18ECC205J ANALOG AND DIGITAL COMMUNICATION

Course Credit : 4

Theory : 9 Hours

Singh. R. P & Sapre. S. D, “Communication Systems: Analog & Digital,” 3rd edition, McGrawHill Education, Seventh Reprint, 2016.

Simon Haykin, “Communication Systems”, John Wiley & Sons, 4th Edition, 2008.

Unit 1 Week 1

Session 1: Modulation, Need for Modulation, Amplitude Modulation

Session 2: Types of Amplitude Modulation ,DSBFC

Session 3: DSBSC,SSBSC,VSB

Reference Books

Singh. R. P & Sapre. S. D, “Communication Systems: Analog & Digital,” 3rd edition, McGrawHill Education, Seventh Reprint, 2016.

UNIT I: What are we studying?

Analog Modulation

- Base Band Modulation Schemes
  - Amplitude Modulation DSBFC
    - DSBSC, SSBSC, VSB
  - Angle Modulation
    - FM, PM

What is Communication?

Communication is a process of conveying or transferring message or information from one place to another place.

Examples of messages : Audio signals in speech transmissions, Picture (Video) signals in television transmissions and data (say text) signals in data transmission.

Types

. Line communication

. Radio communication

Block Diagram of Communication System

The communication system consists of three basic components.

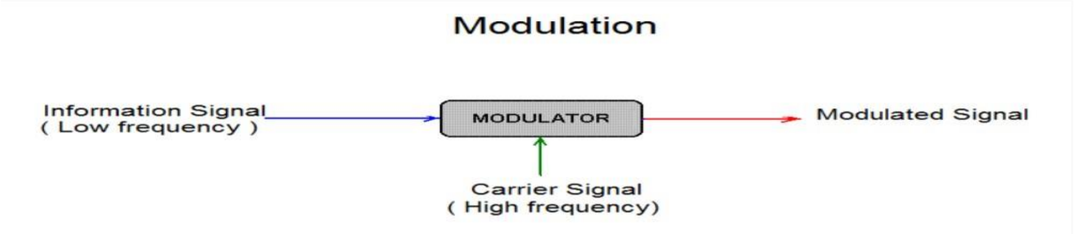
1.**Transmitter 2.Transmission media 3.Receiver**

Transmitter is the equipment which converts physical message, such as sound, words, pictures etc., into corresponding electrical signal.

Receiver is an equipment which converts electrical signal back to the physical message.

Channel may be either transmission line or free space, which provides transmission path between transmitter and receiver.

Modulation: Modulation is defined as the process by which some characteristics (i.e. amplitude, frequency, and phase) of a carrier is varied in accordance with instantaneous value of modulating signal



Carrier Signal : High frequency signal to carry the message. Its frequency will be in the range of MHz.
Message/ Modulating Signal : Contains the information to be transmitted. Its frequency will be in the range of 20Hz to 20KHz.

Demodulation is the reverse process of modulation, which is used to get back the original message signal. Modulation is performed at the transmitting end whereas demodulation is performed at the receiving end.

NEED FOR MODULATION

1.Multiplexing-It helps in transmitting a number of messages simultaneously over a single channel and therefore the number of channels needed will be less. This reduces the cost of installation and maintenance of more channels. If transmitted without modulation,the several message over a single channel will interfere with one another.

2. Practicability of antenna - To reduce antenna height.

If f=5KHz, then height of the antenna

$$\frac{\lambda}{2} = \frac{c}{2f} = \frac{3 \times 10^8}{2 \times 5 \times 10^3} = 30km$$

