Generation and Demodulation of DSB-SC Amplitude Modulated Signals

1 Objectives

- Generation of DSB-SC amplitude modulated signals using a diode-based switching modulator circuit.
- Demodulation of the generated AM signal using envelope detector circuit.

2 Theory Overview

A double-sideband, suppressed carrier (DSB-SC) AM signal is obtained by multiplying the message signal $m(t)$ with the carrier signal $c(t)$. Thus, we have the amplitude modulated signal [1]

$$s(t) = m(t)c(t) = A_c m(t) \cos(2\pi f_c t). \tag{1}$$

Accordingly, the device used to generate the DSB-SC modulated wave is referred to as a product modulator. We also note that unlike conventional amplitude modulation, DSB-SC modulation is reduced to zero whenever the message signal is switched off.

Also, observe that the modulated signal undergoes a phase reversal whenever the message signal crosses zero, as indicated in Figure 1 for the message signal depicted in part (a) of the figure. The envelope of a DSB-SC modulated signal is therefore different from the message signal, which means that simple demodulation using an envelope detection is not a viable option for DSB-SC modulation.

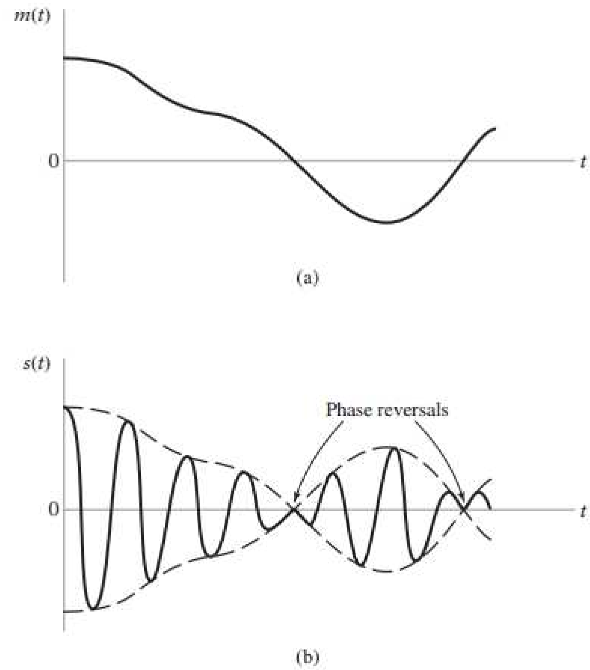

Figure 1: Message signal and DSB-SC modulated wave [1]

3 Circuit and Its Working Principle

The product operation needed for the generation of DSB-SC signals (as shown in (1)), is realized with the help of diode-based *switching modulator* circuit. The process of the generation of the DSB-SC signals is depicted in Figure 2. The circuit for the same is shown in Figure 3.

The switching modulator comprises of a diode-bridge having four diodes D1, D2, D3 and D4. The switching of the diodes is controlled by the carrier signal $c(t)$ [2]. It is also known as Chopper modulator. When the voltage at **A** is greater than that at **B**, all the diodes will be reverse-biased and the amplitude of the message signal will be output. When the voltage at **A** is smaller than that at **B**, then all the four diodes will be forward-biased and then zero-output is obtained. This switching results in the multiplication of the message signal $m(t)$ with a periodic square wave $w(t)$ with period equal to the carrier frequency f_c [3]. Since $w(t)$ is a periodic square signal with fundamental frequency f_c, it can be expressed in terms of Fourier series and it contains many harmonics of f_c. The signal $m(t)w(t)$ contains infinite number of modulated signals with carrier frequencies $f_c, 3f_c, 5f_c \ldots$. However, we are interested only in $A_c m(t)\cos(2\pi f_c t)$. In order to extract this component, a band-pass filter is appended to the bridge circuit. The center frequency of the filter should be f_c.

To apply the envelope detector for the DSB-SC signals, sometimes, a DC offset is added to the modulating signal $m(t)$. This ensures that $m(t) \geq 0$ and the modulated signal $s(t)$ does not undergo phase reversal. Hence, the message signal can be extracted from the positive envelope (But the question: Is the carrier suppression maintained?) Consider a simple envelope detector as shown in Figure 4. Here, the RC value should be greater than $1/f_c$ but less than $1/f_m$.

