Chapter 1

Experiment-8

1.1 Single Sideband Suppressed Carrier Modulation

1.1.1 Objective

This experiment deals with the basic of Single Side Band Suppressed Carrier ($SSB - SC$) modulation, and demodulation techniques for analog communication. The student will learn the basic concepts of SSB modulation and using the theoretical knowledge of courses. Upon completion of the experiment, the student will:

* Understand SSB modulation and the difference between SSB and DSB modulation

* Learn how to construct SSB modulators

* Learn how to construct SSB demodulators

* Examine the I Q modulator as SSB modulator.

* Possess the necessary tools to evaluate and compare the $SSB - SC$ modulation to $DSB - SC$ and DSB_TC performance of systems.

1.1.2 Prelab Exercise

1.Using Matlab or equivalent mathematics software, show graphically the frequency domain of $SSB - SC$ modulated signal (see equation-2) . Which of the sign is given for USB and which for LSB.

2. Draw a block diagram and explain two method to generate $SSB-SC$ signal.

3. Draw a block diagram and explain two method to demodulate $SSB-SC$ signal.

4. According to the shape of the low pass filter (see appendix-1), choose a carrier frequency and modulation frequency in order to implement LSB SSB modulator, with minimun of 30 dB attenuation of the USB component.

1.1.3 Background Theory

SSB Modulation

DEFINITION: An upper single sideband ($USSB$) signal has a zero-valued spectrum for $|f|<f_c$where f_c, is the carrier frequency.

A lower single sideband ($LSSB$) signal has a zero-valued spectrum for $|f| > f_c$ where f_c, is the carrier frequency. There are numerous ways in which the modulation $s(t)$ may be mapped into the complex envelope $g[m]$ such that an SSB signal will be obtained.

SSB-AM, which is detected by using a product detector, is by far the most popular type. It is widely used by the military and by radio amateurs in high-frequency (HF) communication systems, and it is popular because the bandwidth is the same as that of the modulating signal (which is half the bandwidth of an AM or $DSB-SC$ signal). For this reason, we will concentrate on this type of SSB signal.

THEOREM: An SSB signal is obtained by using the complex envelope

$$g(t) = A[s(t) \pm \hat{s}(t)] \tag{1.1}$$

which results in the SSB signal waveform

$$s_m(t) = A[s(t)\cos 2\pi ft \mp \hat{s}(t)\sin 2\pi ft] \tag{1.2}$$

where the upper (-) sign is used for $USSB$ and the lower (+) sign is used for $LSSB$. $\hat{s}(t)$ denotes the Hilbert transform of $s(t)$, which is given by

$$\hat{s}(t) \triangleq s(t) * h(t)$$

where

$$h(t) = \frac{1}{\pi t} \tag{1.3}$$

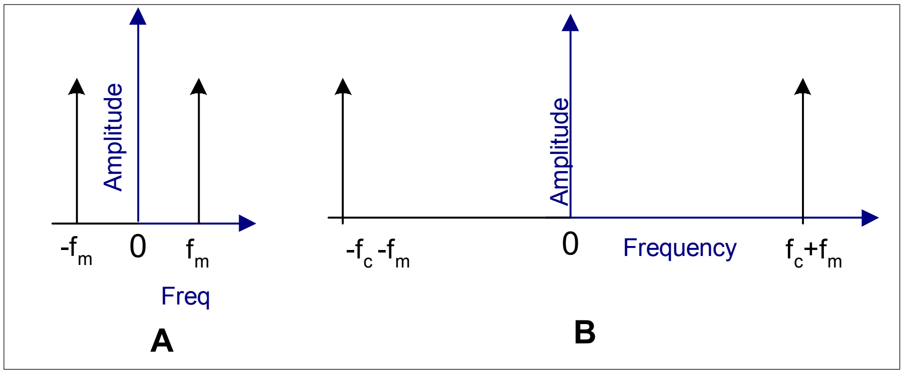


Figure 1.1: **A**- Spectrum of baseband signal. **B-** Spectrum of USSB signal

and $H(f) = F[h(t)]$ corresponds to a - 90^o phase shift network:

$$H(f) = \begin{cases} -j, & f > 0 \\ j, & f < 0 \end{cases} \quad (1.4)$$

Figure 1 illustrates this theorem. Assume that $s(t)$ has a magnitude spectrum that is of sinewave shape, as shown in Fig.1a. Then for the case of $USSB$ (upper signs), the spectrum of $g(t)$ is zero for negative frequencies, and $s(t)$ has the $USSB$ spectrum shown in Fig.1b.

