*College of Engineering &Technology*

*University of Sargodha*

*Department of Electrical Engineering Technology*

**ET-314**

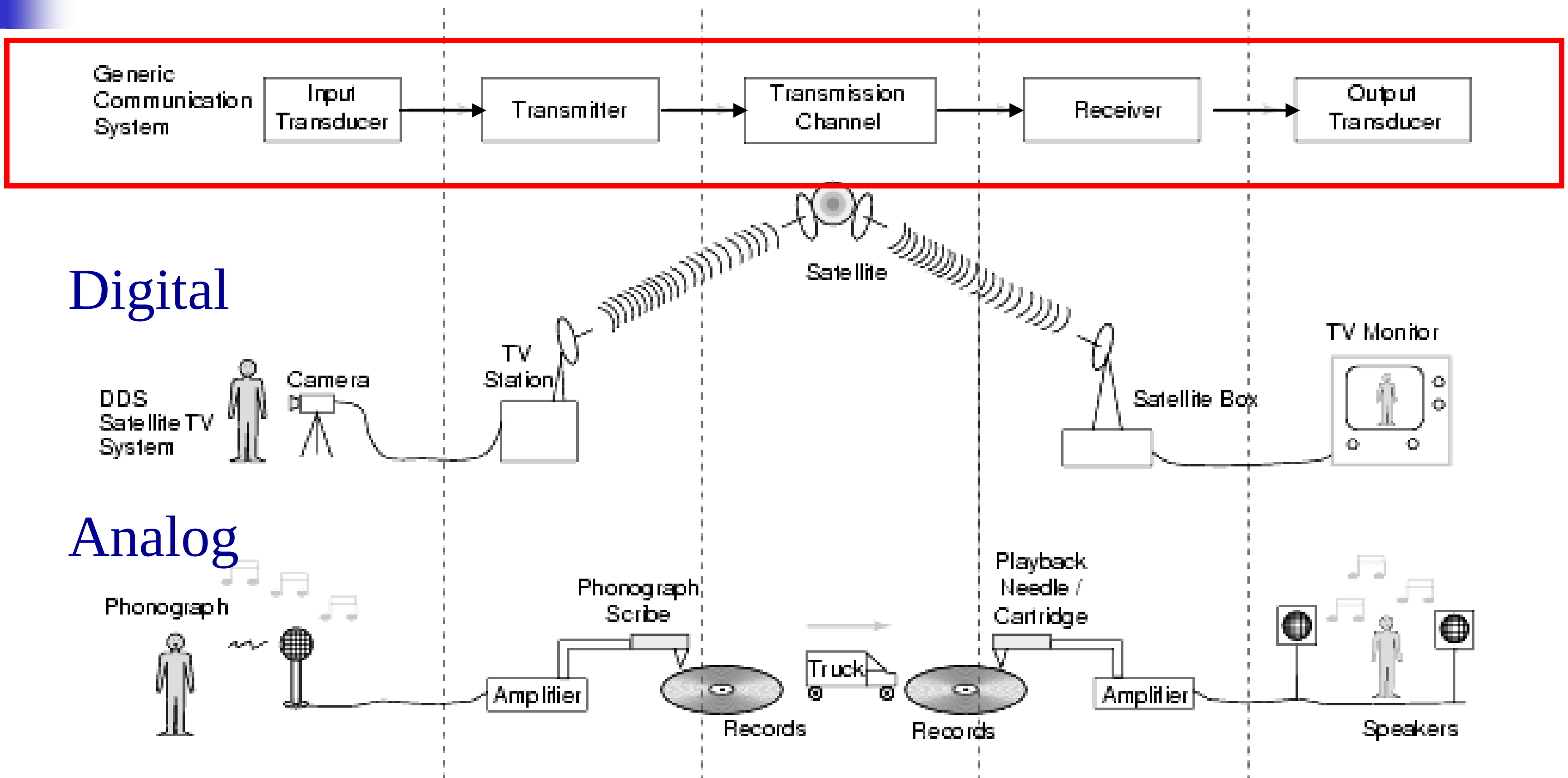
**Telecommunication Technology**

# Lecture 07

*Modulation Techniques*

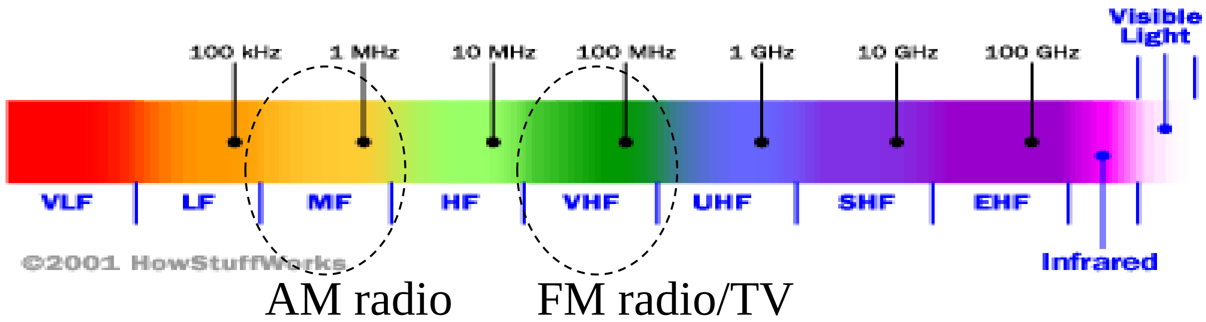
*Instructor: Engr. Erum Rehman*

# ❖Communication systems




- The  block diagram on the top shows the blocks common to all communication systems

- Since this baseband signal must be transmitted through a communication channel such as air using electromagnetic waves, an appropriate procedure is needed to shift the range of baseband frequencies to other frequency ranges suitable for transmission, and a corresponding shift back to the original frequency range after reception. This is called the process of *modulation* and *demodulation*
- Remember the radio spectrum:



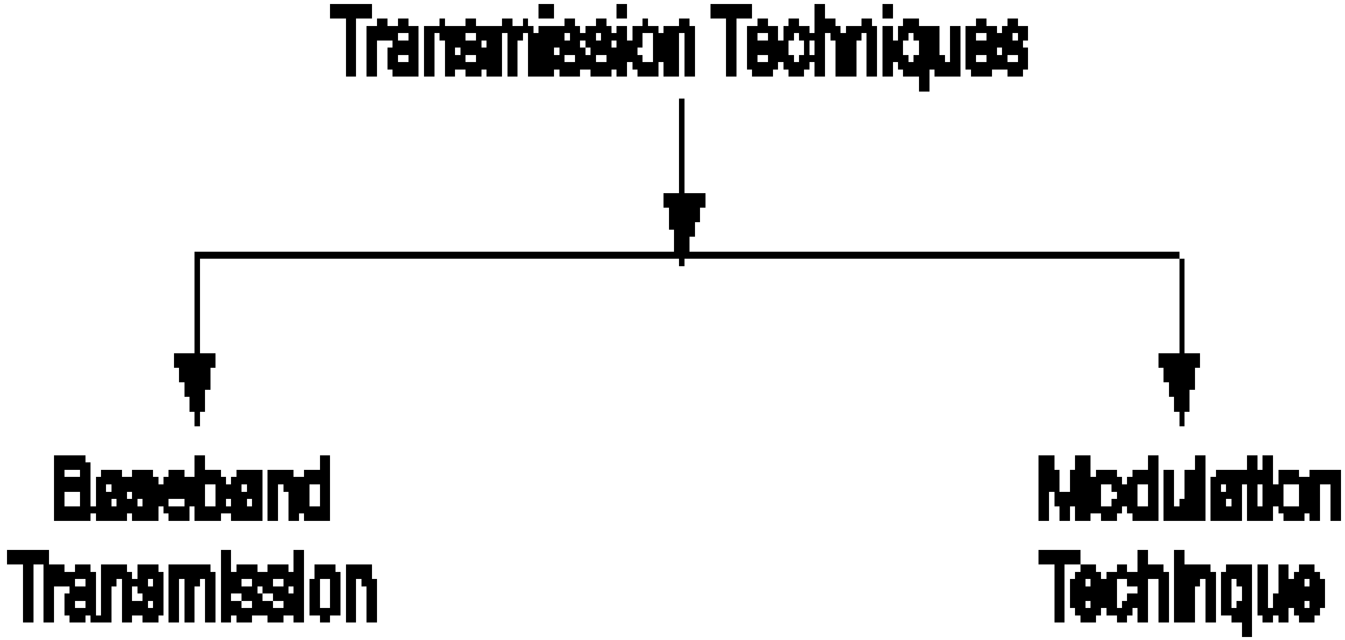

- For example, an AM radio system transmits electromagnetic waves with frequencies of around a few hundred kHz (MF band)
- The FM radio system must operate with frequencies in the range of 88-108 MHz (VHF band)

# Radio Frequency Spectrum

Table 1: Radio frequency classification

| Classification | Frequency ($f$) | Wavelength ($\lambda$) |
|---|---|---|
| **Low frequency (LF)** | 30 KHz—300 KHz | 10 km—1km |
| **Medium frequency (MF)** | 300 KHz—3 MHz | 1km—100 m |
| **High frequency (HF)** | 3 MHz—30 MHz | 100 m—10 m |
| **Very high frequency (VHF)** | 30 MHz—300 MHz | 10 m—1 m |
| **Ultra high frequency (UHF)** | 300 MHz—3GHz | 1 m—10 cm |
| **Super high frequency (SHF)** | 3 GHz—30 GHz | 10 cm—1 cm |
| **Extremely high frequency (EHF)** | 30 GHz—300 GHz | 1 cm—1 mm |

# Transmission Techniques



# Baseband Transmission

**The electrical equivalent of original information is known as the baseband signal.**

The communication system in which the baseband signals are transmitted directly is known as **baseband transmission**.

Baseband transmission is effective only for wire communication.

Example, Telephone network, data communication in computer networks through coaxial cable.

But it is inefficient for wireless or radio communication.

## Limitations of Baseband Transmission

1)Baseband signal having small frequency range from 20 Hz to 20 KHz only
(so no large channel accommodation, mixing of signals).

2)Due to small frequency range, baseband signal cannot travel long distance in free space or air.

3)After a travel of short distance signal gets suppressed. So not used for radio communication. i.e. wireless communication.

To make the baseband signal efficient for radio communication modulation technique is used.

# Modulation Technique

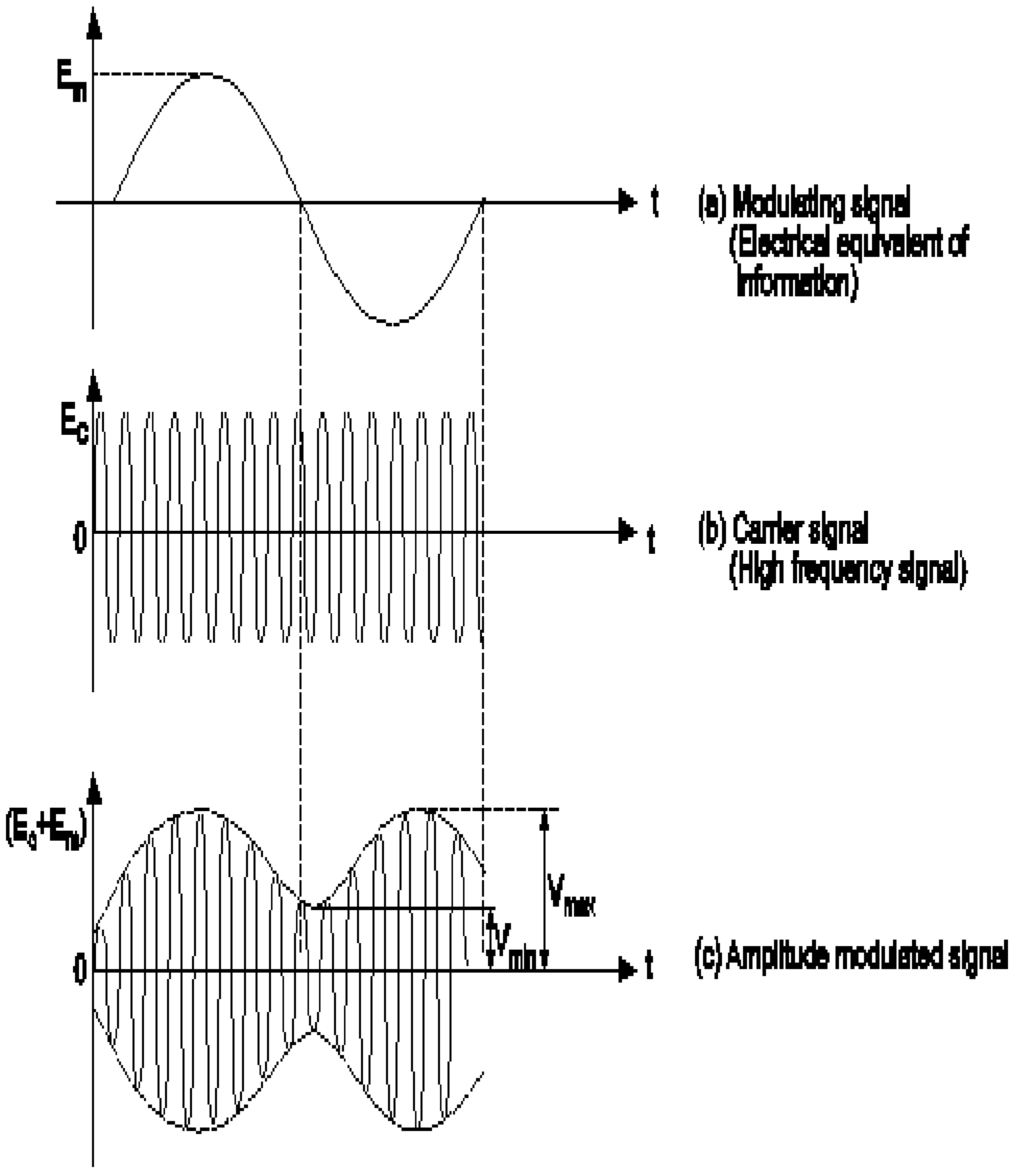
To overcome the drawbacks of baseband transmission and to transmit baseband signals by radio, modulation techniques must be used.

Baseband signal (Information signal) is a low-frequency signal and cannot travel longer distance. Just like we cannot walk at longer distance.

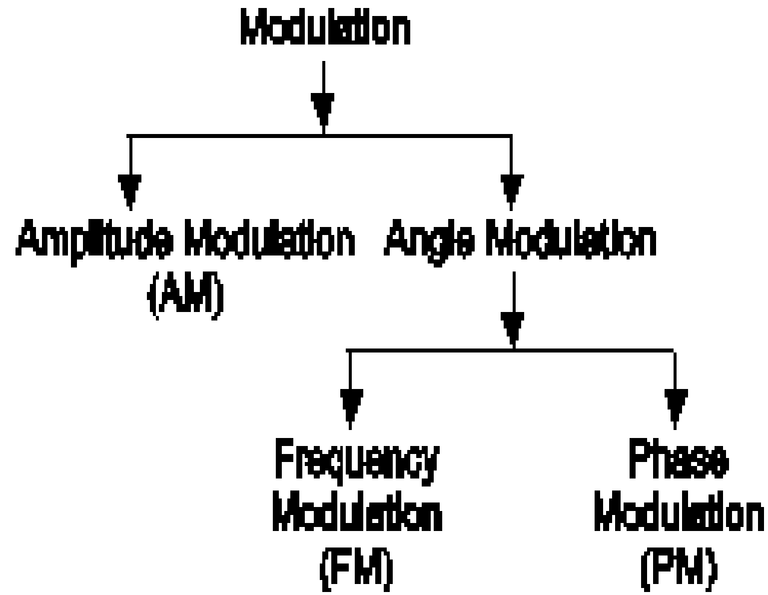
**Definition:**

**Modulation is the process of superimposing low-frequency information signal on a high-frequency carrier signal**

# Modulation Technique

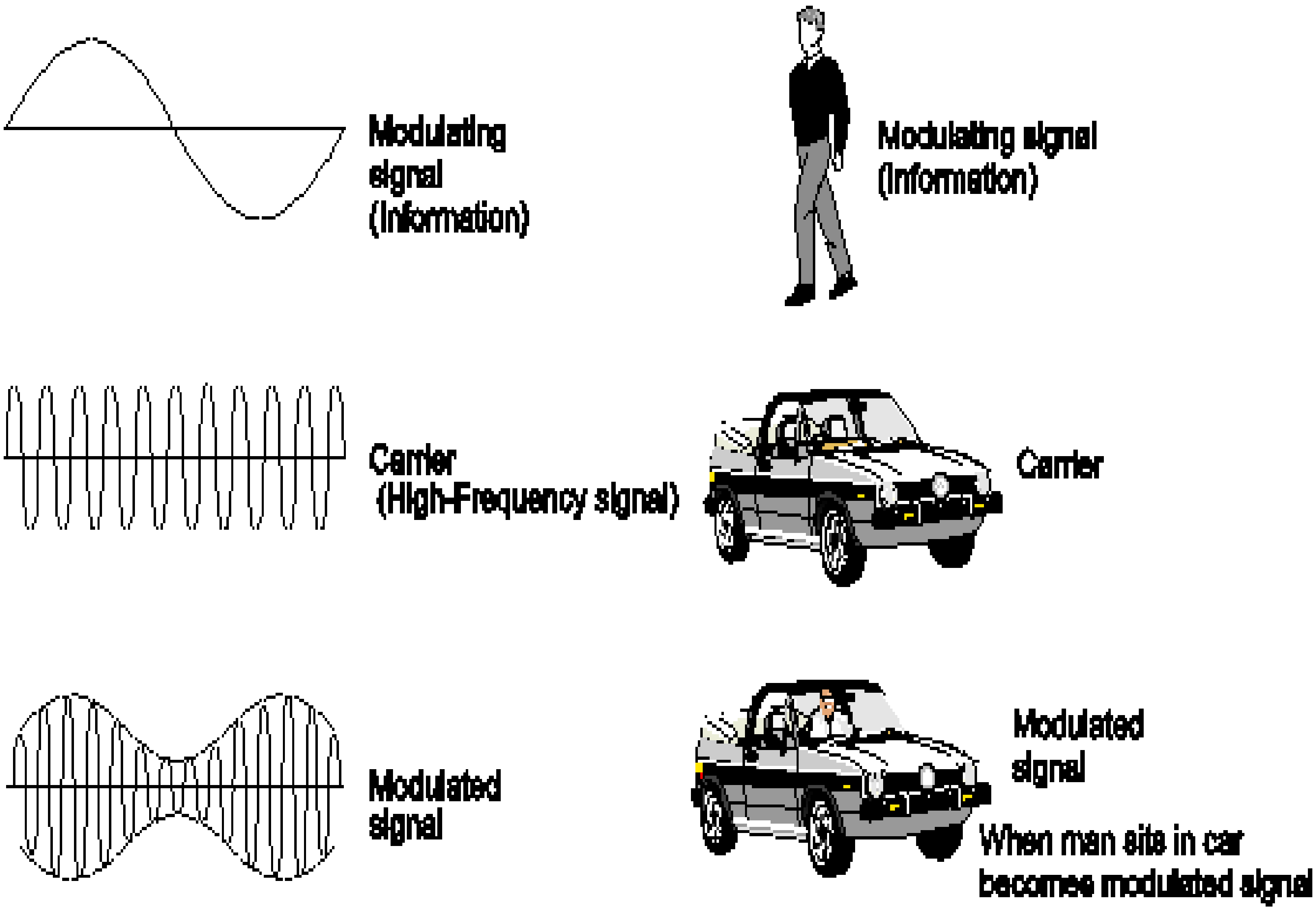


E_m
t
(a) Modulating signal (Electrical equivalent of information)
E_c
0
t
(b) Carrier signal (High frequency signal)
(E_c+E_m)
V_max
V_min
0
t
(c) Amplitude modulated signal

Modulation
Amplitude Modulation (AM)
Angle Modulation
Frequency Modulation (FM)
Phase Modulation (PM)

# Modulation Technique



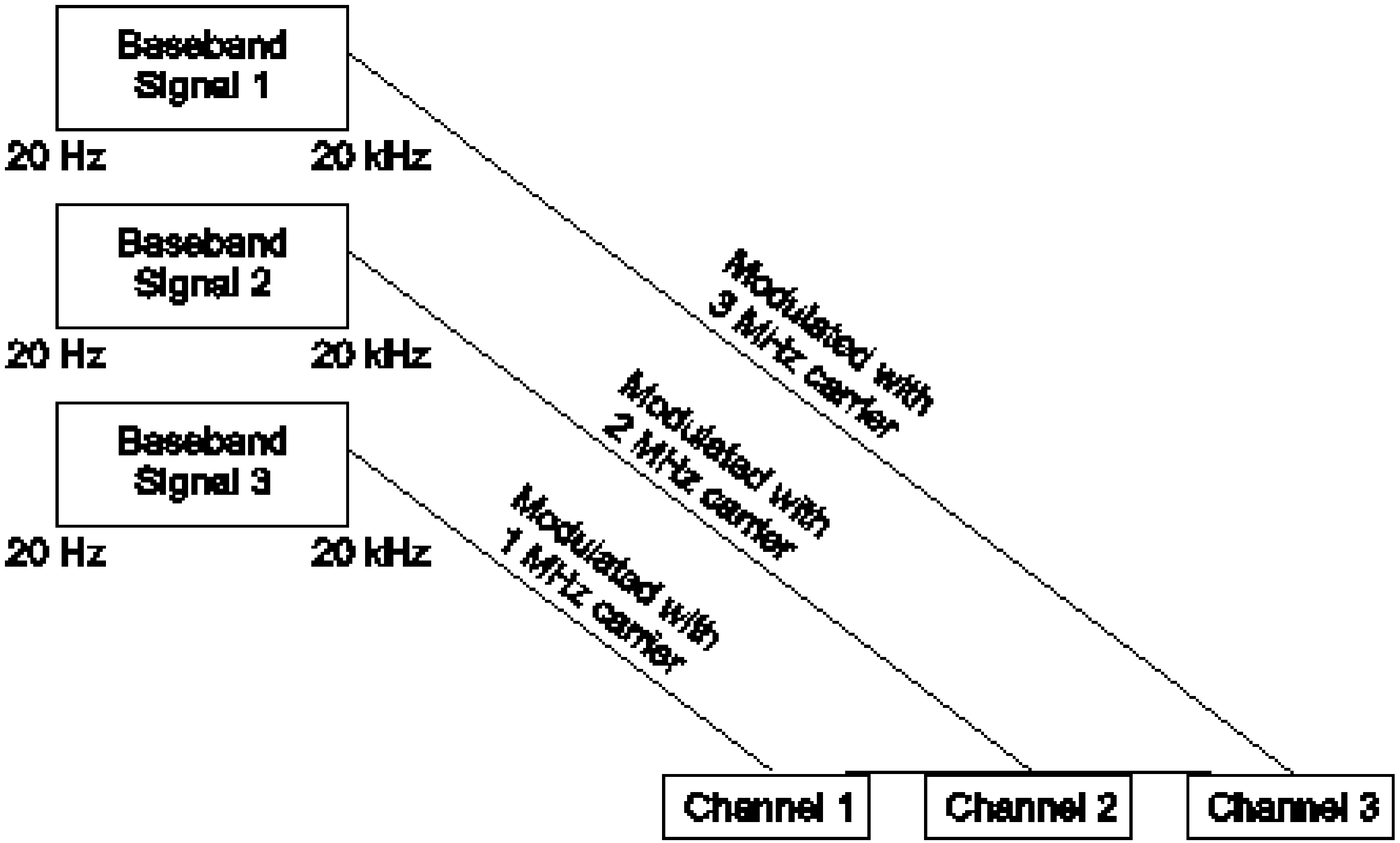
## Need of Modulation

Baseband signal transmission cannot be used for radio communication. To transmit the baseband signal for radio communication, modulation must be used.