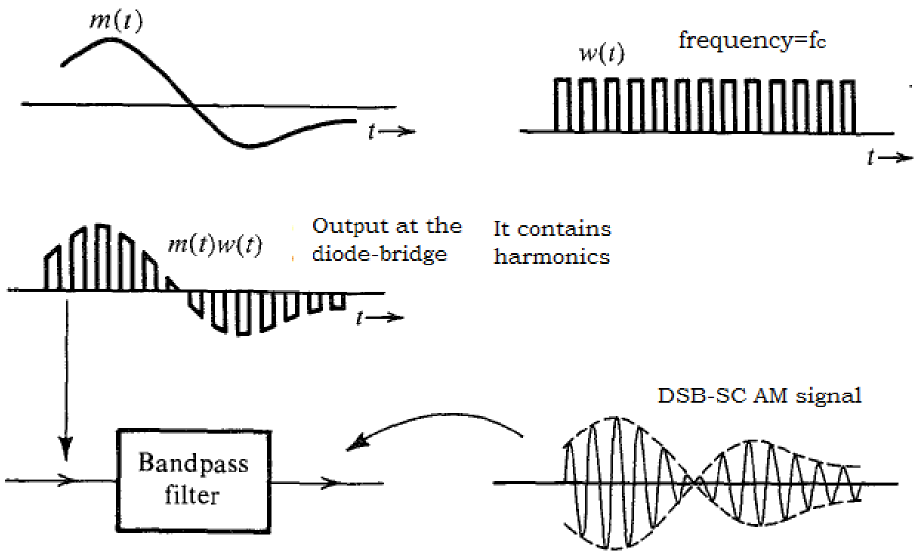

Figure 2: Generation of DSB-SC signals [3]

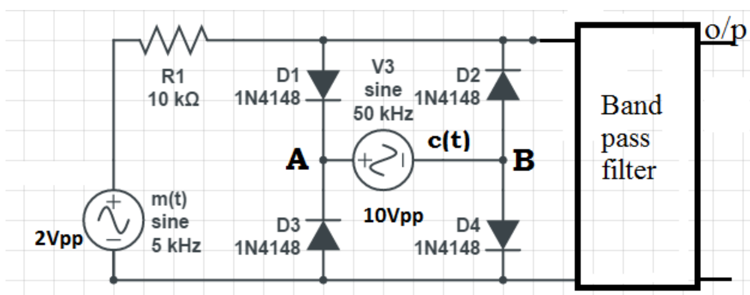

Figure 3: Circuit for generation of DSB-SC signals

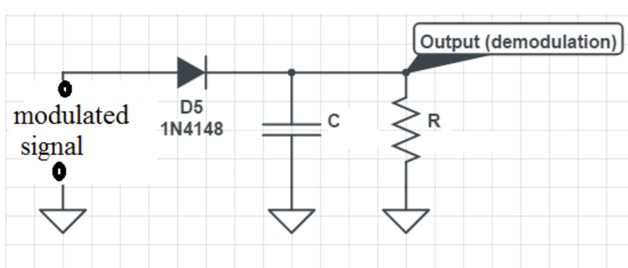

Figure 4: Circuit for Envelope Detector

4 Lab Procedures

Perform the following steps:

- Modulation
  - Assemble the circuit as shown in the circuit diagram of Figure 3.
  - Apply a sinusoidal message signal of Vpp=2V, f_m=5 kHz and a carrier signal of Vpp=10V and f_c=50kHz.
  - Observe the signal after the diode-based bridge circuit stage.
  - Design the band-pass filter so that the unnecessary harmonics are filtered out.
  - Observe the output of the band-pass filter.
  - Now apply a dc offset of 4V to the message signal. Explain the changes in the output of the band-pass filter.
- Demodulation
  - Design the envelope detector circuit in Figure 4 which is to be connected in cascade to the circuit in Figure 3.
  - Measure the output across the resistor R.
  - Observe the waveform carefully. It should be a scaled form of the input modulating signal if the demodulation has been accurate.

Questions

1. What is the modulation index? Does it depend on the offset value of the message/modulating signal?
2. Explain the switching of the diodes.
3. Write down the challenges faced in the experiment if any and the ways to resolve those issues.

References

[1] Haykin and Moher, *An Introduction to Analog and Digital Communications*, (Wiley, Second edition 2012).

[2] Proakis and Salehi, *Communication System Engineering*, (2nd edition, Prentice Hall, 2003).

[3] B.P Lathi and Zhi Ding, *Modern Digital And Analog Communication Systems*, (Oxford University Press, Fourth edition 2017).