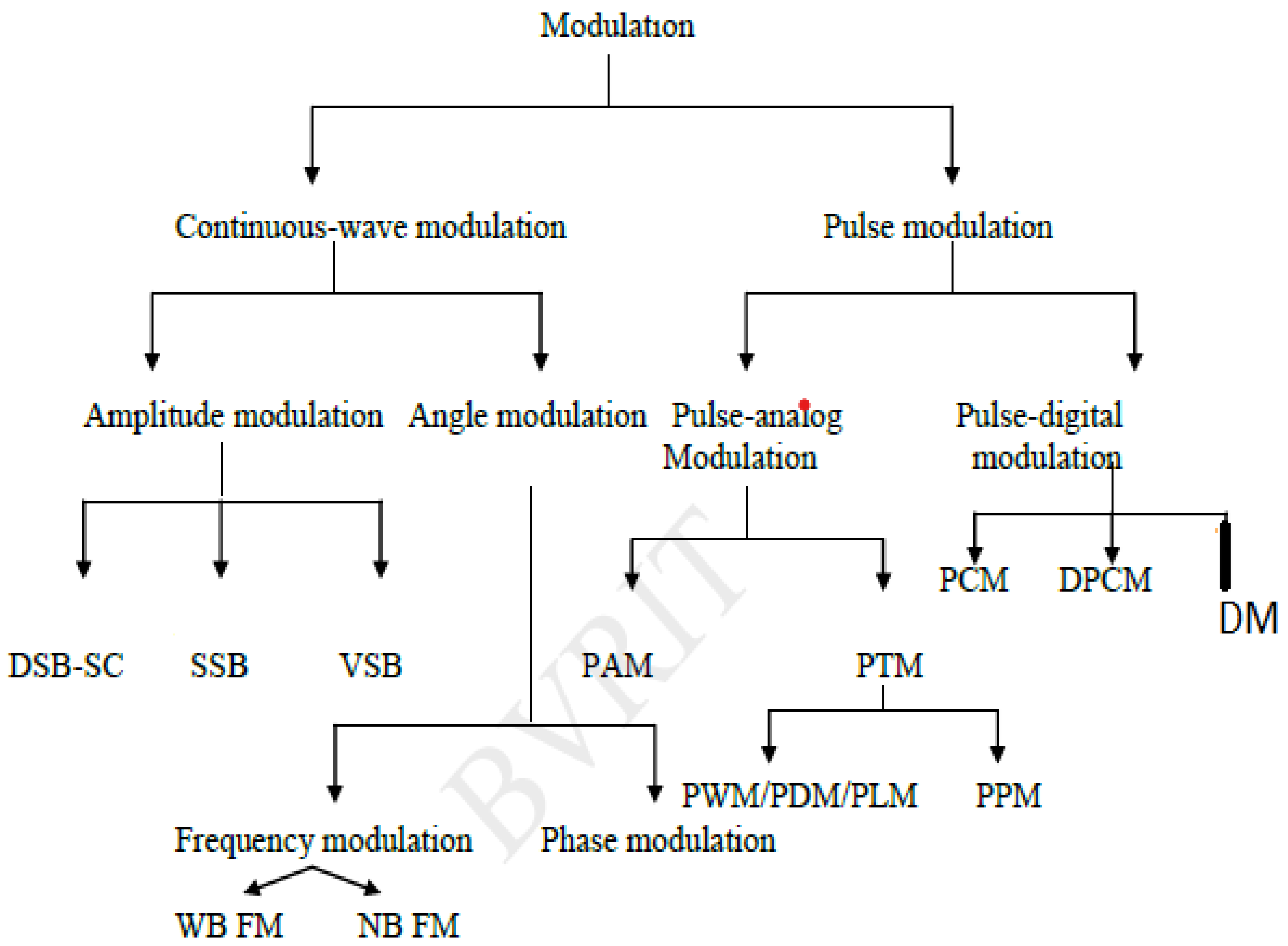
If f=10MHz, then height of the antenna

$$\frac{\lambda}{2} = \frac{3 \times 10^8}{2 \times 10^7}$$

=15m

3.Narrowbanding

Types of Modulation



AMPLITUDE MODULATION

A modulation process in which amplitude of the carrier signal is varied in accordance with instantaneous value of the modulating signal is known as amplitude modulation.

Representation of Amplitude modulated signal:

Carrier signal is mathematically denoted as $e(t) = E_c \cos\omega_c t$,

E_c = Amplitude of the carrier signal, ω_c = angular frequency of the carrier signal(rad/sec).

Modulating signal is mathematically denoted as $f(t) = E_m \cos\omega_m t$,

E_m = Amplitude of the carrier signal, ω_m = angular frequency of the carrier signal(rad/sec).

After AM, Amplitude of carrier signal ,$E_c = E_c + f(t)$

$e_{AM}(t) = [E_c + f(t)] \cos\omega_c t$, $\mathbf{(t) = E_c \cos\omega_c t + \mathit{f(t)} \cos\omega_c t}$

e_{AM} ***carrier sidebands***

Substitute $f(t) = E_m \cos\omega_m t$

$e_{AM}(t) = E_c \cos\omega_c t + E_m \cos\omega_m t \cos\omega_c t$

$= E_c \cos\omega_c t(1 + E_m/E_c \cos\omega_m t)$

Modulation index, $E_m/E_c = m_a$ (Ratio of modulating voltage to carrier voltage)

