CSE 311
Data Communication Assignment
Group 11
Section: B2

Masfiqur Rahman-1505111

Md. Sakhawat Hossain-1505112

Ahmed Nafis Fuad-1505113

Md Awsaf Alam-1505114

Arghya Pratim Pal-1505115

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Chapter 1

Lecture 1 (1505114)

1.1 Modulation

1.1.1 Introduction

Modulation is done when message signal is not capable of propagating long distance, we change the signal by multiplying another high frequency signal and send the modulated signal.

If the characteristics of the message signal is changed, the message contained in it also alters. Hence, is must be ensured that the message signal is not altered in anyway. A high frequency signal can travel up to a longer distance, without getting affected by external disturbances. We take the help of such high frequency signal which is called as a carrier signal to transmit our message signal. Such a process is simply called as Modulation.

Modulation is the process of changing the parameters of the carrier signal, in accordance with the instantaneous values of the modulating signal.

1.1.2 Advantages of Modulation

The antenna used for transmission, had to be very large, if modulation was not introduced. The range of communication gets limited as the wave cannot travel a distance without getting distorted.

Following are some of the advantages for implementing modulation in the communication systems.

- Reduction of antenna size
- No signal mixing
- Increased communication range
- Multiplexing of signals
- Possibility of bandwidth adjustments

- Improved reception quality

1.1.3 Types of Modulation

There are many types of modulations. Depending upon the modulation techniques used, they are classified as shown in the following figure.

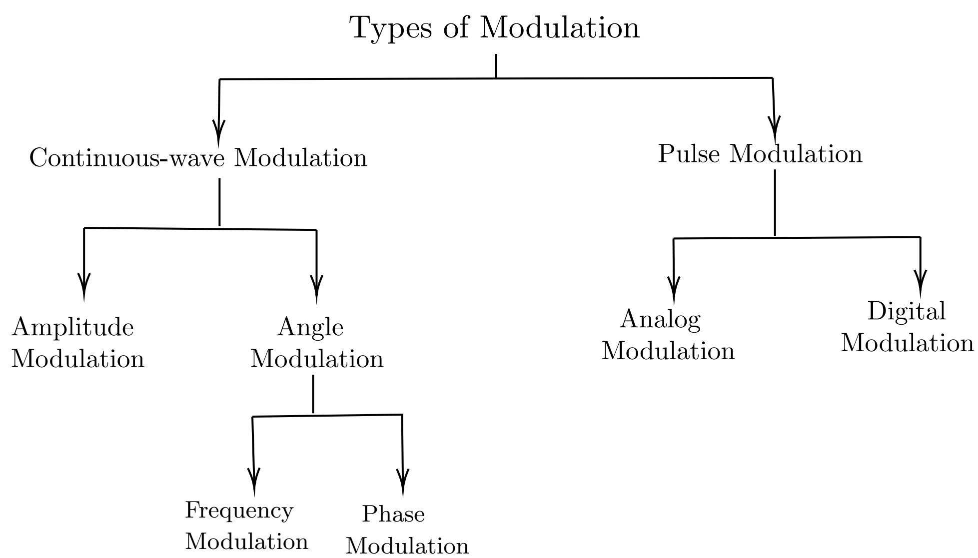


Figure 1.1: Types of Modulation

1.2 Amplitude Modulation & Demodulation

In this chapter we will focus on classic analog modulations

1. Amplitude Modulation
2. Angle Modulation

Before we begin our discussion of different analog modulations, it is important to distinguish between communication systems that do not use modulation (**baseband communications**) and systems that use modulation (**carrier communications**).

1.2.1 Baseband & Carrier communication

The term **baseband** is used to designate the frequency band of the original message signal from the source.

1. **Baseband communication**
   Message signals are directly transmitted without any modification. Because most baseband signals such as audio and video contain significant low-frequency content, they cannot be effectively transmitted over radio (wireless) links. So,dedicated user channels such as wires and coaxial cables are assigned to each user for long distance communication.

   Baseband signals will interfere with one another severely since their band overlaps. FDM allow utilization of one channel by signals through modulation and shifting of spectra to nonoverlapping bands.

2. **Carrier communication**
   Communication that uses modulation to shift the frequency spectrum of a signal is known **carrier communication**.There are three parts of a **sinusoidal carrier** :

   - Amplitude A_c
   - Frequency f_c
   - Phase ϕ

   One of these parameters is varied linearly with the baseband signal $m(t)$,in the case of analog modulation. This results in amplitude modulation(AM), frequency modulation(FM),or phase modulation (PM), respectively.**Amplitude modulation** is *linear* while the latter two types of carrier modulation are similar and *nonlinear* (called **angle modulation**)

1.2.2 Amplitude Modulation (AM)

In analog modulation, the amplitude of the carrier signal is made to follow that of the modulating signal. Several variants of amplitude modulation are used in practice. They are Double Side Band Suppressed Carrier (DSBSC) Modulation, Single Sideband Suppressed Carrier (SSBSC) Modulation and Vestigial Sideband Amplitude Modulation (VSBAM).

Introduction

Let $m(t)$ denote a signal that contains information to be transmitted. The information can take analog form or digital form. In traditional analog radio broadcast, $m(t)$ would be an audio signal. In digital communication systems, $m(t)$ may be a sequence of pulses that carries binary data. The information-bearing signal $m(t)$ will be called a **message signal** for convenience. Also, we will assume that $m(t)$ is a **baseband signal** with bandwidth W Hz.

Let $c(t) = A_c cos(2\pi f_c t + \phi)$ denote a *sinusoidal carrier wave*, where A_c is the carrier amplitude and f_c is the carrier frequency. We wish to use the carrier wave to carry the message signal, so that the message signal can appropriately be transmitted over a bandpass channel.There are various carrier modulation techniques. Among them, amplitude modulation (AM) is considered the oldest.