$SSB - SC$ **Modulators**

Figure -2 illustrates one technique to generate SSB signal. The frequency discrimination method or filtering method is a special case, where RF processing (by using the sideband filter) is used to form the equivalent $g(t)$, instead of using baseband processing to generate $g[m]$ directly. The filter method is the most popular method used since excellent sideband suppression can be obtained when a ceramic or other type of filter is used.

Another popular method to generate SSB signal is known as Phase Shift Method, illustrated in Fig-3. The phase shifter delays all frequency components of $s(t)$ by $\frac{\pi}{2}$. If we let $\hat{s}(t)$ be the output of the phase shifter due the input signal $s(t)$, then the SSB output signal can be represented by

$$s_m(t) = A[s(t)\cos 2\pi ft \mp \hat{s}(t)\sin 2\pi ft] \quad (1.5)$$

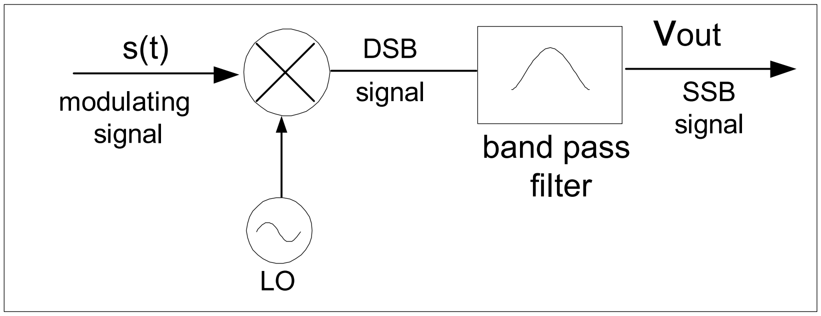


Figure 1.2: Frequency discrimination method

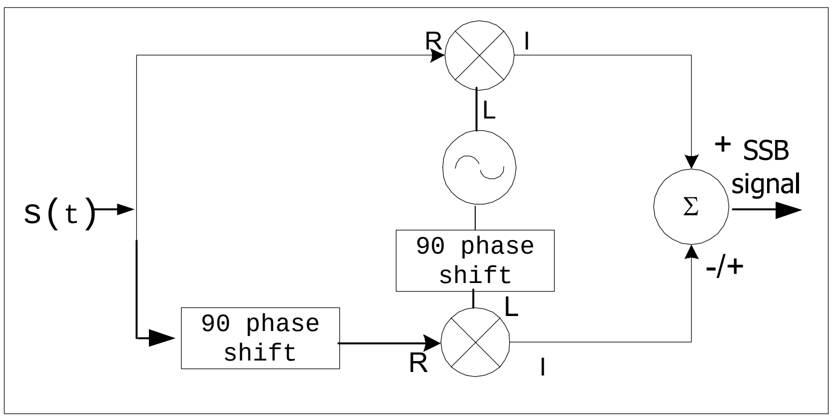


Figure 1.3: Phase shift nethod

Vestigial sideband modulation

Vestigial Sideband VSB modulation is a compromise between waste of bandwidth in DSB modulation and expensive implementation of SSB modulation. In this modulation one sideband is passed completely and just a part or vestige of the other sideband is retained. Typical bandwidth required to

VSB system is about 1.25 times of SSB system. VSB signal can be generated using $DSB - SC$ or $DSB - TC$ through a VSB filter.Fig 4 shows a way for generating VSB signal,the base band spectrum and the spectrum of the modulated signal.

IQ Modulation

One modulation technique that lends itself well to digital processes is called "IQ Modulation", where "I" is the "in phase" component of the wave form, and "Q" represents the the quadrature component. in its various forms,IQ modulation is an efficient way to transfer information, and it also works well with digital formats. Fig.3 shows a schematic diagram of a SSB modulator using I&Q modulator.This modulator is based on the phase shift method.In order to get SSB signal, the I and Q signal, which are the base band signal (information), need to have a $90°$ phase difference between them.That is way there is a phase shifter prior to the I&Q modulator.

