**SIDDARTHA INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(Autonomous)**
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)
(NAAC Accredited Institution with ‘A’ Grade)
SIDDHARTH NAGAR, NARAYANAVANAM ROAD, PUTTUR – 517 583
CHITTOOR DIST., A.P., INDIA

# Unit – I
# Amplitude Modulation & Demodulation-I

**Prepared**
**By**
**Dr.B.SAROJA Ph.D(Professor)**
**S.ROJA M.Tech(Assistant Professor)**

# COURSE OBJECTIVES

- Students are able to study the fundamental concepts of the analog communication system.
- Students are able to analyze various analog modulation and demodulation techniques.
- Students are able to know the working of various transmitters and receivers.
- Students are able to understand the influence of noise on the performance of analog communication systems, and to acquire the knowledge about information and capacity.

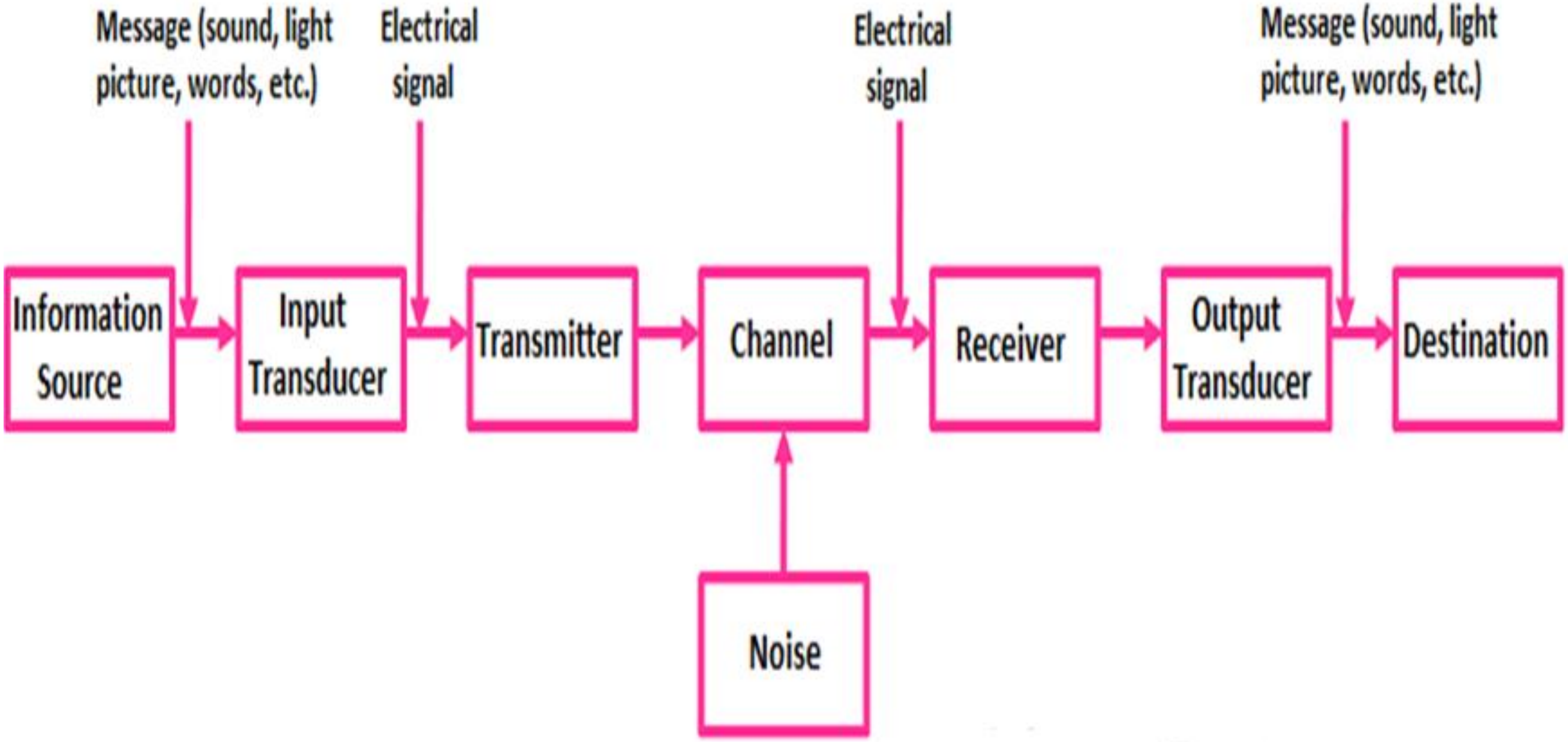
# COURSE OUTCOMES

- Describe the fundamentals of Analog Communication Systems
- Express the concept of various Analog Modulation schemes and Multiplexing.
- Compute various parameters of continuous and pulse wave modulation Techniques.
- Analyze various continuous and pulse wave modulation and Demodulation Schemes.
- Estimate the performance of Analog Communication System in the presence of noise.
- Identify different Radio receivers and understand the concept of coding schemes in Information theory.

# CONTENTS

- Introduction communication systems
- Modulation
- Need for Modulation
- Introduction to Amplitude Modulation
- Power and transmission efficiency
- Single tone AM
- Generation of AM wave
- Square law Modulator
- Switching modulator
- Detection of AM Wave
- Square law detector
- Envelope detector
- AM Transmitters

# Introduction to Communication System



# MODULATION

- It is the process of varying the characteristics of high frequency carrier in accordance with instantaneous values of modulating or message or baseband signal.

(Or)