Amplitude Modulation Principle

Let the *Fourier Transform* of $m(t)$ is denoted by $M(f)$. To move the frequency response of $m(t)$ to a new frequency band centered at f_cHz, we use the *frequency shifting property*. In other words, all we need to do is to multiply $m(t)$ by a sinusoid of frequency f_c such that

$$s_1(t) = m(t)cos\ 2\pi f_c t$$

This immediately acheives the basic aim of modulation by moving the signal frequency content to be centered at f_c via

$$S_1(f) = \frac{1}{2}M(f - f_c) + \frac{1}{2}M(f + f_c)$$

This allow changes in the amplitude of the sinusoid $s_1(t)$ to be proportional to the message signal (Amplitude Modulation)

Envelope Formation

The amplitude-modulated wave may be described by the following formula

$$s(t) = [1 + k_a m(t)]c(t) = A_c[1 + kam(t)]cos(2\pi f_c t), \tag{1.1}$$

where k_a is a constant and is called the amplitude sensitivity. Figures 1.2.(a)-(b) gives an illustration of the AM process. In the illustration of the AM wave in Figure 1.2(b), the constant k_a is adjusted such that $1 + k_a m(t) \geq 0$ for all t. It is observed that the envelope of the AM wave takes the same shape as the message signal (more precisely, the waveform $1 + k_a m(t)$). In fact, the idea of AM is to use the envelope of the modulated wave $s(t)$ to carry the message signal. There is a requirement for AM to operate properly. Specifically, we must have

$$|k_a m(t)| \leq 1,\ for\ all\ t. \tag{1.2}$$

The condition in 1.2 implies that $1+kam(t) \geq 0$ for all t. Figure 1.2.(c) shows a situation where $1 + k_a m(t) < 0$ for some t. We see that the envelope of the AM wave now becomes a distorted version of the message signal. This phenomenon is sometimes known as overmodulation, which can happen when k_a is set too large.

We consider several modifications of the previously studied AM scheme, namely, double sideband-suppressed carrier modulation, single sideband modulation and quadrature amplitude modulation.

While the AM scheme is rarely seen in modern communication, we still see some AM concepts,particularly quadrature amplitude modulation, being used—that includes advanced digital com- munication systems.

1.3 Double Side-Band Suppressed Carrier

Recall that m(t) denotes the message signal, and $c(t) = A_c cos(2\pi f_c t)$ denotes the sinusoidal carrier wave. Also recall that m(t) is assumed to be a baseband

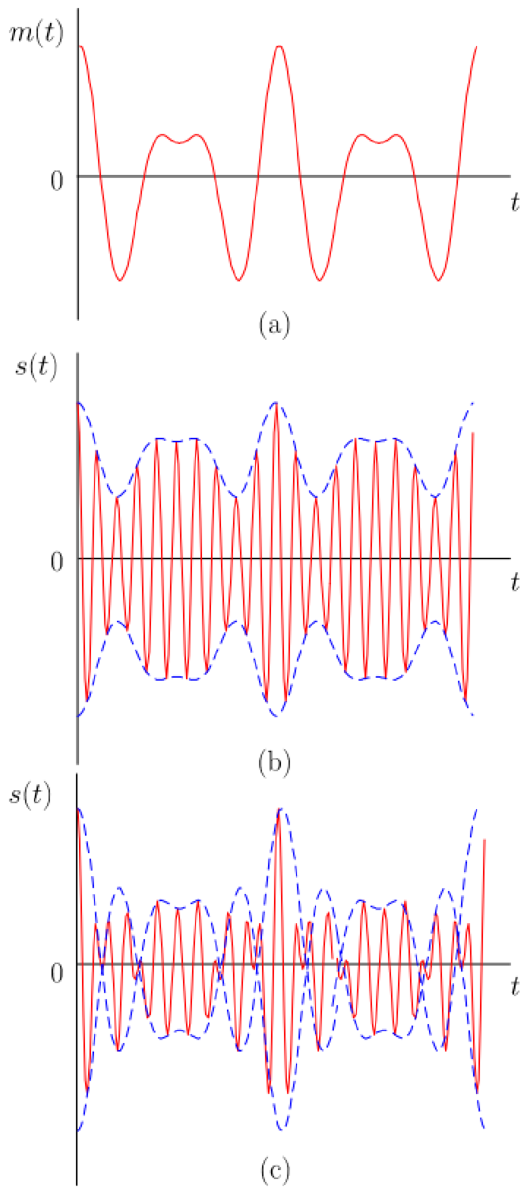


Figure 1.2: An illustration of the AM process. (a) The message signal m(t). (b) The AM wave s(t) when $|k_a m(t)| \leq 1$ holds for all t. (b) The AM wave s(t) when we have $|k_a m(t)| > 1$ for some t.

signal with bandwidth W Hz. In double sideband-suppressed carrier (DSB-SC) modulation, the modulated wave is given by

$$s(t) = m(t) \cdot c(t) = A_c m(t) cos\ w_c t \tag{1.3}$$

If the carrier amplitude A_c is made directly proportional to the modulating signal $m(t)$ then the modulated signal is simply $m(t)cos\ w_c t$ as shown in Figure 1.3.

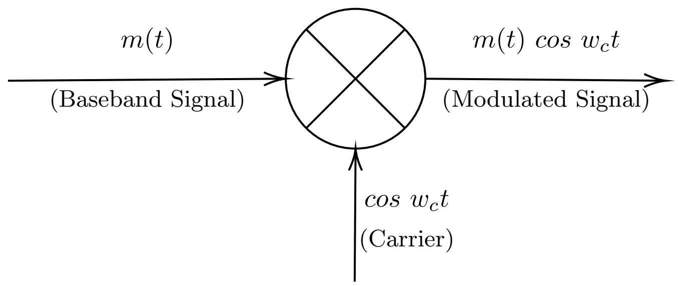


Figure 1.3: DSB-SC Modulation block Diagram

1.3.1 Modulation

This type of modulation simply shiftsthe spectrum of $m(t)$ to the carrier frequency.Thus, if

$$m(t) \Longleftrightarrow M(w) \tag{1.4}$$

$$then, \qquad m(t)cos\ 2\pi f_c t \Longleftrightarrow \frac{1}{2}[M(f - f_c) + M(f + f_c)] \tag{1.5}$$