$e_{AM}(t) = E_c \cos\omega_c t(1 + m_a \cos\omega_m t)$

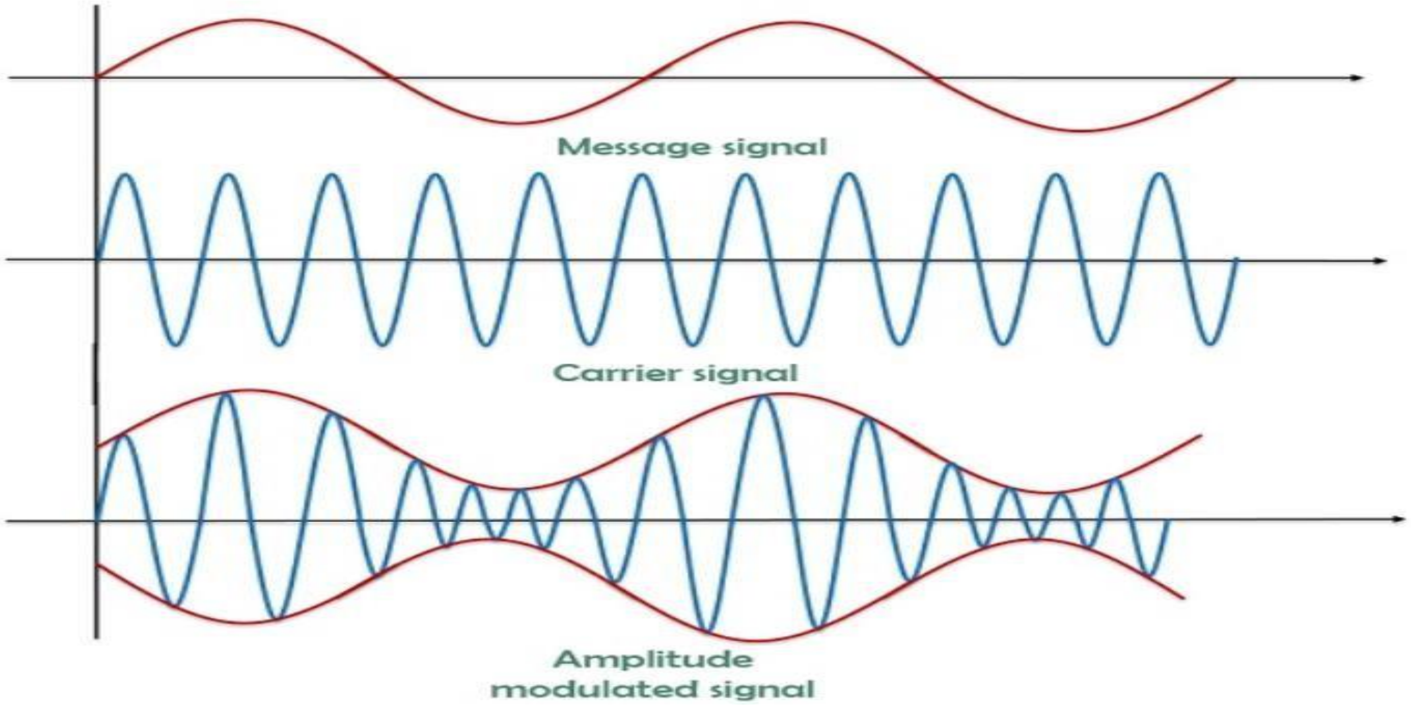
$e_{AM}(t) = E_c \cos\omega_c t + m_a E_c \cos\omega_c t \cos\omega_m t$, Apply cos A cos B formula, Then we get

$e_{AM}(t) = E_c \cos\omega_c t + m_a E_c/2 [\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$

Carrier signal USB LSB

$e_{AM}(t)$=**Amplitude modulated signal**

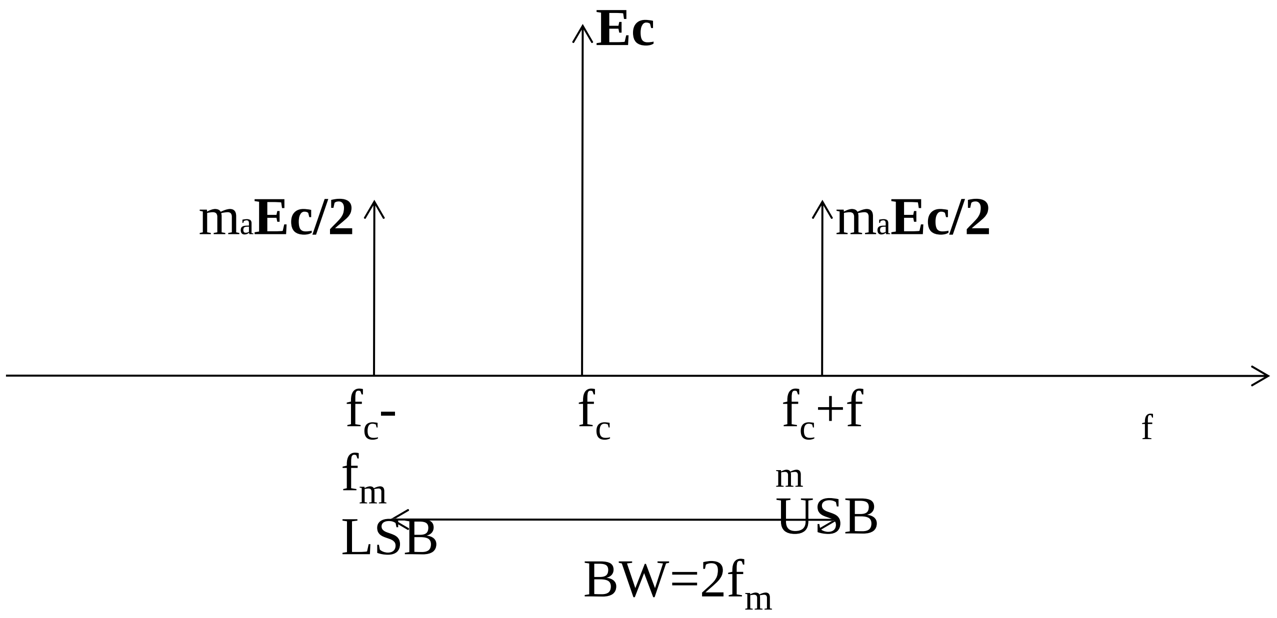
<u>Time domain representation of DSB-FC</u>