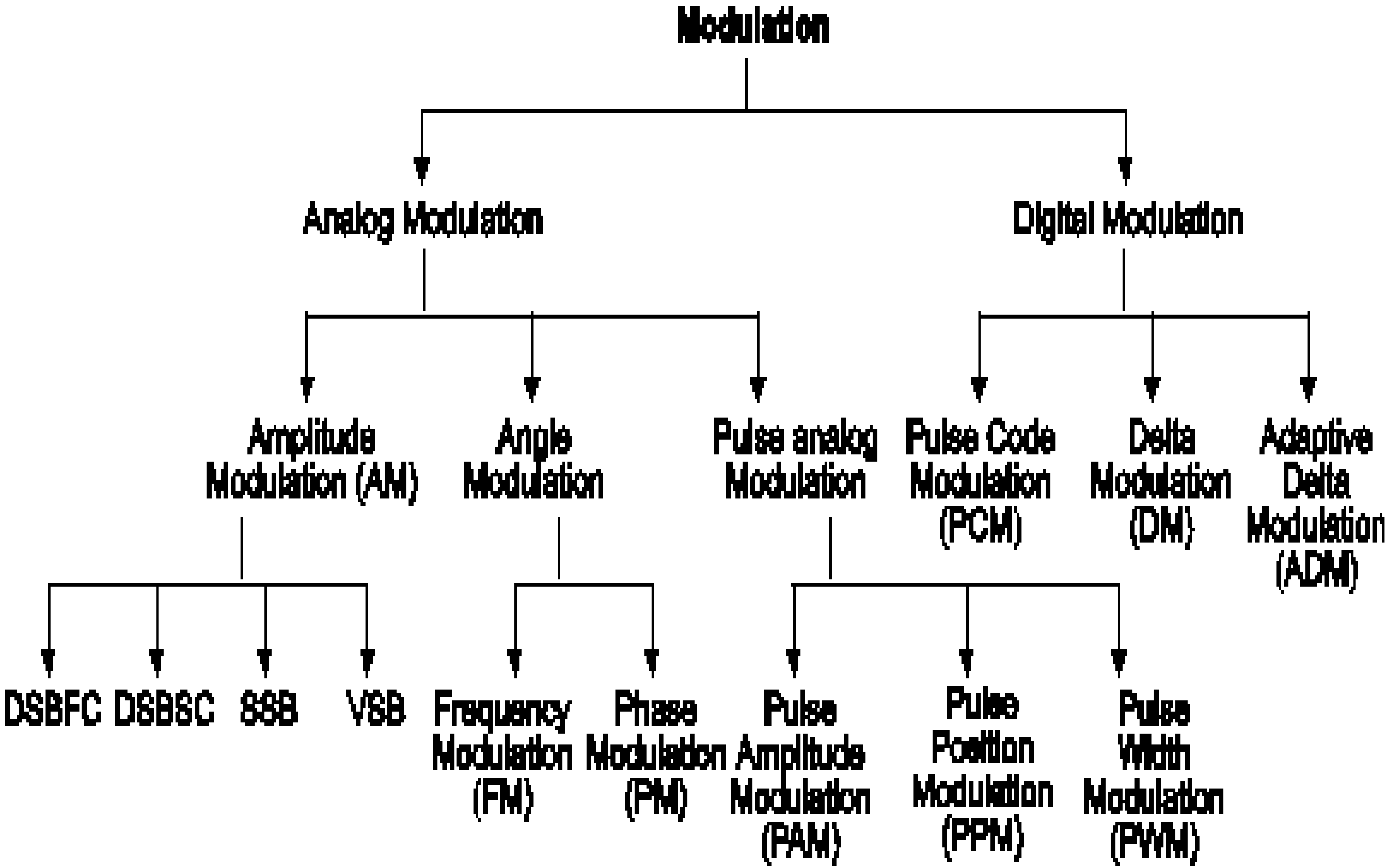
Modulation is necessary because of following advantages:

1. Reduction in height of antenna.
2. Avoids mixing of signals.
3. Increase the range of communication.
4. Multiplexing is possible.
5. Improves quality of reception

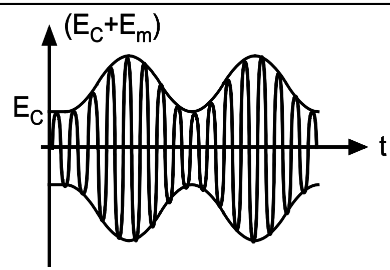
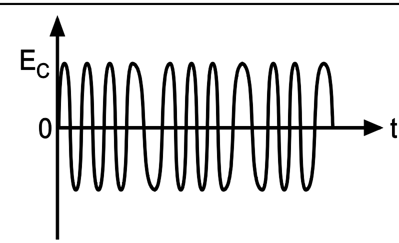
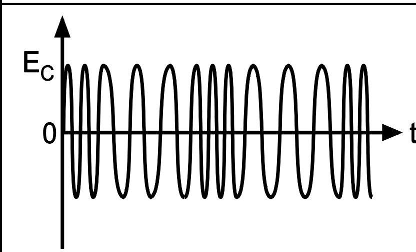
# Avoids Mixing of Signal



# Classification of Modulation



# Types AM, FM, PM Definition, Waveforms

| Sr. No. | Parameter | AM | FM | PM |
|---|---|---|---|---|
| 1. | Definition | Amplitude modulation is a technique of modulation, in which amplitude of carrier varies in accordance with amplitude of modulating signal. Keeping frequency and phase constant. | Frequency modulation is a technique of modulation, in which frequency of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and phase constant. | Phase modulation is a technique of modulation in which phase of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and frequency constant. |
| 1. | Definition | Amplitude modulation is a technique of modulation, in which amplitude of carrier varies in accordance with amplitude of modulating signal. Keeping frequency and phase constant. | Frequency modulation is a technique of modulation, in which frequency of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and phase constant. | Phase modulation is a technique of modulation in which phase of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and frequency constant. |
| 2. | Waveforms | <br>**Fig. 2.3** | <br>**Fig. 2.4** | <br>**Fig. 2.5** |

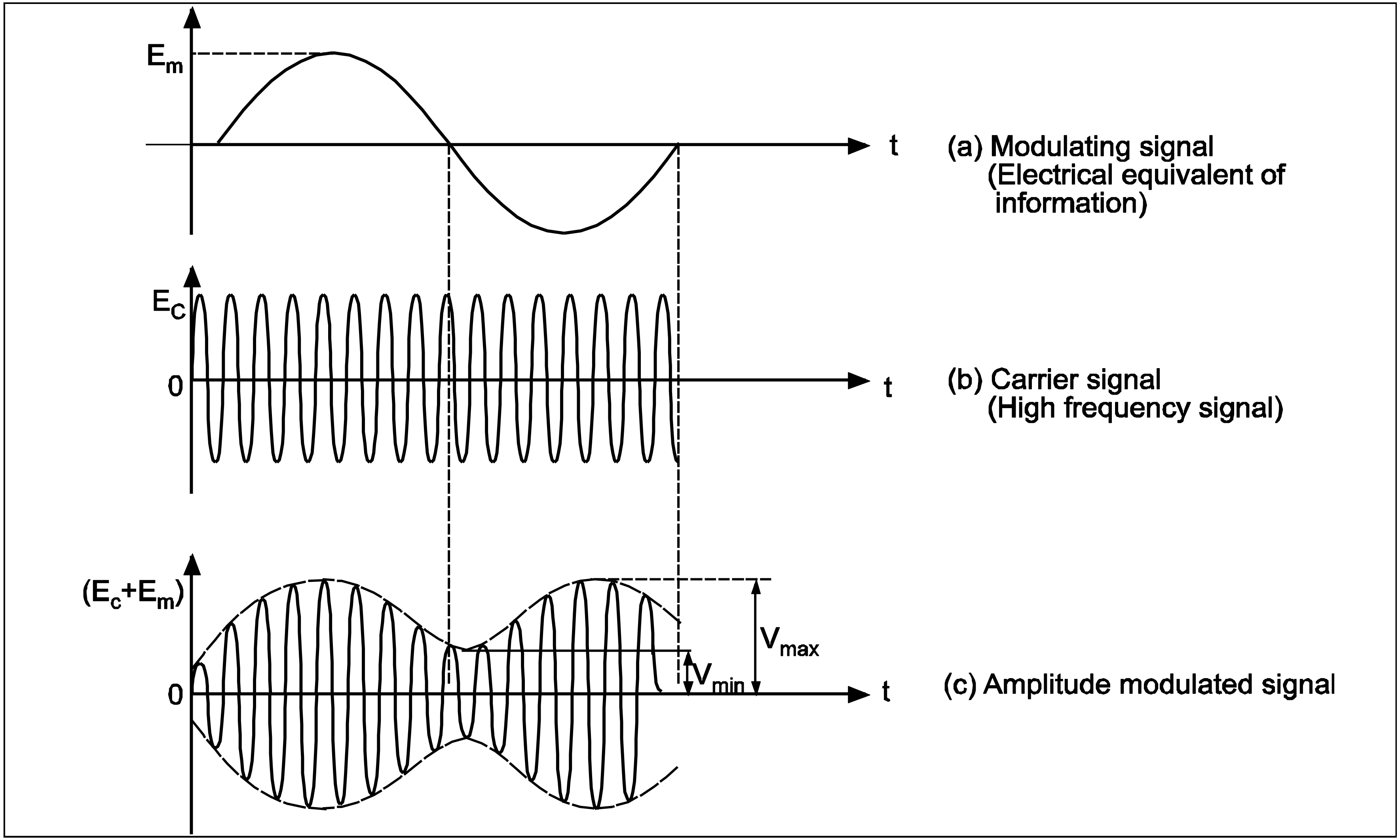
# Amplitude Modulation

**Definition:**

**Amplitude modulation, is a technique of modulation in which the instantaneous amplitude of carrier signal varies in accordance with amplitude of modulating signal**.

While **frequency** and **phase** of carrier **remains constant**. Nature of Amplitude Modulated waveform shown in Fig. below.

# Continued….



$E_m$
t
(a) Modulating signal
(Electrical equivalent of information)
$E_C$
0
t
(b) Carrier signal
(High frequency signal)
$(E_c+E_m)$
0
$V_{max}$
$V_{min}$
t
(c) Amplitude modulated signal

# Modulation Index

**Definition:**

**In AM, the modulation index (m) is defined as the ratio of amplitudes of modulating signal to the carrier signal.**

$$M.I. = \frac{\text{Modulating Signal Amplitude}}{\text{Carrier Signal Amplitude}}$$

$$\boxed{m = \frac{E_m}{E_c}} \qquad \ldots (2.4)$$

If modulation index is expressed in percentage, it is called **'percentage modulation'.**

i.e.

$$\boxed{\%m = \frac{E_m}{E_c} \times 100} \qquad \ldots (2.5)$$

Referring to Fig. 2.6, the modulation index is

$$\boxed{m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

# Effect of Modulation Index on Modulated Signal

1. **For m < 1,**

   i.e. $E_m < E_c$

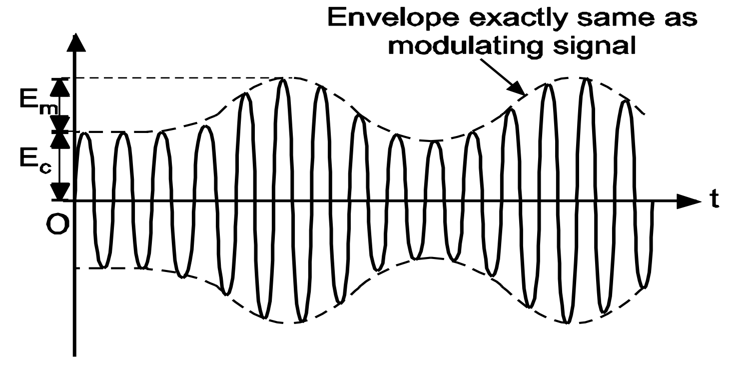



**Fig. 2.9 (b) AM Wave for m < 1 (Under Modulation)**

2. **For m = 1**

   i.e. $E_m = E_c$.   i.e. m = 100%.

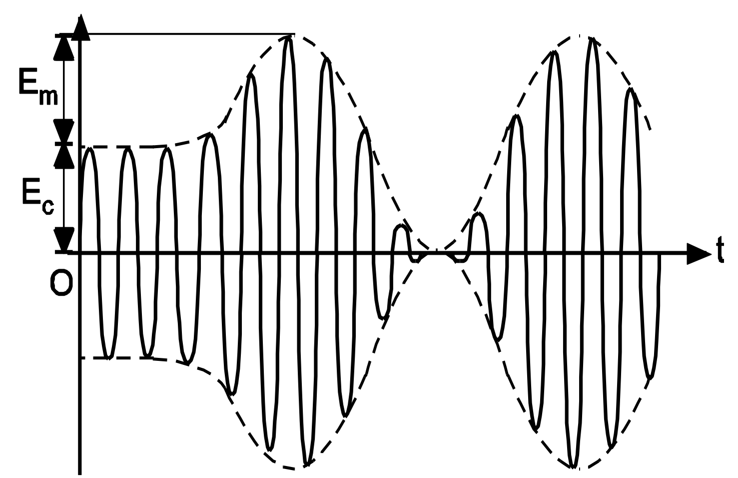



**Fig. 2.9 (c) AM Wave for m = 1 (Fully Modulated)**

# Continued….

**3. For m > 1**

i.e. $E_m > E_c$

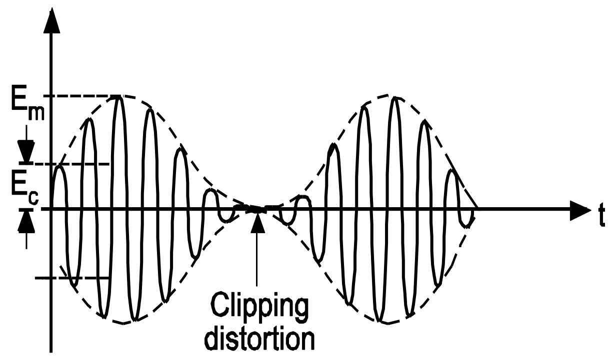



**Fig. 2.9 (d) AM Wave at m > 1 (Over Modulation)**

**For m = 0**

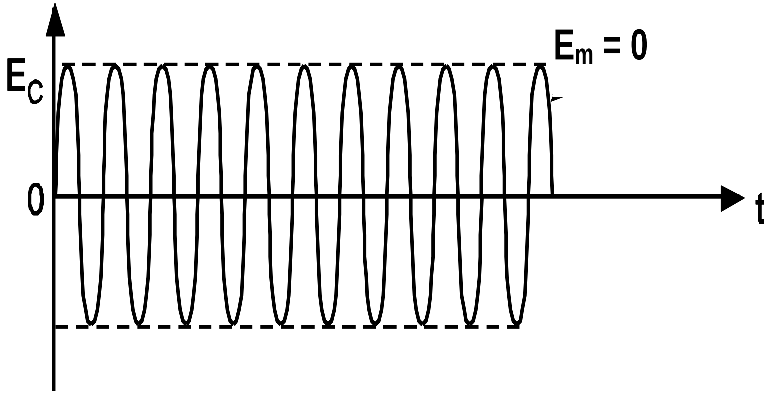
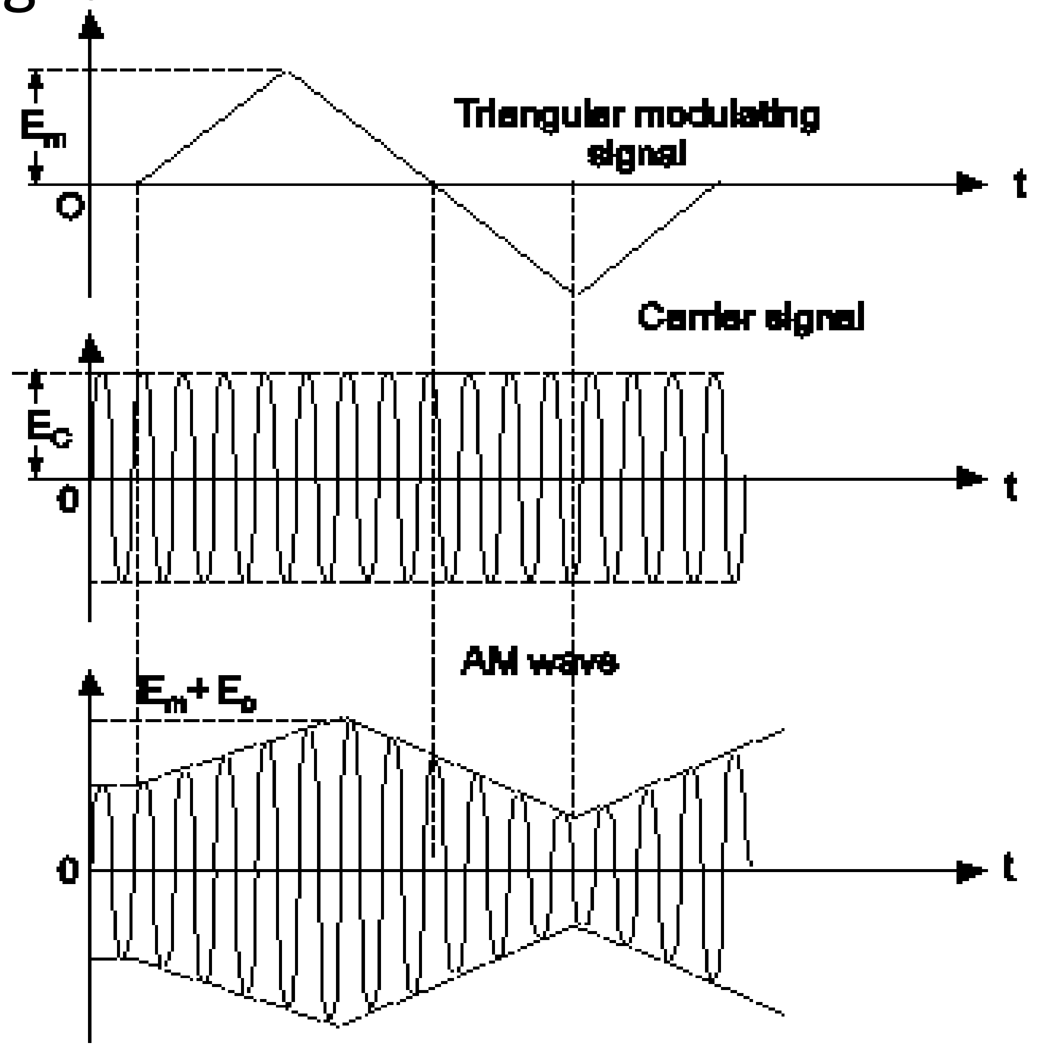



**Fig. 2.9 (e) AM Wave at m = 0 (No Modulation Takes Place)**

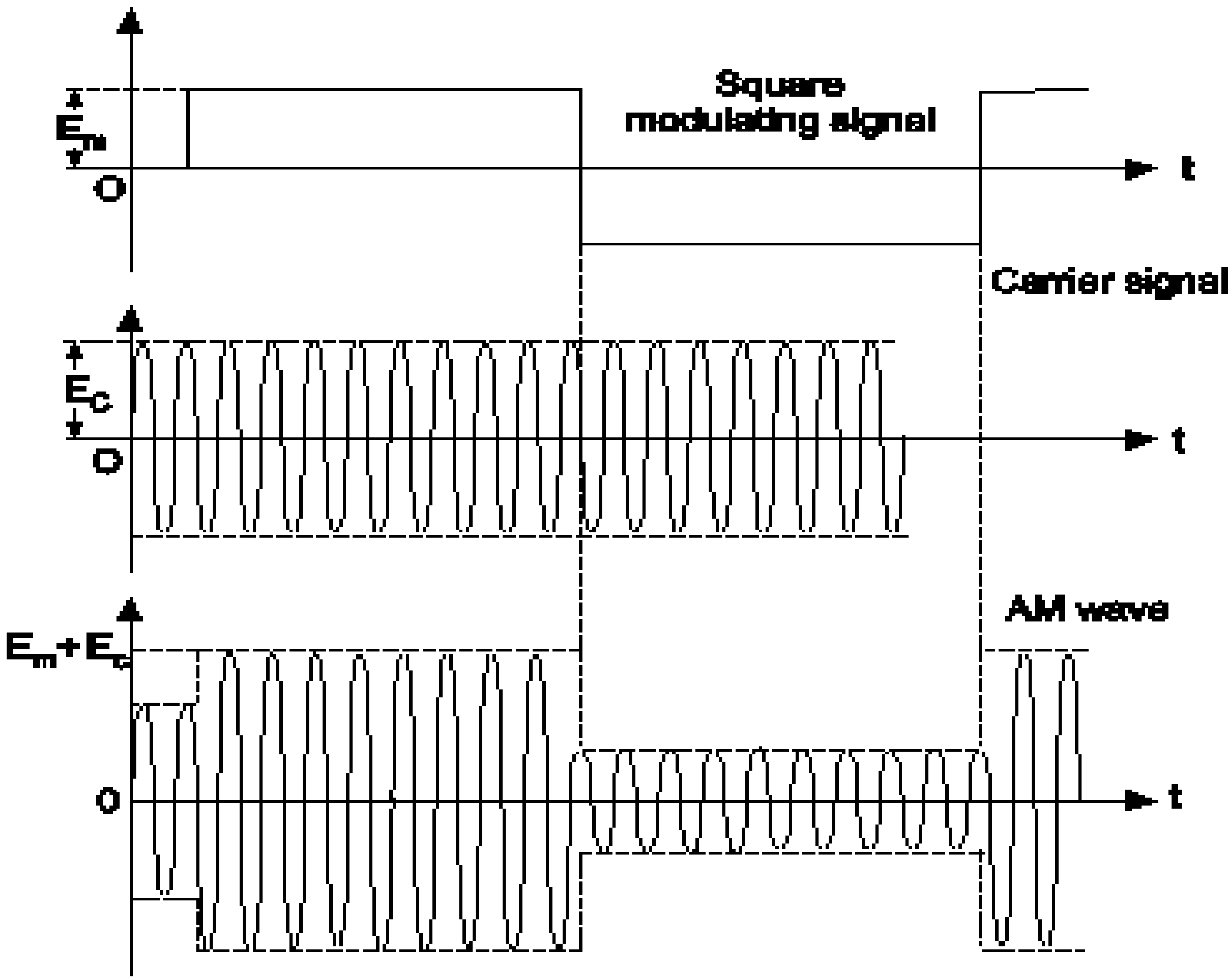
# Example

Draw the AM wave for triangular and square wave modulating signal.

**Solution:**

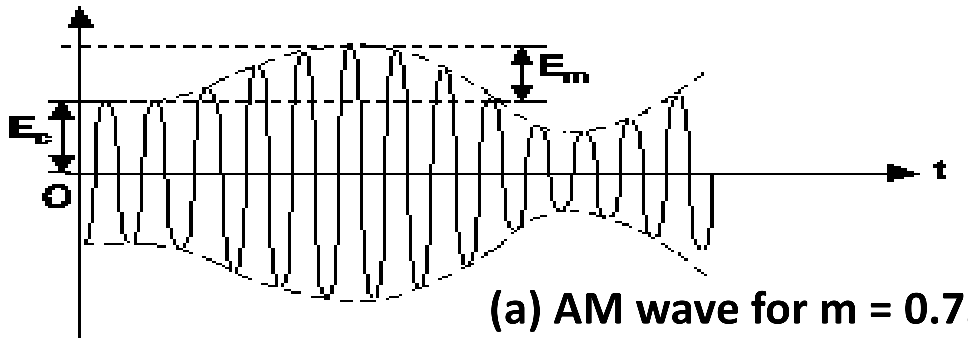


# For square wave input.



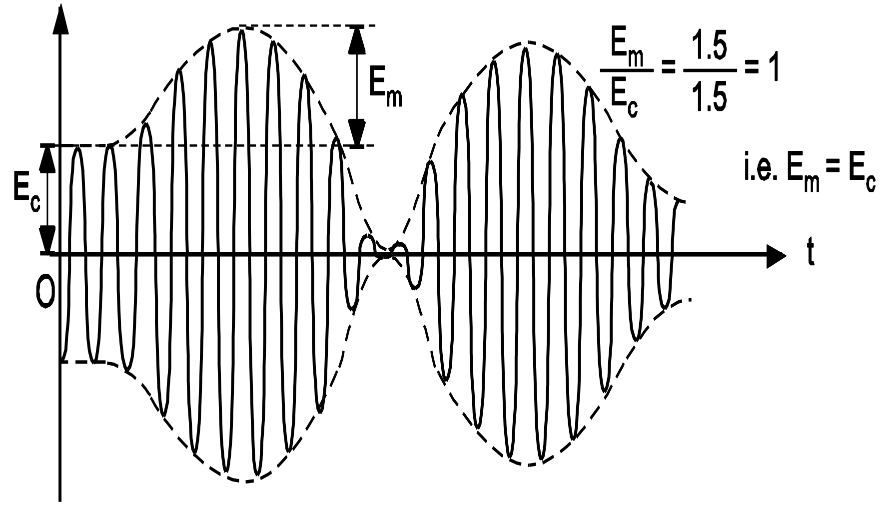
**Example 2** Draw the AM waveform for the modulation index m = 0.75, m = 1 and m = 1.25.

Take a graph paper and adjust the value of $E_m$ and $E_C$ in such a way that $\frac{E_m}{E_c} = 0.75$, $\frac{E_m}{E_c} = 1$, $\frac{E_m}{E_c} = 1.25$.

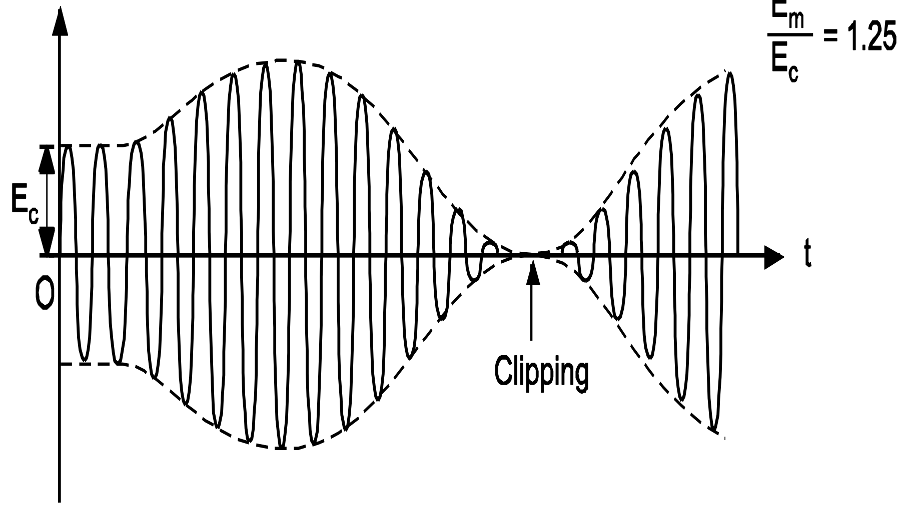



**(a) AM wave for m = 0.75**

# Continued…




(b) AM Wave for m = 1




(c) AM Wave for m = 1.25

# Frequency Spectrum

Representation of AM wave in frequency domain is also known as **frequency spectrum of AM wave.**

**Definition:**

**Frequency spectrum is a graph of amplitude versus frequency.**

The frequency spectrum of **AM wave tells us about number of sidebands present in AM wave with corresponding amplitudes.**

# Continued……

- Consider equation of AM wave (equation 2.12).

$$e_{AM} = (E_C + E_m \sin \omega_m t) \sin \omega_c t \qquad \text{... (2.12)}$$

$$e_{AM} = E_C \left(1 + \frac{E_m}{E_c} \sin \omega_m t\right) \sin \omega_c t$$

But,

$$m = \frac{E_m}{E_c}$$

$\therefore$

$$e_{AM} = E_C(1 + m \sin \omega_m t) \sin \omega_c t \qquad \text{... (2.13)}$$

Simplifying we get,

$$e_{AM} = E_C \sin \omega_c t + mE_C \sin \omega_m t \sin \omega_c t \qquad \text{... (2.14)}$$

There is a trigonometric identity that says that the product of two sin waves is

$$\sin A \sin B = \frac{\cos (A - B)}{2} - \frac{\cos (A + B)}{2}$$

By substituting this identify into equation becomes

$$e_{AM} = \underbrace{E_C \sin \omega_c t}_{\text{Carrier}} + \underbrace{\frac{mE_C}{2} \cos (\omega_c - \omega_m) t}_{\text{LSB}} - \underbrace{\frac{mE_C}{2} \cos (\omega_c + \omega_m) t}_{\text{USB}} \qquad \text{... (2.15)}$$

Carrier LSB USB

# Features of Frequency spectrum

From equation (2.15) of AM wave, it consists of three terms:

(i) The first term is sine term called unmodulated **carrier signal**.

(ii) The second term is cos term at frequency ($f_c - f_m$) called Lower Side Band (LSB) with amplitude $\frac{mE_C}{2}$. (□ $w_c = 2\pi f_c$ and $w_m = 2\pi f_m$).

(iii) The third term is cos term at frequency ($f_c + f_m$) called **upper sideband (USB)** with amplitude $\frac{mE_C}{2}$.

- **This shows that AM wave, having two sidebands which contains actual information and one carrier.**
- From equation 2.15, plot of frequency spectrum shown in Fig. 2.13 (a).