Recall that $M(f - f_c)$ is $M(f)$ shifted to the right by f_c and $M(f + f_c)$ is $M(f)$ shifted to the left by f_c. Thus the process of modulation shifts the spectrum of the modulating signal to the left and to the right by f_c.The Fourier transform of the DSB-SC modulated signal s(t) is given by

$$
\begin{aligned}
m(t) &\Longleftrightarrow M(w) \\
M(w) &= \int_{-\infty}^{+\infty} m(t)e^{-jwt}\ dt \\
We\ Know,\quad m(t) &= Acos(w_c t + \phi) \\
Assuming,\ A = 1\ and\ Q = 0 & \\
m(t) &= cos\ w_c t \\
m(t)cos\ w_c t &= \frac{1}{2}(e^{jw_c t} + e^{-jw_c t})m(t) \\
&= \frac{1}{2}(e^{jw_c t}m(t) + \frac{1}{2}(e^{-jw_c t}m(t) \\
\therefore M_1(w) &= \frac{1}{2}\int_{-\infty}^{+\infty} e^{jw_c t}m(t)e^{-jwt}\ dt \\
&= \frac{1}{2}\int_{-\infty}^{+\infty} m(t)e^{-j(w-w_c)t}\ dt \\
&= \frac{1}{2}\overline{M}(w - w_c) \\
Similarly, M_2(w) &= \frac{1}{2}\overline{M}(w + w_c) \\
m(t)cos\ 2\pi w_c t &\Longleftrightarrow M(w) \\
M(w) &= \frac{1}{2}[M(f - f_c) + M(f + f_c)]
\end{aligned} \tag{1.6}
$$

$$m(t)cos\ w_c t = \frac{1}{2}(e^{jw_c t} + e^{-jw_c t})m(t) \tag{1.7}$$

$$= \frac{1}{2}(e^{jw_c t}m(t) + \frac{1}{2}e^{-jw_c t})m(t) \tag{1.8}$$

$$S(f) = \frac{A_c}{2}[M(f - f_c) + M(f + f_c)] \tag{1.9}$$

Figure 1.4 illustrates the corresponding amplitude spectrum. As can be seen in the figure, the transmission bandwidth of DSB-SC modulation is 2W Hz—the same as the AM transmission bandwidth.We also observe that the modulated signal spectrum centered at $\pm f_c$ consists of two parts: a portion that lies outside $\pm f_c$, known as the *upper sideband (**USB**)*, and a portion that lies outside $\pm f_c$, known as the *lower sideband (**LSB**)*.

Also, the modulated signal does not have any discrete component of the carrier frequency f_c. For this reason it is called **double-sideband suppressed carrier (DSB-SC) modulation**

The relationshop of B to f_c is of interest. Figure 1.5 shows that $f_c \geq B$, thus avoiding overlap of the modulated spectra centered at f_c and $-f_c$. If $f_c < B$, the the two copies of message spectra overlap and the information of $m(t)$ is

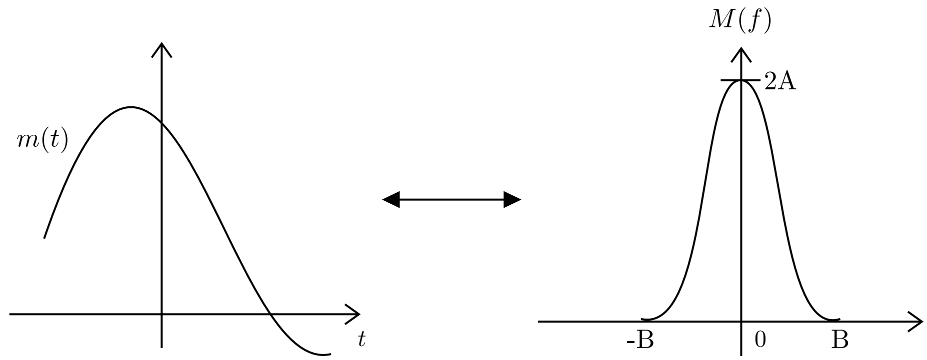


Figure 1.4:

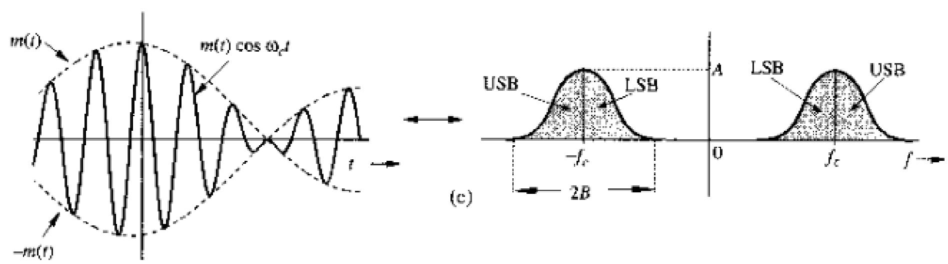


Figure 1.5:

lost during modulation, which makes it impossible to get back the m(t) from the modulated signal $m(t)cos\ w_c t$.

The difference between AM and DSB-SC modulation is that the DSB-SC modulated wave does not have the pure carrier component. Consequently, one hundred percent of the transmission power is spent on sending the message signal.

1.3.2 Demodulation

DSB-SC modulation shifts spectrum to right and left by f_c.To recover the original signal m(t) from the modulated signal, it is necessary to retranslate the spectrum to its original position. This process is known as **demodulation**. If modulated signal spectrum in Figure 1.5 is shifted to the left and to the right by f_c and multiplied by half, we obtain 1.6

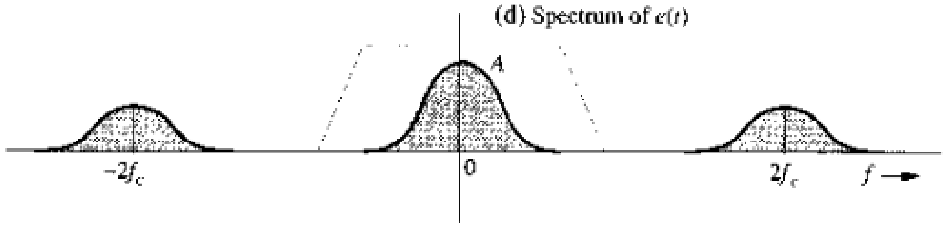


Figure 1.6:

The figure contains the desired baseband spectrum plus and unwanted spectrum at $\pm 2f_c$. The unwanted spectrum can be suppressed by a low-pass filter.

Demodulation consists of multiplication of the incoming modulated signal $m(t)cos\ w_ct$ by a carrier $cos\ w_ct$ followed by a low pass filter.

