CT 214 Analog and Digital Communications

Lab # 5: Conventional Amplitude Modulation (AM) and Double Sideband (DSB)-AM*

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Guidelines:

- **Pre lab preparation: Please try to read Amplitude Modulation portion of Chapter 4 of the textbook.**
- **Ensure you answer all the questions that have been asked as part of this lab.**
- **Please attach the corresponding code and plots along with your final report.**

1. **Aim:** The purpose of this lab is to generate (i) conventional (standard) AM and and (ii) DSB-SC. We will also discuss the demodulation of DSB-SC.

2. **Introduction:** In amplitude modulation (AM) the message signal say $x(t)$ modulates a high frequency carrier $A_c \cos(\omega_c t)$. A unique property of AM is that the envelope of the modulated carrier follows the shape of the message signal.

   The *conventional AM signal* that is used in practice extensively is given as

$$\begin{aligned} x_{\mathrm{AM}}(t) &= A_c\left[1+\mu x_{\mathrm{normalized}}(t)\right]\cos\omega_c t \qquad (1) \\ &= A_c\cos\omega_c t + A_c \mu x(t)\cos\omega_c t \ , \end{aligned}$$

   where μ is a constant called the **modulation index** and $x_{\mathrm{normalized}}(t) = x(t)/\max|x(t)|$ is the normalized message signal.

   The envelope reproduces the message signal $x(t)$ if $f_c >> W$ and $\mu << 1$. Under these conditions $x(t)$ can be easily extracted $x_c(t)$ by using a simple **envelope detector.** Indeed this simplicity of the envelope detector is what makes AM so popular for broadcasting.

   Note: In (1) the message signal $x(t)$ and the carrier $A_c \cos\omega_c t$ have the same phase reference. In practice they could have different phase references since they come from independent and unsynchronized sources.

   One of the common disadvantage of using conventional AM is that it is highly power inefficient. Indeed more than half of the total transmitter power is lost in the carrier. This motivates us to consider a variant of it which is known as *DSB-suppressed carrier* AM technique which is abbreviated as DSB-SC. The DSB-SC can be obtained from (1) by setting $\mu = 1$ and suppressing the unmodulated carrier frequency component $A_c \cos \omega_c t$. Thus,

$$x_{\text{DSB-SC}} = A_c x(t) \cos \omega_c t \ . \tag{2}$$

The gain in power efficiency obtained by using DSB-SC comes at the expense of complicated demodulation circuitry. Indeed to demodulate a DSB-SC signal one needs to generate the carrier accurately at the receiver side. Needless to say the carrier signal generated at the receiver could be subject to errors leading to frequency and phase mismatch which can affect the demodulation performance adversely.

The procedure for DSB-SC demodulation is summarized in the following block diagram:

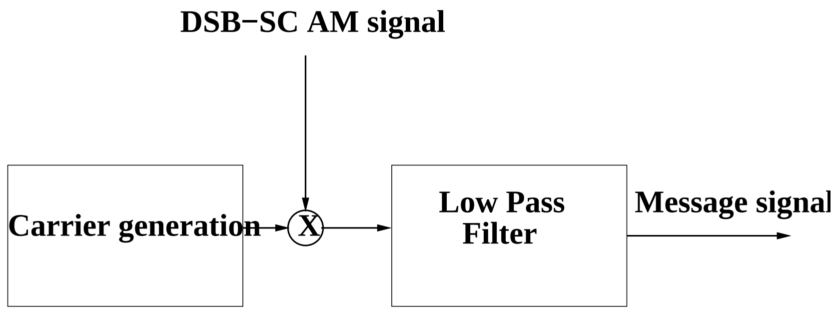

Figure 1: The figure above shows the block diagram of a DSB-SC Demodulator.

3. **Lab Exercises:** Wherever the message signal is not given explicitly assume the message signal $x(t)$ to be

$$\cos(\omega_m t) + 2\cos(2\omega_m t) + 4\cos(3\omega_m t) + 5\cos(5\omega_m t) \tag{3}$$

you may assume the frequency of the message f_m to be 50Hz and the carrier frequency f_c can be chosen to be (say) $20 f_m$Hz (since $f_c >> f_m$).

(a) **Conventional AM Generation:**

i. Generate and plot the message signal in (3) and the corresponding conventional AM modulated signal $x_{\text{AM}}(t)$ for $\mu = 0.8$ (4 marks).

ii. Repeat the second part of part (a) above for $\mu = 1.2$. What do you notice and why (3 marks)??

iii. Compute and plot the spectrum of $x(t)$ and $x_{\text{AM}}(t)$ (3 marks).

(b) **DSB-SC AM Generation:**

i. Generate and plot the message signal in (3) and the corresponding DSB-SC AM modulated signal $x_{\text{DSB-SC}}(t)$ in both frequency and time domain (5 marks).

(c) **DSB-SC Demodulation:** For this part generate a DSB-SC AM signal assuming the message signal $x(t) = \cos(2\pi 50t)$.

i. Demodulate the above generated bandpass DSB-SC AM signal as per the block diagram given above. You may use the carrier generated at the receiver to be (1) $\cos(2\pi 50t)$, (2) $\cos(2\pi 50t + \pi/4)$ and (3) $\cos(2\pi 50t + \pi/2)$. For each case observe the spectrum and comment on it (10 Marks).

Note: You may have to choose the cutoff frequency of the low pass filter (LPF) as equal to the bandwidth of the signal (or somewhat larger). The following two commands namely: `butter (iir_butter), filter` can help you create a Butterworth LPF. Take a look at the help menu to explore further.