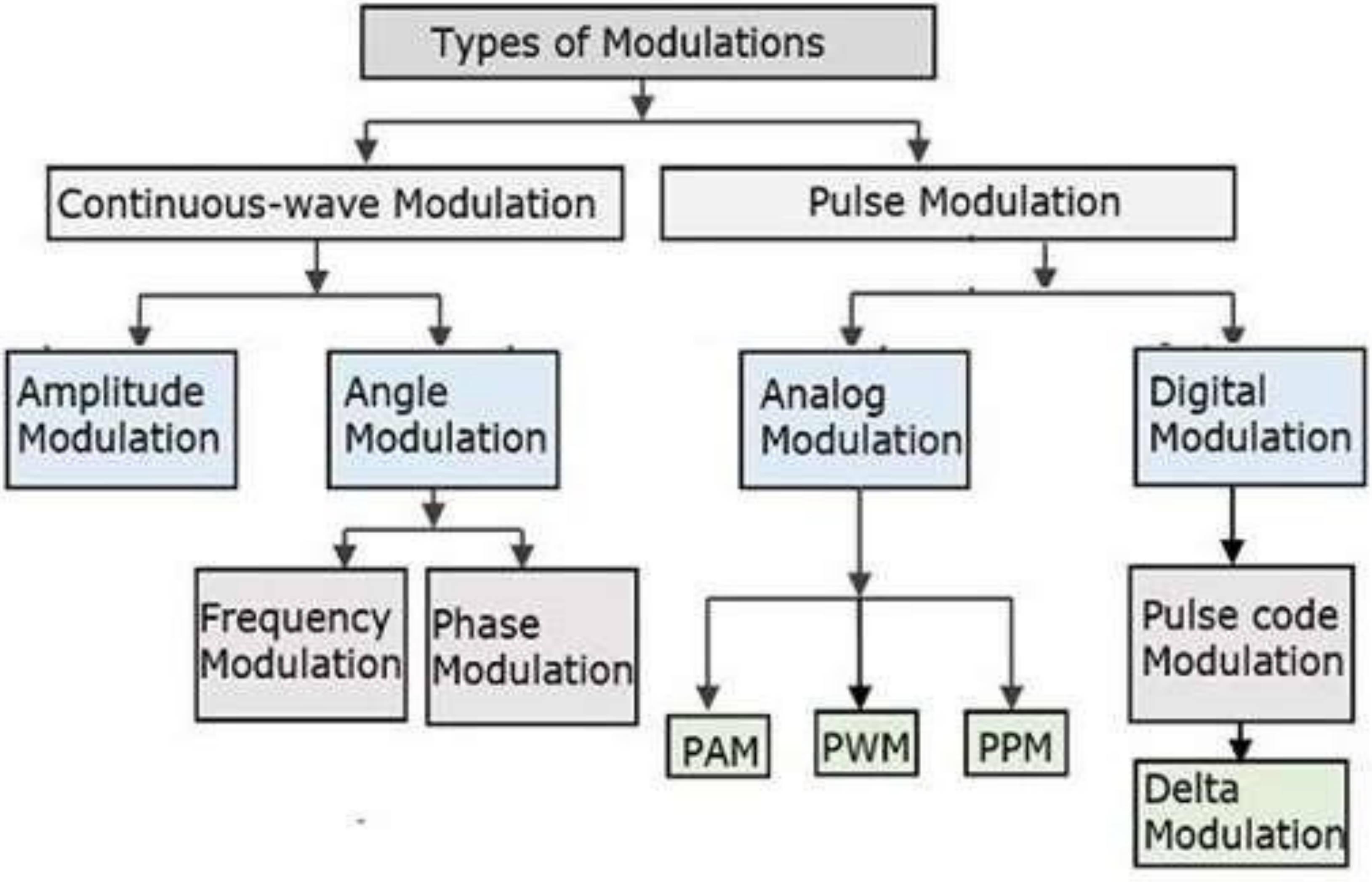
- It is a frequency translation technique which converts baseband or low frequency signal to bandpass or high frequency signal.

- Modulation is used in the transmitter.

# NEED FOR MODULATION

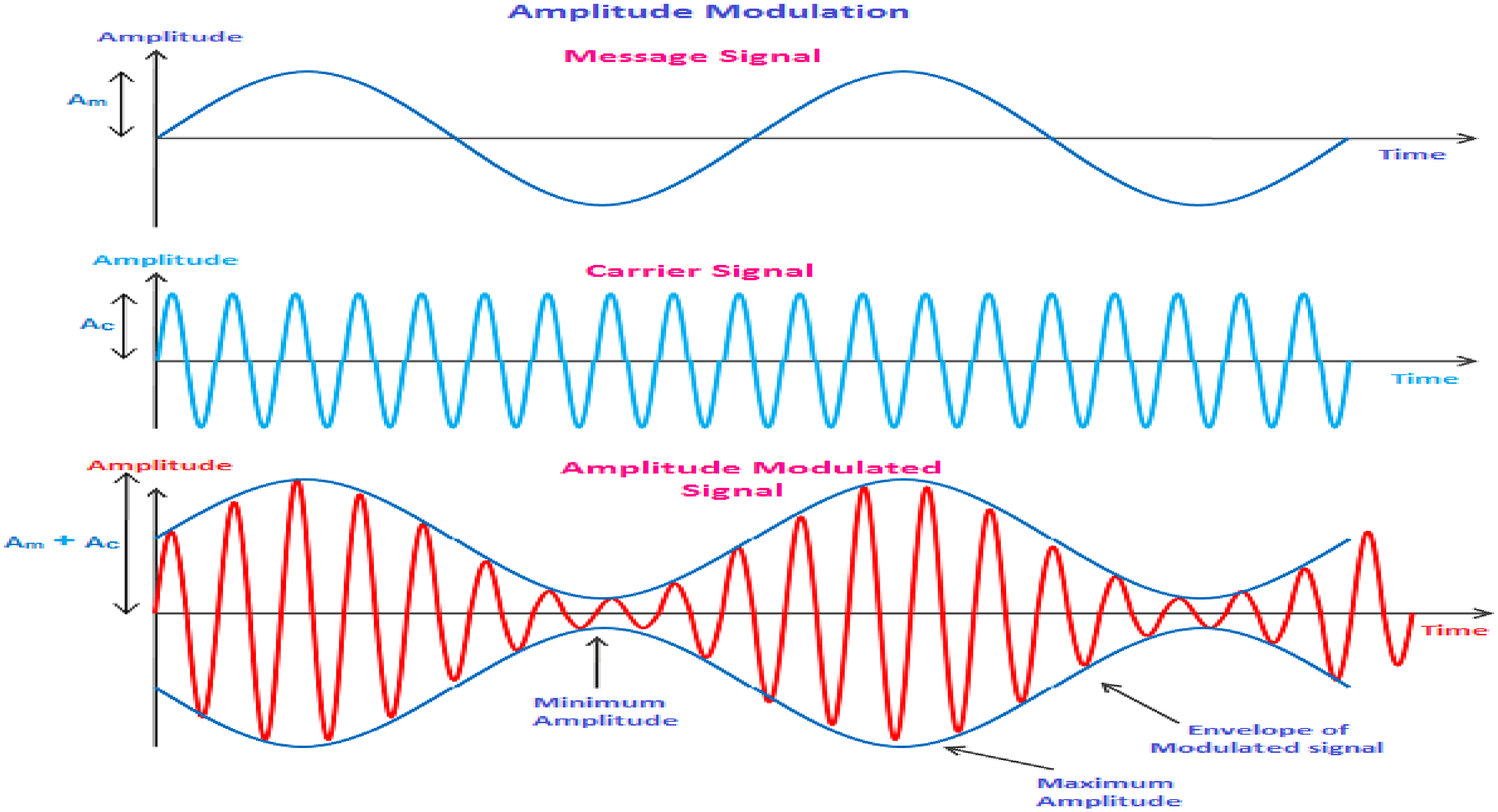
- To reduce the length or height of antenna
- For multiplexing
- For narrow banding or to use antenna with single or same length
- To reduce noise effect
- To avoid equipment limitation or to reduce the size of the equipment.

# TYPES OF MODULATION



# Introduction to Amplitude Modulation

- The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.



# POWER AND TRANSMISSION EFFICIENCY

- Consider the following equation of amplitude modulated wave.

$$s(t) = A_c \cos(2\pi f_c t) + \frac{A_c \mu}{2} \cos[2\pi (f_c + f_m) t] + \frac{A_c \mu}{2} \cos[2\pi (f_c - f_m) t]$$

- Power of AM wave is equal to the sum of powers of carrier, upper sideband, and lower sideband frequency components.