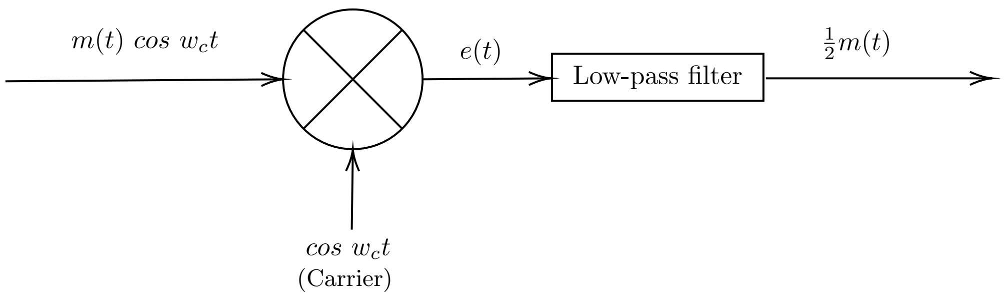


Figure 1.7: DSB-SC Demodulation Block Diagram

This can be verified in the time domain by observing $e(t)$ as follows:

$$e(t) = m(t)cos^2\ w_ct = \frac{1}{2}[m(t) + m(t)cos\ 2w_ct] \tag{1.10}$$

Therefore, the Fourier transform of the signal $e(t)$ is

$$E(f) = \frac{1}{2}M(f) + \frac{1}{4}[M(f + 2f_c) + M(f - 2f_c)] \tag{1.11}$$

Signal $e(t)$ consists of two components $\frac{1}{2}m(t)$ and $\frac{1}{2}m(t)cos\ 2w_ct$, with their nonoverlapping spectra The spectrum of the second component, being a modulated signal with carrier frequency $2f_c$, is centered at $\pm 2f_c$ This component is suppressed by low-pass filter. On the other hand, the desired component $\frac{1}{2}M(f)$, being a low-pass spectrum (centered at f = 0) passes through the filter unharmed, resulting in $\frac{1}{2}m(t)$. We can get rid of the inconvenient fraction $\frac{1}{2}$ in the output by using a carrier $cos\ 2w_ct$ instead of $cos\ w_ct$ This method of recovering the baseband signal is called synchronous detection or coherent detection where we use a carrier of exactly the same frequency(same phase) as the carrier used for modulation.

1.4 Non Linear Modulation

Modulation can be acheived by using non linear devices, such as a semi-conductor diode or a transistor. Figure 1.8 shows one possible scheme, which uses two identical nonlinear elements (boxes marked NL).

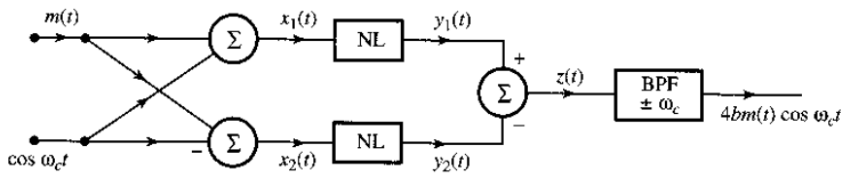


Figure 1.8: Nonlinear DSB-SC modulator

Let the input-output characteristics of either of the nonlinear elements be approximated by a power series.

$$x_1(t) = cos\ w_c t + m(t)$$
$$x_2(t) = cos\ w_c t - m(t)$$
$$y(t) = ax(t) + bx^2(t)$$

where x(t) and y(t) are the input and the output, respectively, of the nonlinear element. The summer output z(t) in the Figure 1.8 is given by

$$z(t) = y_1(t) - y_2(t) = [ax_1(t) + bx_1^2(t)] - [ax_2(t) + bx_2^2(t)]$$

Substituting the two inputs $x_1(t) = cos\ w_c t + m(t)$ and $x_2(t) = cos\ w_c t - m(t)$ in this equation gives

$$z(t) = 2a.m(t) + 4b.m(t)cos\ w_c t$$

When z(t) is passed through the bandpass filter turned to w_c, the signal $am(t)$ is suppressed and the desired modulated signal $4bm(t)cos\ w_c t$ can pass through the system without distortion.

Chapter 2

Lecture 2(1505111)

2.1 Double Side-Band with Carrier

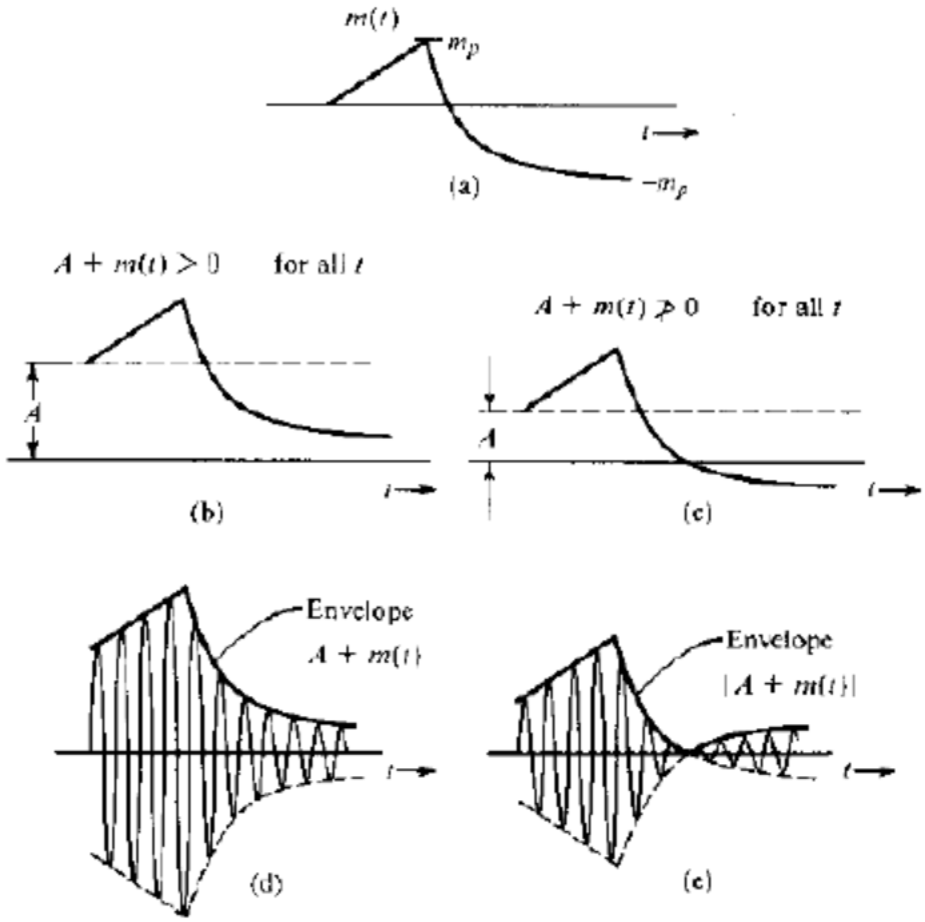
The second option for transmitting a carrier along with the modulated signal is the choice in broadcasting because of its desirable trade-offs. This leads to so called (amplitude modulation), in which the transmitted signal is given by,