Frequency Spectrum of DSB - FC

Bandwidth = Highest frequency – Lowest frequency

$= (fc + fm) - (fc - fm) = 2f_m$



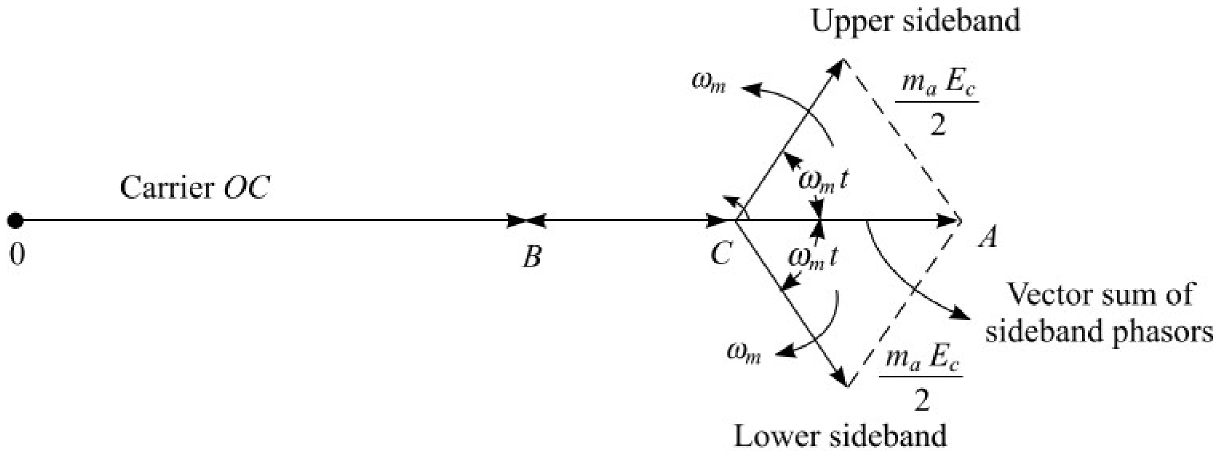
Frequency spectrum of DSB FC

The frequency spectrum of AM waveform contains three parts:

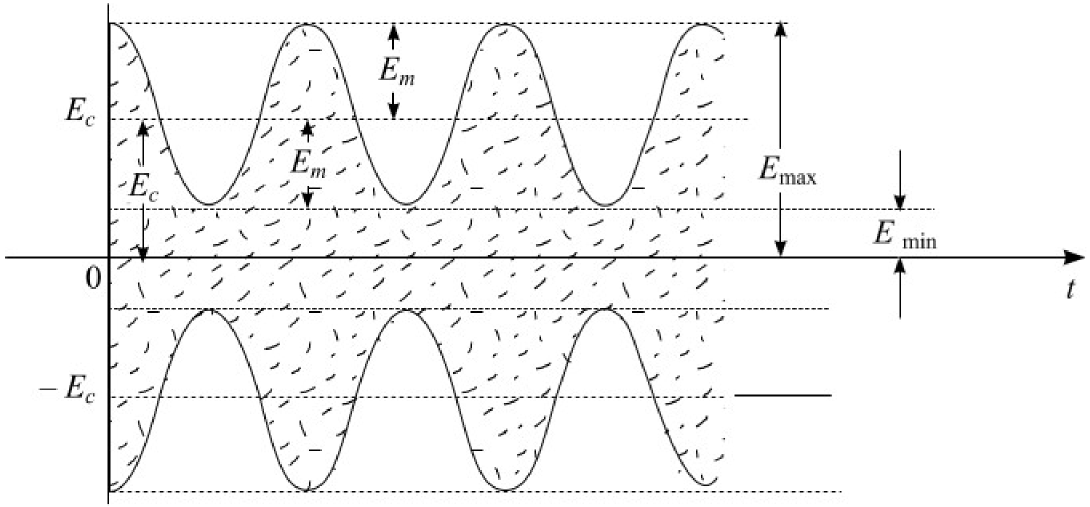
1. A component at the carrier frequency f_c
2. An upper side band (USB), whose highest frequency component is at f_c+f_m
3. A lower side band (LSB), whose highest frequency component is at f_c-f_m

The bandwidth of the modulated waveform is twice the information signal bandwidth.