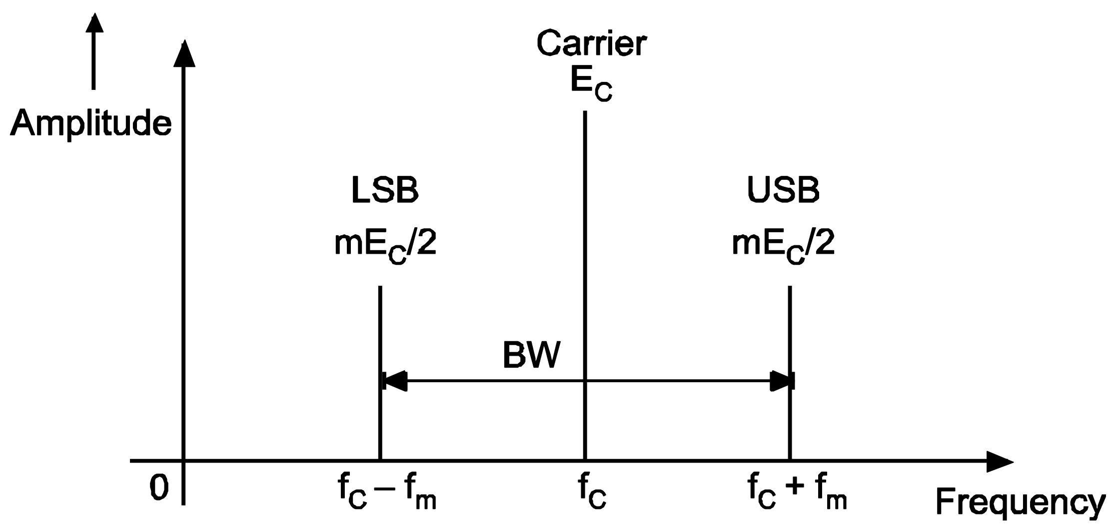



**Fig. 2.13 (a): Frequency Spectrum of AM Wave**

## Bandwidth Requirement

**The bandwidth of AM signal is defined as the frequency range from upper sideband to lower sideband frequency in frequency spectrum.**

$$BW = f_{USB} - f_{LSB}$$

$$= (f_c + f_m) - (f_c - f_m) \quad \ldots \text{ (from Fig. 2.13)}$$

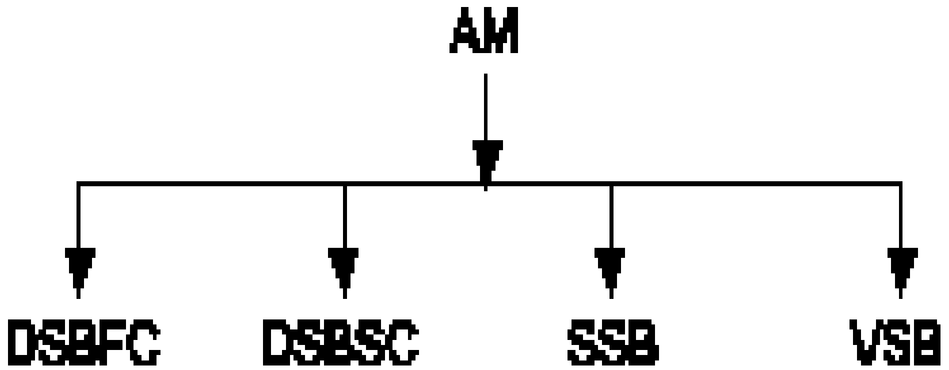
$$= f_c + f_m - f_c + f_m$$

$$= \mathbf{2\, f_m}$$

$\therefore \quad \rightarrow$ BW required for AM signal.

**Hence, bandwidth of AM signal is twice the modulating signal frequency.**

# Sideband Concept (DSB and SSB)

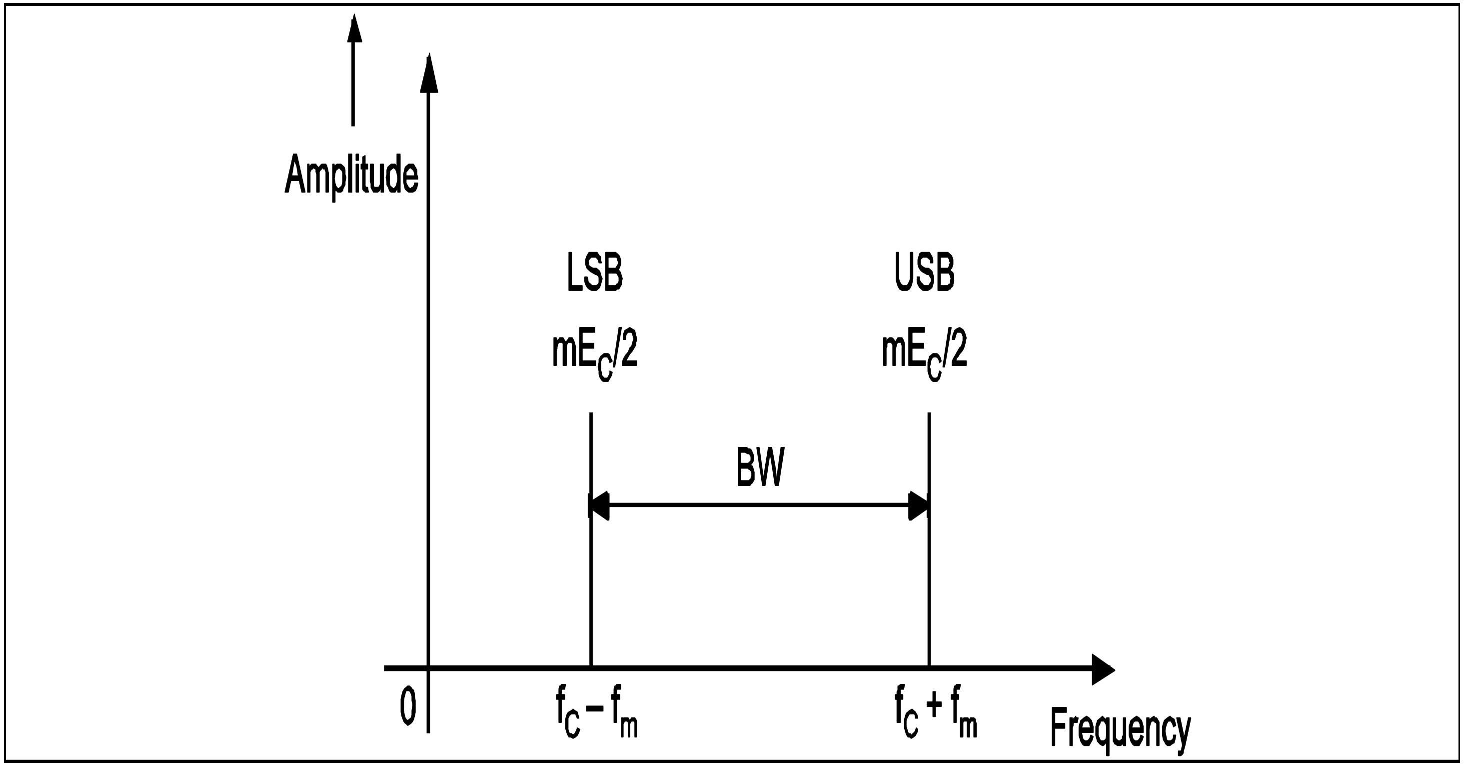



**DSBFC:**

Means double sideband full carrier as shown in Fig. 2.13 (a). Its BW = 2fm.

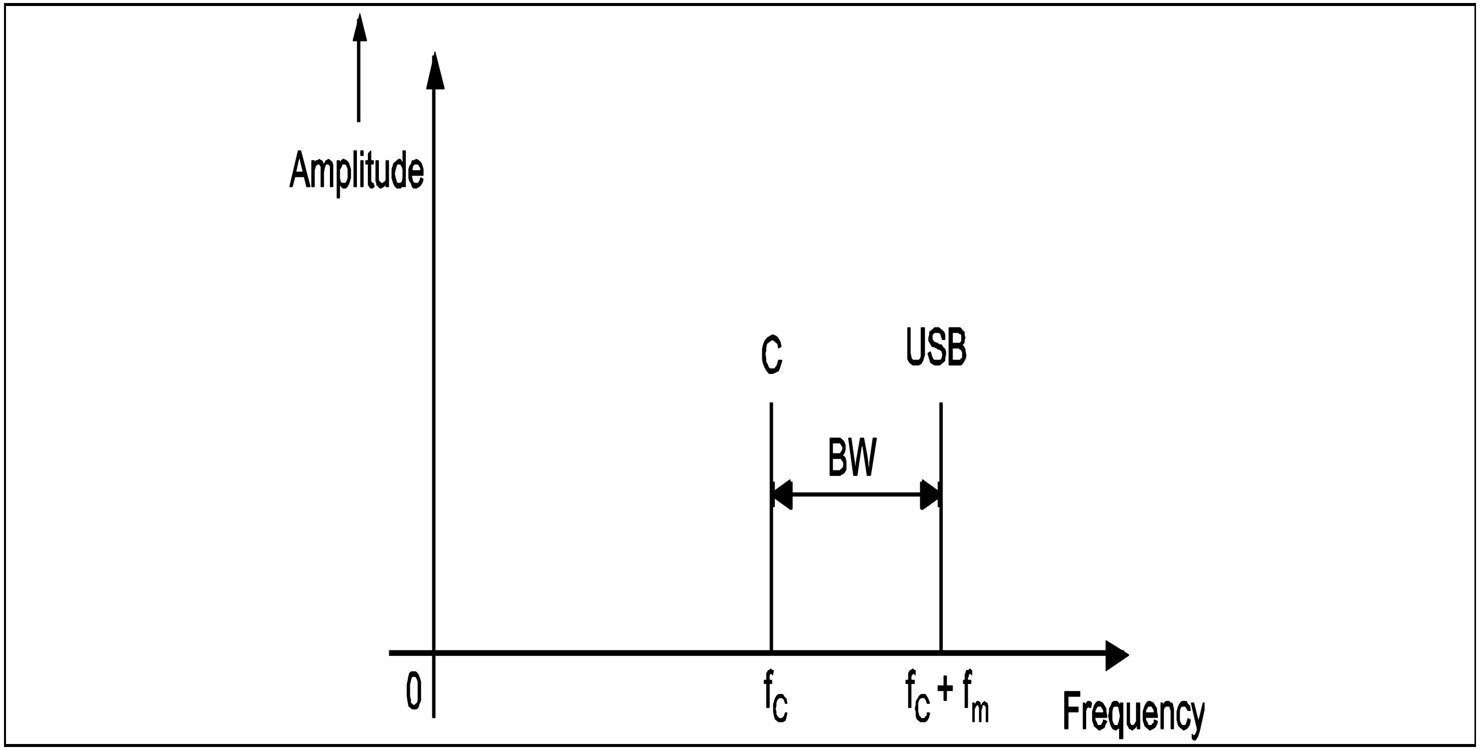
# Continued…

## DSBSC (or DSB):



# Continued…

**SSB:**



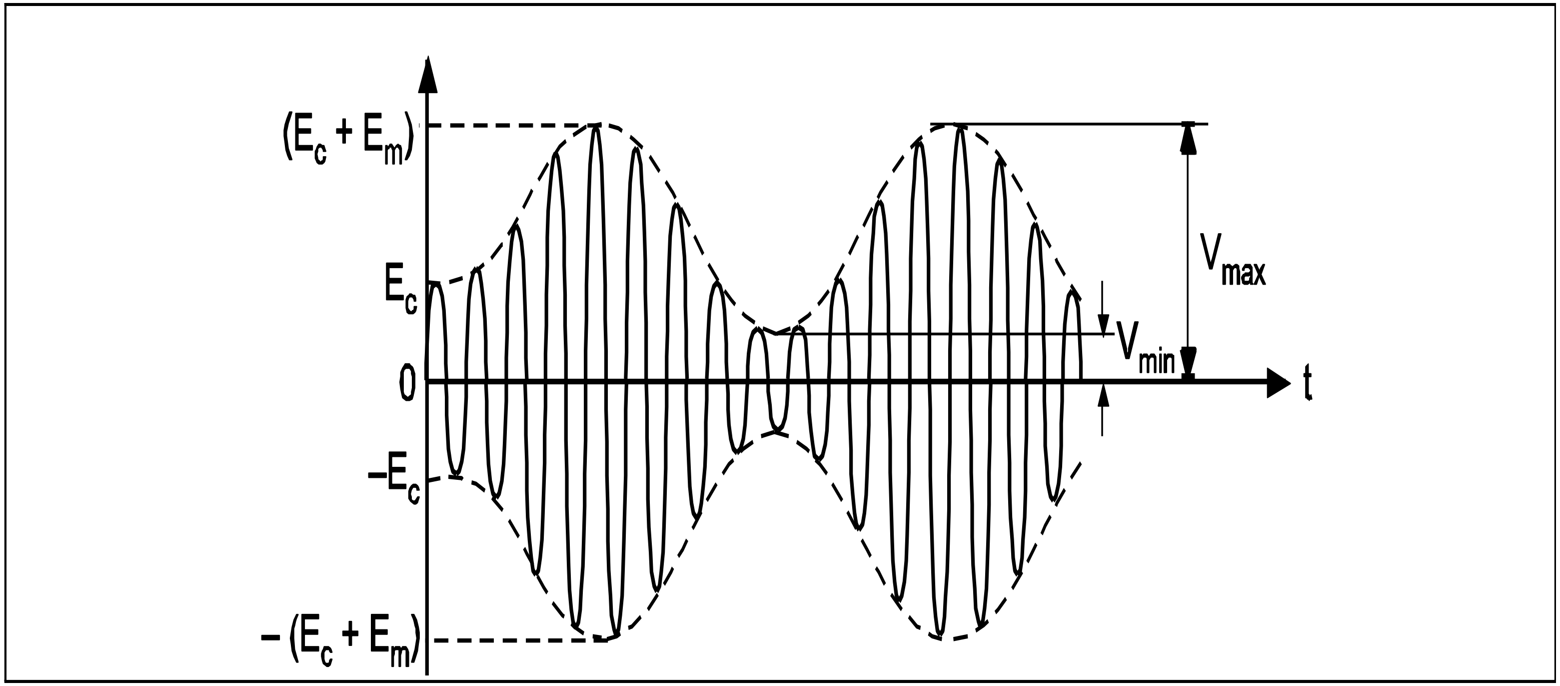
# Representation of AM Wave

AM wave is represented in two ways:

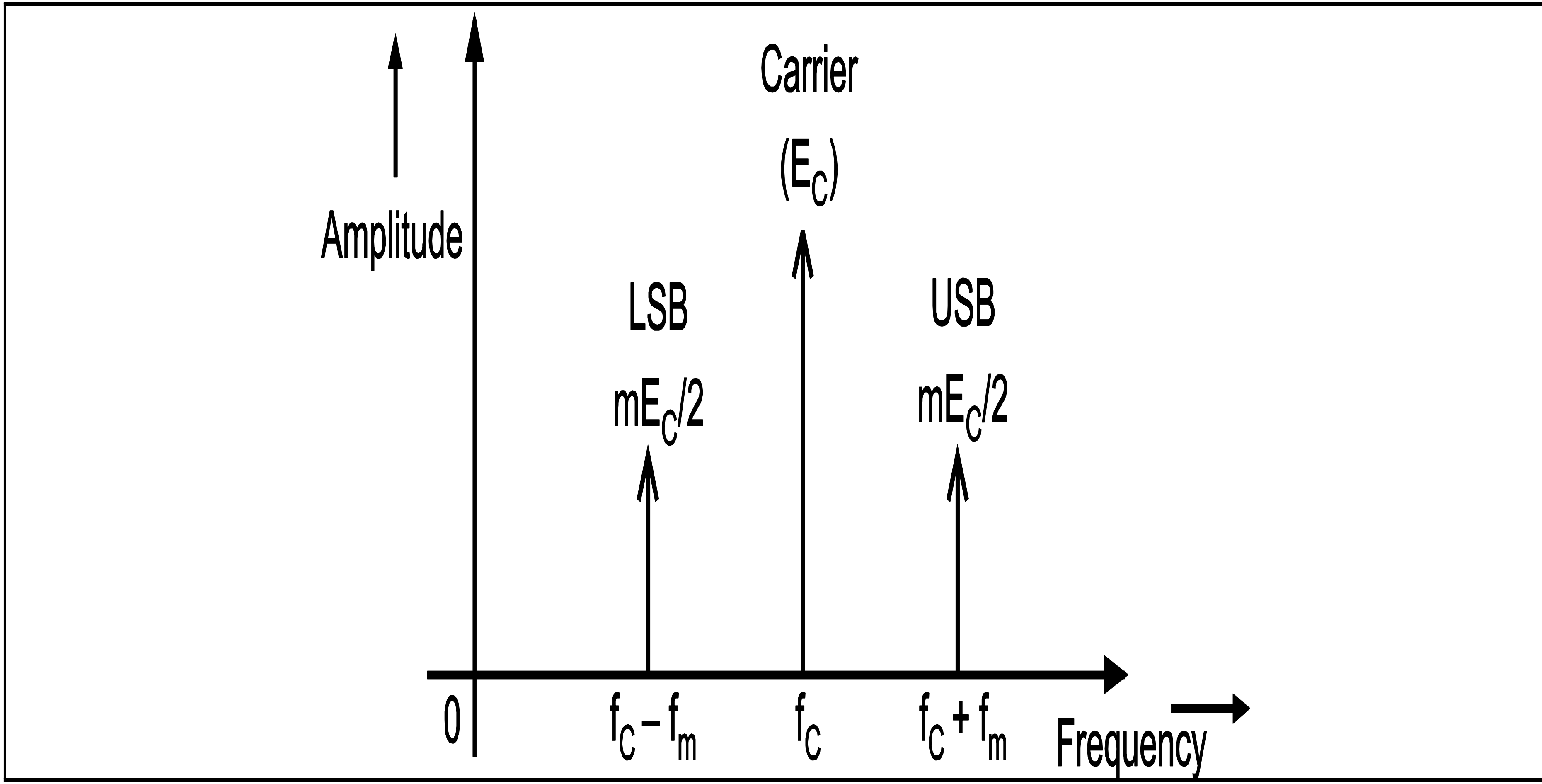
(i) In Time Domain

(ii) In Frequency Domain

**AM in Time Domain**



# AM in Frequency Domain



# Power Relations in AM Wave

**(i) The Total Power in AM ($P_t$):**

$$P_t = (\text{Carrier Power}) + (\text{Power in USB}) + (\text{Power in LSB})$$

$$P_t = P_c + P_{USB} + P_{LSB} \qquad \text{...(2.16)}$$

$$\therefore \quad P_t = \frac{E_{carr}^2}{R} + \frac{E_{USB}^2}{R} + \frac{E_{LSB}^2}{R}$$

where, $E_{carr}$, $E_{USB}$, $E_{LSB}$ = r.m.s. values of the carrier and side band amplitudes

$R$ = Characteristic resistance of antenna in which total power is dissipated.

**(ii) Carrier Power ($P_c$):**

The carrier power is given by,

$$P_c = \frac{E_{carr}^2}{R}$$

$$= \frac{(E_c/\sqrt{2})^2}{R}$$

$$\boxed{P_c = \frac{E_c^2}{2R}} \qquad \text{... (2.17)}$$

where, $E_c$ = Peak carrier amplitude

# Continued…

**(iii) Power in sidebands:**

The power in USB and LSB is same as,

$$P_{USB} = P_{LSB} = \frac{E_{SB}^2}{R}$$

From equation (2.15),

$$\text{Peak amplitude of sideband} = \frac{mE_c}{2}$$

$$\therefore \quad P_{USB} = P_{LSB} = \frac{(mE_c/2\sqrt{2})^2}{R}$$

$$= \frac{m^2E_c^2}{8R}$$

$$\therefore \quad P_{USB} = P_{LSB} = \frac{m^2}{4} \times \frac{E_c^2}{2R}$$

From equation (2.17),

$$\frac{E_c^2}{2R} = P_c$$

$$\therefore \quad \boxed{P_{USB} = P_{LSB} = \frac{m^2}{4} P_c}$$

# Continued….

**(iv) Total Power in AM:**

From equation (2.16),

The total power in AM wave is,

$$P_t = P_c + P_{USB} + P_{LSB}$$

$$= P_c + \frac{m^2}{4} P_c + \frac{m^2}{4} P_c$$

$$\therefore \quad \boxed{P_t = \left(1 + \frac{m^2}{2}\right) P_c} \quad \text{...(2.19)}$$

From this equation, we can say that as value of 'm' increases, total power also increases.

For m = 1, total power will be maximum. (i.e. for unity M.I.)

$$\therefore \quad \boxed{P_t = 1.5\, P_c}$$

# Example 1:

A modulating signal 20 sin $(2\pi \times 10^3 t)$ is used to modulate a carrier signal 40 sin $(2\pi \times 10^4 t)$. Find:

(a) Modulation index

(b) Percentage modulation

(c) Sideband frequencies and their amplitude

(d) Bandwidth of AM wave

(e) Draw the frequency spectrum.

**Solution:**

**Given:** Modulating signal,

$e_m = 20 \sin (2\pi \times 10^3 t)$ ... (1)

$e_m = E_m \sin (2\pi f_m t)$ ... (2)

$\therefore$ Compare equation (1) and (2), we get

$E_m = 20$ V

$f_m = 10^3$ Hz = 1 kHz

Similarly, carrier signal

$e_c = 40 \sin (2\pi \times 10^4 t)$ ... (3)

But, $e_c = E_c \sin (2\pi f_c t)$ ... (4)

Compare equation (3) and (4), we get,

$E_c = 40$ v

$f_c = 10^4$Hz = 100 kHz

**(a) Modulation Index:**

m = = = 0.5

**(b) Percentage modulation:**

% modulation = $m \times 100$

= $0.5 \times 100$

= 50%

**(c) Sideband frequencies and their amplitude:**

LSB = $F_{LSB}$ = $f_c - f_m$

= 100 kHz – 1 kHz

= 99 kHz

USB = $F_{USB}$ = $f_c + f_m$

= 100 k + 1 kHz

= 101 kHz

LSB amplitude = USB amplitude

= = 0.5 ×

= 10 V

**(d) Bandwidth of AM**

BW = $2 \times f_m$

= $2 \times 1$ kHz

# AM Transmitter

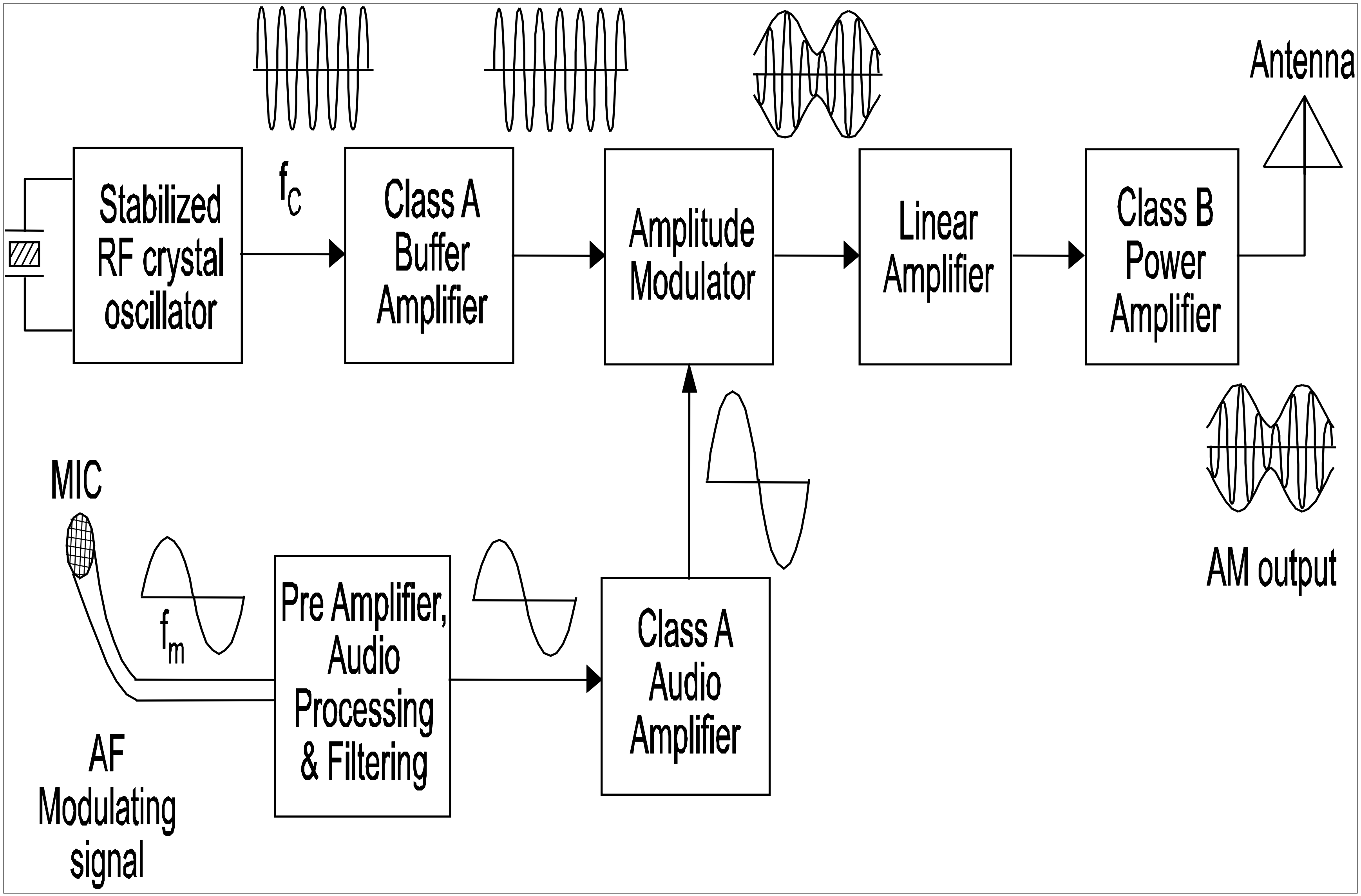
The functions of transmitter are:

1. To convert original information into electrical signal.
2. To amplify the weak signal.
3. To modulate the signal.
4. To increase the power level of modulated signal.
5. To transmit the signal through transmitting antenna.