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

Carrier power

$$P_c = \frac{\left(A_c/\sqrt{2}\right)^2}{R} = \frac{A_c{}^2}{2R}$$

Upper sideband power

$$P_{USB} = \frac{\left(A_c\mu/2\sqrt{2}\right)^2}{R} = \frac{A_c{}^2\mu^2}{8R}$$

Similarly, we will get the lower sideband power same as that of the upper side band power.

$$P_{LSB} = \frac{A_c{}^2\mu^2}{8R}$$

Now, let us add these three powers in order to get the power of AM wave.

$$P_t = \frac{A_c{}^2}{2R} + \frac{A_c{}^2\mu^2}{8R} + \frac{A_c{}^2\mu^2}{8R}$$

$$\Rightarrow P_t = \left(\frac{A_c{}^2}{2R}\right)\left(1 + \frac{\mu^2}{4} + \frac{\mu^2}{4}\right)$$

$$\Rightarrow P_t = P_c\left(1 + \frac{\mu^2}{2}\right)$$

# TRANSMISSION EFFICIENCY

$$\eta = \frac{P_{LSB} + P_{USB}}{P_t} = \frac{[\frac{m^2}{4}P_c + \frac{m^2}{4}P_c]}{[1 + \frac{m^2}{2}]P_c}$$

or,

$$\eta = \frac{\frac{m^2}{2}}{1 + \frac{m^2}{2}} = \frac{m^2}{2 + m^2}$$

The percent transmission efficiency is given by ,

$$\eta = \frac{m^2}{2+m^2} \text{ x } 100\%$$

# SINGLE TONE AM

- The standard equation for amplitude modulated signal is expressed as,

$S(t)= Ac\ Cos2\pi f_ct[1+m_a(Cos2\pi f_mt)]$

Where, $m_a = Am/Ac$ = Modulation Index

**Time Domain representation of AM**:

$S(t)=AcCos2\pi fct+\mu Ac/2Cos[2\pi fc+2\pi fm]t+\mu Ac/2Cos[2\pi fc-2\pi fm]t$

I term: Carrier signal with amplitude Ac and frequency fc.

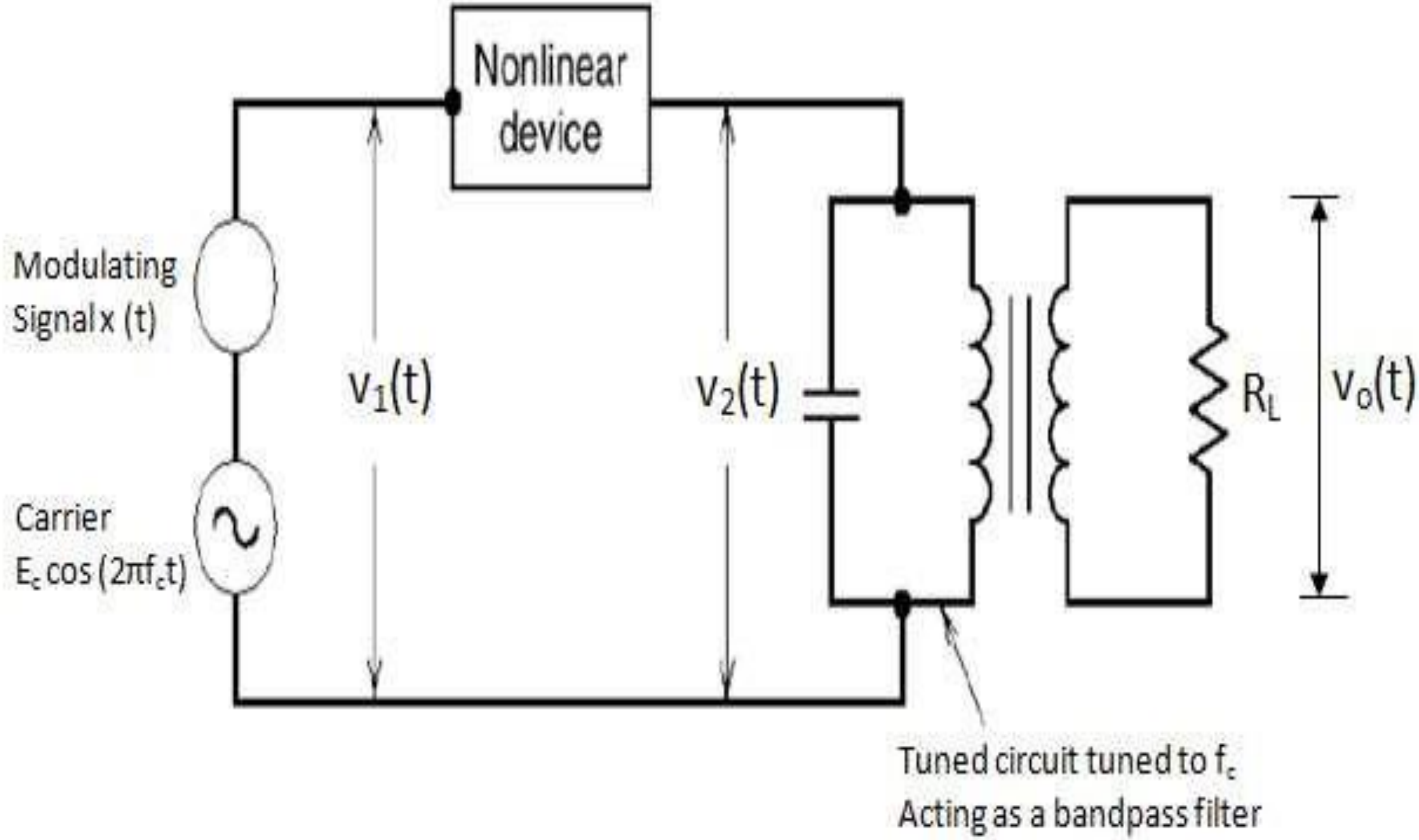
II term: Amplitude= $\mu$Ac/2, frequency= fc+fm , Upper sideband frequency

