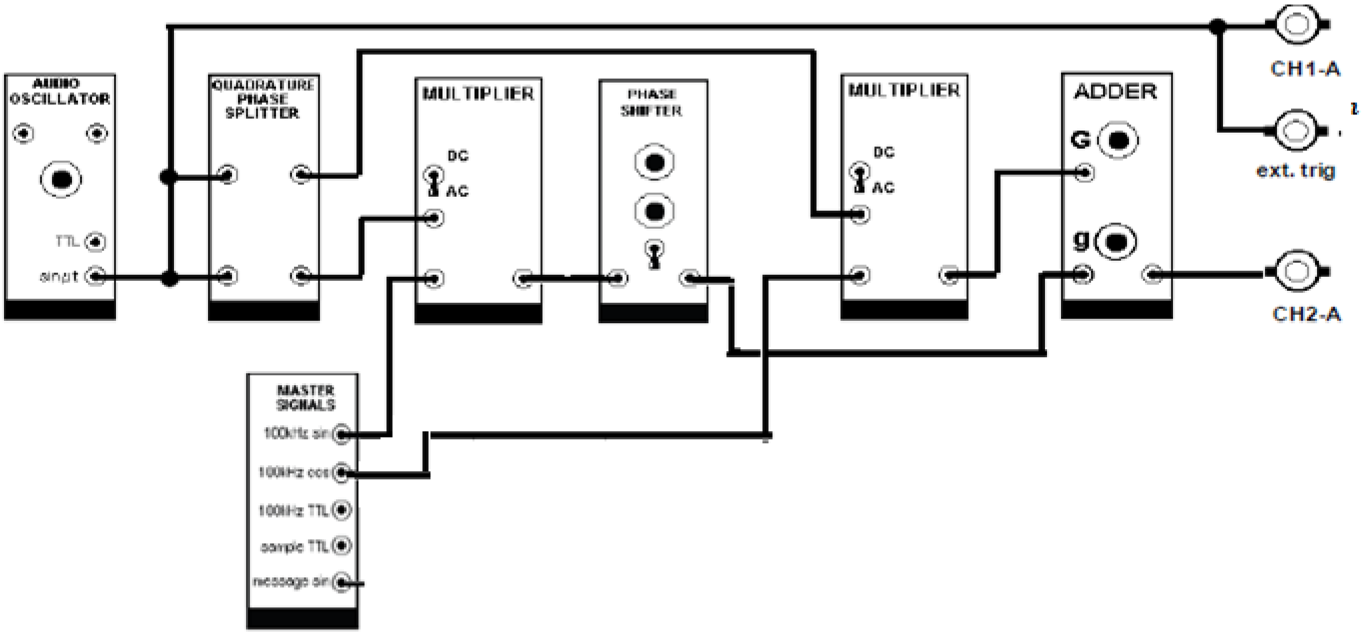


Figure 5. The TIMS Model of The Block Diagram of Figure 2.

Note:

In the TIMS model we discard the phase shifter because the Master Signal has internal phase shifterbut we have used the phase shifter to provide minus sign at the second output of the adder (in other word convert the adder to subtractor) .

2. Use the Frequency Counter to set the Audio Oscillator to about 2 kHz.
3. Set the adder gains fully clockwise.
4. Switch the Scope Selector to CH1-A and CH2-A.
5. Use the Oscilloscope to Plot the waveforms of the input signal , and the carrier signal, in you lab sheets.
6. Use the PicoScope to plot the spectrum of SSB Signal in you lab sheets.
7. Switch the Phase Shifter to 180^{o},then repeat point 5.

Part ll: SSB Regeneration

1. Construct The block diagram of Figure 3, which models the SSB Regeneration block diagram, by using TIMS as shown in figure 6.

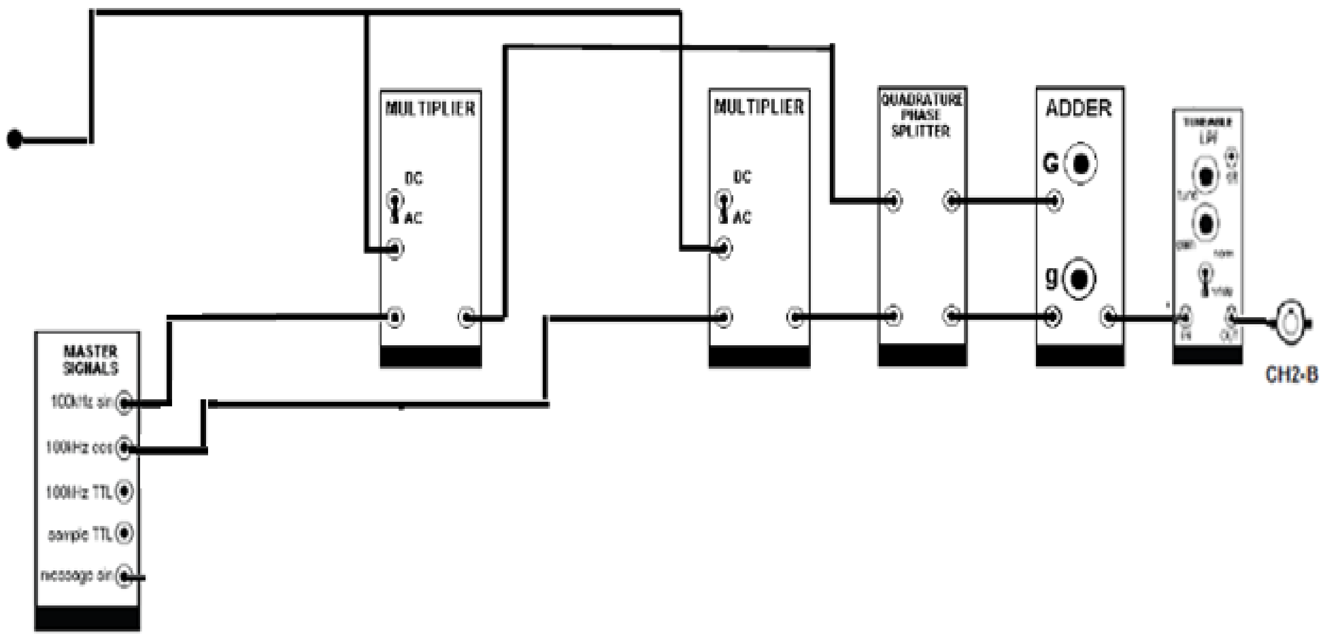


Figure 6. The TIMS Model of The Block Diagram of Figure 3

1. Switch the Scope Selector to CH1-A and CH2-B.
2. Observe the signal in time and frequency domains before and after the LPF simultaneously.
3. Vary the cutoff frequency of the LPF, and find the range of acceptable values for best recovery of the message.
4. Plot, in time, the best recovered signal you can obtain in your lab sheets.