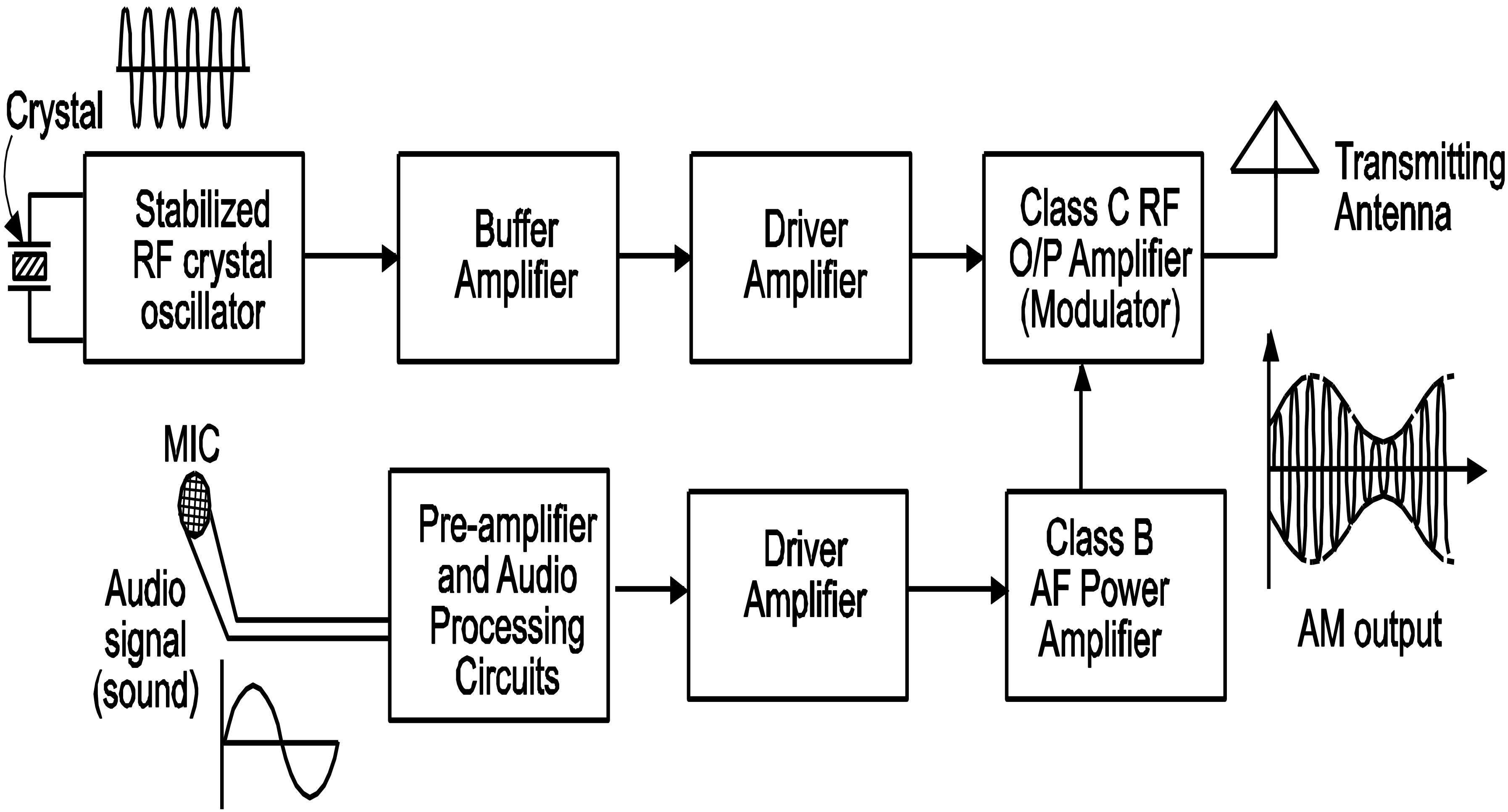
**The AM transmitters are of two types:**

1. Low level modulated transmitter.
2. High level modulated transmitter.

# Low Level Modulated AM Transmitter



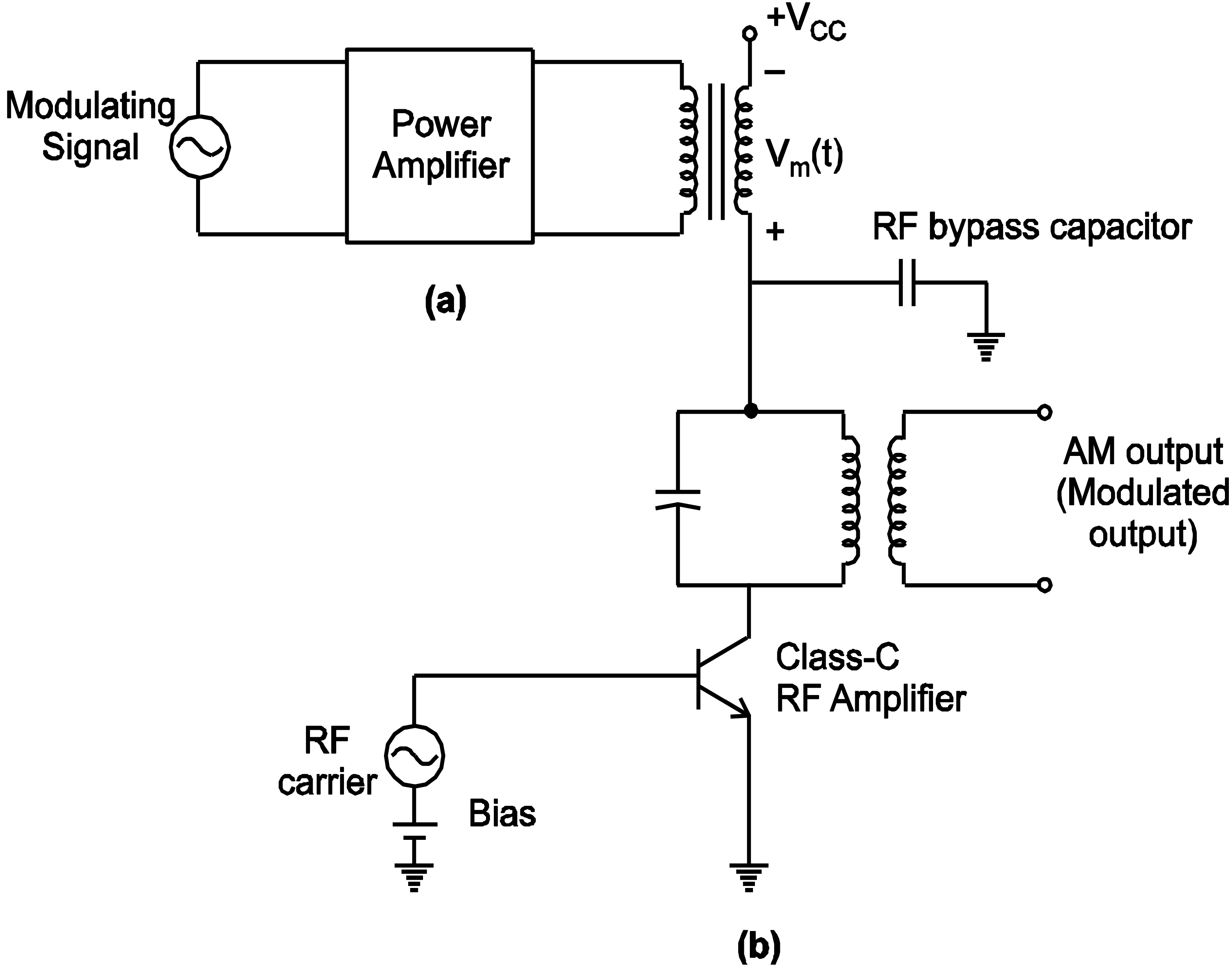
# High Level Modulated AM Transmitter



# Comparison between High Level and Low Level Modulation

| Sr. No. | High Level Modulation | Low Level Modulation |
|---|---|---|
| 1. | Modulation takes place at high power level. | Modulation takes place at low power level. |
| 2. | Class-C amplifier are used which are highly efficient. | After modulation linear amplifiers (Class A, AB or B) are used. |
| 3. | Very high efficiency. | Low efficiency than high level modulation. |
| 4. | Complex because of very high power. | Easy because of low power. |
| 5. | Used in high power broadcast transmitters. | Used in TV transmitters (IF modulation method).<br>In laboratory equipments, walkie-talkies etc. |

# AM Modulator Circuit using BJT



## Operation

The transistor is normally operated in the **Class-c Mode** in which it is biased well beyond cut-off.

•The **carrier input** to the base must be sufficient to drive the transistor into conduction over the part of RF cycle, during which collector current flows in the form of pulses.

•The tuned circuit in the collector is tuned to resonate at the fundamental component, thus, the RF voltage at the collector is sinusoidal.

•When **modulating signal** is applied to the steady collector voltage, changes to a slowly varying voltage given by $V'_{cc} = V_{cc} + V_m(t)$.

•The modulating voltage $\mathbf{V_m(t)}$ is applied in series with $V_{cc}$ through the low frequency transformer.

•The **RF bypass capacitor** provides a low impedance path for the RF to ground so that negligible RF voltage is developed across the LF Transformer secondary.

•The modulated output is obtained through mutual inductive coupling as shown in circuit diagram.

- The coupling prevents the 'steady' voltage from being transferred to the output,
- so that $R_f$ varies about mean value of zero shown in Fig.

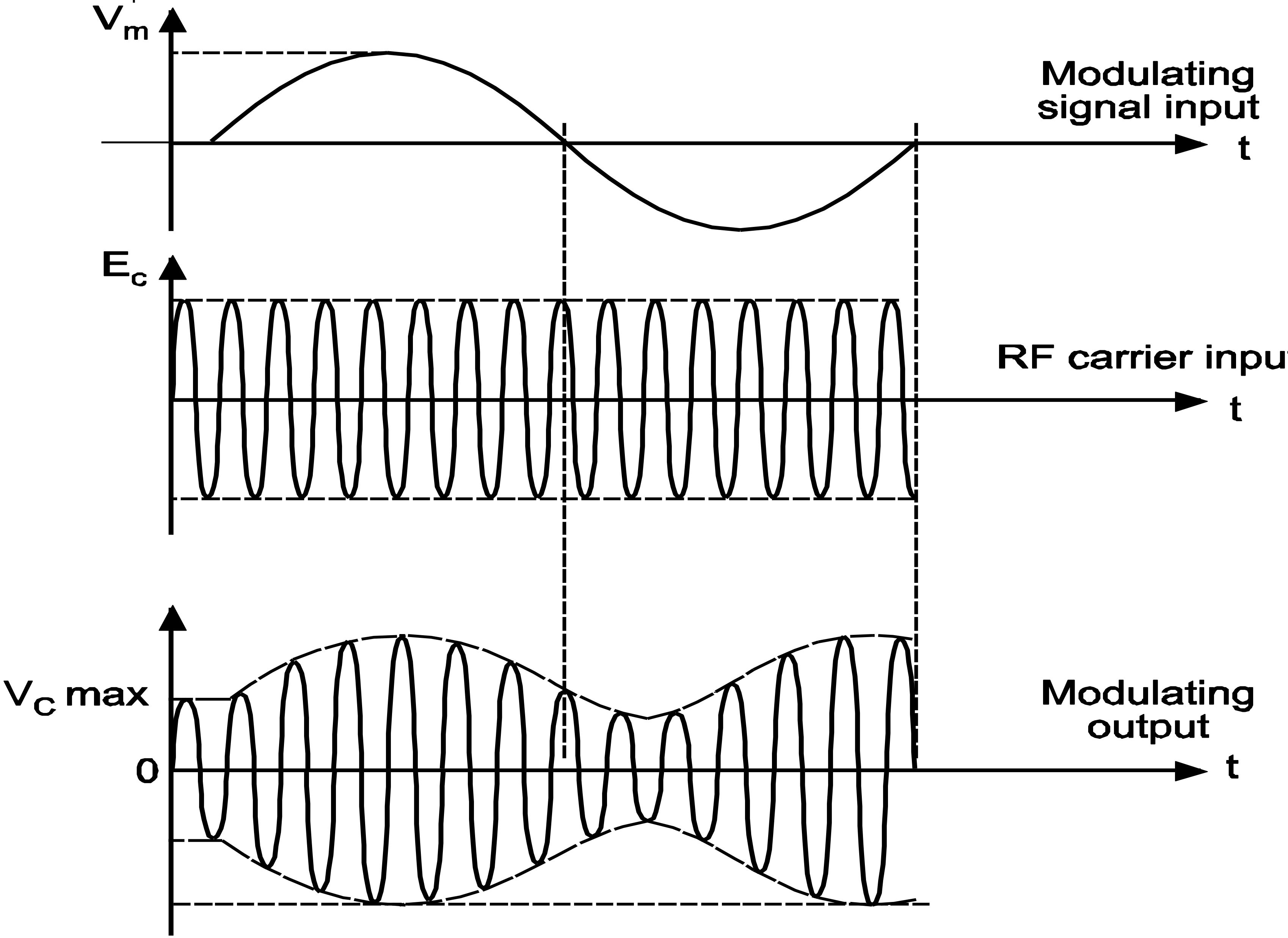



**Fig. Input/Output waveform of AM Modulator**

## Advantages of AM

1. AM transmitters are not complex.
2. AM receivers are simple and easy to detect.
3. Less expensive.
4. Covers large distance.

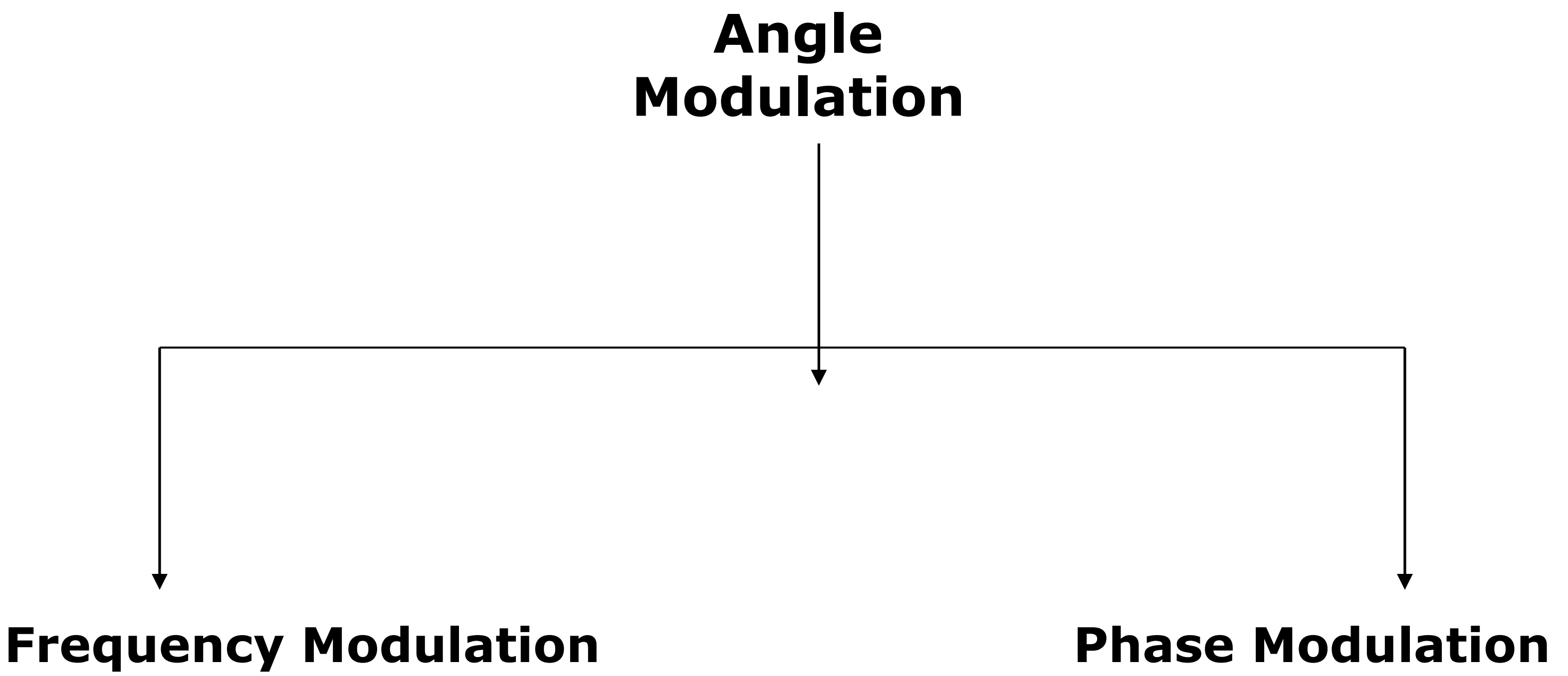
## Disadvantages of AM

1. Requires large bandwidth.
2. Requires large power.
3. Gets affected due to noise.

## Applications of AM

1. Radio broadcasting.
2. Picture transmission in TV (VSB is used).

# Angle Modulation

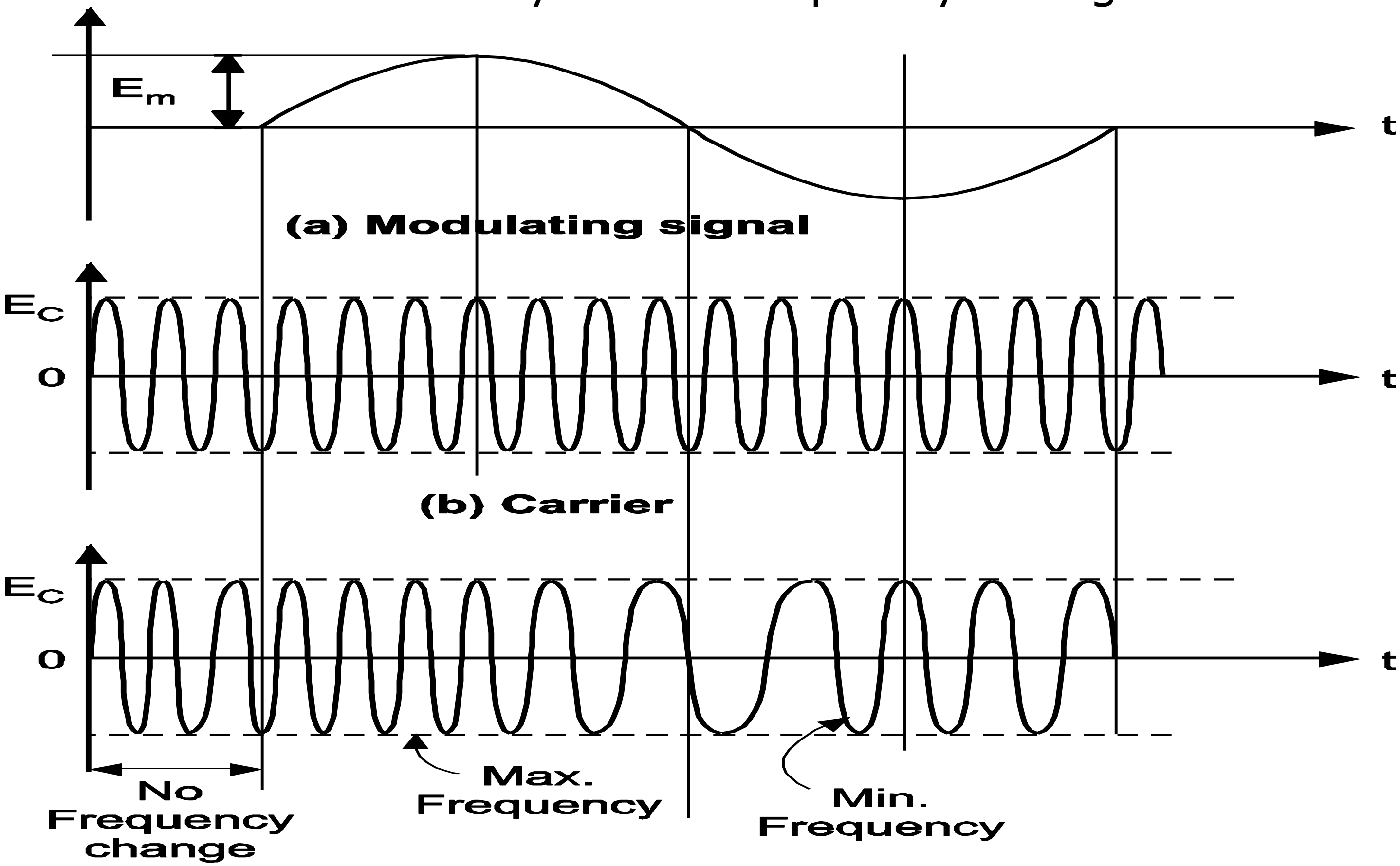


# Frequency Modulation

**Definition of FM:**

**Frequency modulation is a technique of modulation in which the frequency of carrier is varied in accordance with the amplitude of modulating signal.**

- In FM, amplitude and phase remains constant.
- Thus, the information is conveyed via. frequency changes




(c) FM wave
(variation in frequency, amplitude and phase remains constant)

# Modulation Index

**Definition:**

**Modulation Index is defined as the ratio of frequency deviation (δ) to the modulating frequency ($f_m$).**

$$M.I. = \frac{\text{Frequency Deviation}}{\text{Modulating Frequency}}$$

$$mf = \frac{\delta}{fm}$$

**In FM M.I.>1**

**Modulation Index of FM decides –**
**(i)Bandwidth of the FM wave.**
**(ii)Number of sidebands in FM wave.**

# Deviation Ratio

**The modulation index corresponding to maximum deviation and maximum modulating frequency is called deviation ratio.**

$$\text{Deviation Ratio} = \frac{\text{Maximum Deviation}}{\text{Maximum modulating Frequency}}$$

$$= \frac{\delta max}{fmax}$$

In FM broadcasting the maximum value of deviation is limited to **75 kHz.** The maximum modulating frequency is also limited to **15 kHz.**

# Percentage M.I. of FM

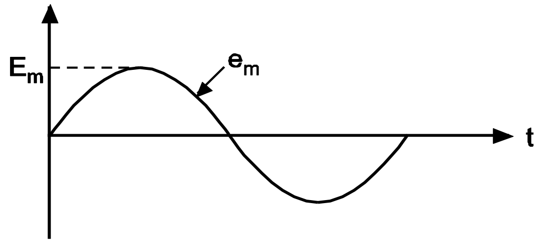
**The percentage modulation is defined as the ratio of the actual frequency deviation produced by the modulating signal to the maximum allowable frequency deviation.**

$$\% \text{ M.I} = \frac{\text{Actual deviation}}{\text{Maximum allowable deviation}}$$

∴

# Mathematical Representation of FM

**(i) Modulating Signal:**




**It may be represented as,**

$$e_m = E_m \cos \omega_m t \qquad \ldots(1)$$

**Here cos term taken for simplicity**

**where,**

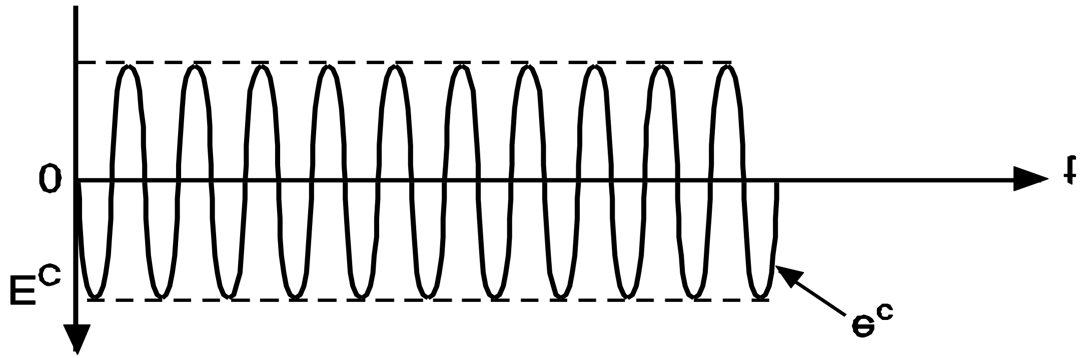
$e_m$ = **Instantaneous amplitude**

$\omega_m$ = **Angular velocity**

= $2\pi f_m$

$f_m$ = **Modulating frequency**

## (ii) Carrier Signal:




**Carrier may be represented as,**

$$e_c = E_c \sin(\omega_{ct} + \phi) \qquad \text{-----(2)}$$

**where,**

| | | |
|---|---|---|
| $e_c$ | = | **Instantaneous amplitude** |
| $\omega_c$ | = | **Angular velocity** |
| | = | $2\pi f_c$ |
| $f_c$ | = | **Carrier frequency** |
| $\phi$ | = | **Phase angle** |

## (iii) FM Wave:

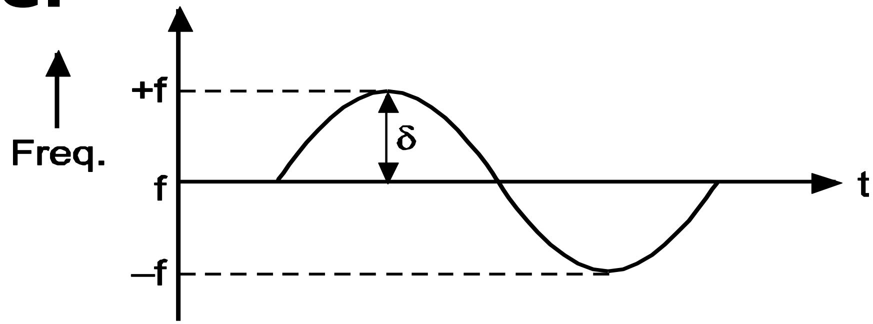



**Fig. Frequency Vs. Time in FM**

FM is nothing but a deviation of frequency.

From Fig. 2.25, it is seen that instantaneous frequency 'f' of the FM wave is given by,

$$\mathbf{f = f_c\,(1 + K\,E_m \cos \omega_m t)} \ldots (3)$$

where,

$f_c$ = Unmodulated carrier frequency

K = Proportionality constant

$E_m \cos \omega_m t$ = Instantaneous modulating signal

(Cosine term preferred for simplicity otherwise we can use sine term also)

- The maximum deviation for this particular signal will occur, when $\cos \omega_m t = \pm 1$ i.e. maximum.

∴ Equation (2.26) becomes,

$$\mathbf{f = f_c\,(1 \pm K\,E_m)} \qquad \ldots \mathbf{(4)}$$

$$\therefore \qquad \mathbf{f = f_c \pm K\,E_m f_c} \qquad \ldots \mathbf{(5)}$$

So that maximum deviation $\delta$ will be given by,

$$\boldsymbol{\delta = K E_m f_c} \quad \ldots (6)$$

The instantaneous amplitude of FM signal is given by,

$$e_{FM} = A \sin [f(\omega_c, \omega_m)]$$

$$= A \sin \theta \quad \ldots (7)$$

where,

$f(\omega_c, \omega_m)$= Some function of carrier and modulating frequencies

Let us write equation (2.26) in terms of $\omega$ as,

$$\boldsymbol{\omega = \omega_c (1 + K E_m \cos \omega_m t)}$$

To find $\theta$, $\omega$ must be integrated with respect to time.

