Experiment 6

DSB-SC Modulation and Demodulation

Objectives :

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

1. Demonstrate the modulation and demodulation process of DSB-SC.
2. Realize the real-life difficulties and challenges in designing coherent demodulators.
3. Examine the implications of the lack of perfect coherence on the recovered signal, and distinguish the different forms of distortion.

Introduction :

Double Side Band Suppress Carrier (DSB-SC) is one type of Amplitude Modulation. The modulation process is straightforward: the message is multiplied by a high-frequency carrier. The modulated signal occupies double the bandwidth of the baseband signal.

Consider two sinusoids, or cosinusoids, $\boldsymbol{A_m}\mathbf{Cos(\ 2\pi} \boldsymbol{f_m}\mathbf{t)}$ (Message Signal) and $\boldsymbol{A_c}\mathbf{Cos(2\pi}\boldsymbol{f_c}\mathbf{t})$ (Carrier Signal). DSBSC, is defined as their product, namely:

$$\textbf{DSB-SC} = \mathbf{E\ Cos(\ 2\pi} \boldsymbol{f_m t}\ \mathbf{)\ .\ Cos(2\pi}\boldsymbol{f_c t}\mathbf{)}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(1)}$$

$$= \frac{E}{2}\,\mathbf{Cos(2\pi}\ (\boldsymbol{f_c} - \boldsymbol{f_m})\mathbf{t)} + \frac{E}{2}\,\mathbf{Cos(2\pi}\ (\boldsymbol{f_c} + \boldsymbol{f_m})\mathbf{t)}\ \ldots\ldots\ldots\ldots\ldots\mathbf{(2)}$$

Where:

$\boldsymbol{A_m}$: is the message signal amplitude.
$\boldsymbol{f_m}$: is the message signal frequency.
$\boldsymbol{A_c}$: is the carrier signal amplitude.
$\boldsymbol{f_c}$: is the carrier signal frequency.
E : is equal to $\boldsymbol{A_m}.\ \boldsymbol{A_c}$.

The time domain appearance of a DSB-SC (eqn. 1) is generally as shown in Figure 1**.**

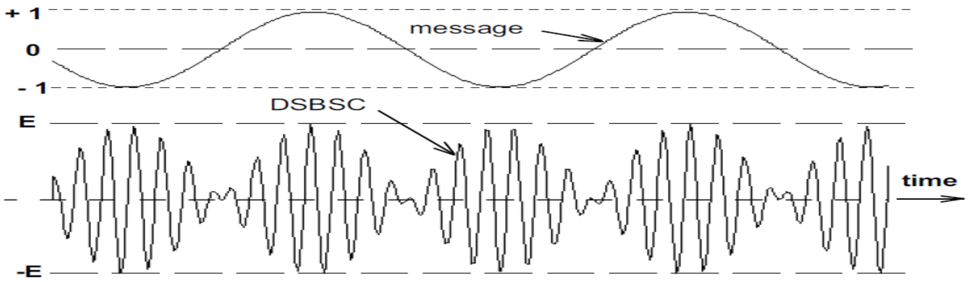

Figure 1. DSB-SC Time Domain Waveform

Spectral Analysis :

Equation (2) shows that the product is represented by two new signals, one on the sum frequency $(f_c + f_m)$,and one on the difference frequency $(f_c - f_m)$ see Figure 2.

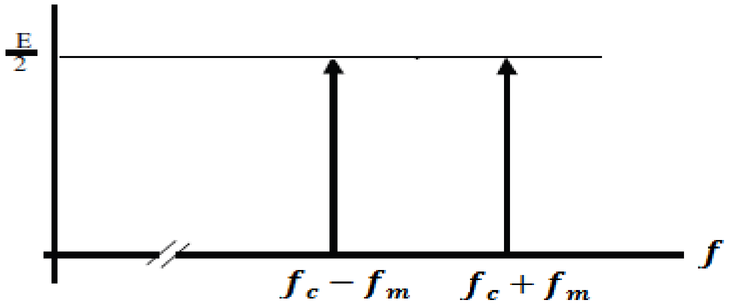

Figure .2 The Spectral Components of DSB-SC

DSB-SC Generation Block diagram :

A block draigram, showing how equation (1) could be modelled with hardware, is shown in Figure 3 below.