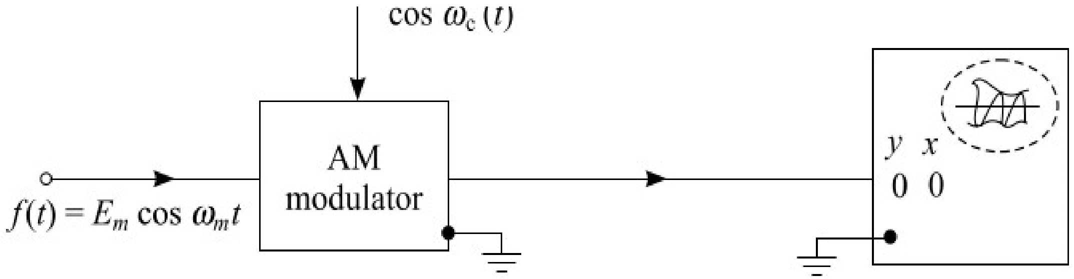
Phasor Diagram of DSB FC



Waveform of DSB FC



Measurement of m_a by CRO



Measurement of m_a by CRO

Measurement of m_a by CRO

From the Waveform of DSB FC

$E_m = E_{max} - E_c = E_c - E_{min}$

$2E_m = E_{max} - E_{min}$

$E_m = (E_{max} - E_{min})/2$

$E_c = E_{max} - E_m = E_{min} + E_m$

$E_c = E_{max} - [(E_{max} - E_{min})/2] = (E_{max} + E_{min})/2$

$m_a = Em/Ec$

$\mathbf{m_a} = (E_{max} - E_{min})/(E_{max} + E_{min})$

Total Radiated Power and Current of DSB FC

$e_{AM}(t) = A \cos\omega_c t + f(t) \cos\omega_c t$ A=Amplitude of carrier signal

carrier *sidebands*

Carrier power(Pc)**:**

Pc= $\overline{(A\cos\omega_c t)^2}$ = $A^2/2$ = Mean square value of modulating signal

Side band power (P_S) **:**

$$P_s = \overline{[f(t)\cos\omega_c t]^2} = \frac{1}{2\pi}\int_0^{2\pi} f^2(t)\cos^2\omega_c t\, d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{1}{2} f^2(t)[1+\cos 2\omega_c t]\, d(\omega t)$$

.

$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{1}{2} f^2(t) d(\omega t) + \frac{1}{2\pi}\int_0^{2\pi} \frac{1}{2} f^2(t)\cos 2\omega_c t\, d(\omega t)$$

The second integral is filtered out by BPF centered around ω_c .

$P_S = \frac{1}{2}\overline{f^2(t)} = \frac{1}{2}\overline{(E_m \cos\omega_m t)^2} = \frac{E_m^{\ 2}}{4}$, $\overline{f^2(t)}$ = Mean square value of modulating signal

$P_S = P_{LSB} + P_{USB} = Em^2/4$

Total Radiated Power:

$P = Pc + P_S$, $E_m/E_c = m_a$

Total Radiated Power and Current of DSB FC

$E_m = m_a A$

Side band power $P_S = m_a^2 A^2/4$

Total power $P = Pc + P_S$

$P = Pc + m_a^2 P_c/2$

$= P_c[1+(m_a^2/2)]$

$P = 1.5P_c$ $\quad m_a = 1$ for Critical modulation

Total current

$I = I_c \sqrt{1 + \frac{ma^2}{2}}$

rms value of Modulating Signal

rms value:

The rms value is under root of the rms value (power) of the AM signal

$$V_{\text{rms}} = \sqrt{P} = \sqrt{P_c\left(1+\frac{m_a^2}{2}\right)}$$

by putting $\sqrt{P_c} = V_{c_{\text{rms}}}$ (rms value of unmodulated carrier),

$$V_{\text{rms}} = V_{c_{\text{rms}}}\sqrt{1+\frac{m_a^2}{2}}$$

Transmission Efficiency

The amount of useful message power Ps present in AM is expressed by a term called transmission efficiency denoted by Eff.It is defined as percentage of total power contributed by the sidebands.

$$(Eff)_{AM} = \frac{P_s}{P} \times 100 = \frac{\frac{1}{2}\overline{f^2(t)}}{\frac{1}{2}A^2 + \frac{1}{2}\overline{f^2(t)}} \times 100 = \frac{100\overline{f^2(t)}}{A^2 + \overline{f^2(t)}}$$