Thus,

$$\theta = \omega \, dt$$

$$= \omega_c (1 + K E_m \cos \omega_m t) \, dt$$

$$\theta = \omega_c (1 + K E_m \cos \omega_m t) \, dt$$

$$= \omega_c \left(t + KEm \frac{\sin \omega mt}{\omega m}\right)$$

$$= \omega_c t + KEm\omega_c \frac{\sin \omega mt}{\omega m}$$

$$= \omega_c t + KEmf_c \frac{\sin \omega mt}{\omega m}$$

$$= \omega_c t + \frac{\delta}{fm} \sin \omega mt \qquad [\because \quad \delta = K E_m f_c]$$

$\therefore$

Substitute value of $\theta$ in equation (7)

Thus,

$$e_{FM} = A \sin\left(\omega_c t + \frac{\delta}{fm} \sin \omega mt\right) \text{---(8)}$$

$$e_{FM} = A \sin\left(\omega_c t + mf \sin \omega mt\right) \text{---(9)}$$

This is the equation of FM.

# Frequency Spectrum of FM

**Frequency spectrum is a graph of amplitude versus frequency**. The frequency spectrum of FM wave tells us about number of sideband present in the FM wave and their amplitudes.

The expression for FM wave is not simple. It is complex because it is sine of sine function.

Only solution is to use **'Bessels Function'.**

Equation (2.32) may be expanded as,

$$
\begin{aligned}
e_{FM} = \quad & \{A\, J_0\,(m_f) \sin \omega_c t \\
& + J_1\,(m_f)\,[\sin(\omega_c + \omega_m)\,t - \sin(\omega_c - \omega_m)\,t] \\
& + J_1\,(m_f)\,[\sin(\omega_c + 2\omega_m)\,t + \sin(\omega_c - 2\omega_m)\,t] \\
& + J_3\,(m_f)\,[\sin(\omega_c + 3\omega_m)\,t - \sin(\omega_c - 3\omega_m)\,t] \\
& + J_4\,(m_f)\,[\sin(\omega_c + 4\omega_m)\,t + \sin(\omega_c - 4\omega_m)\,t] \\
& + \ldots\ldots\} \qquad \ldots (2.33)
\end{aligned}
$$

From this equation it is seen that the FM wave consists of:

(i)Carrier (First term in equation).

(ii)Infinite number of sidebands (All terms except first term are sidebands).

The amplitudes of carrier and sidebands depend on 'J' coefficient.

$\omega_c = 2\pi f_c, \qquad \omega_m = 2\pi f_m$

So in place of $\omega_c$ and $\omega_m$, we can use $f_c$ and $f_m$.

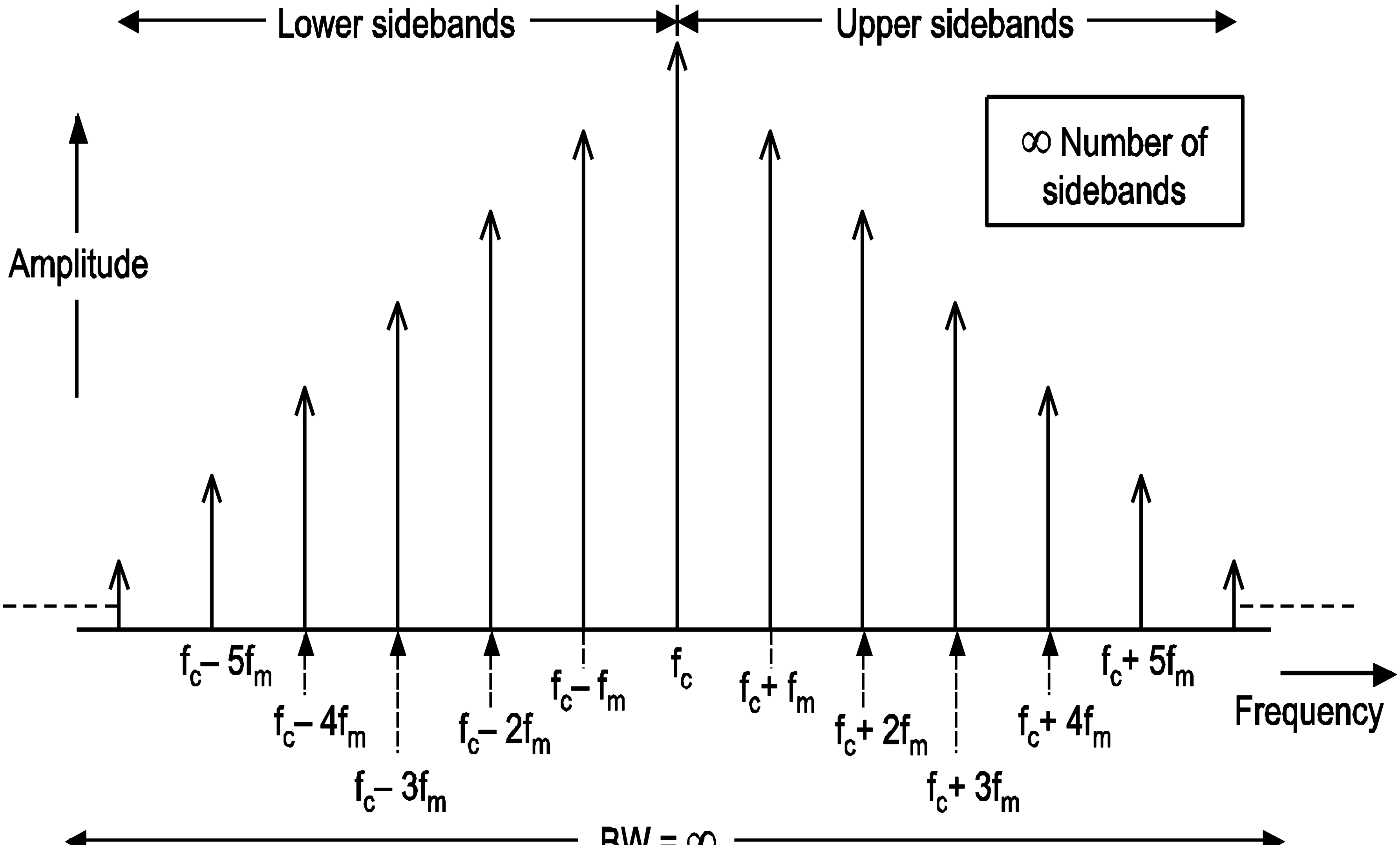



**Fig. : Ideal Frequency Spectrum of FM**

# Bandwidth of FM

From frequency spectrum of FM wave shown in Fig. 2.26, we can say that the bandwidth of FM wave is infinite.

But practically, it is calculated based on how many sidebands have significant amplitudes.

(i)The Simple Method to calculate the bandwidth is –

BW=2fmx Number of significant sidebands --(1)

With increase in modulation index, the number of significant sidebands increases. So that bandwidth also increases.

(ii)The second method to calculate bandwidth is by **Carson's rule.**

**Carson's rule states that, the bandwidth of FM wave is twice the sum of deviation and highest modulating frequency.**

$$BW=2(\delta + fmmax) \qquad ...(2)$$

Highest order side band = To be found from table 2.1 after the calculation of modulation Index m where, m = **δ/fm**

e.g. If m= 20KHZ/5KHZ

From table, for modulation index 4, highest order side band is 7th. Therefore, the bandwidth is

$$B.W. = 2\ f_m \times \text{Highest order side band}$$
$$= 2 \times 5\ kHz \times 7$$
$$= 70\ kHz$$

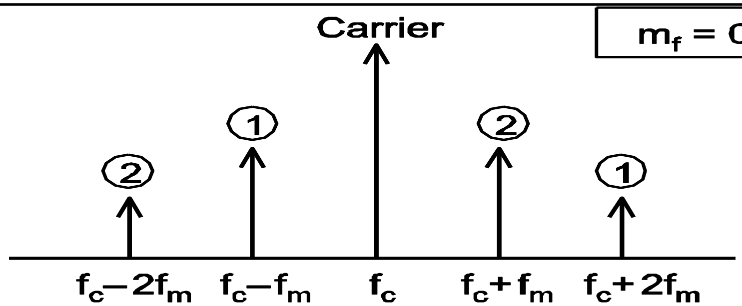
# Carrier Distribution Charts:

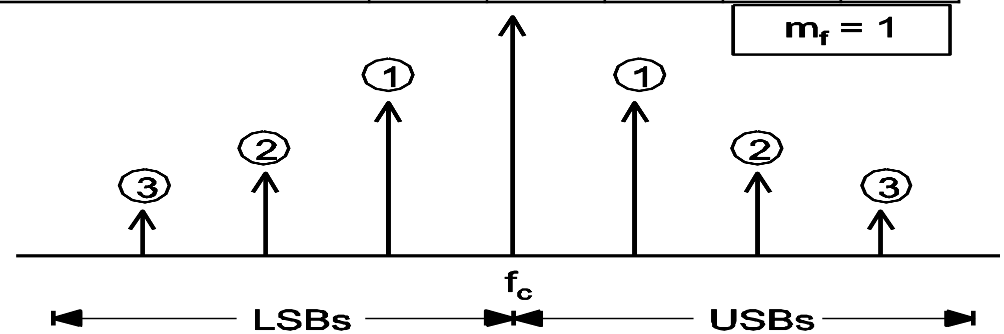
**Table 2.2: Carrier Side Band Distribution Chart for different Modulation**

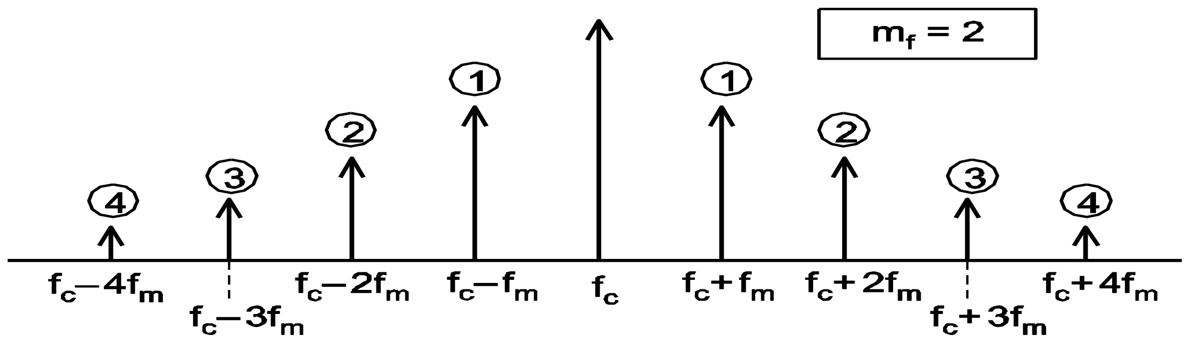
| Modulation Index m | Carrier $J_0$ | Side Frequencies | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st $J_1$ | 2nd $J_2$ | 3rd $J_3$ | 4th $J_4$ | 5th $J_5$ | 6th $J_6$ | 7th $J_7$ | 8th $J_8$ | 9th $J_9$ | 10th $J_{10}$ | 11th $J_{11}$ | 12th $J_{12}$ |
| 0.25 | 0.98 | 0.12 | 0.01 | | | | | | | | | | |
| 0.5 | 0.94 | 0.24 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1 | 0.77 | 0.44 | 0.11 | 0.06 | 0.03 | 0.04 | 0.05 | 0.05 | 0.03 | 0.01 | 0.02 | 0.03 | 0.02 |
| 1.5 | 0.51 | 0.56 | 0.23 | 0.13 | 0.06 | 0.13 | 0.13 | 0.09 | 0.06 | 0.02 | 0.06 | 0.05 | |
| 2 | 0.22 | 0.58 | 0.35 | 0.2 | 0.13 | 0.26 | 0.19 | 0.13 | 0.13 | 0.02 | 0.1 | | |
| 2.4 | 0 | 0.52 | 0.43 | 0.31 | 0.28 | 0.32 | 0.25 | 0.23 | 0.22 | 0.13 | | | |
| 3 | −0.26 | 0.34 | 0.49 | 0.43 | 0.39 | 0.36 | 0.34 | 0.32 | 0.28 | 0.18 | | | |
| 4 | −0.4 | −0.07 | 0.36 | 0.36 | 0.4 | 0.35 | 0.34 | 0.34 | | | | | |
| 5 | −0.18 | −0.33 | 0.05 | 0.26 | 0.36 | 0.19 | 0.34 | | | | | | |
| 5.5 | 0 | −0.34 | −0.12 | 0.11 | 0.16 | 0.03 | | | | | | | |
| 6 | 0.15 | −0.28 | −0.24 | −0.17 | −0.1 | | | | | | | | |
| 7 | 0.3 | 0 | −0.3 | −0.29 | 0.03 | | | | | | | | |
| 8 | 0.17 | 0.23 | −0.11 | −0.24 | | | | | | | | | |
| 8.65 | 0 | 0.27 | 0.06 | | | | | | | | | | |

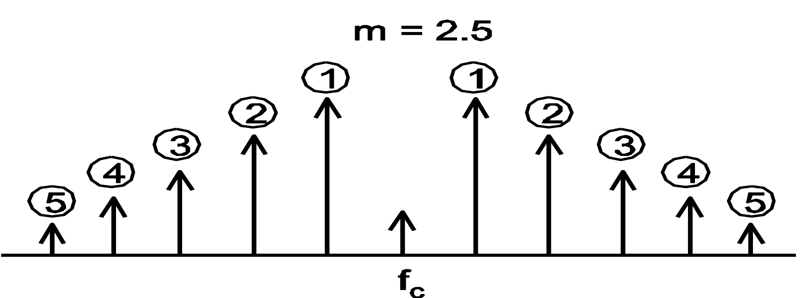
# Effect of Modulation Index on Sidebands

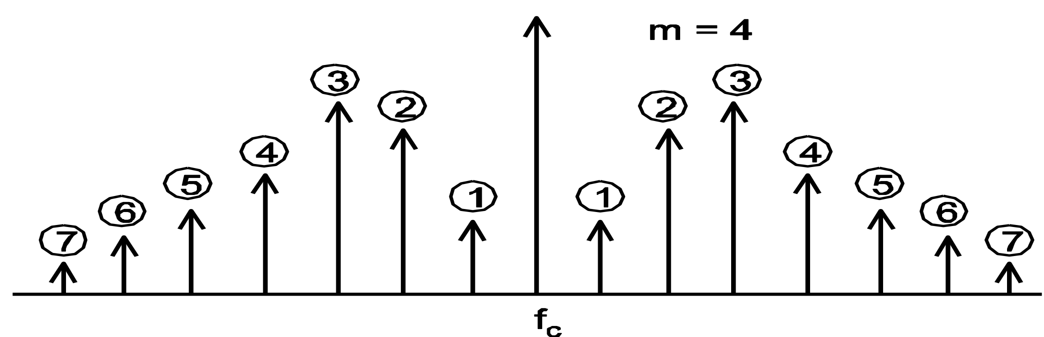
| | | | | | |
|---|---|---|---|---|---|
| Modulation index | 0.5 | 1 | 2 | 2.5 | 4 |
| Number of significant sideband on either side of carrier | 2 | 3 | 4 | 5 | 7 |



# Types of Frequency Modulation

**FM (Frequency Modulation)**

Narrowband FM
(NBFM)
[When modulation index is small]

Wideband FM
(WBFM)
[When modulation index is large]

# Comparison between Narrowband and Wideband FM

| Sr. No. | Parameter | NBFM | WBFM |
|---|---|---|---|
| 1. | Modulation index | Less than or slightly greater than 1 | Greater than 1 |
| 2. | Maximum deviation | 5 kHz | 75 kHz |
| 3. | Range of modulating frequency | 20 Hz to 3 kHz | 20 Hz to 15 kHz |
| 4. | Maximum modulation index | Slightly greater than 1 | 5 to 2500 |
| 5. | Bandwidth | Small approximately same as that of AM<br>$BW = 2f_m$ | Large about 15 times greater than that of NBFM.<br>$BW = 2(\delta + fmmax)$ |
| 6. | Applications | FM mobile communication like police wireless, ambulance, short range ship to shore communication etc. | Entertainment broadcasting (can be used for high quality music transmission) |

# Representation of FM

FM can be represented by two ways:

1. Time domain.
2. Frequency domain.

**1. FM in Time Domain**

Time domain representation means continuous variation of voltage with respect to time as shown in Fig.

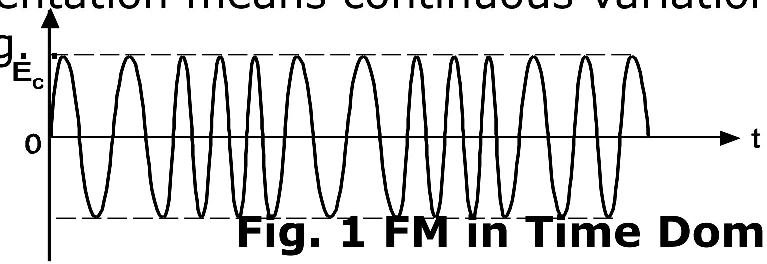



**Fig. 1 FM in Time Domain**

**2. FM in Frequency Domain**

- Frequency domain is also known as **frequency spectrum.**
- FM in frequency domain means graph or plot of amplitude versus frequency as shown in Fig. 2.29.

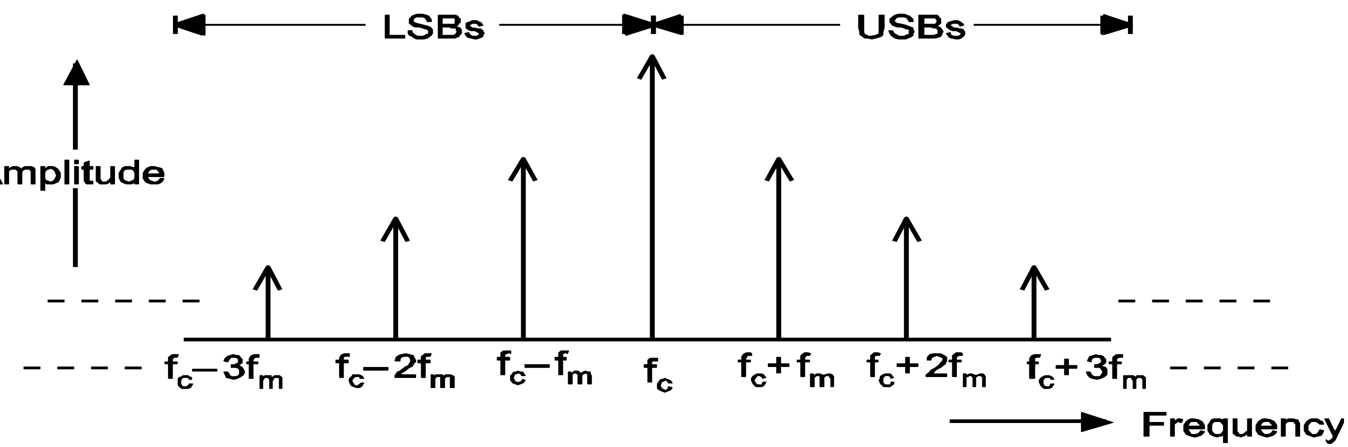



**Fig. 2: FM in Frequency Domain**

# Pre-emphasis and De-emphasis

- Pre and de-emphasis circuits are used only in frequency modulation.
  - Pre-emphasis is used **at transmitter** and de-emphasis **at receiver**.

**1. Pre-emphasis**

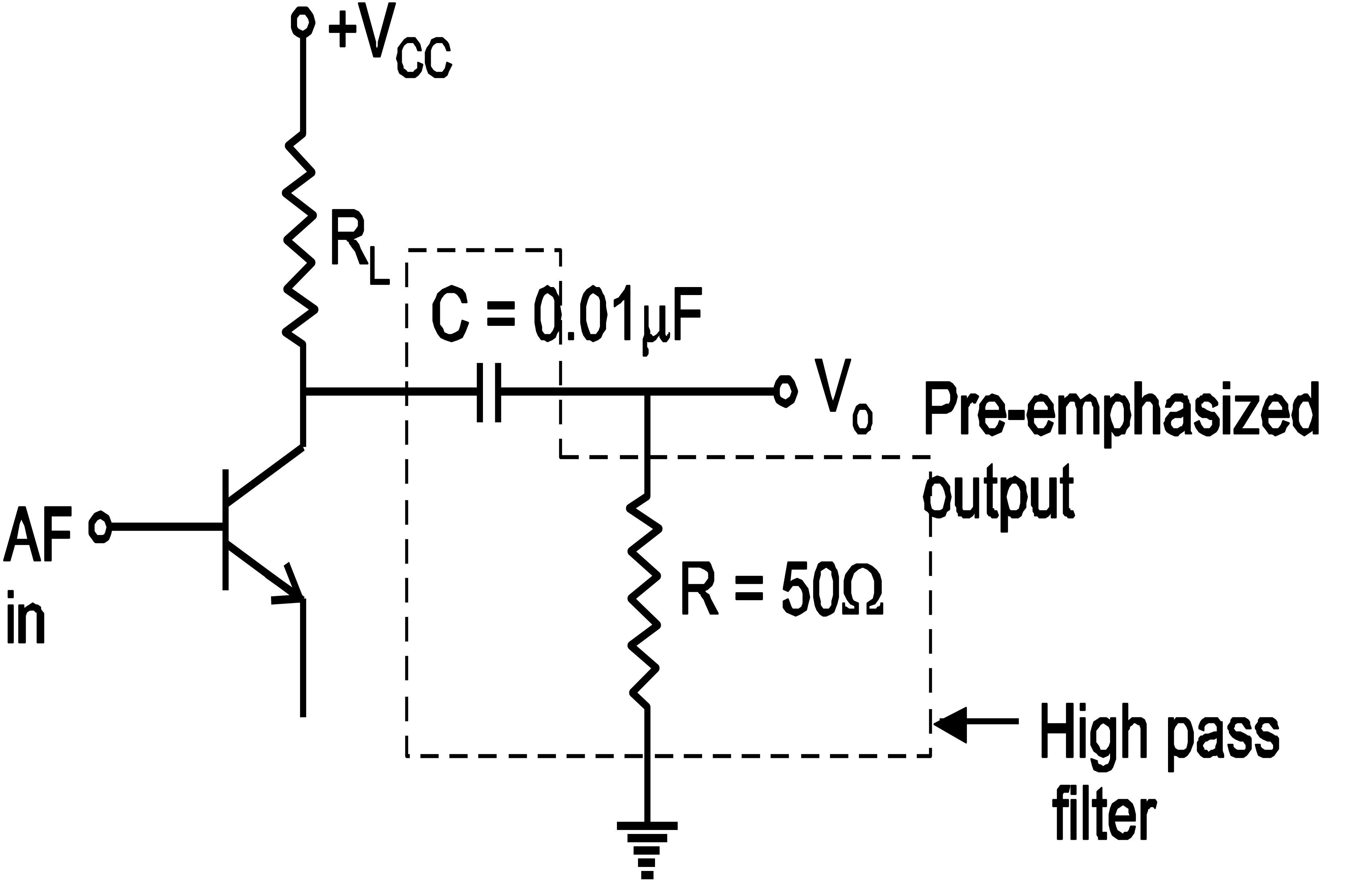
- In FM, the noise has a greater effect on the higher modulating frequencies.
- This effect can be reduced by increasing the value of modulation index ($m_f$), for higher modulating frequencies.
- This can be done by increasing the deviation '$\delta$' and '$\delta$' can be increased by increasing the amplitude of modulating signal at higher frequencies.

**Definition:**

**The artificial boosting of higher audio modulating frequencies in accordance with prearranged response curve is called pre-emphasis.**

- Pre-emphasis circuit is a high pass filter as shown in Fig. 1

## Fig. 1: Pre-emphasis Circuit



As shown in Fig. 1, AF is passed through a high-pass filter, before applying to FM modulator.

- As modulating frequency ($f_m$) increases, capacitive reactance decreases and modulating voltage goes on increasing.

$f_m \propto$ Voltage of modulating signal applied to FM modulat

Boosting is done according to pre-arranged curve as shown in Fig. 2.

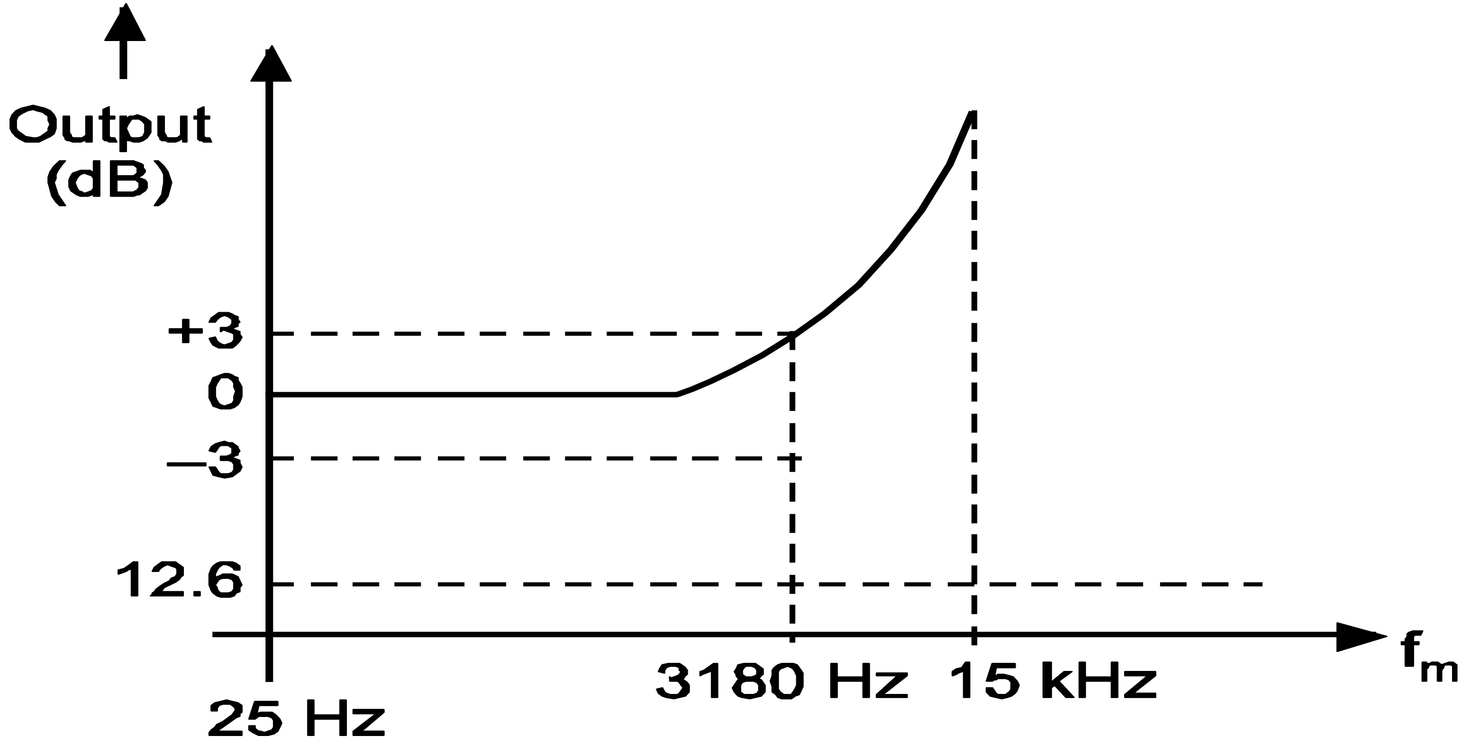



Fig. 2: P re-emphasis Curve

•
The time constant of pre-emphasis is at 50 μs in all CCIR standards.