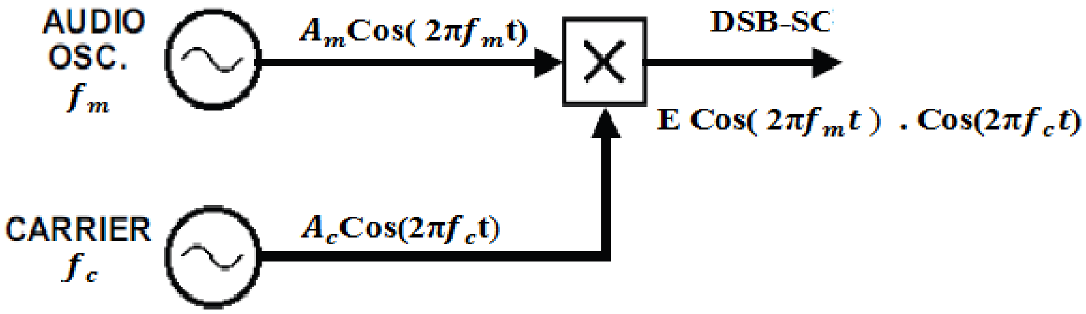

Figure .3 DSB-SC Generation Block Diagrams

DSB-SC Demodulation :

Recovering the message signal from the demodulated signal is performed coherently. That is, the demodulated signal is multiplied by a high-frequency sinusoid in perfect synchronization (in phase and frequency) with the incoming carrier.

This requirement poses a challenge on the design of the demodulator circuit, as it would then require a part for carrier-recovery. Failing to accomplish perfect synchronization will result in phase mismatch or frequency mismatch, leading to some form of distortion in the recovered signal.

Multiplying the modulated signal with a local carrier will produce a baseband signal as well as a signal modulated at double the carrier frequency. Therefore, a LPF is needed at the far end of the demodulator to recover the baseband signal .

DSB-SC Generation Block Diagram :

A block diagram of DSB-SC Demodulation (Coherent Detection), is shown in Figure 34 below.

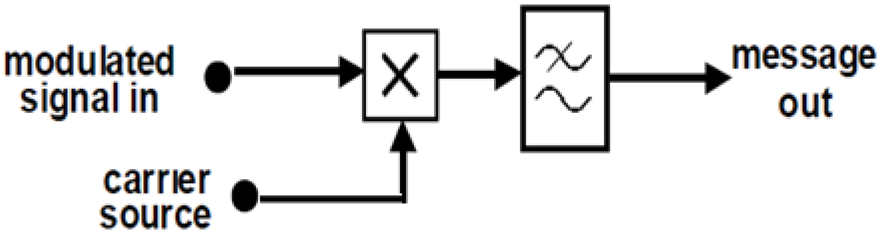

Figure .4 DSB-SC Demodulation Block Diagram

Lab Work

This experiment consists of four parts. In Part I we generate the DSBSC signal using single-tone message signal. In Part II we demodulate the signal, assuming perfect synchronization of incoming and local carriers. We also examine the effect of improper filtering. In part III and IV, we examine the effect of phase and frequency mismatch, respectively.

Modules :

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

Part I: DSB-SC Modulation

Procedure :

1. Construct The block diagram of Figure 3, which models the AM equation, by using TIMS as shown in figure 6.
2. Use the Frequency Counter to set the Audio Oscillator to about 10 kHz.
3. Switch the Scope Selector to CH1-A and CH2-A.
4. Use the Oscilloscope to Plot the waveforms of the input signal ,the carrier signal, and the DSB-SC signal in you lab sheets.
5. Use the PicoScope to plot the spectral components of DSB-SC Signal in you lab sheets.