$$Eff = \frac{\overline{f^2(t)}}{A^2 + \overline{f^2(t)}} \times 100$$

$$\text{Efficiency} = \frac{\frac{Em^2}{2}}{A^2 + \frac{Em^2}{2}} \times 100$$

Dividing numerator and denominator by $A^2/2$ We get,

Eff $= m_a^2/(2+m_a^2)$ we know $E_m/A = m_a$

$m_a = 1$, 100% modulation or Critical modulation

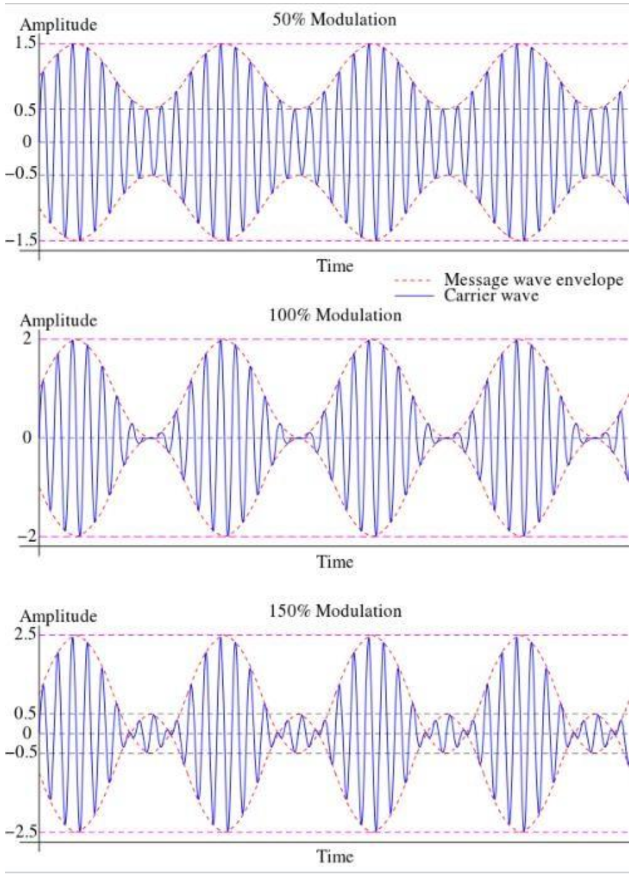
Eff = (1/3) x100 =33.3%

<u>**Different types AM with respect to modulation index**</u> m_a

$m_a < 1$ Under modulation

$m_a = 1$ Critical modulation

$m_a > 1$ Over modulation



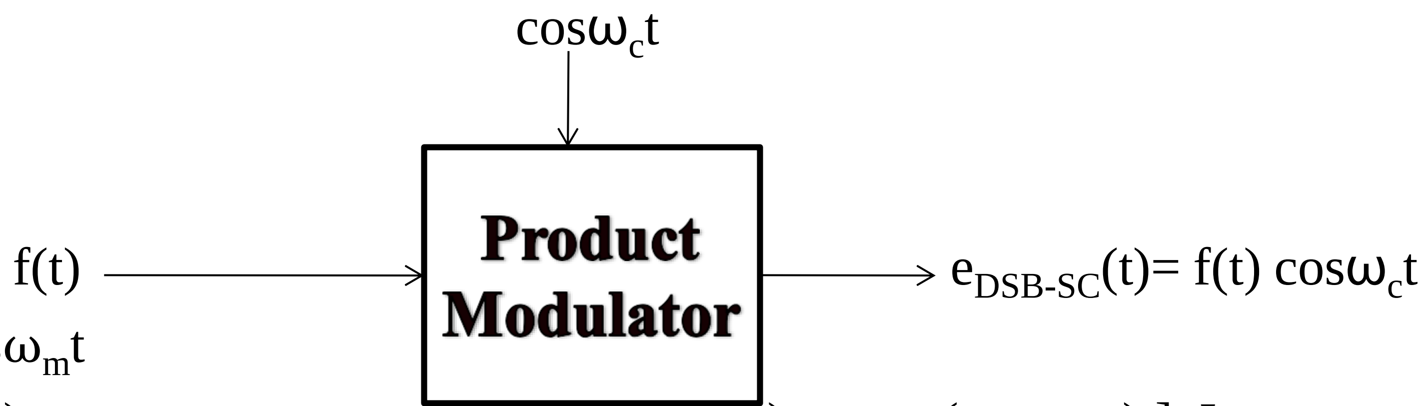
Practically, we prefer under modulation condition only. That is $m_a < 1. E_m < E_c$

Types of Amplitude Modulation

- 1.DSB SC (Double Sideband Suppressed Carrier)
- 2.SSB SC (Single Sideband Suppressed Carrier)
- 3.VSB (Vestigial Side Band modulation)

1.Reprsentation of DSB SC (Double Sideband Suppressed Carrier)

Product Modulator



$f(t) = \cos\omega_m t$

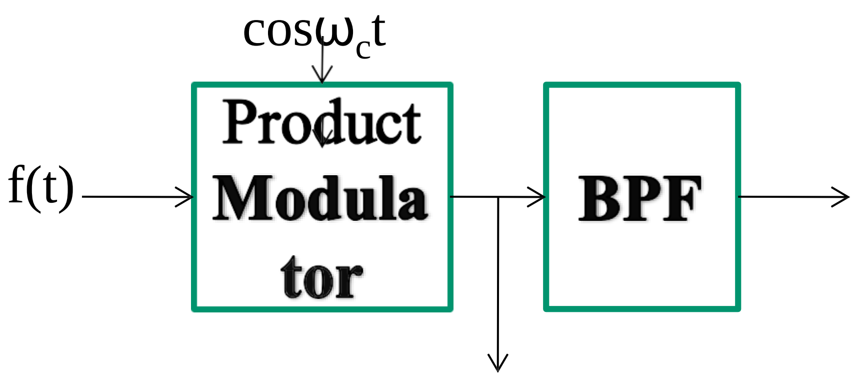
$e_{DSB-SC}(t) = \cos\omega_m t \cos\omega_c t = 1/2[\cos(\omega_c+\omega_m)t + \cos(\omega_c - \omega_m)t]$,It contains only two sidebands .There is no separate carrier signal.