- In systems employing American FM and TV standards, networks having time constant of 75 μsec are used.
- **The pre-emphasis is used at FM transmitter** as shown in Fig. 3.

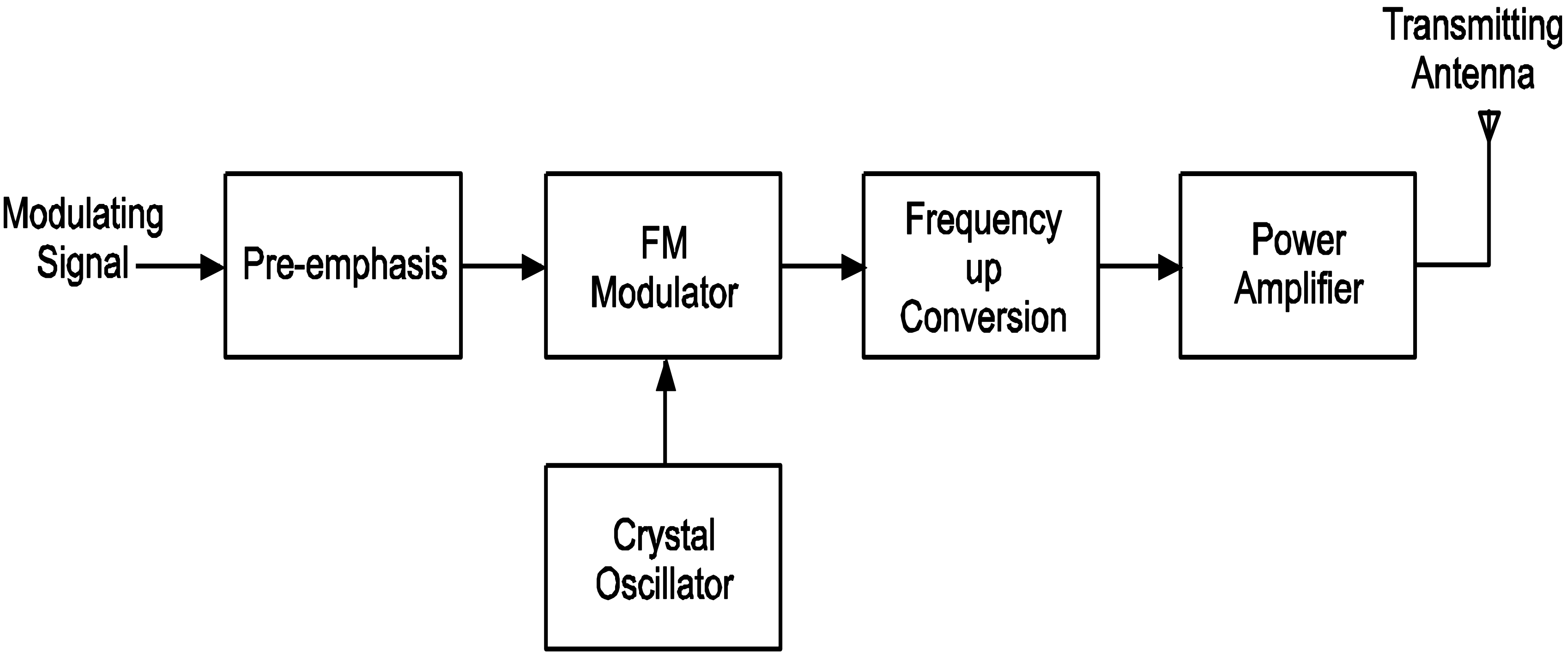



**Fig. 3: FM Transmitter with Pre-emphasis**

# De-emphasis

- De-emphasis circuit is **used at FM receiver**.

**Definition:**

**The artificial boosting of higher modulating frequencies in the process of pre-emphasis is nullified at receiver by process called de-emphasis.**

- De-emphasis circuit is a low pass filter shown in Fig. 4.

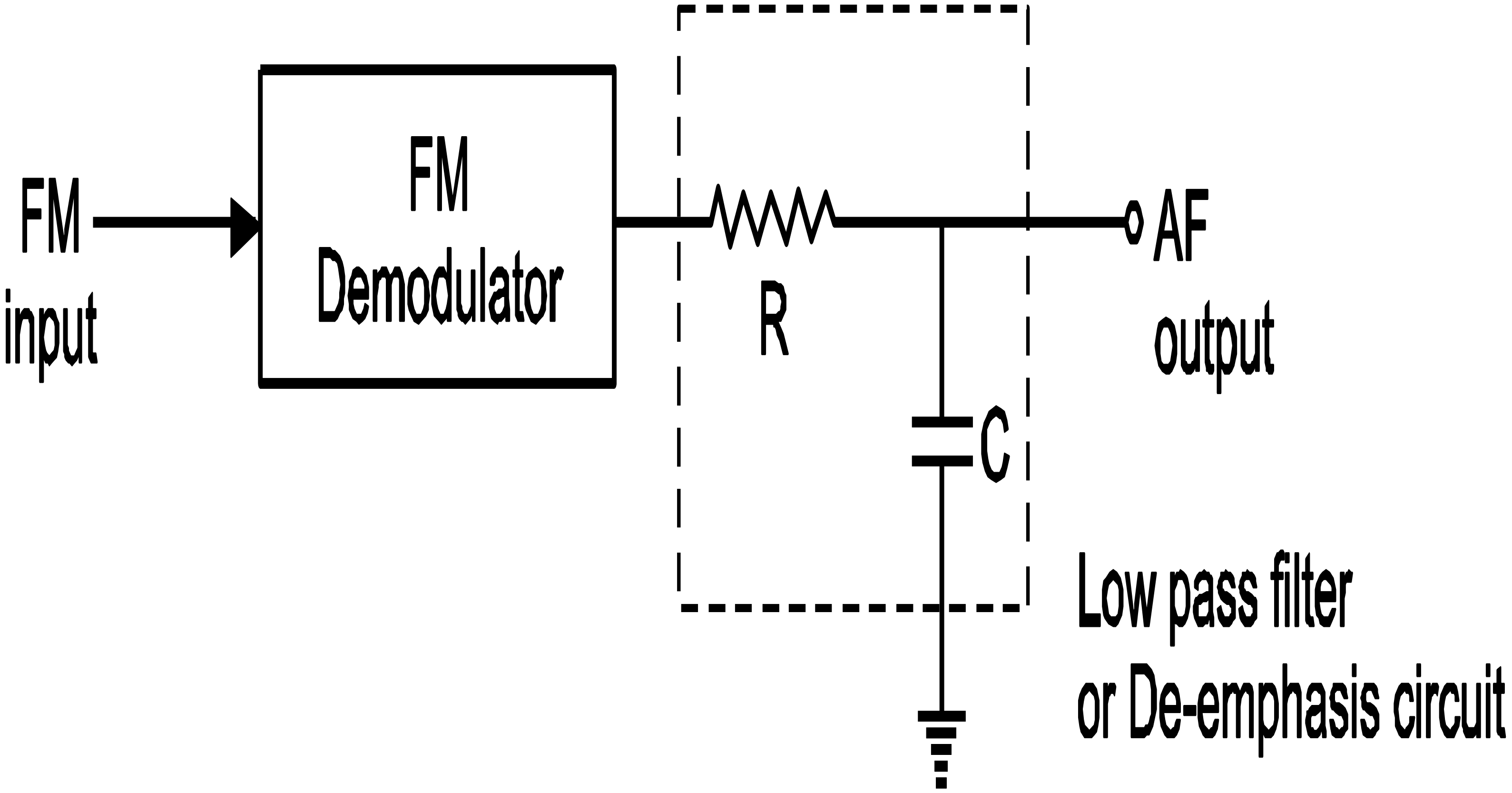
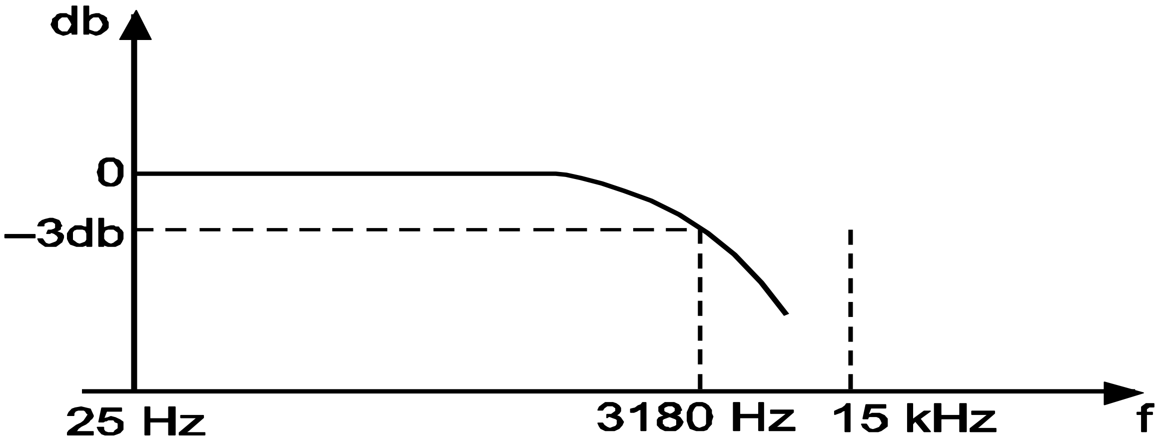



**Fig. 4: De-emphasis Circuit**

**Fig. 5: De-emphasis Curve**




As shown in Fig.5, de-modulated FM is applied to the de-emphasis circuit (low pass filter) where with increase in $f_m$, capacitive reactance $X_c$ decreases. So that output of de-emphasis circuit also reduces •

Fig. 5 shows the de-emphasis curve corresponding to a time constant

50 μs. A 50 μs de-emphasis corresponds to a frequency response curve that is 3 dB down at frequency given by,

$$f = 1/\ 2\pi RC$$

$$= 1/\ 2\pi \times 50 \times 1000$$

$$= 3180 \text{ Hz}$$

The de-emphasis circuit is used after the FM demodulator at the FM receiver shown in Fig. 6.

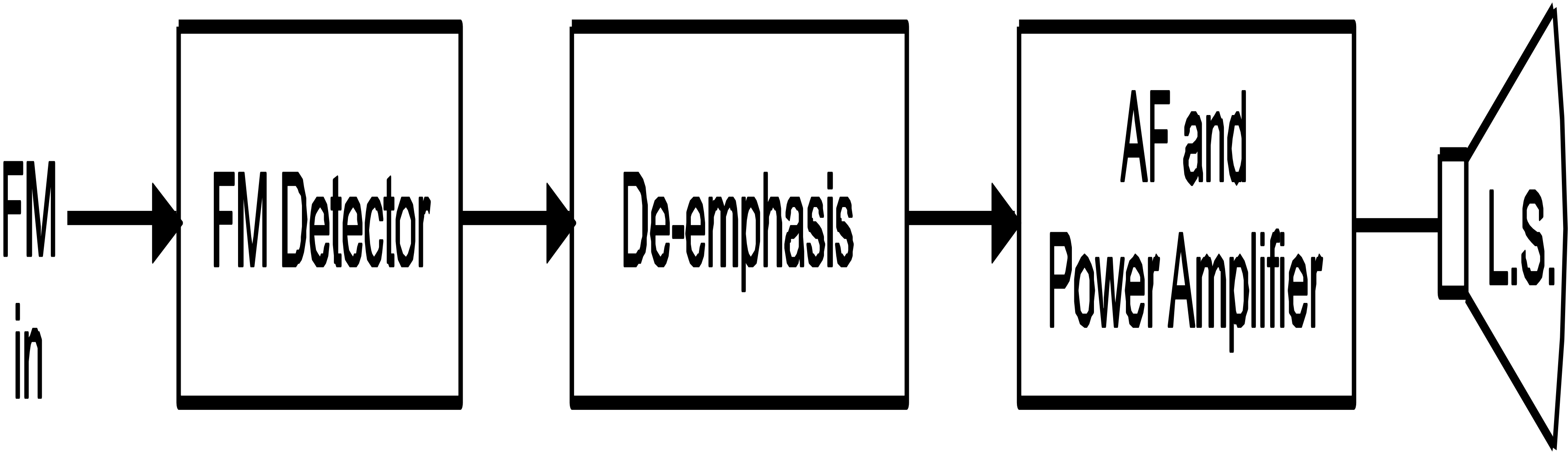
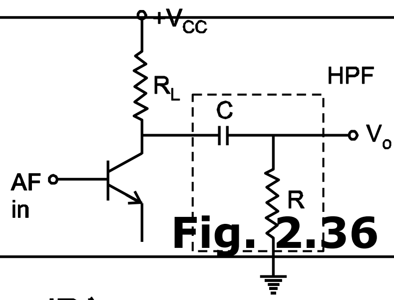
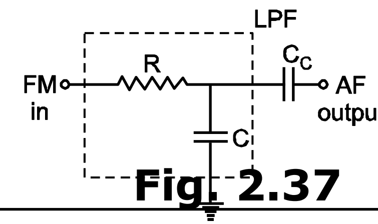
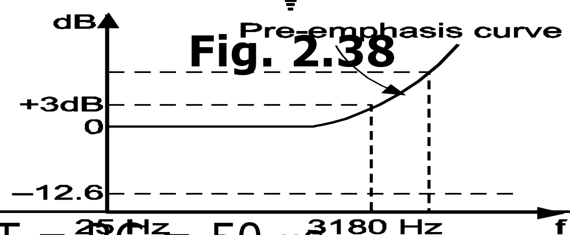
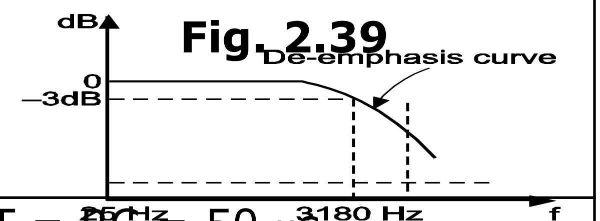
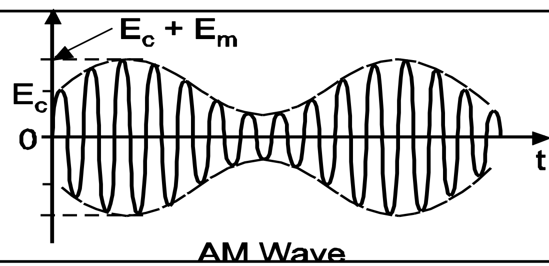
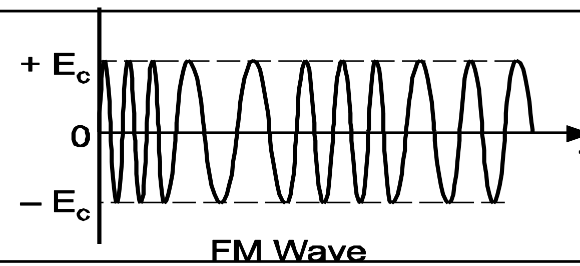



**Fig. 6: De-emphasis Circuit in FM Receiver**

# Comparison between Pre-emphasis and De-emphasis

| Parameter | Pre-emphasis | De-emphasis |
|---|---|---|
| 1. Circuit used | High pass filter. | Low pass filter. |
| 2. Circuit diagram | <br>**Fig. 2.36** | <br>**Fig. 2.37** |
| 3. Response curve | <br>**Fig. 2.38** | <br>**Fig. 2.39** |
| 4. Time constant | $T = RC = 50\ \mu s$ | $T = RC = 50\ \mu s$ |
| 5. Definition | Boosting of higher frequencies | Removal of higher frequencies |
| 6. Used at | FM transmitter | FM receiver. |

# Comparison between AM and FM

| Parameter | AM | FM |
|---|---|---|
| 1. Definition | Amplitude of carrier is varied in accordance with amplitude of modulating signal keeping frequency and phase constant. | Frequency of carrier is varied in accordance with the amplitude of modulating signal keeping amplitude and phase constant. |
| 2. Constant parameters | Frequency and phase. | Amplitude and phase. |
| 3. Modulated signal |  |  |
| 4. Modulation Index | m=Em/Ec | m = δ/ fm |
| 5. Number of sidebands | Only two | Infinite and depends on $m_f$. |
| 6. Bandwidth | BW = $2f_m$ | BW = $2\ (\delta + f_{m\ (max)})$ |
| 7. Application | MW, SW band broadcasting, video transmission in TV. | Broadcasting FM, audio transmission in TV. |

# FM Generation

There are two methods for generation of FM wave.

**Generation of FM**

Direct Method

1. Reactance Modulator
2. Varactor Diode

Indirect Method

1. Armstrong Method

# Reactance Method

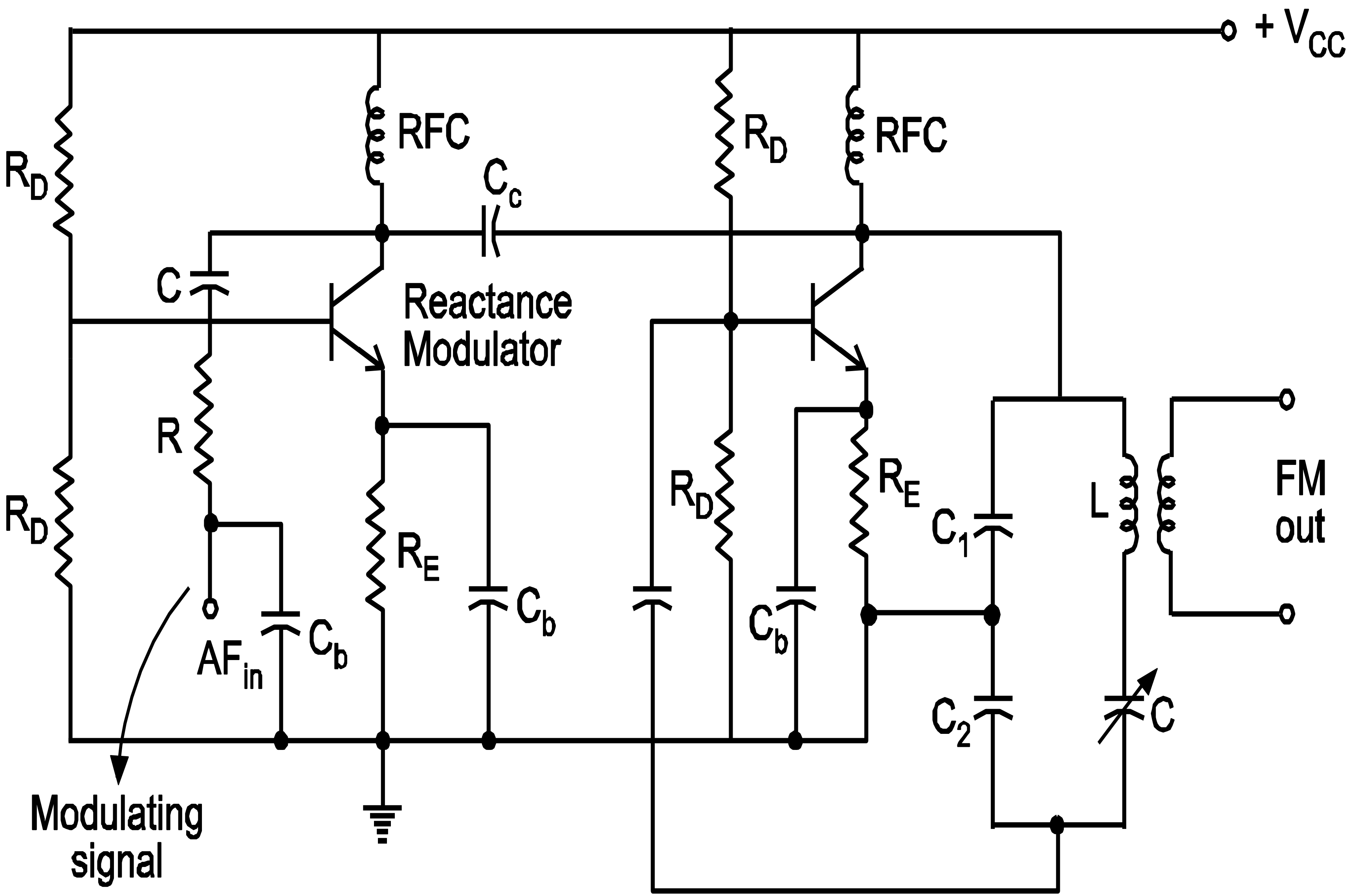



**Fig. : Transistorized Reactance Modulator**

# Varactor Diode Modulator

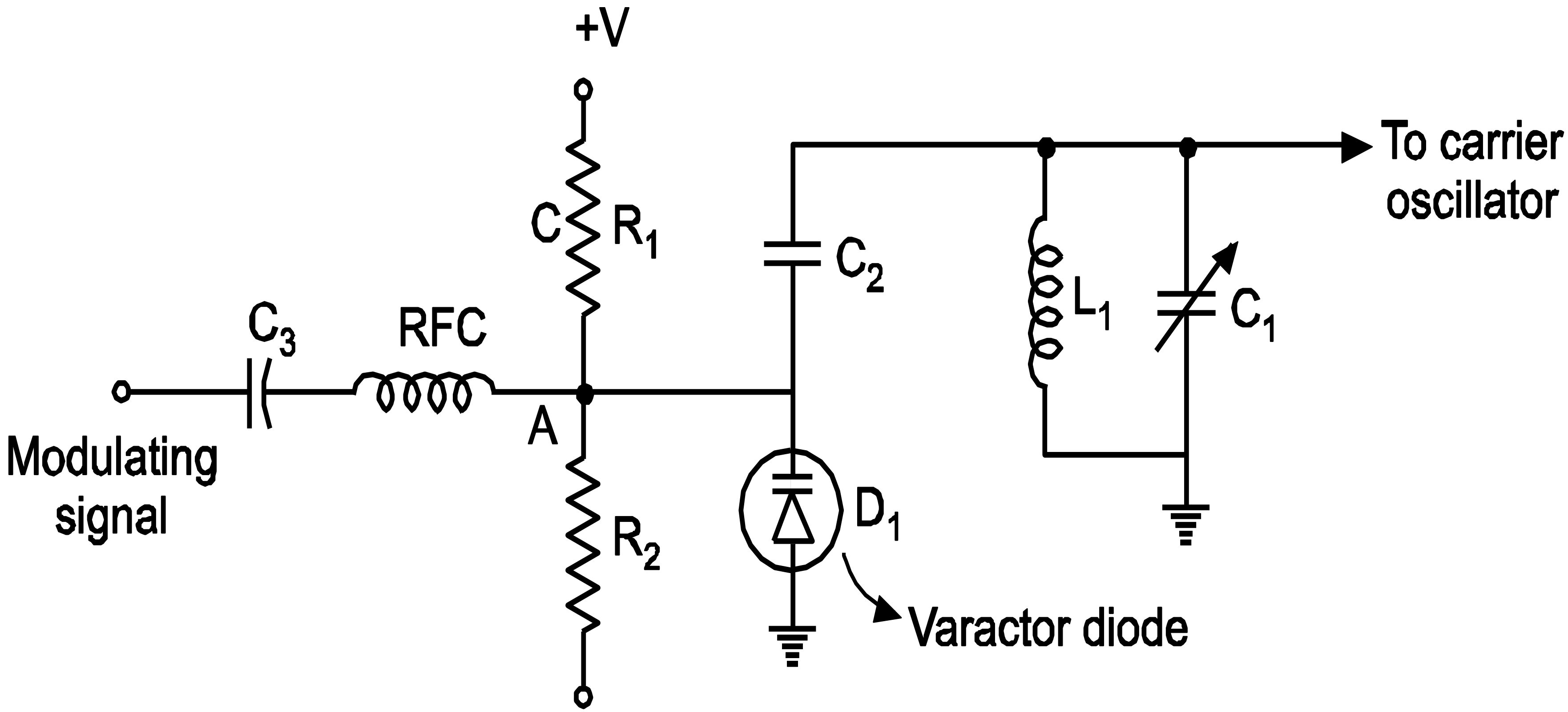


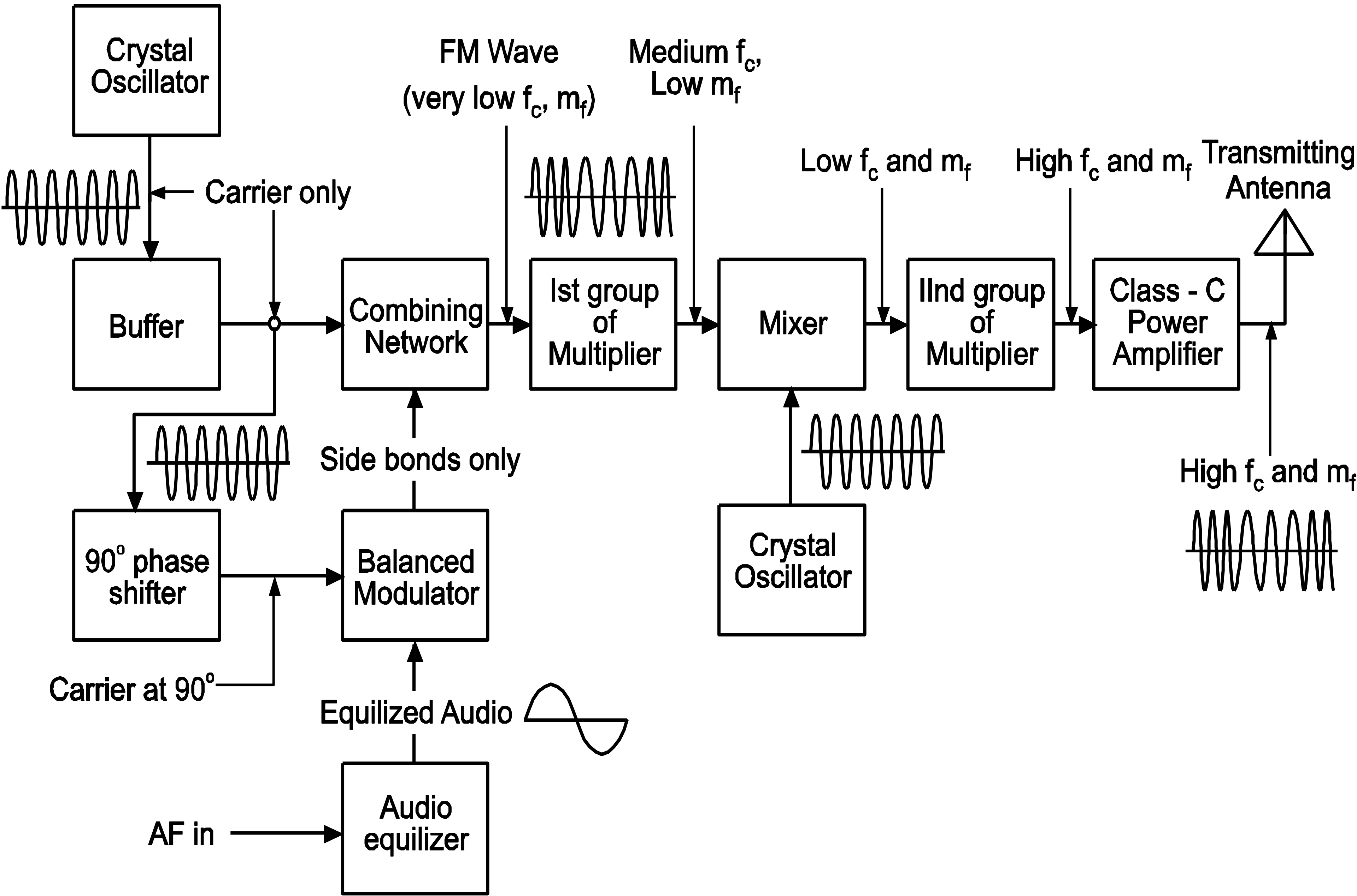

**Fig. : Varactor Diode Frequency Modulator**

# Limitations of Direct Method of FM Generation

1. In this method, it is very difficult to get high order stability in carrier frequency because in this method the basic oscillator is not a stable oscillator, as it is controlled by the modulating signal.