III term: Amplitude= $\mu$Ac/2, frequency= fc-fm , Lower sideband frequency

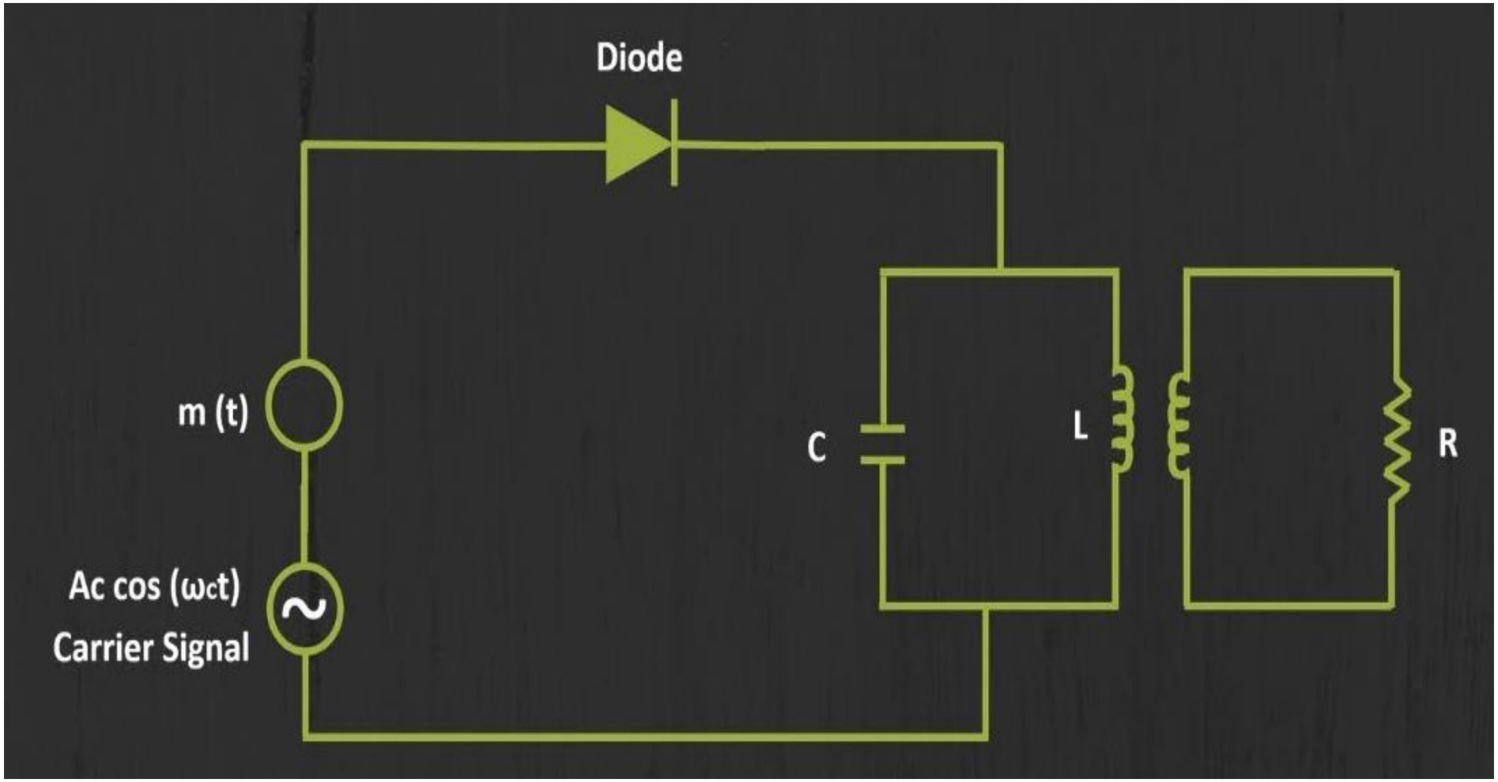
# GENERATION OF AM WAVES

- Square Law Modulator
- Switching Modulator

# SQUARE LAW MODULATOR



# SWITCHING MODULATOR



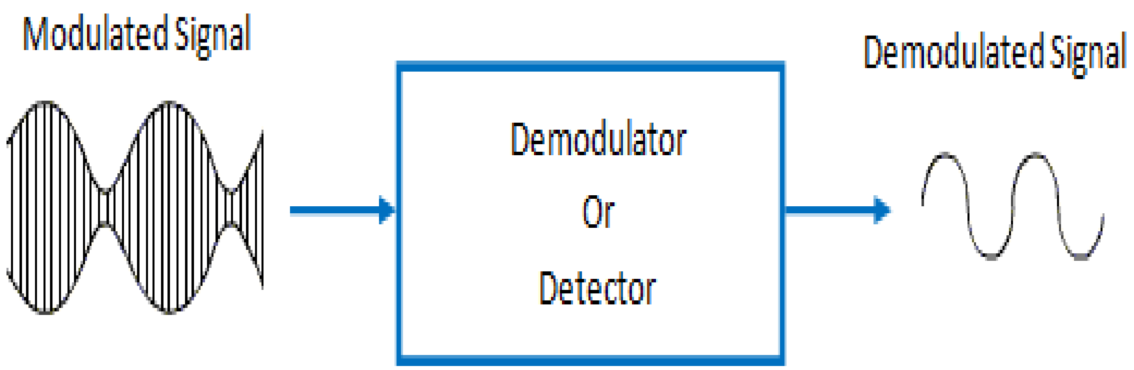
# DETECTION OF AM WAVE

- Demodulation or detection is the process of recovering the original message signal from the received modulated signal.
- **Types ofAM Detectors**:

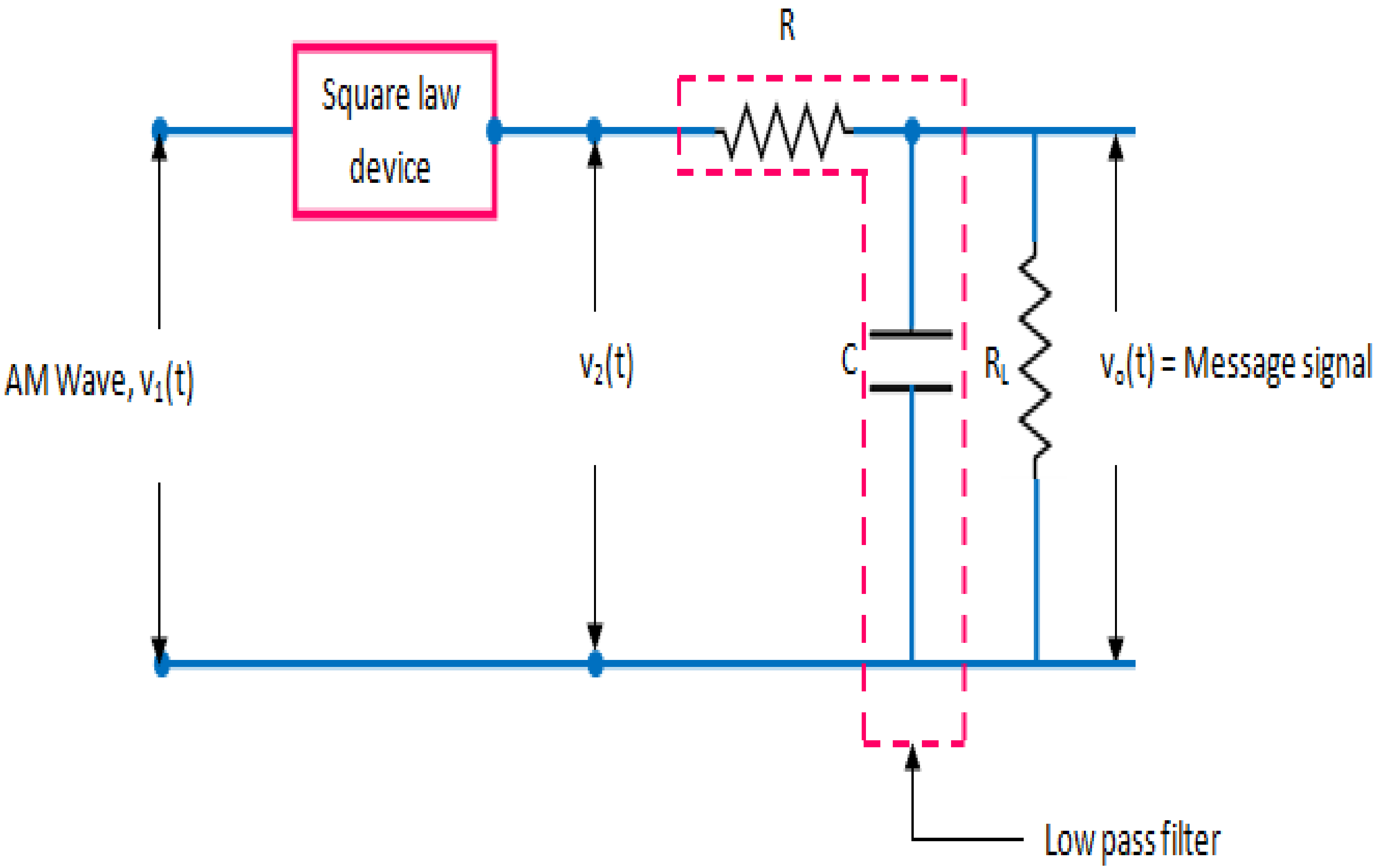
  I.Square Law detector

  II.Envelope detector

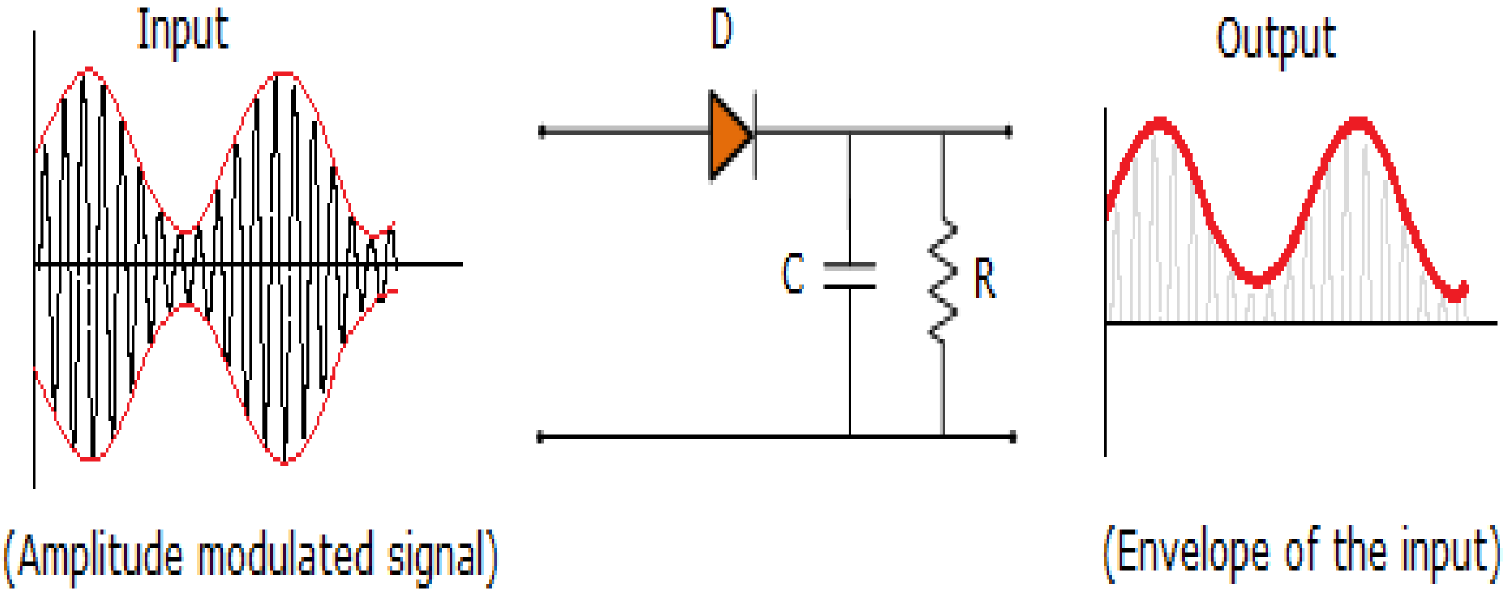
  III. Rectifier detector



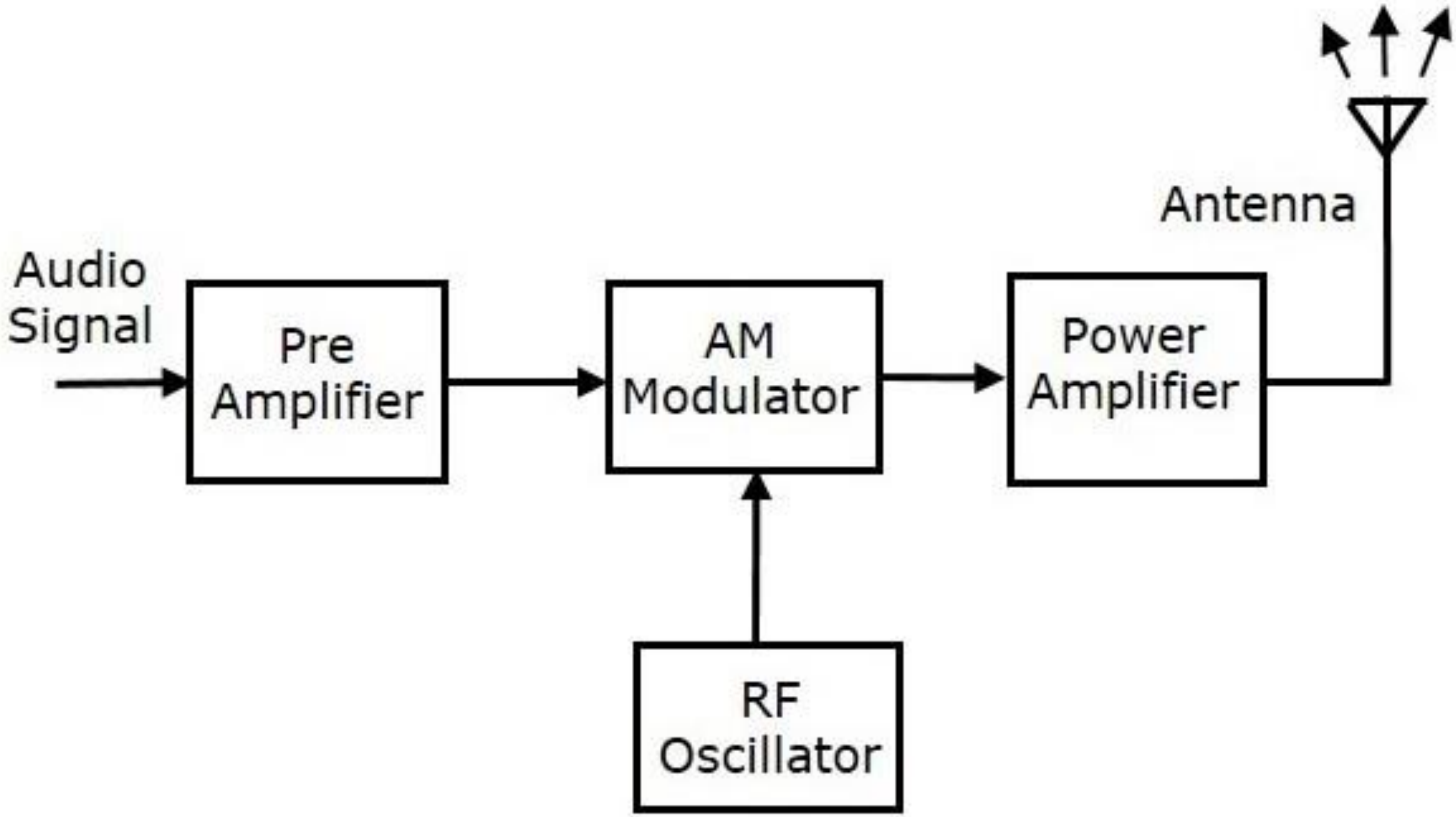
# SQUARE LAW DETECTOR



# ENVELOPE DETECTOR



# AM TRANSMITTER



# REFERENCES


- https://www.electronics-notes.com/articles/radio/modulation/am-diode-detector-demodulator.php
- https://www.tutorialspoint.com/analog_communication/analog_communication_numerical_problems_2.htm