Bandwidth BW= (fc + fm) – (fc - fm) =$2f_m$

% of power saving =(P –Ps)/P = 66.67%, Transmission efficiency =100%

SSB-SC

Filter method for generating SSB-SC



$e_{DSB\text{-}SC}(t) = f(t)\cos\omega_c t$

$f(t) = \cos\omega_m t$

The output of Product modulator is given by

$e_{DSB\text{-}SC}(t) = \cos\omega_m t \cos\omega_c t$, It contains only two sidebands .

BPF will be used to eliminate one of the sidebands. So $e_{SSB\text{-}SC}(t)$ contains only one sideband either USB or LSB.

$e_{SSB\text{-}SC}(t) = \cos(\omega_c - \omega_m)t$ only Lower sidebands in this case based on tuning of BPF

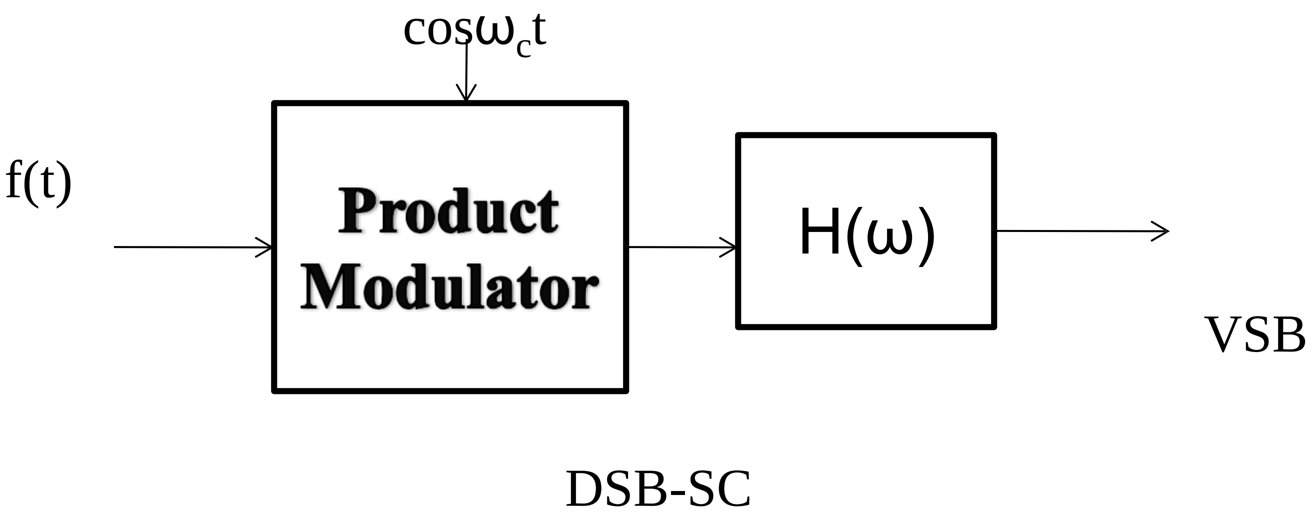
BW= fc - (fc-fm) = f_m

% of power saving =83.33%, Transmission efficiency =100%

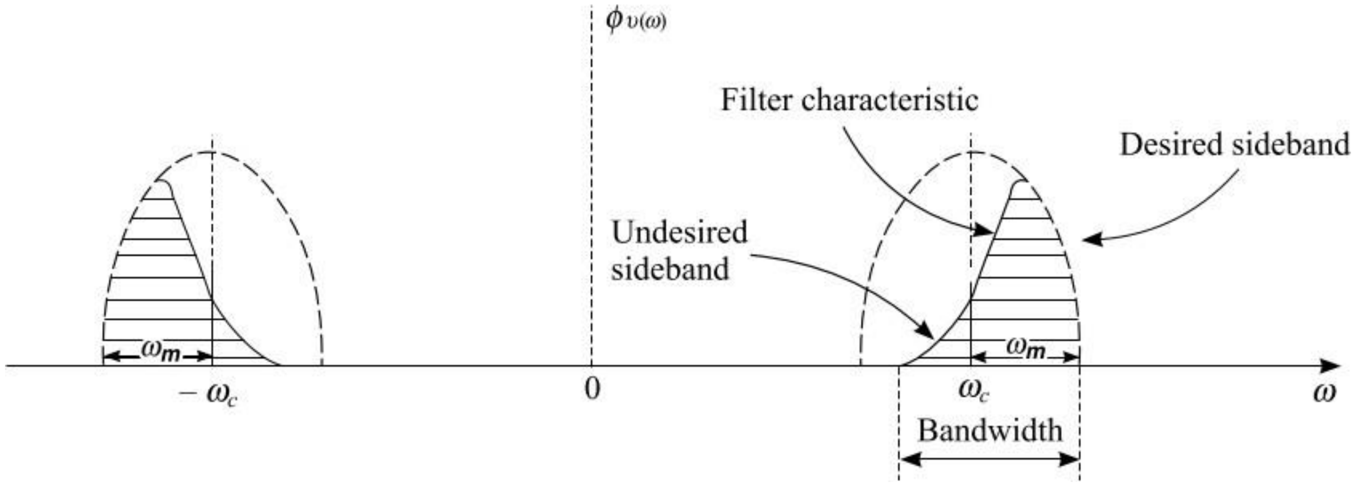
VSB