2. Generally in this method we get distorted FM, due to non-linearity of the varactor diode.

# FM Transmitter (Armstrong Method)



# FM Generation using IC 566

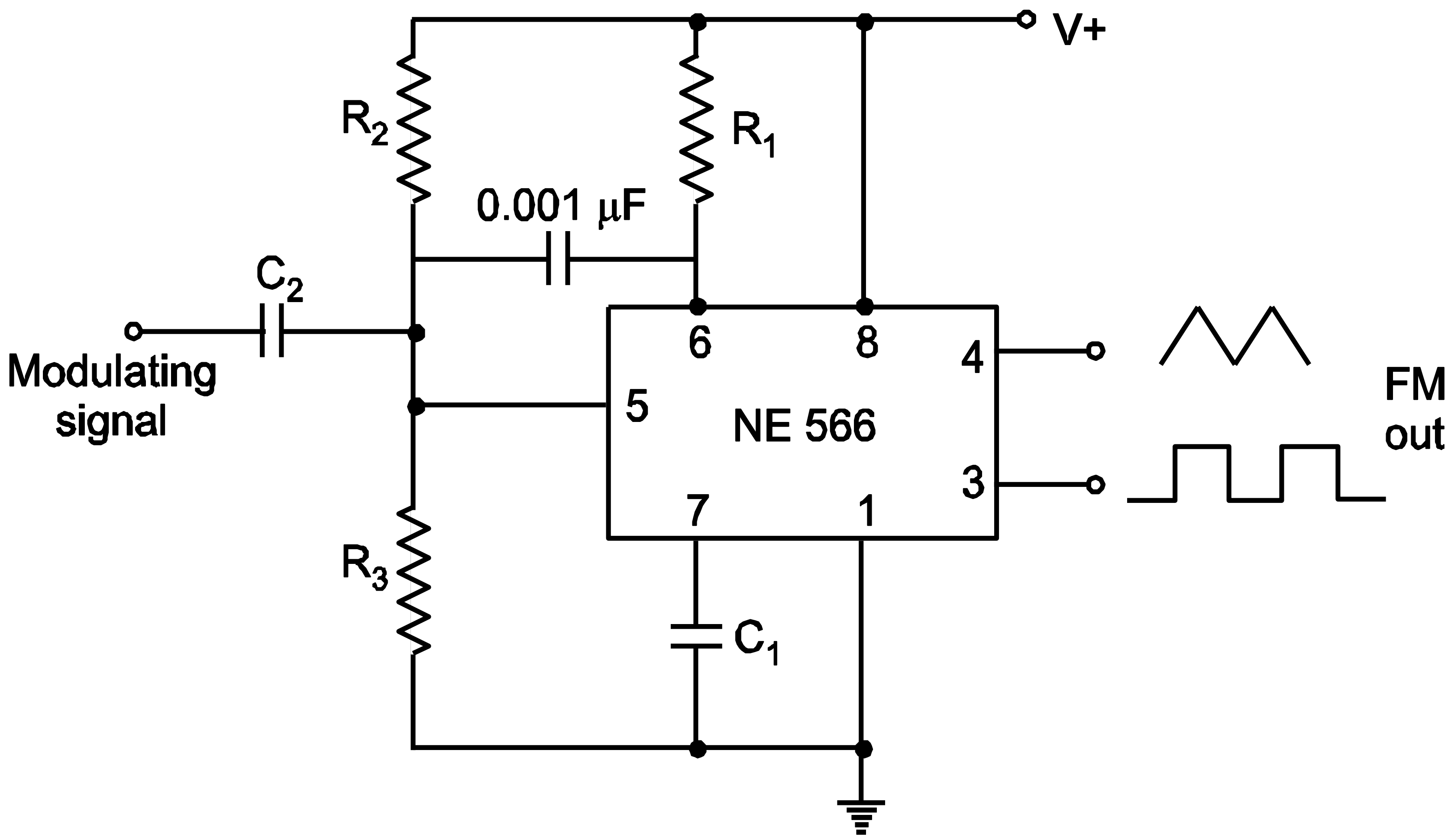



**Fig. : Basic Frequency Modulator using NE566 VCO**

# Advantages / Disadvantages / Applications of FM

**Advantages of FM**

1. Transmitted power remains constant.
2. FM receivers are immune to noise.
3. Good capture effect.
4. No mixing of signals.

**Disadvantages of FM**

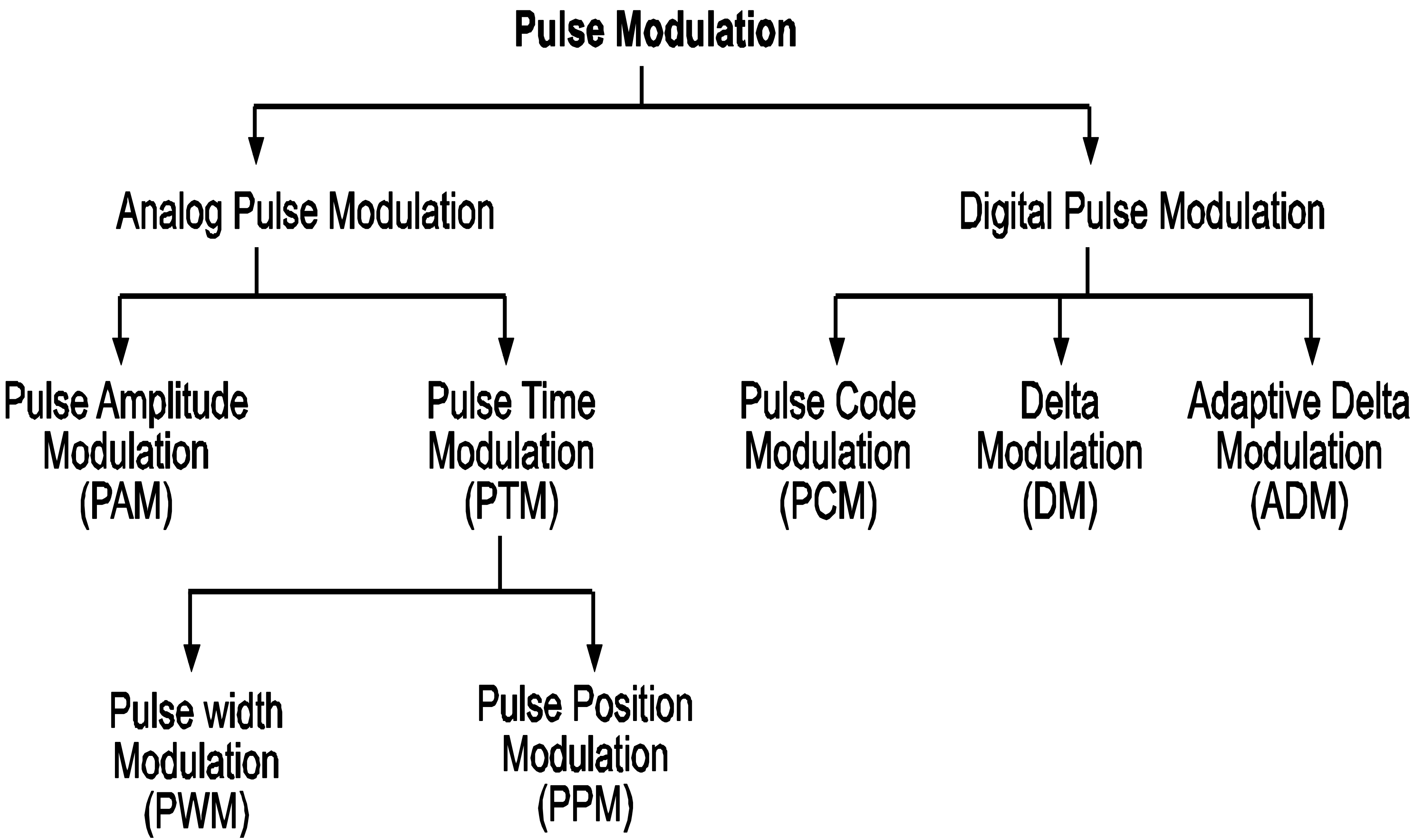
The greatest disadvantages of FM are:

1. It uses too much spectrum space.
2. The bandwidth is wider.
3. The modulation index can be kept low to minimize the bandwidth used.
4. But reduction in M.I. reduces the noise immunity.
5. Used only at very high frequencies.

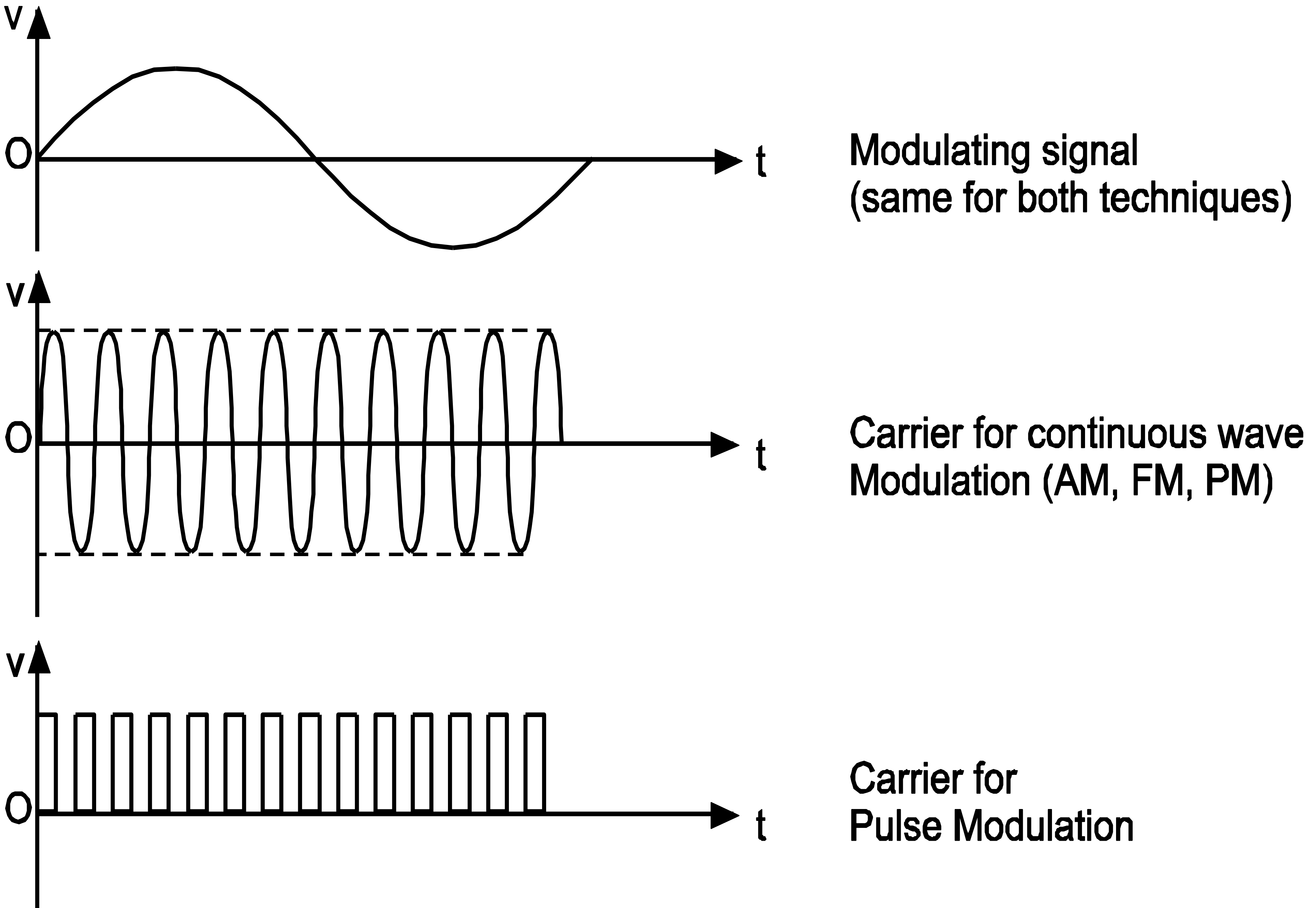
**Applications of FM**

1. FM radio broadcasting.
2. Sound transmission in TV.
3. Police wireless.

# Pulse Modulation Technique



## Fig. : Carrier for Continuous Wave and Pulse Modulation



# Need of Pulse Modulation

- Comparing to continuous wave modulation (like AM, FM), the performance of all pulse modulation schemes except PAM in presence of noise is very good.
- Due to better noise performance, it requires less power to cover large area of communication.
- Due to better noise performance and requirement of less signal power, the pulse modulation is most preferred for the communication between space ships and earth.

# Pulse Amplitude Modulation (PAM)

**Definition:**

- **The amplitude of the pulsed carrier varies in accordance with the instantaneous value of modulating signal, is called PAM where width and position remains constant.**

# Generation of PAM

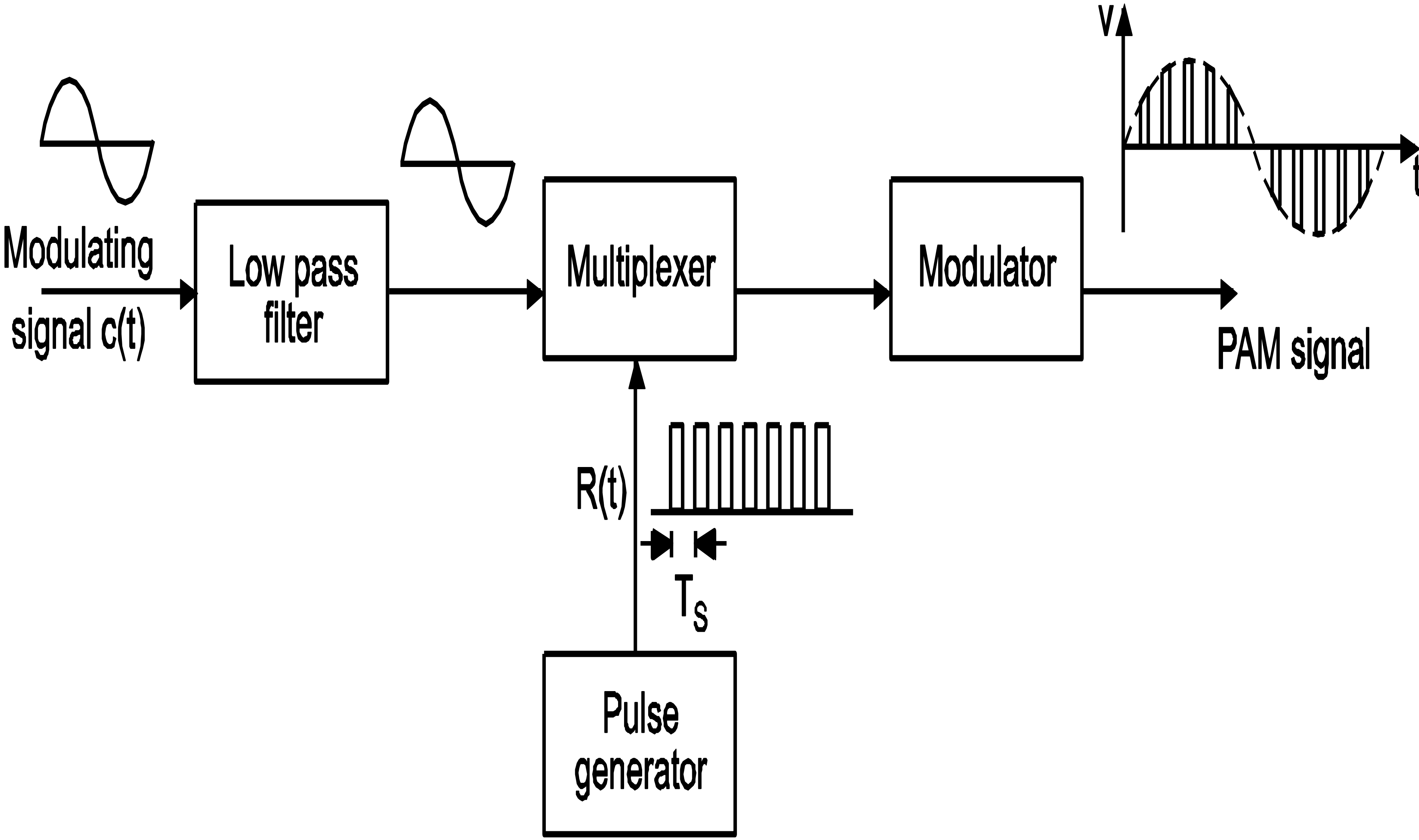
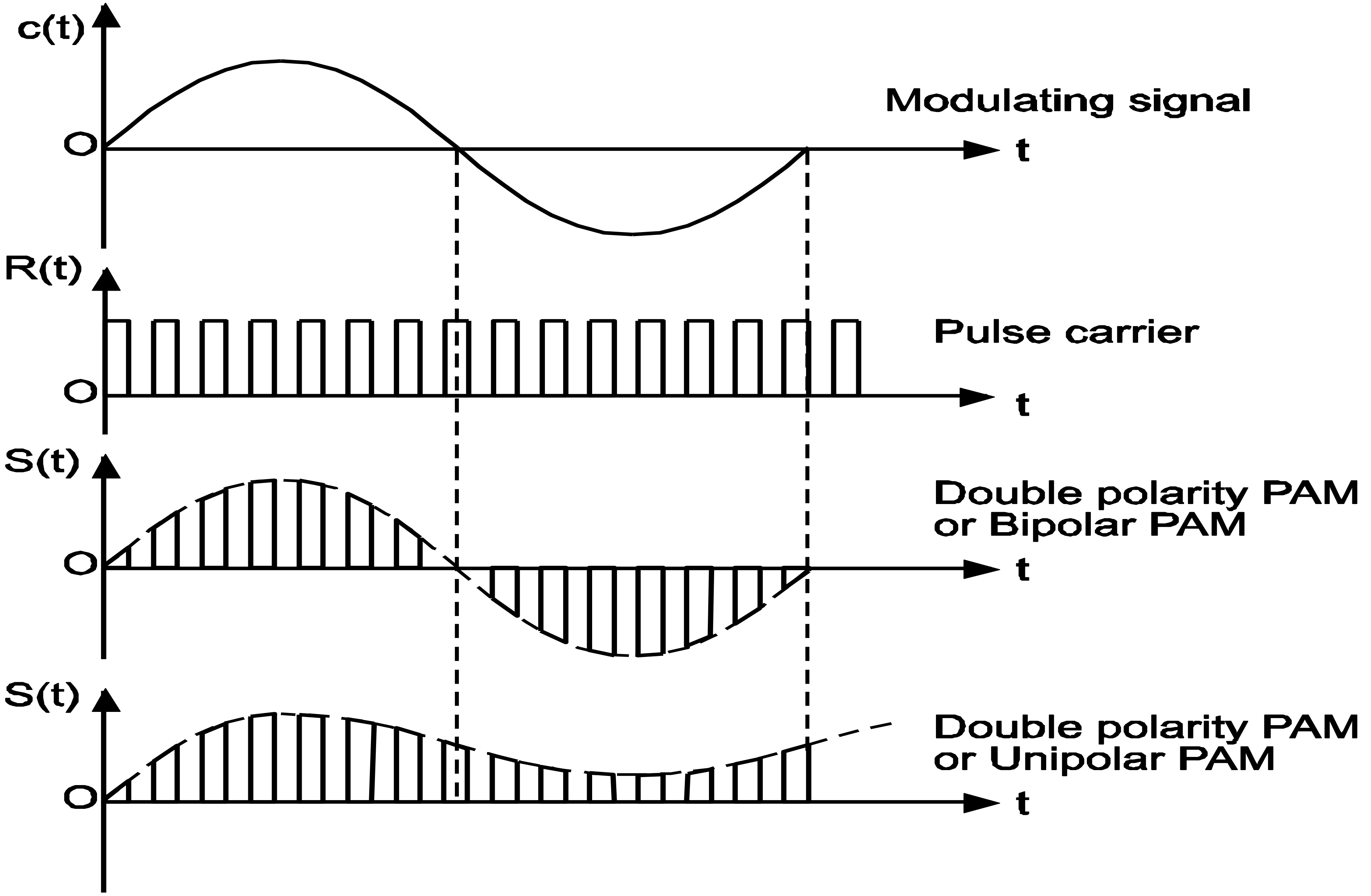



**Fig. : Generation of PAM Block diagram**

# Waveforms of PAM



## Advantages of PAM

- It is easy to generate and demodulate PAM.

## Disadvantages of PAM

1. Since PAM does not utilize constant amplitude pulses, output is distorted due to additive noise so that it is infrequently used.
2. Transmission bandwidth required is too large.
3. Transmitted power is not constant.

## Application of PAM

- Used in **radio telemetry** for remote monitoring and sensing.