**SIDDARTHA INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(Autonomous)**
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)
(NAAC Accredited Institution with 'A' Grade)
SIDDHARTH NAGAR, NARAYANAVANAM ROAD, PUTTUR – 517 583
CHITTOOR DIST., A.P., INDIA

# Unit – 2
# Amplitude Modulation & Demodulation-II

**Prepared By**
**Dr.B.SAROJA Ph.D(Professor)**
**S.ROJA M.Tech(Assistant Professor)**

# COURSE OBJECTIVES

- Students are able to study the fundamental concepts of the analog communication system.
- Students are able to analyze various analog modulation and demodulation techniques.
- Students are able to know the working of various transmitters and receivers.
- Students are able to understand the influence of noise on the performance of analog communicationsystems, and to acquire the knowledge about information and capacity.

# COURSE OUTCOMES

- ➢ Describe the fundamentals of Analog Communication Systems
- ➢Express the concept of various Analog Modulation schemes and Multiplexing.
- ➢Compute various parameters of continuous and pulse wave modulation Techniques.
- ➢Analyze various continuous and pulse wave modulation and Demodulation Schemes.
- ➢Estimate the performance of Analog Communication System in the presence of noise.
- ➢Identify different Radio receivers and understand the concept of coding schemes in Information theory.

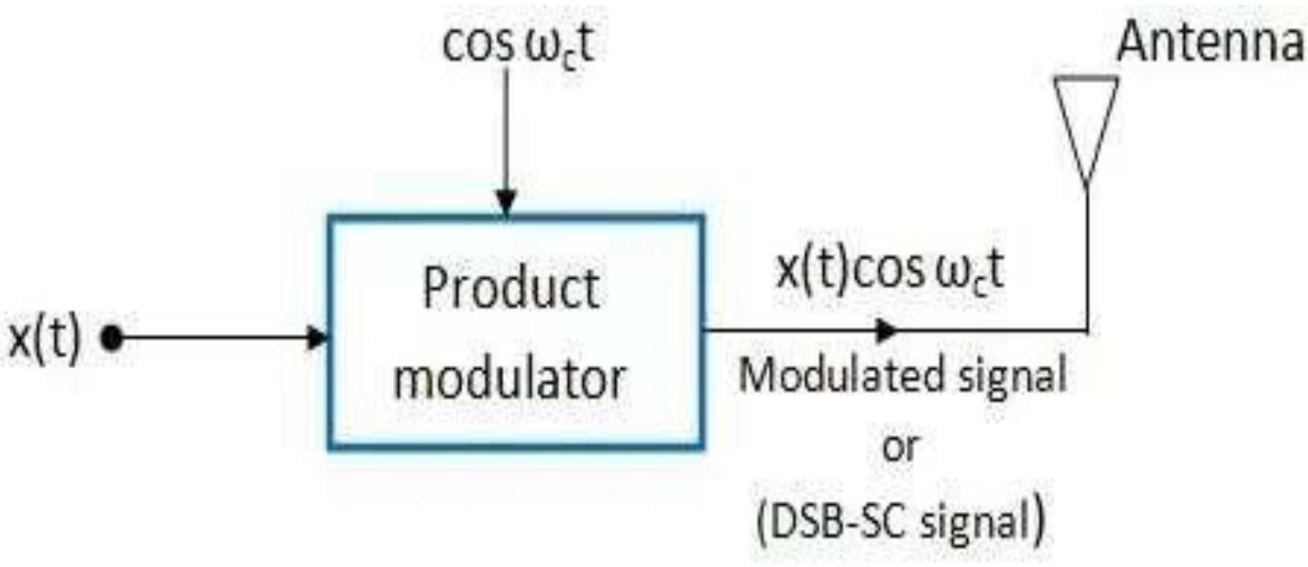
# CONTENTS

- Introduction to DSB-SC
- Power calculations
- Generation of DSB-SC
- Balanced Modulators
- Ring Modulator
- Coherent detection of DSB-SC
- Time domain description of SSB
- Hilbert transform,
- Generation of SSB wave
- Frequency discrimination & Phase discrimination method,
- Demodulation of SSB Wave
- Introduction to Vestigial sideband (VSB)modulation
- Comparison of AM Techniques

# Introduction to DSB-SC

- A DSB-SC signal is obtained by multiplying the modulating signal x(t) with carrier signal c(t).

So, we need a product modulator for the generation of DSB-SC wave.



# POWER CALCULATIONS

**Power of DSB :**

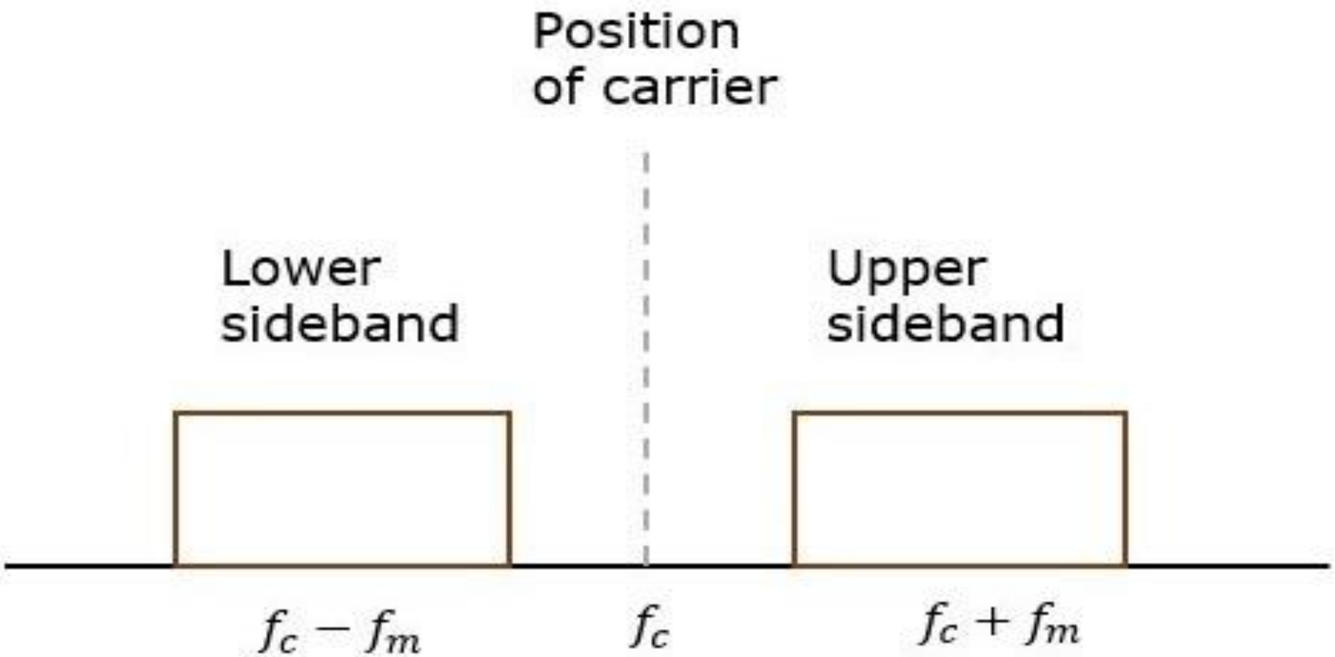
$$P_t = P_{SB} + P_c$$
(X)

As it only contains sidebands.