$$\begin{aligned} \varphi_{AM} &= A\cos\omega_c t + m(t)\cos\omega_c t \\ &= [A + m(t)]\cos\omega_c t \end{aligned} \tag{2.1}$$

The spectrum $\phi_{AM}(t)$ is basically the same as that of $\varphi_{DSB-SC}(t) = m(t)\cos\omega_c t$ except for the two additional impulses at $\pm f_c$.

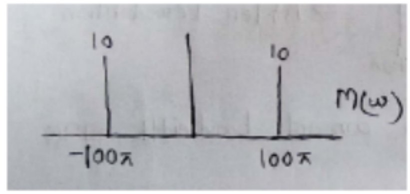
$$\varphi_{AM}(t) \Leftrightarrow \frac{1}{2}[M(f+f_c)] + \frac{A}{2}[\delta(f+f_c) + \delta(f-f_c)] \tag{2.2}$$

If A is not sufficient amount for which $m(t) + A$ is always ≥ 0 then, envelope detection will not work.

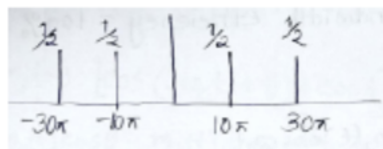


m(t)
m_p
t
(a)
$-m_p$
$A + m(t) > 0$ for all t
A
t
(b)
$A + m(t) \not> 0$ for all t
A
t
(c)
Envelope
$A + m(t)$
t
(d)
Envelope
$|A + m(t)|$
t
(e)

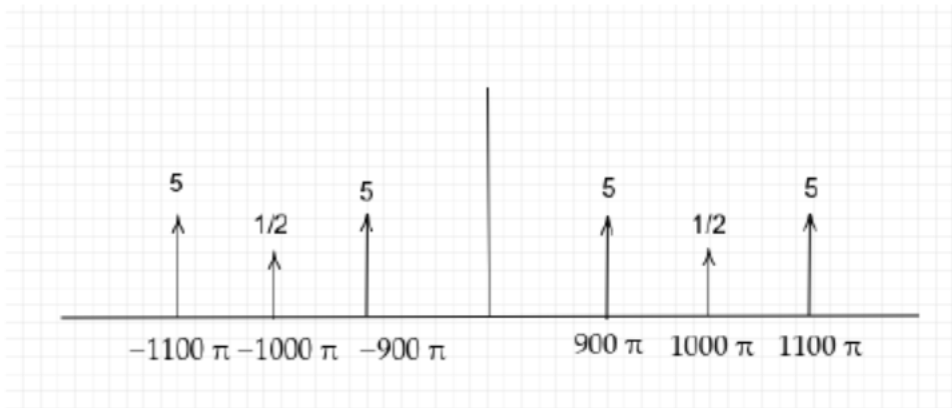
1) $m(t) = 10 \cos \pi t$.



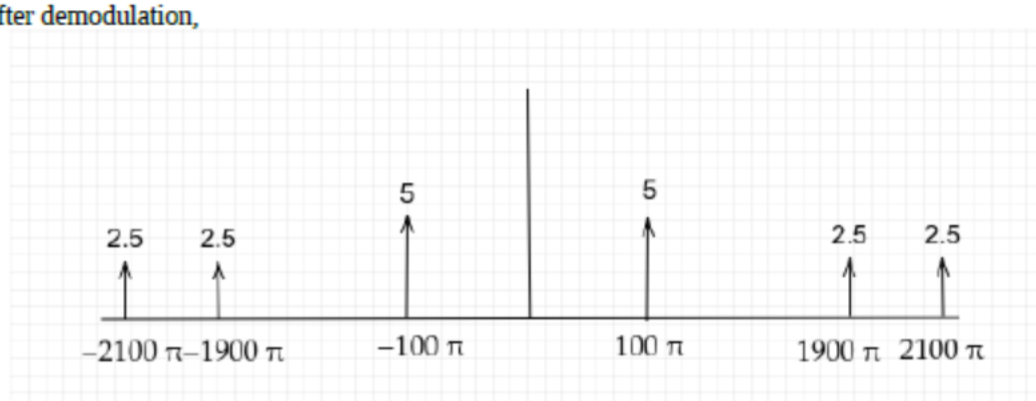
2) $\sin 10\pi t - \cos 20 \pi t$
$= ½ \sin 30 \pi t - ½ \sin 10 \pi t$



3) carrier: $\cos 1000\pi t$; $m(t) = 10 \cos 100\pi t$.

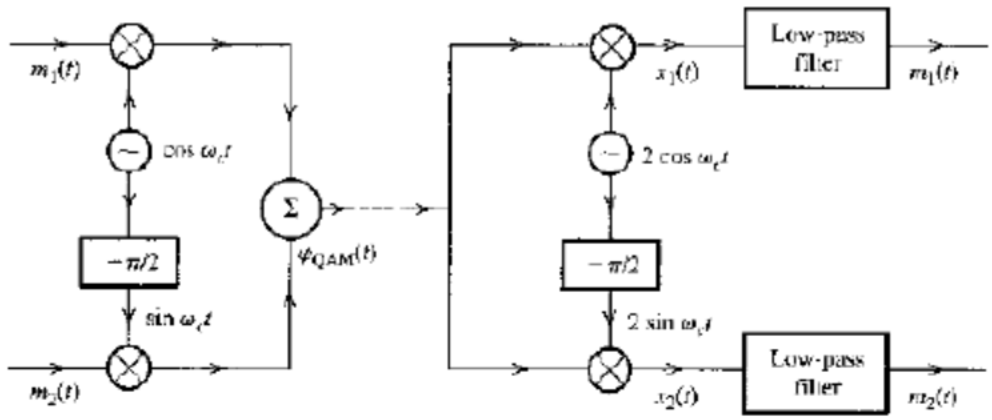


After demodulation,



As, to send B amount of data 2B bandwidth needed, efficiency 50%.