In Vestigial sideband modulation, the desired sideband is allowed to pass completely. Whereas just a small portion of the undesired sideband is also allowed. The transmitted vestige of the undesired sideband components for the loss of the desired sideband. Mainly used for Television(TV) signal transmission.

Generation of VSB signal using filter method



VSB Filter Characteristics

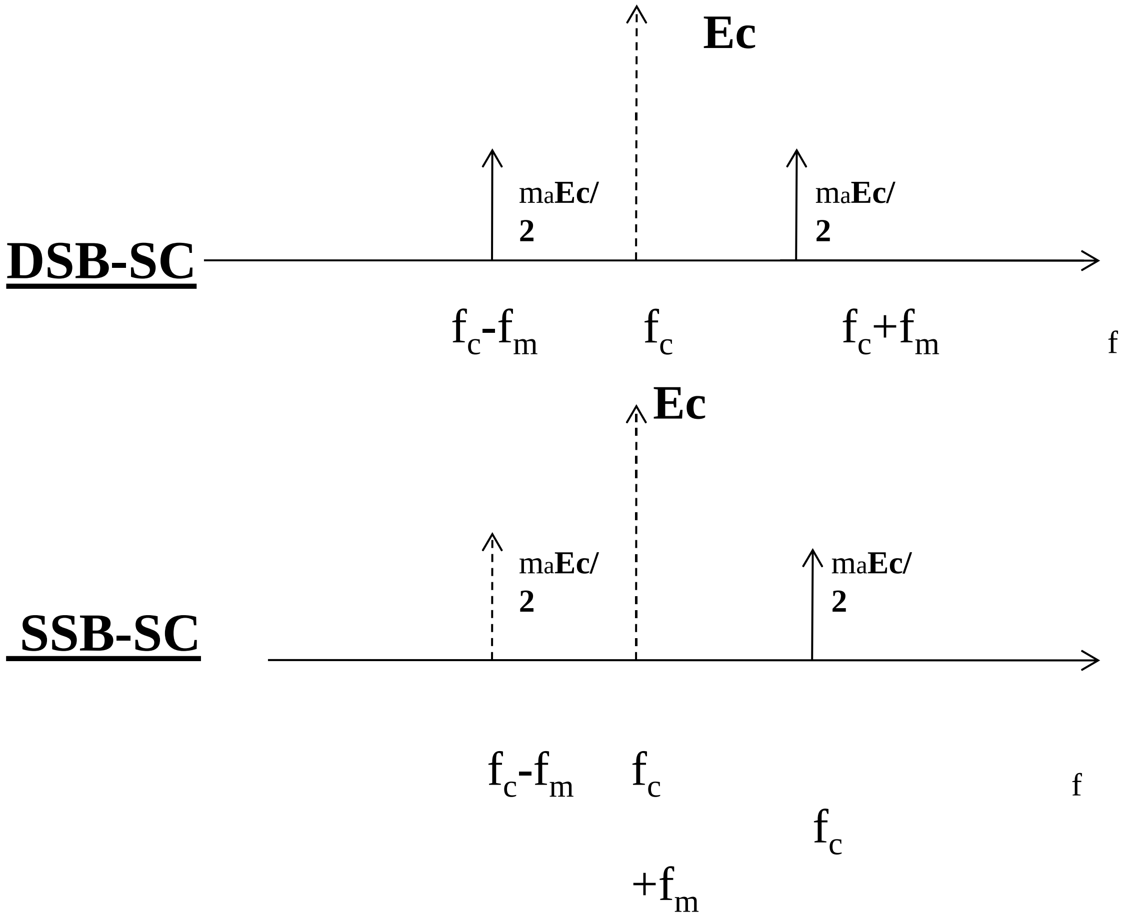


Comparison of Different Amplitude modulation Techniques

Performance Comparison of AM Techniques:

Parameter of Comparison	DSBFC	DSBSC	SSB	VSB
Carrier Suppression	NA	Fully	Fully	NA
Sideband Suppression	NA	NA	One SB completely	One SB suppressed partially
Bandwidth	$2f_m$	$2f_m$	f_m	$f_m < BW < 2f_m$
Transmission efficiency	Minimum	Maximum	Maximum	Moderate
Applications	Radio broadcasting	Radio broadcasting	Point to point mobile communication	TV

Frequency spectrum of DSB-SC&SSB-SC



Phasor Diagram of DSB-SC&SSB-SC