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

$$P_{USB} = \left(\frac{A_c A_m}{2}\right)^2 / 2R = \frac{A_c^2 A_m^2}{8R} = P_{LSB}$$

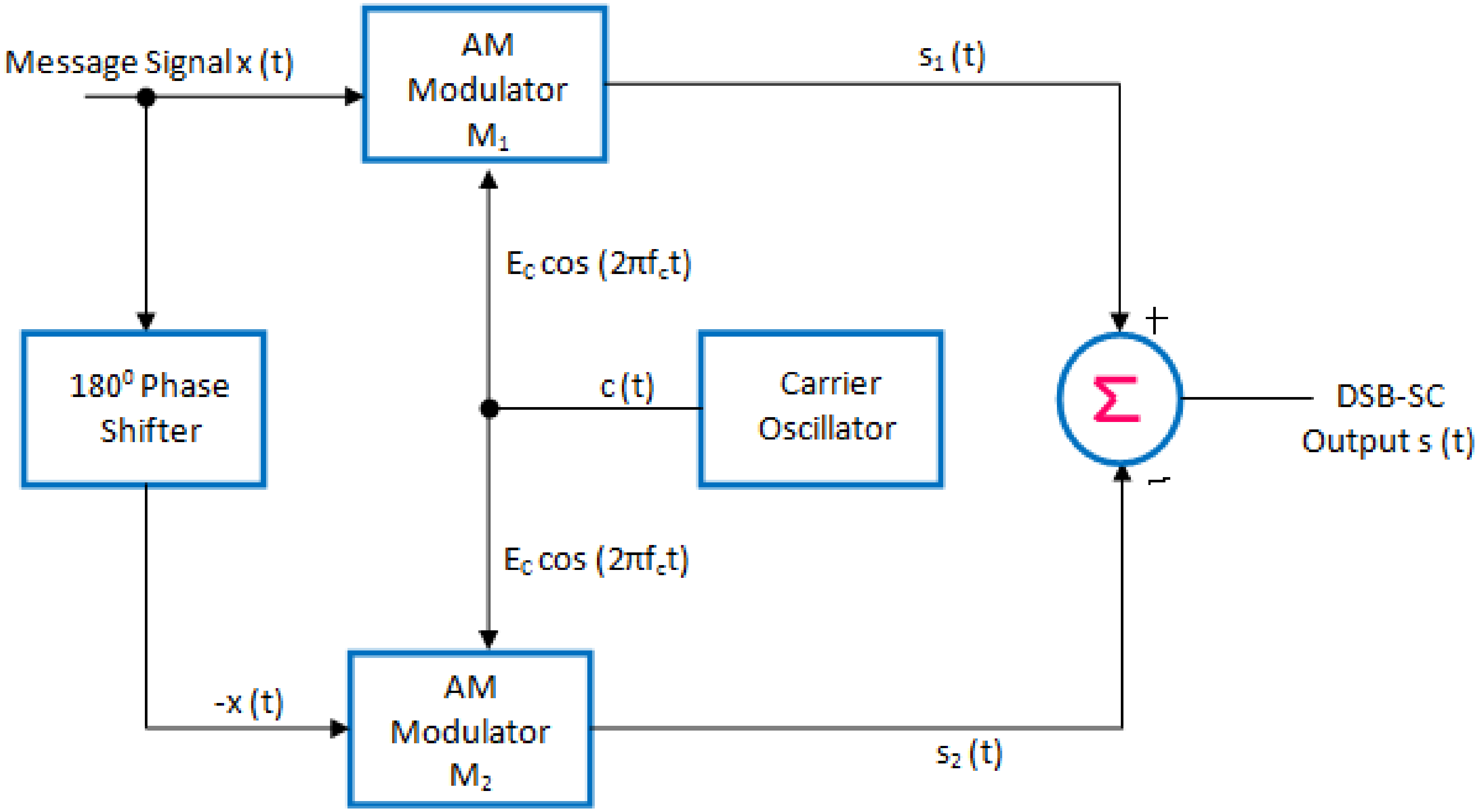
$$\boxed{P_t = \frac{A_c^2 A_m^2}{4R}}$$