2.2 Quadrature Amplitude Modulation



Modulation:

$$\Phi_{QAM}(t) = m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t \tag{2.3}$$

Demodulation:

$$\begin{aligned} x_1(t) &= 2\Phi_{QAM}(t)\cos\omega_c t \\ &= 2[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t]\cos\omega_c t \\ &= m_1(t) + m_1(t)\cos 2\omega_c t + m_2(t)\sin 2\omega_c t \end{aligned} \tag{2.4}$$

$$\begin{aligned} x_2(t) &= 2\Phi_{QAM}(t)\sin\omega_c t \\ &= 2[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t]\sin\omega_c t \\ &= m_2(t) - m_2(t)\cos 2\omega_c t + m_1(t)\sin 2\omega_c t \end{aligned} \tag{2.5}$$

Thus, two baseband signals, each of bandwidth B Hz, can be transmitted simultaneously over a bandwidth 2B by using DSB transmission and quadrature multiplexing.

Problem: However, QAM demodulation must be synchronous, An error in the phase or the frequency of the carrier at the demodulation in QAM will result in loss and interference between the two channels. To show this, let the carrier at the demodulator be $2\cos(\omega_c t + \theta)$.

In this case,

$$\begin{aligned} x_1(t) &= 2[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t]\cos\omega_c t \\ &= m_1(t) + m_1(t)\cos 2\omega_c t + m_2(t)\sin 2\omega_c t \end{aligned} \tag{2.6}$$

The low pass filter suppresses the two signals modulated by carrier of angular frequency $2\omega_c$, resulting in the first demodulator output,

$$m_1(t)\cos\theta - m_2(t)\sin\theta \tag{2.7}$$

Thus, in addition to the desired signal $m_1(t)$, we also received signal $m_2(t)$ in the upper reciever branch.

Chapter 3

Lecture 3 (1505113)

3.1 Amplitude Modulation:Single Sideband(SSB)

The DSB spectrum has two sidebands: the upper sideband(USB) and the lower sideband(LSB),both containing the complete information of the baseband signal.A scheme in which only one sideband is transmitted is known as **single side-band(SSB) transmission**,which requires only one-half the bandwidth of the DSB signal. An SSB signal can be coherently(synchronously) demodulated.For example, multiplication of a USB signal by $\cos\omega_c t$ shifts its spectrum to the left and write by ω_c.The case is similar with the LSB signals.Hence the demodulation of SSB signal is identical to that of DSB-SC signals.

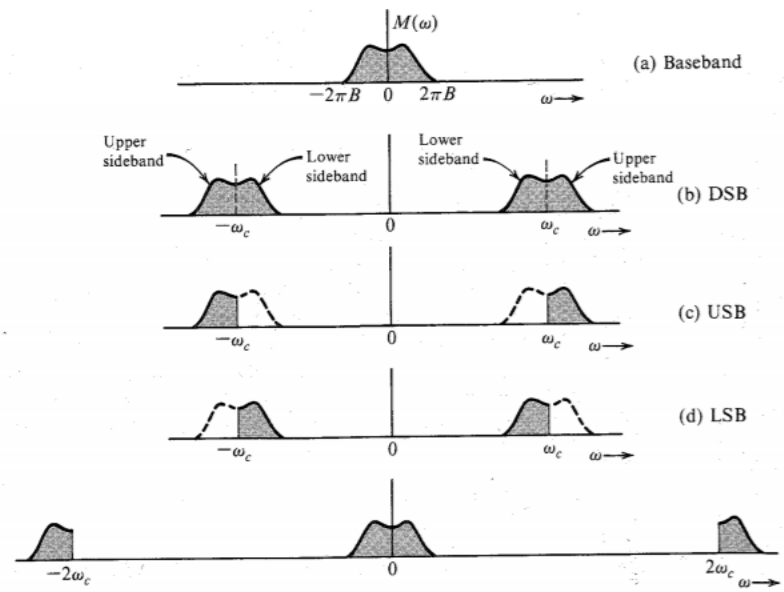


Figure 3.1: SSB Spectra

3.1.1 Time Domain Representation of SSB Signals

Because the building block of an SSB signal are the sidebands, we shall first obtain a time domain expression for each sideband. Figure 2 shows the spectrum M(ω).The USB and LSB are also shown there.From the figure we can obtain that $M_+(\omega)$=$M(\omega)u(\omega)$ and $M_-(\omega)$=$M(\omega)u(-\omega)$. Let $m_+(t)$ and $m_-(t)$ be the inverse Fourier transforms of $M_+(\omega)$ and $M_-(\omega)$ respectively.we can express,

$$m_+(t) = 1/2[m(t) + jm_h(t)] \tag{3.1}$$

$$m_-(t) = 1/2[m(t) - jm_h(t)] \tag{3.2}$$

where $m_h(t)$ is unknown.To determine $m_h(t)$ we note that,

$$\begin{aligned} M_+(\omega) &= M(\omega)u(\omega) \\ &= 1/2M(\omega)[1 + sgn(\omega)] \\ &= 1/2M(\omega) + 1/2M(\omega)sgn(\omega) \end{aligned} \tag{3.3}$$

From the above equations we can write,

$$M_h(\omega) = -jM(\omega)sgn(\omega) \tag{3.4}$$

Application of the duality property to pair yeilds $1/\pi$t $\Longleftrightarrow$ $-jsgn(\omega)$. Applying this result and time convolution property yields $m_h(t) = m(t) * 1/\pi t$. That is,

$$m_h(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{m(\alpha)}{t-\alpha} d\alpha \tag{3.5}$$

The right side of the equation defines the **Hilbert Transform** of $m(t)$.Thus the signal $m_h(t)$ is the **Hilbert Transform** of $m(t)$.