Demodulation of SSB Signal

SSB Signal can be easily detected using Product Detector, as used in previous experiments (DSB and AM), as illstrated in Fig.5 . Fig.5A shows SSB signal which multiplied by the LO to produce $x(t)$, and passing through LPF to isolate the baseband signal.Fig.5B shows the specrum of the SSB signal. Fig.5C shows the specrum of x(t), which contains the baseband frequency and higher frequency produced by the LO. this frequency can easily be removed by a LPF. Fig.5D shows the spectrum of the signal passing throw the LPF. you can see that the higher frequency where filterd to obtain the baseband frequency.

1.2 Experiment Procedure

1.2.1 Required Equipment

1.Spectrum Analyzer.

2.Oscilloscope.

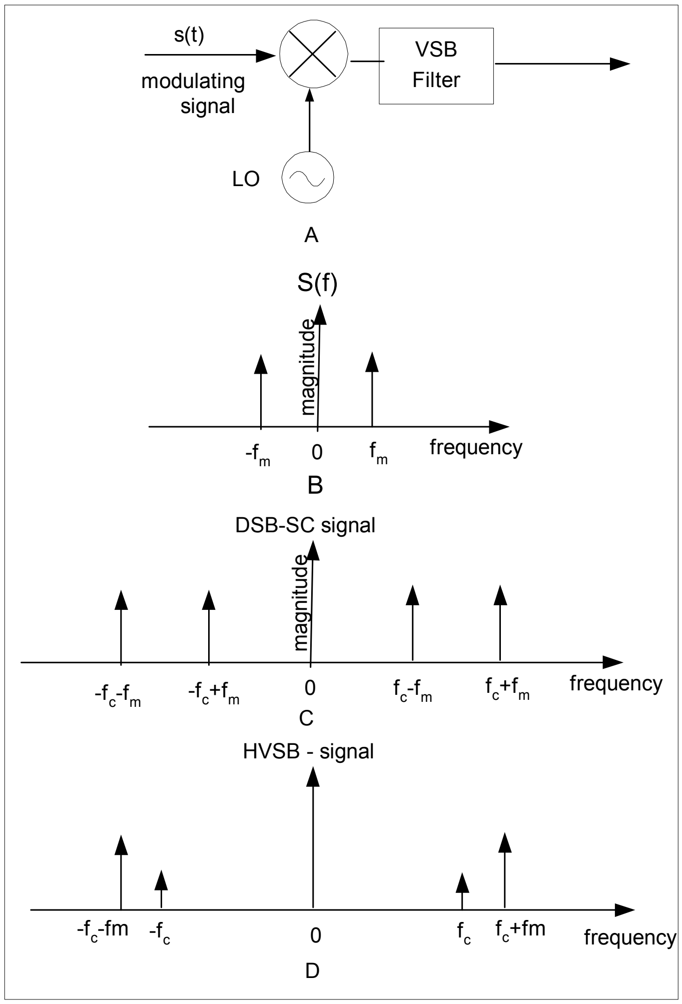


Figure 1.4: spectrum of : B- baseband signal, C-DSB signal,D-HVSB signal.