# Generation of PAM Transistorized Circuit

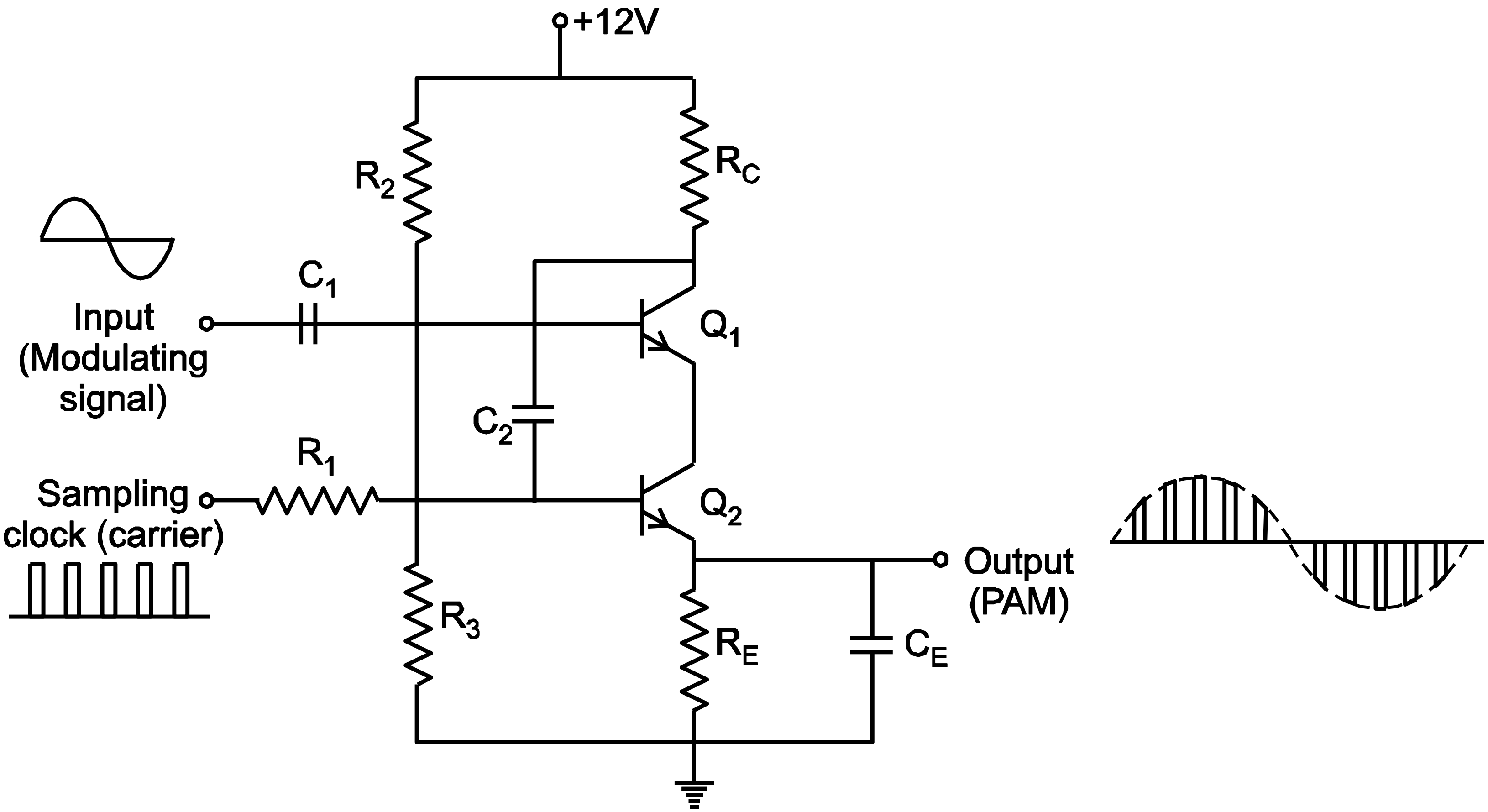
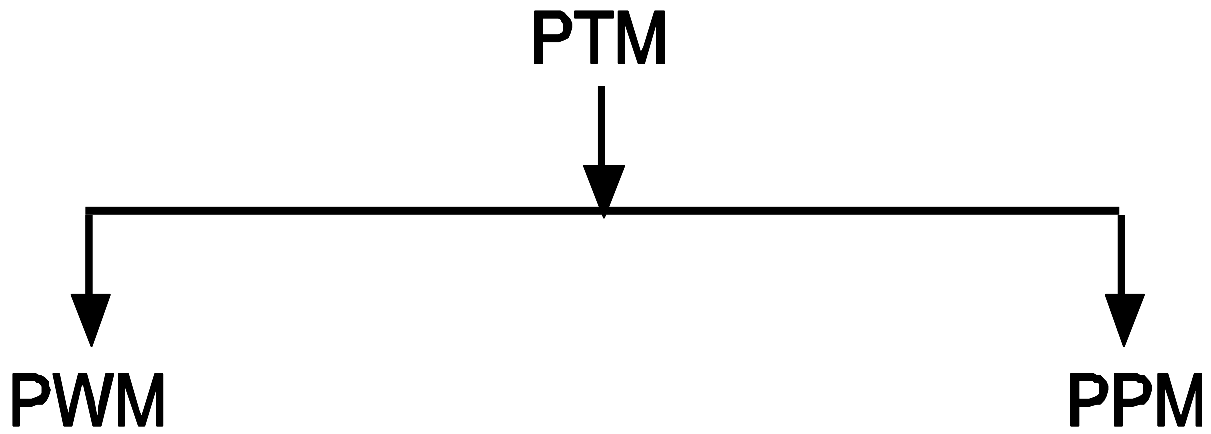



**Fig. : Transistorized circuit for generation of PAM**

# Pulse Width Modulation (PWM)




**Definition:**

- **When the width of pulsed carrier varies in accordance with the instantaneous amplitude of modulating signal, is called PWM where amplitude and position remains constant.**

# Generation of PWM

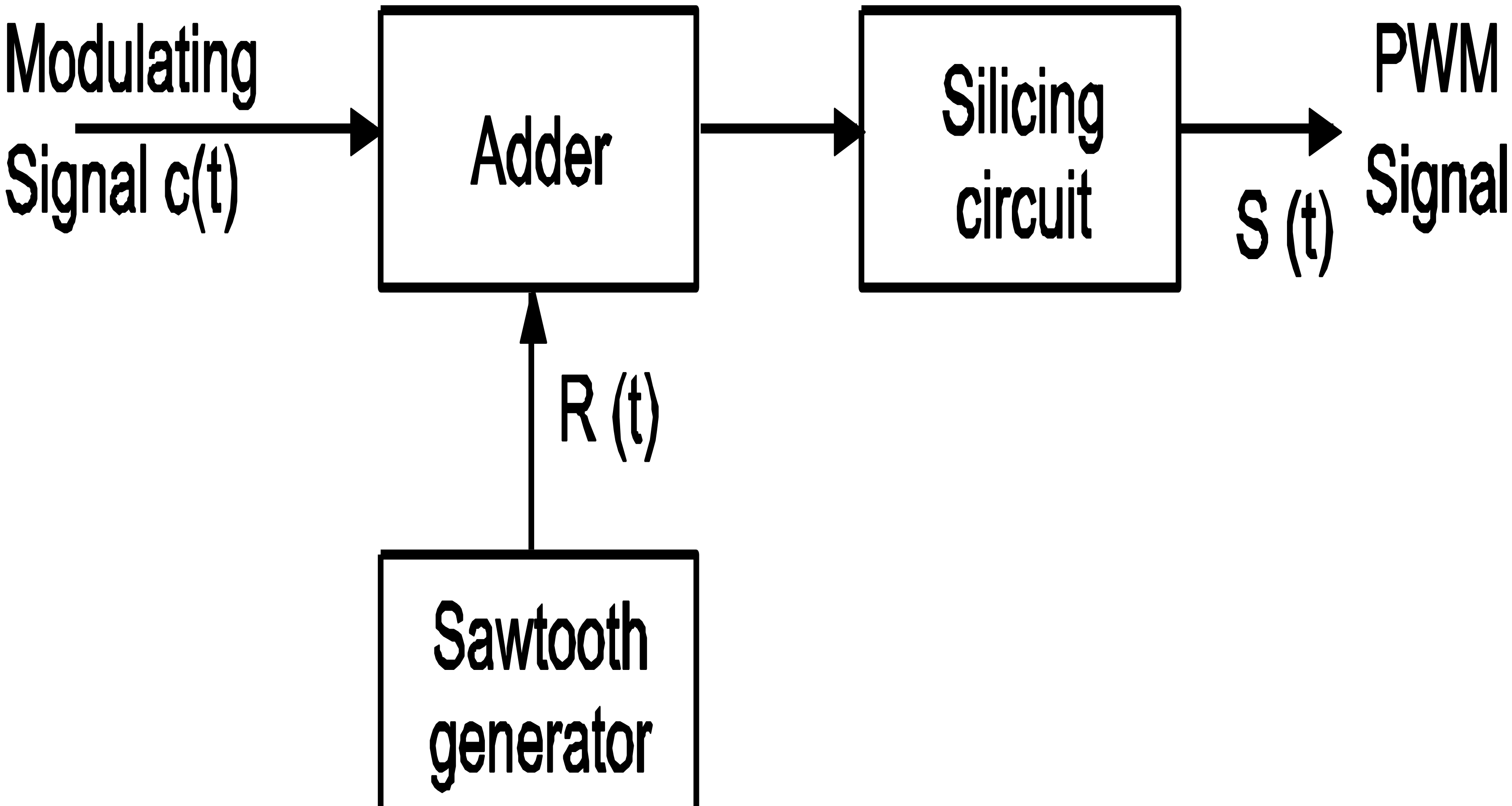
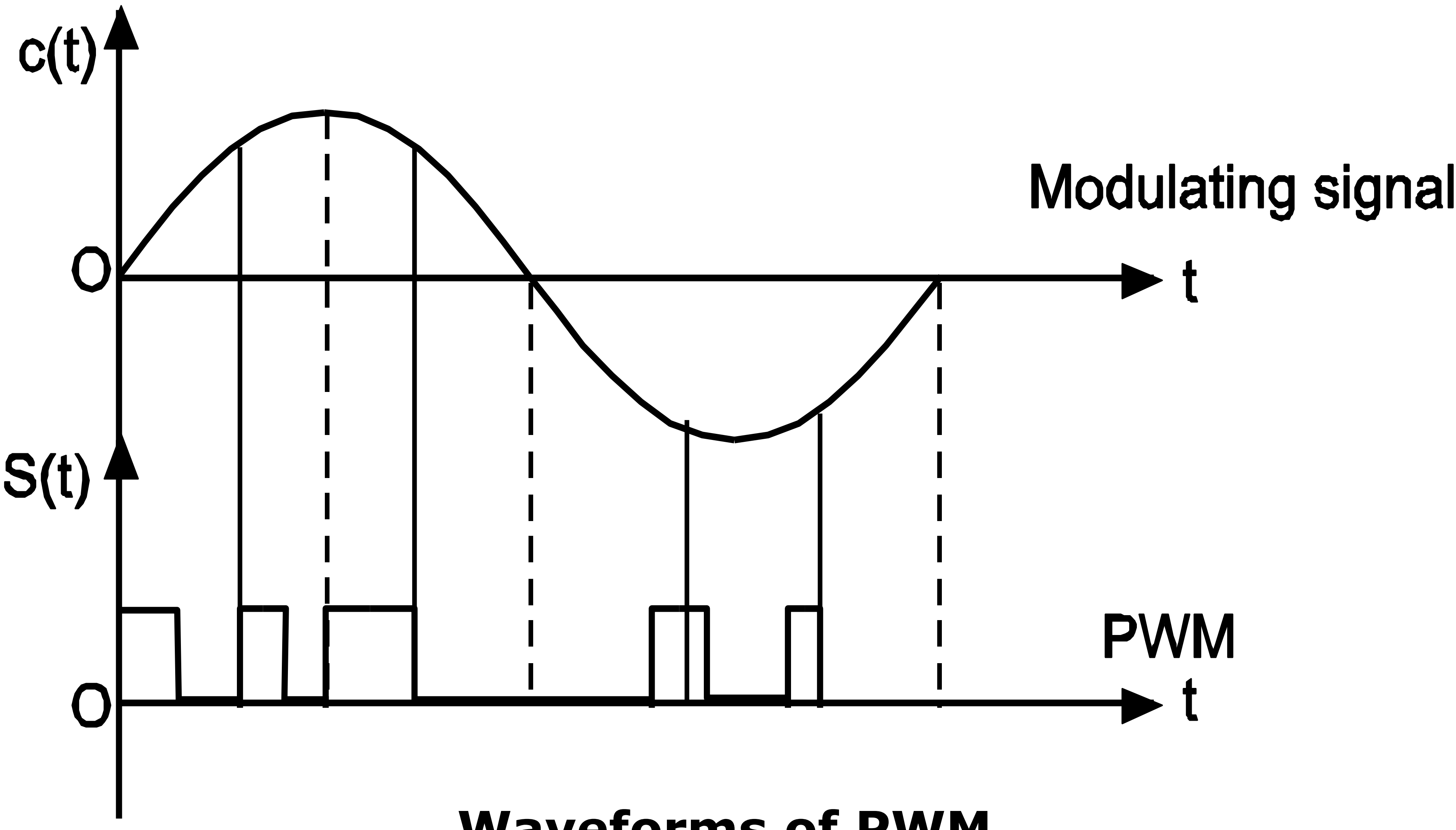



Fig.:B.D. of generation of PWM




**Waveforms of PWM**

# Generation of PWM using IC 555

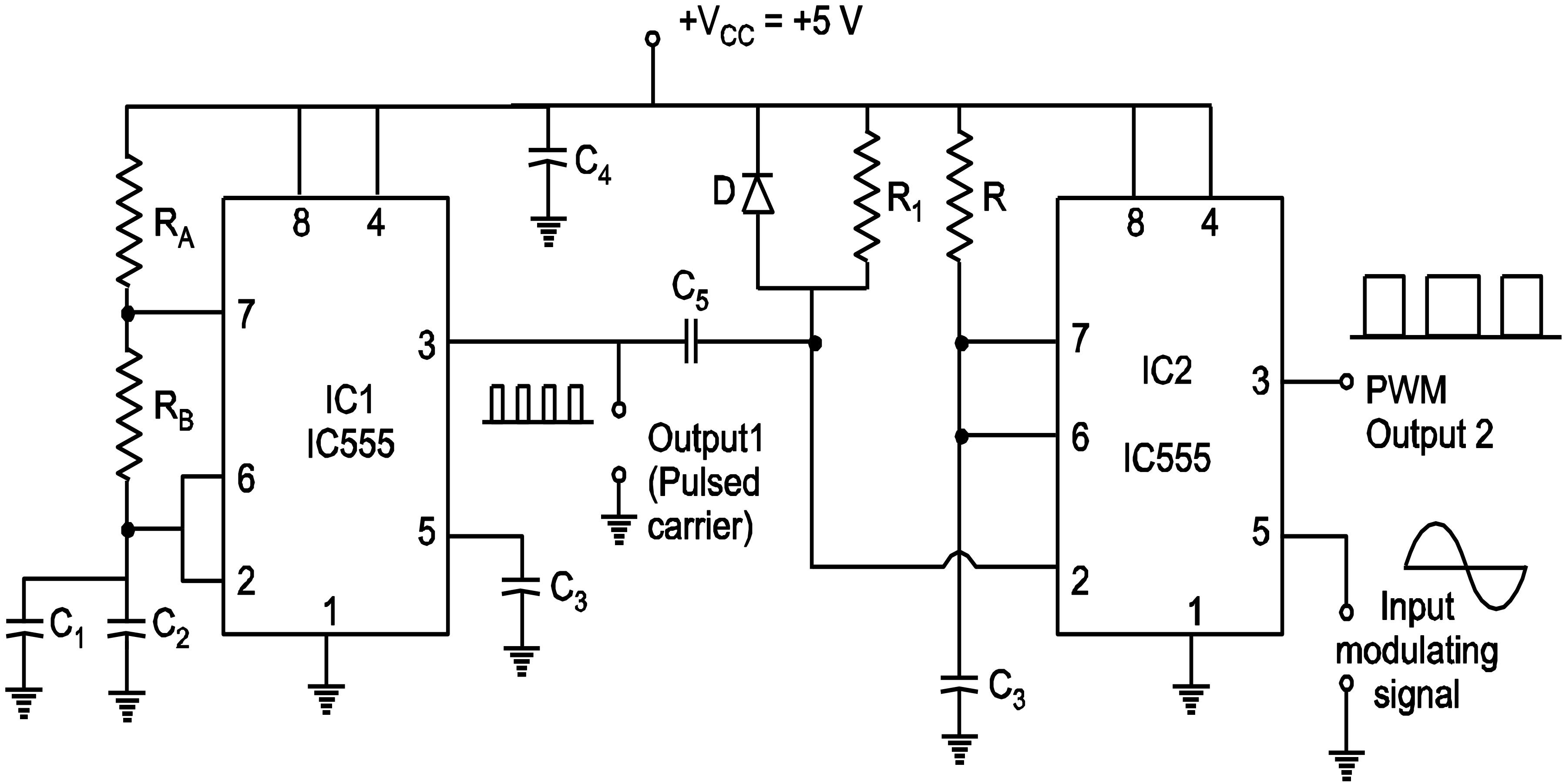



**Fig. : Generation of PWM using IC 555**

.

## Advantages of PWM

1. More immune to noise.
2. Synchronization between transmitter and receiver is not required.
3. Possible to separate out signal from noise.

## Applications of PWM

- PWM is used in special purpose communication systems mainly for **military** but is seldom used for **commercial digital transmission system.**

# Pulse Position Modulation (PPM)

**Definition**

- **When position of pulse carrier varies in accordance with the instantaneous value of modulating signal is called PPM, where width and amplitude of carrier remains constant.**

# Generation of PPM

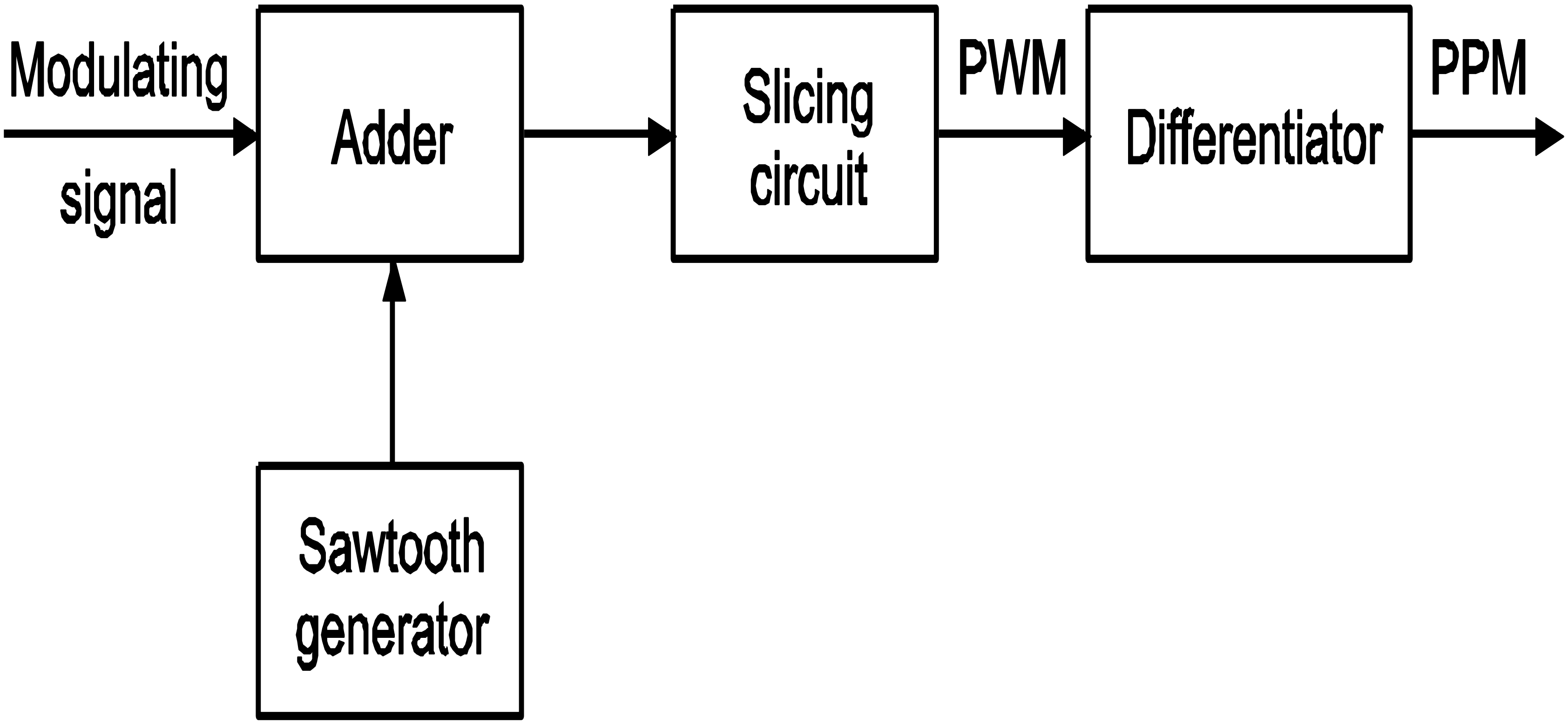
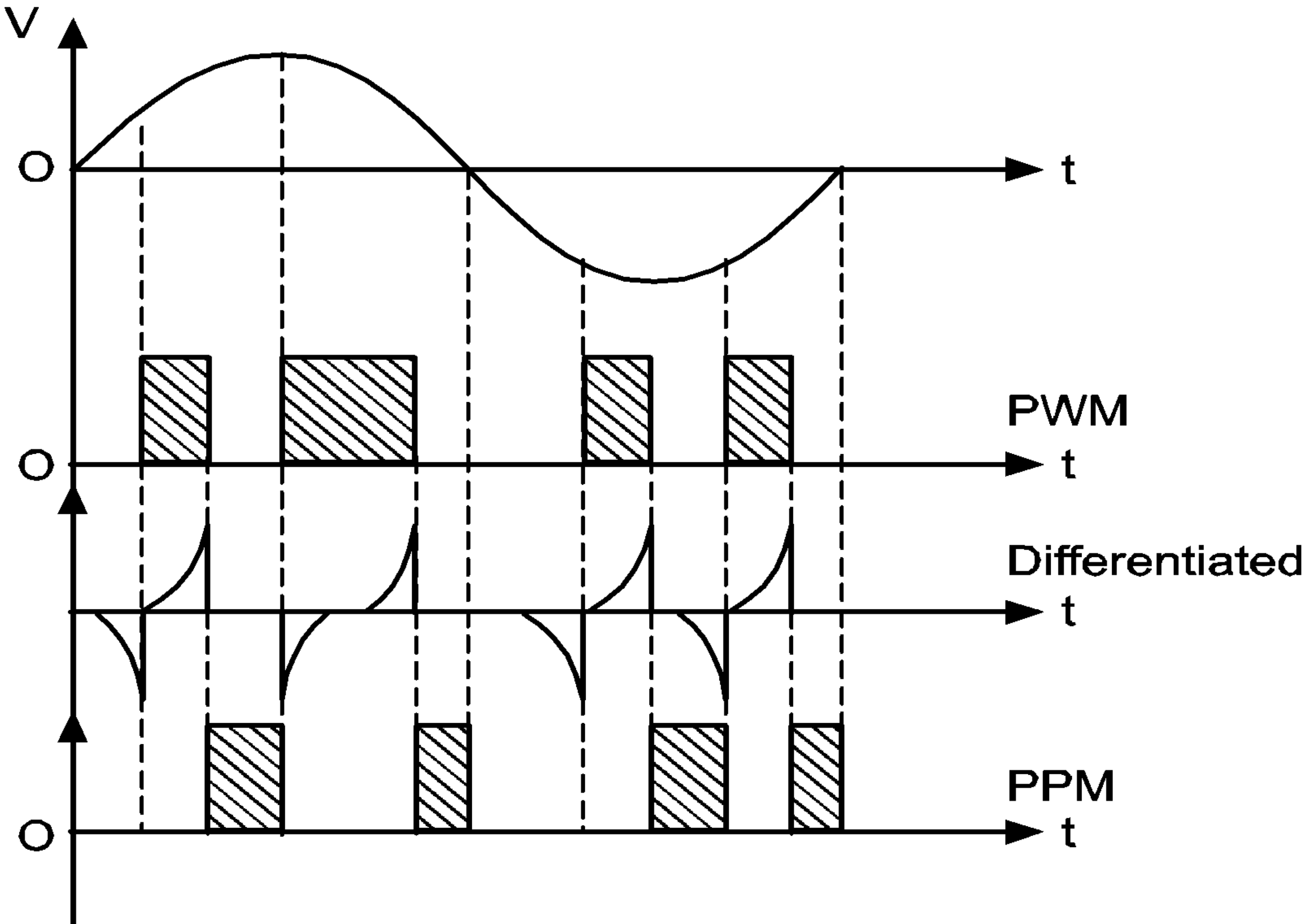



Fig.:Block diagram of PPM generation

# Waveforms of PPM



## Advantages of PPM

1. Good noise immunity.
2. Requires constant transmitter power output.

## Disadvantages of PPM

1. Requires synchronization between transmitter and receiver.
2. Large Bandwidth requirement.

## Applications of PPM

1. It is used for optical communication system where there is no multipath interference.
2. PPM is useful for narrowband FM channel allocation, with these channel characteristics in the **radio control** and model aircraft, boats and cars.
3. PPM is also used for military applications.

# Generation of PPM using IC 555

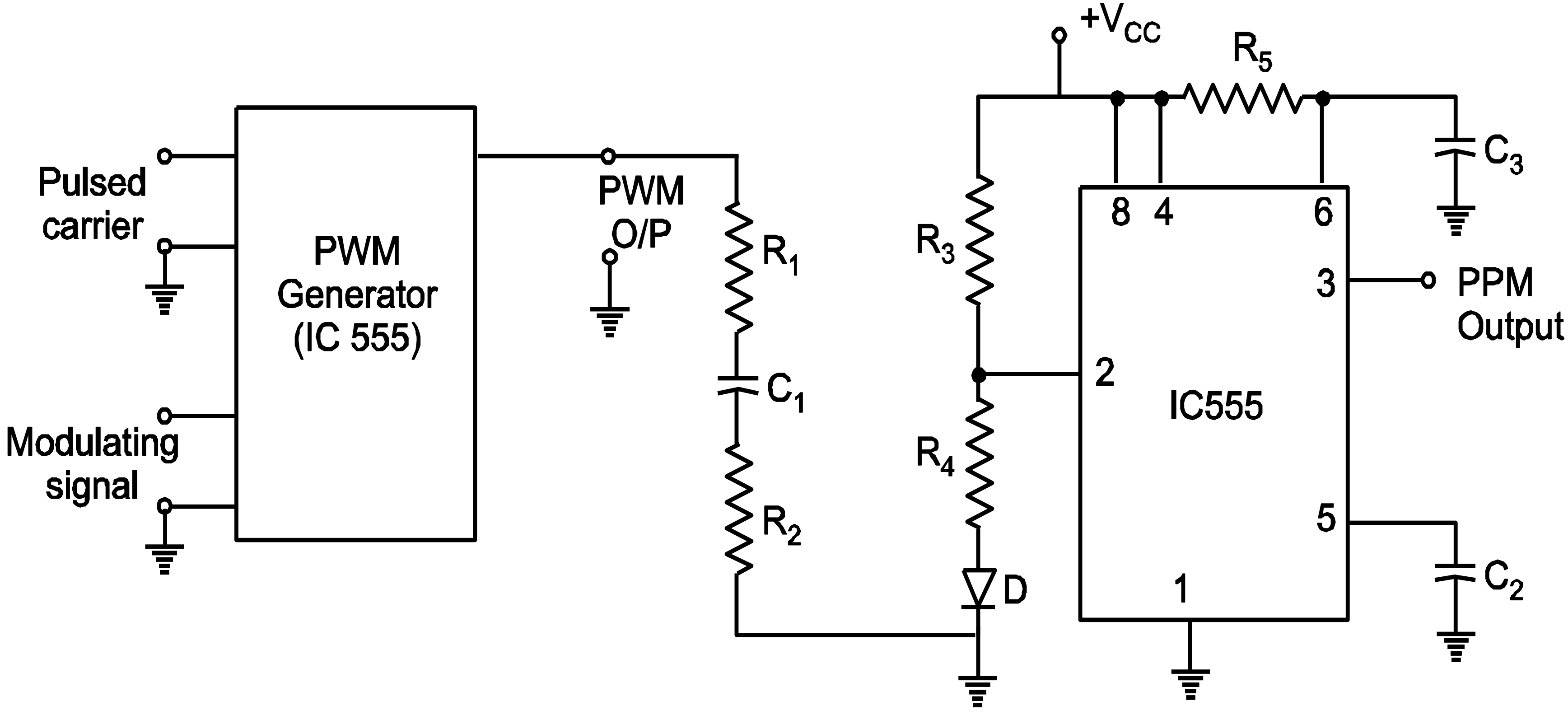
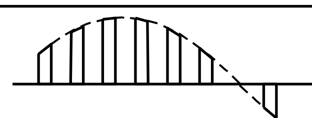
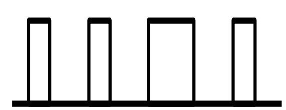



**Fig. : Generation of PPM using IC 555**

# Comparison of PAM, PWM and PPM

| Parameter | PAM | PWM | PPM |
|---|---|---|---|
| 1. Variable parameter of pulsed carrier. | Amplitude | Width | Position |
| 2. Bandwidth requirement | Low | High | High |
| 3. Transmitted power | Varies with amplitude of pulses | Varies with variation in width | Remains constant |
| 4. Noise immunity | Low | High | High |
| 5. Information contained in | Amplitude variations | Width variations | Position variation |
| 6. Output waveform |  |  |  |

# ANY QUESTION?

*For more detail contact us*