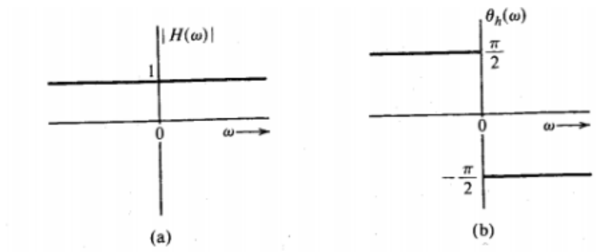


Figure 3.2: Transfer function of an ideal $\pi/2$ phase shifter(Hilbert Transformer)

It follows that if $m(t)$ is passed through a transfer function $H(\omega) = -jsgn(\omega)$, then the output is $m_h(t)$,the Hilbert Transform of $m(t)$. Because,
when $\omega > 0$,

$$\begin{aligned} H(\omega) &= -jsgn(\omega) \\ &= -j = 1e^{-j\pi/2} \end{aligned} \tag{3.6}$$

when $\omega < 0$,

$$\begin{aligned} H(\omega) &= -jsgn(\omega) \\ &= j = 1e^{j\pi/2} \end{aligned} \tag{3.7}$$

It follows that $|H(\omega)| = 1$ and that $\theta_h(\omega) = -\pi/2$ for $\omega > 0$ and $\pi/2$ for $\omega < 0$ as shown in the above figure.Hilbert Transformer is an ideal phase shifter that shifts the phase of every spectral component by -$\pi/2$.We can now express the SSB signal in terms of $m(t)$ and $m_h(t)$.It is clear that the USB spectrum $\Phi_{USB}(\omega)$ can be expressed as,

$$\Phi_{USB}(\omega) = M_+(\omega - \omega_c) + M_-(\omega + \omega_c) \tag{3.8}$$

The inverse transform of this equation yields,

$$w\phi_{USB}(t) = m_+(t)e^{j\omega_c t} + m_-(t)e^{-j\omega_c t} \tag{3.9}$$

Substituting it in the previous equation yields,

$$\phi_{USB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t \tag{3.10}$$

Using a similar argument we can show that,

$$\phi_{LSB}(t) = m(t)\cos\omega_c t + m_h(t)\sin\omega_c t \tag{3.11}$$

Hence, a general SSB signal $\phi_{SSB}(t)$ can be expressed as,

$$\phi_{SSB}(t) = m(t)\cos\omega_c t \pm m_h(t)\sin\omega_c t \tag{3.12}$$

3.1.2 Demodulation of SSB-SC Signals

It was shown earlier that SSB-SC signals can be coherently demodulated.We can readily varify this in another way,

$$\phi_{SSB}(t) = m(t)\cos\omega_c t \pm m_h(t)\sin\omega_c t \tag{3.13}$$

Hence,

$$\phi_{SSB}(t)\cos\omega_c t = \frac{1}{2}m(t)[1+\cos 2\omega_c t] \pm \frac{1}{2}m_h(t)\sin 2\omega_c t \tag{3.14}$$

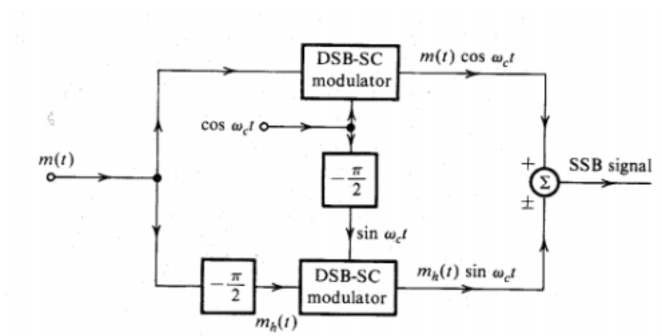


Figure 3.3: SSB Generation by Phase Shift Method

3.1.3 Envelope Detection of SSB Signals with a Carrier(SSB+C)

We now consider SSB signals with additional carrier. Such signals can be expressed as,

$$\phi_{SSB+C} = A\cos\omega_c t + [m(t)\cos\omega_c t + m_h(t)\sin\omega_c t] \tag{3.15}$$

Although $m(t)$ can be recovered by synchronous detection,if A, the carrier amplitude is large enough. $m(t)$ can also be recovered from ϕ_{SSB+C} by envelope or rectifier detection. This can be shown by rewriting ϕ_{SSB+C} as

$$\begin{aligned} \phi_{SSB+C} &= [A + m(t)]\cos\omega_c t + m_h(t)\sin\omega_c t \\ &= E(t)\cos(\omega_c t + \theta) \end{aligned} \tag{3.16}$$

Where $E(t)$ the envelope of ϕ_{SSB+C} is given by,

$$\begin{aligned} E(t) &= [[A + m(t)]^2 + {m_h}^2(t)]^{1/2} \\ &= A[1 + \frac{2m(t)}{A} + \frac{m^2(t)}{A^2} + \frac{m_h^2(t)}{A^2}]^{1/2} \end{aligned} \tag{3.17}$$

If A$\gg$ $|m(t)|$, then in general A$\gg$ $m_h(t)$.Thus,

$$E(t) \simeq A[1 + \frac{2m(t)}{A}]^{1/2} \tag{3.18}$$

Using binomial expression we get,

$$\begin{aligned} E(t) &\simeq A[1 + \frac{m(t)}{A}] \\ &= A + m(t) \end{aligned} \tag{3.19}$$

It is evident that for a large carrier, the SSB+C can be demodulated by an envelope detector.

In AM,envelope detection requires the condition $A \geq |m(t)|$ whereas for SSB+C, the condition is $A \gg |m(t)|$. Hence in SSB case the required carrier amplitude is much larger than that in AM,and,consequently, the efficiency of SSB+C is pathetically low.

Chapter 4

Lecture 4 (1505112)

4.1 Amplitude modulation : Vestigial Sideband (VSB)

Vestigial sideband (VSB) is a type of amplitude modulation (AM) technique (sometimes called VSB-AM) that encodes data by varying the amplitude of a single carrier frequency . Portions of one of the redundant sidebands are removed to form a vestigial sideband signal - so-called because a vestige of the sideband remains. VSB transmission is similar to single-sideband (SSB) transmission, in which one of the sidebands is completely removed. In VSB transmission, however, the second sideband is not completely removed, but is filtered to remove all but the desired range of frequencies .