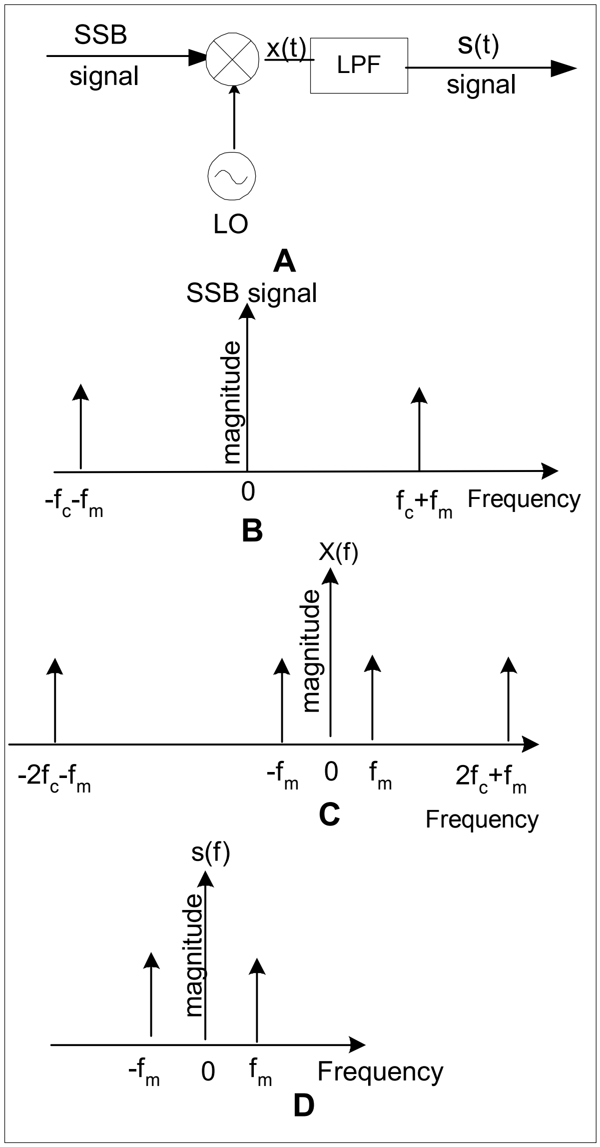


Figure 1.5: A product detector schematic diagram.

3.Signal Generator.
4. Two function generator.
5. Two Double Balanced Mixer
6. Two Low pass filter 1.9 MHz..
7. Splitter.
8. I&Q modulator - Mini Circuits ZFMIQ-10M.
9. I&Q demodulator - Mini Circuits ZFMIQ-10D.

1.2.2 SSB- Frequency Discrimination method

During this experiment you generate SSB signal using two methods frequency discrimination method and, phase shift method. You start with the first method, frequency discrimination method. We replace the sharp Band pass filter with standard low pass filter, using high modulation frequency.

1. Connect the equipment according to Fig.6.

2. Adjust the equipment as follow:

Function generator-1 RF frequency 1 MHz, amplitude -3 dBm.

Function generator-2 LO Carrier frequency 3 MHz, amplitude 0 dBm.

3. Set the spectrum analyzer to frequency 3 MHz , span 4 MHz, bandwidth 10 kHz and reference level to 0 dbm.

4. What is the Bandwidth of the modulated signal?

5. Which major sideband do you see on the screen explain? Place a marker delta on two sidebands and **save data on magnetic media.**

6. Change the frequency of the LO and baseband frequency according to your suggestion in prelab exercise-4 . Which major sideband you see now on SA explain? Print the results.

7. Disconnect the LPF and verify your answers.

save data on magnetic media

Frequency Discrimination method - Demodulation

In this part of the experiment you will construct a product detector to demodulate the baseband (information) signal. connect the equipment according to Fig.7.

A product detector is based on phase synchronization between the LO signal at the receiver, and the transmitter

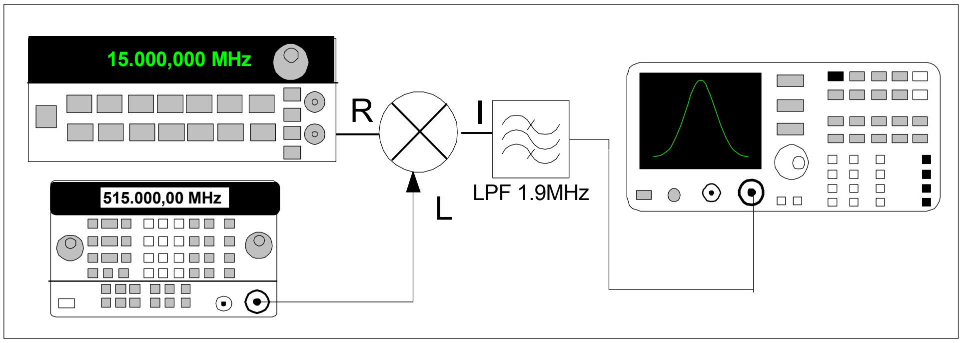


Figure 1.6: SSB modulator-frequency discrimination method.