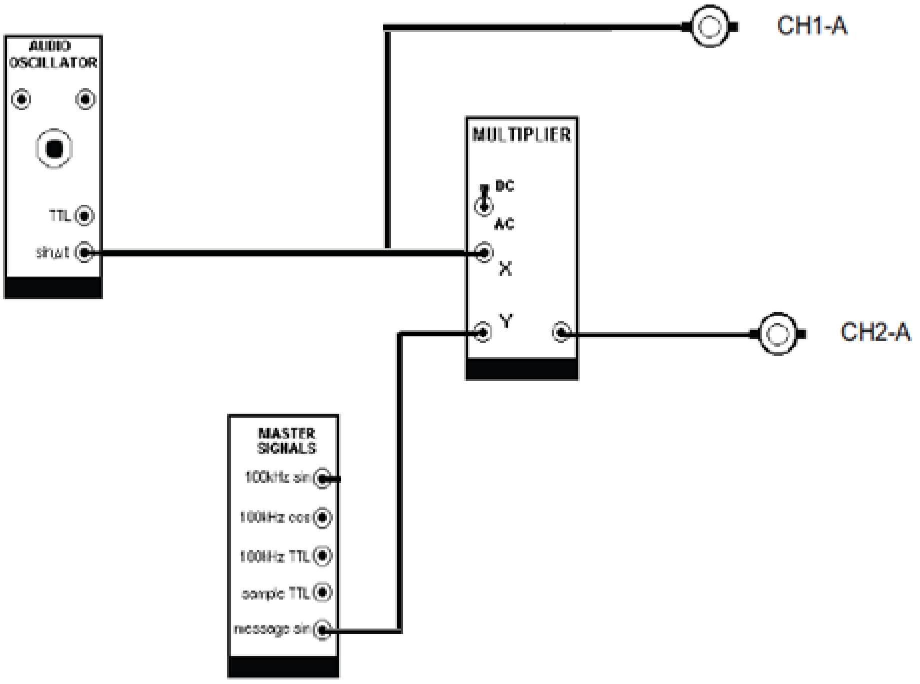

Figure .5 The TIMS Model of The Block Diagram of Figure 3

Part II: DSB-SC Demodulation

Procedure:

1. Use the same carrier of Part I, multiplier and a Tunable LPF to demodulate the DSBSC generated in Part I as shown in below figure.

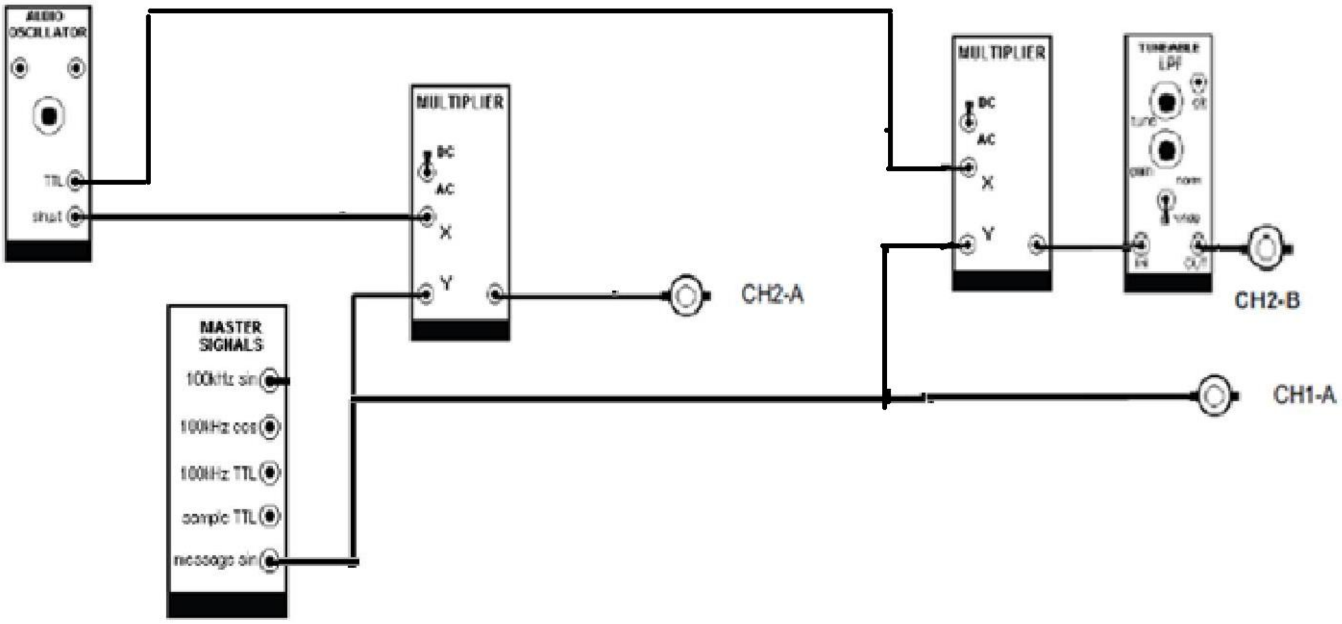

Figure .6 The TIMS Model of The Block Diagram of Figure 4

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

Part III: Effect of Phase Mismatch

In this part we use the Phase Shifter module to introduce a phase error between the carrier at the transmitter and the carrier at the receiver.