4.1.1 Modulation:

This means that the use of SSB modulation is inappropriate for the transmission of such message signals owing to the practical difficulty of building a filter to isolate one sideband completely. This difficulty suggests another scheme known as vestigial sideband modulation (VSB), which is a compromise between SSB and DSB-SC forms of modulation. In VSB modulation, one sideband is passed almost completely whereas just a trace or vestige, of the other sideband is retained. Figure 4.1 illustrates the spectrum of a VSB modulated wave s(t) in relation to that of the message signal m(t) assuming that the lower sideband is modified into the vestigial sideband.

$$\Phi_{VSB}(f) = [M(f + f_c) + M(f - f_c)]H_i(f) \tag{4.1}$$

4.1.2 Demodulation:

We require that $m(t)$ is recoverable from $\phi(t)$ using synchronous demodulaton at the receiver. This is done multiplying $\phi(t)$ by $2cos(\omega t)$. The product e(t)

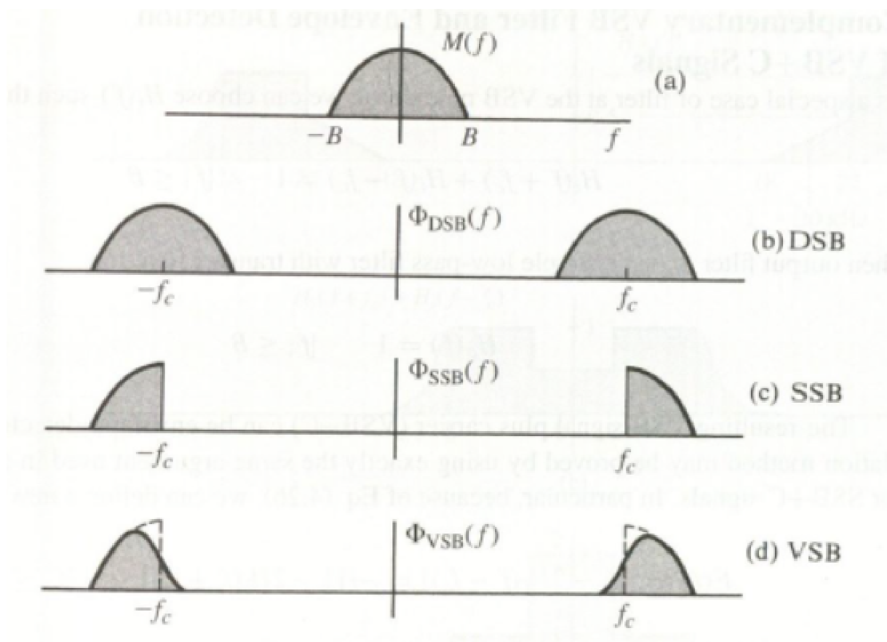


Figure 4.1:

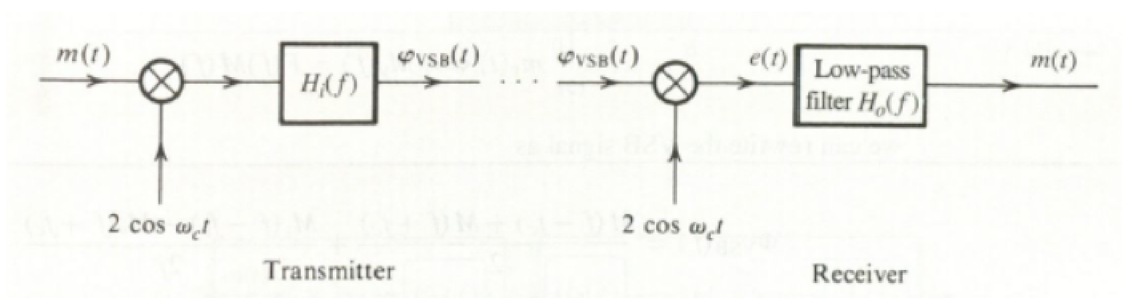


Figure 4.2:

given by

$$e(t) = 2\phi_{VSB}(t)cos(\omega_c t) <=> [\Phi_{VSB}(f + f_c) + \Phi_{VSB}(f - f_c)] \tag{4.2}$$

The signal e(t) is passed through low pass equalizer filter of transfer function H0(f). The output of the filter is required to be m(t). So output spectrum will be

$$M(f) = [\Phi_{VSB}(f + f_c) + \Phi_{VSB}(f - f_c)]H_o(f) \tag{4.3}$$

Substituting equation into this equation and eliminating the spectra at $+-2f_c$ by a low pass filter $H_o(f)$, we obtain

$$M(f) = M(f)[H_i(f+f_c) + H_i(f-f_c)]H_o(f) \tag{4.4}$$

Hence

$$H_o(f) = \frac{1}{H_i(f+f_c) + H_i(f-f_c)} \tag{4.5}$$

4.2 PHASE-LOCKED LOOP (PLL)

The phase lock loop is a very important device used to track the phase and the frequency of the carrier component of an incoming signal. A PLL has three basic components

- A voltage control oscillator (VCO)
- A multiplier, serving as a phase detector (PD) or phase comparator
- A loop filter H(s)

Only phase change:

$$\begin{aligned} &Asin(\omega_c t + \theta_i) * Bcos(\omega_c t + \theta_o) \\ &= \frac{AB}{2}[sin(2\omega_c t + \theta_i + \theta_o) + sin(\theta_i - \theta_o)] \end{aligned} \tag{4.6}$$

here, $sin(2\omega_c t + \theta_i + \theta_o)$ is being filter out
Remaining portion

$$\frac{AB}{2} sin(\theta_i - \theta_o)] \tag{4.7}$$

Demodulation for DSB-SC:

$$\begin{aligned} &m(t)[cos(\omega_c t) * 2cos((\omega_c + \Delta\omega)t + \theta)] \\ &= m(t)[cos(2\omega_c t + \Delta\omega t + \theta) + cos(\Delta\omega t + \theta)] \end{aligned} \tag{4.8}$$

here, $cos(2\omega_c t + \Delta\omega t + \theta)$ is being filter out
Remaining portion

$$m(t)cos(\Delta\omega t + \theta)] \tag{4.9}$$

Impact of phase difference
Let $\Delta\omega$ be 0, then we have

$$m(t)cos(\theta)] \tag{4.10}$$

Impact of frequency difference
Let θ be 0, then we have

$$m(t)cos(\Delta\omega t)] \tag{4.11}$$