1.2.3 Transmitter setting

1 Set the RF function generator to 1 MHz, amplitude -3dBm.
2. Set the LO function generator to 3 MHz, amplitude 0dBm.

1.2.4 Receiver

1. Set the LO signal generator to 3 MHz, amplitude 0dBm.
2. Set a 0°, phase difference between the two LO's signal.

3. Measure the amplitude of the baseband signal on spectrum display, and explain the amplitude difference?.
4. Connect the detected signal to oscillioscope, change the phase between the two LO's (0° to 90°)and explain the variation of the detected signal. **Record the worst and the best detected signals.**

SSB-Phase Shift Method

In this part of the experiment you will modulate/demodulate SSB signal using the I&Q Modulator.

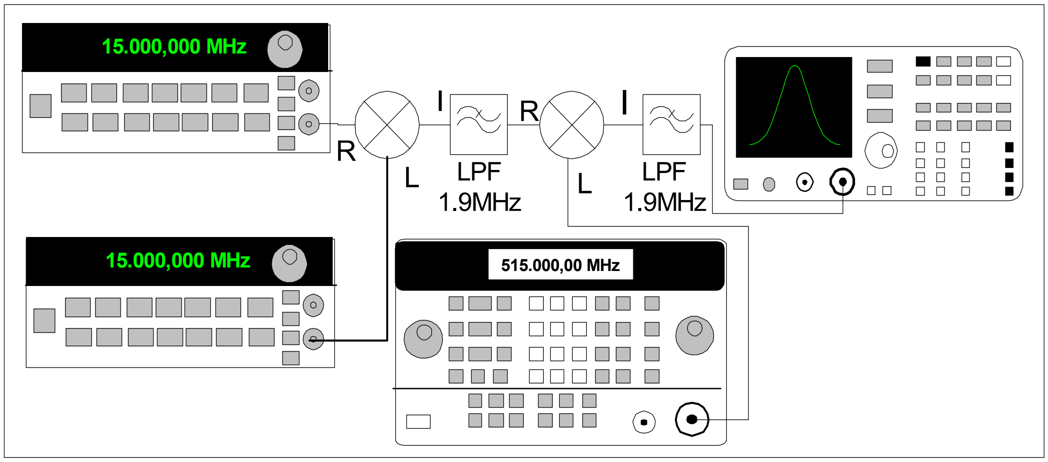


Figure 1.7: SSB demodulator-a product detector.

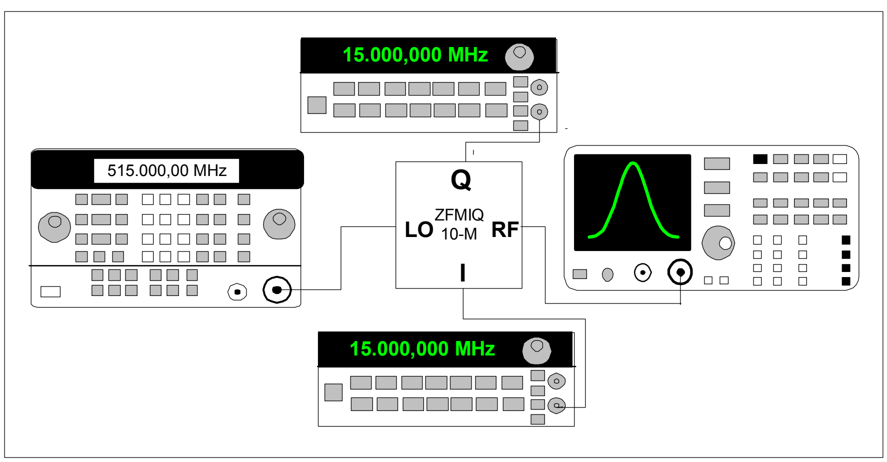


Figure 1.8: SSB modulation using I&Q modulator.