Procedure:

1. Set the cutoff frequency of the LPF in the demodulation circuit to any value in the good range for recovery
2. Instead of borrowing the carrier from the transmitter, feed the carrier of the transmitter to the Phase Shifter module and take the output to the multiplier of the demodulator circuit as shown in below figure.

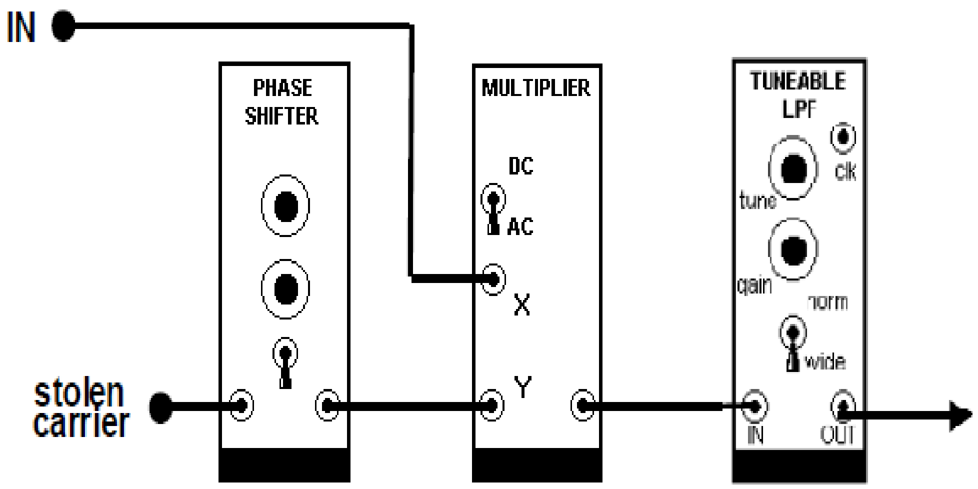

Figure .7 The TIMS Model of DSB-SC Demodulator with Phase Shifter

3. Observe the original message signal and the recovered signal simultaneously in time domain. Vary the phase shift, and describe the effect on the recovered signal.

Part IV: Effect of Frequency Mismatch

Of course, no one is interested in making frequency mismatch intentionally. But in real life you cannot borrow the carrier from the transmitter. (Otherwise you could have borrowed the message itself and saved all the hassle of communication!). One will do his best to reproduce a carrier at the same frequency used at the transmitter, but they cannot be 100% identical. In this part, we use a different source to generate the carrier for the demodulator circuit.

Procedure

1. Generate an independent 10 kHz signal for the receiver circuit. For that you can use the Voltage-Controlled Oscillator (VCO) module as shown below figure.

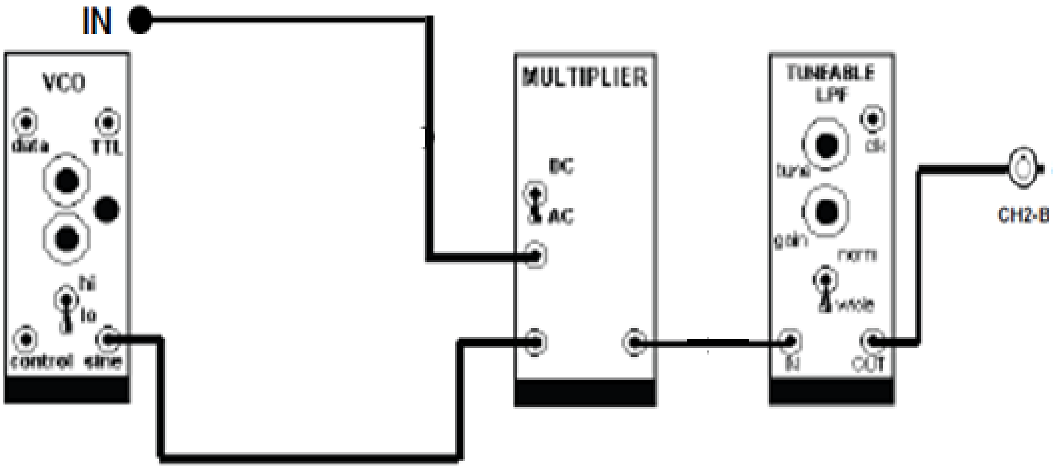

Figure .8 The TIMS Model of DSB-SC Demodulator with VCO.

2. Observe, simultaneously, the original signal and the recovered signal, in time and frequency. Describe the effect of frequency mismatch.

3. Try to eliminate the frequency mismatch by fine tuning oscillator.