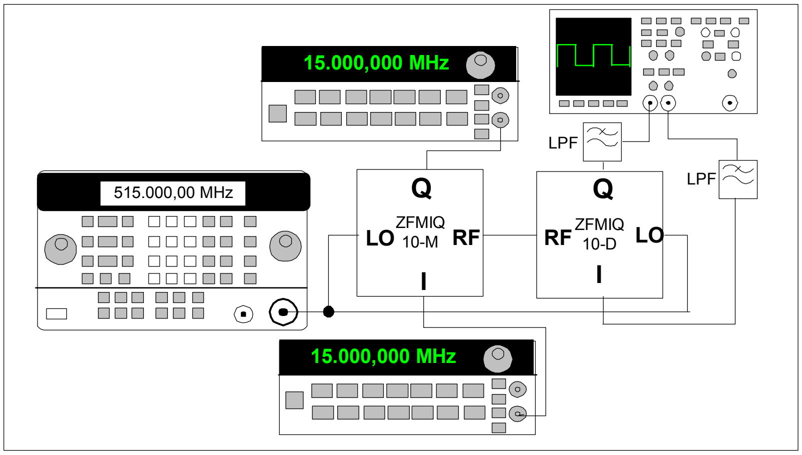


Figure 1.9: SSB demodulator using I&Q modulator/demodulator

1.2.5 SSB Modulation

1. Connect the equipment according to Fig.-8.

2. Set the equipment as follow:
Functoin generator **I** - frequency 100 kHz, amplitude -5 dBm.
Functoin generator **Q** - frequency 100 kHz, amplitude -5 dBm.
Signal generator frequency 10 MHz, amplitude 10 dBm.

3. Set the phase between the two function generators to 90°

4. Set the spectrum analyzer to frequency 10 MHz , span 1 MHz, resolution bandwidth 10 kHz .

5. Change the phase between the two Function generators slightly untill you get a "clean" SSB signal with maximum USSB attenuation. Measure the amplitude of the SSB signal, why it is less then -5 dbm?**save data on magnetic media.**

6. Change the phase between -90, 0, and 90 degrees to get DSB, USSB, and LSSB signals.**save data on magnetic media.**

1.2.6 SSB Demodulation

1. Connect the equipment according to Fig.-9.

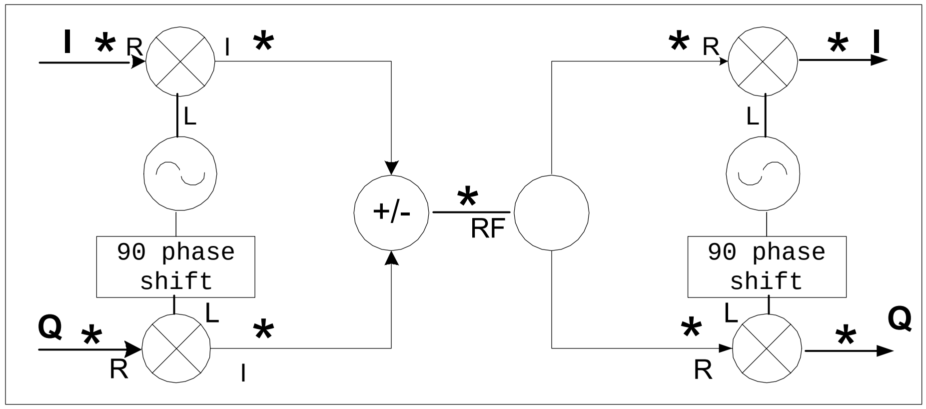


Figure 1.10:

2. Observe the detected I and Q signals on the ocsilloscope display , what is the phase difference between these two signal?

3. Verify that the frequency of the detected **I** signal is the same as the baseband **I** Signal. **save the detected I signal on magnetic media.**

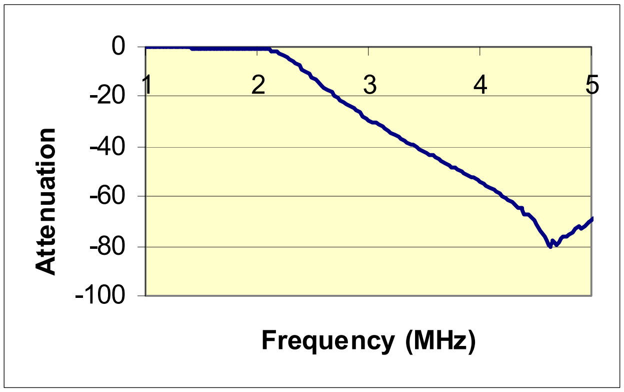
1.3 Final Report

1.Attached all the print results, answers and your analyzes to the following question.

2. Reffer to Fig- 10, Write a mathematical expresion, for each ★ symbol.

1.4 Appendix-1

1.4.1 SSB Low Pass Filter shape



Low pass filter Mini-Circuit BLP-1.9