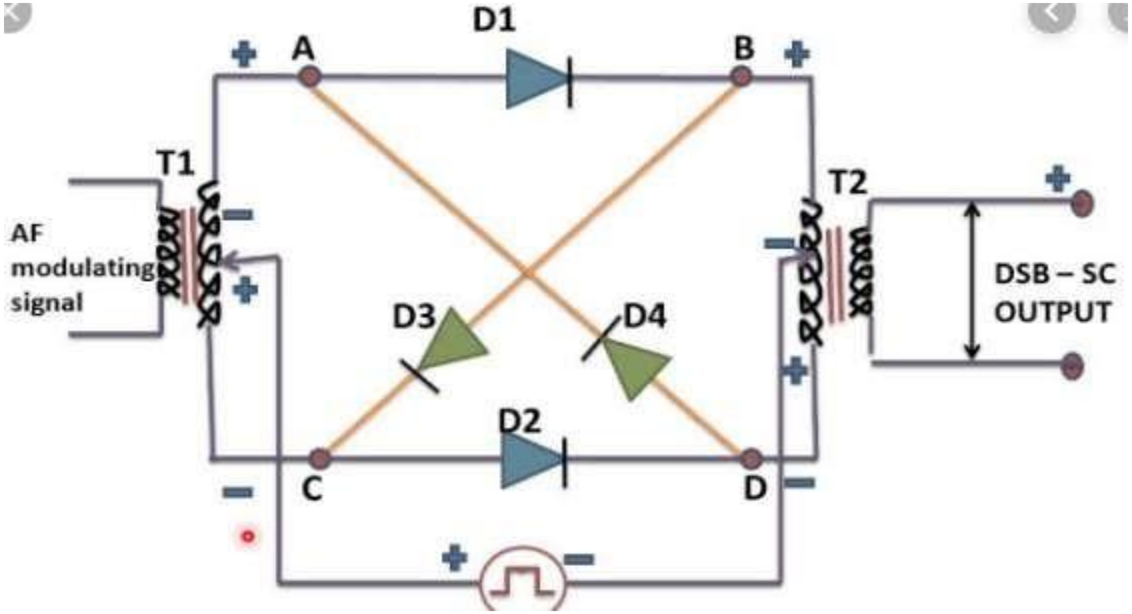

Carrier is suppressed and sidebands
are allowed for transmission

# GENERATION OF DSB-SC

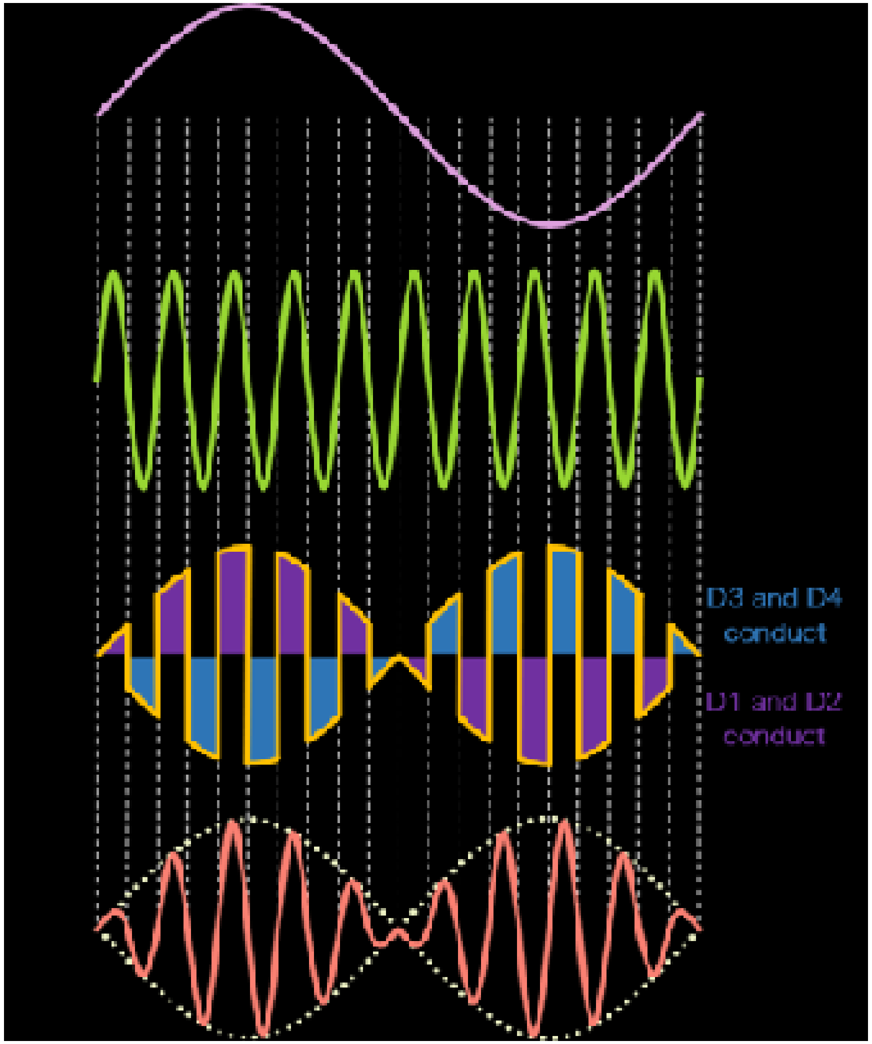
## Balanced Modulator



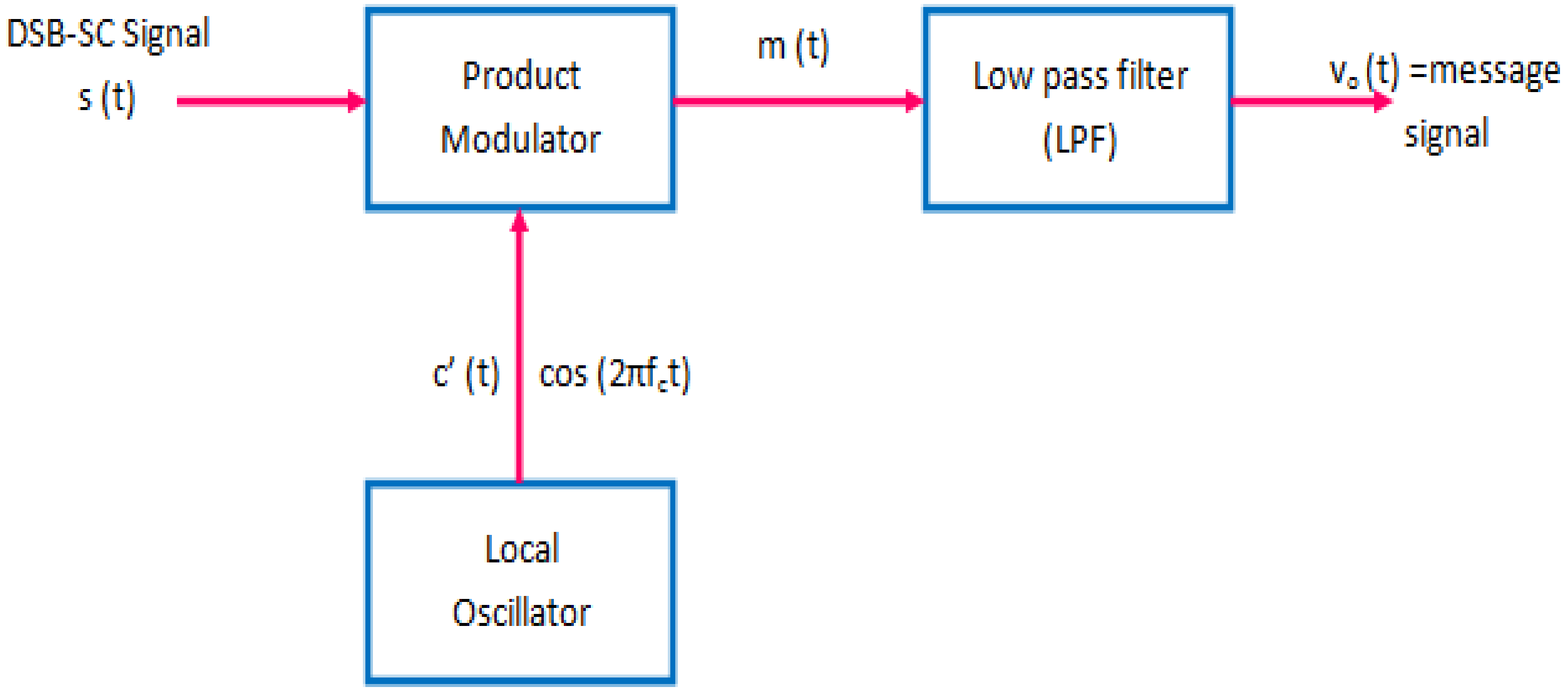
# RING MODULATOR



# RING MODULATOR WAVE FORMS



# COHERENT DETECTION OF DSB-SC



# Time Domain Representation for SSB-SC Signals

i.e., Modulating signal

$$m\left(t\right)=A_m\cos(2\pi f_m t)$$

Carrier signal

$$c\left(t\right)=A_c\cos(2\pi f_c t)$$

Mathematically, we can represent the equation of SSBSC wave as

$$s\left(t\right)=\frac{A_m A_c}{2}\cos[2\pi\left(f_c+f_m\right)t]$$ for the upper sideband

Or

$$s\left(t\right)=\frac{A_m A_c}{2}\cos[2\pi\left(f_c-f_m\right)t]$$ for the lower sideband

# Single Sideband Signal

➢**Theorem :** A SSB signal has **Complex Envelope** and bandpass form as:

$$g(t) = A_c\left[m(t) \pm j\hat{m}(t)\right]$$

$$s(t) = A_c\left[m(t)\cos\omega_c t \mp \hat{m}(t)\sin\omega_c t\right]$$

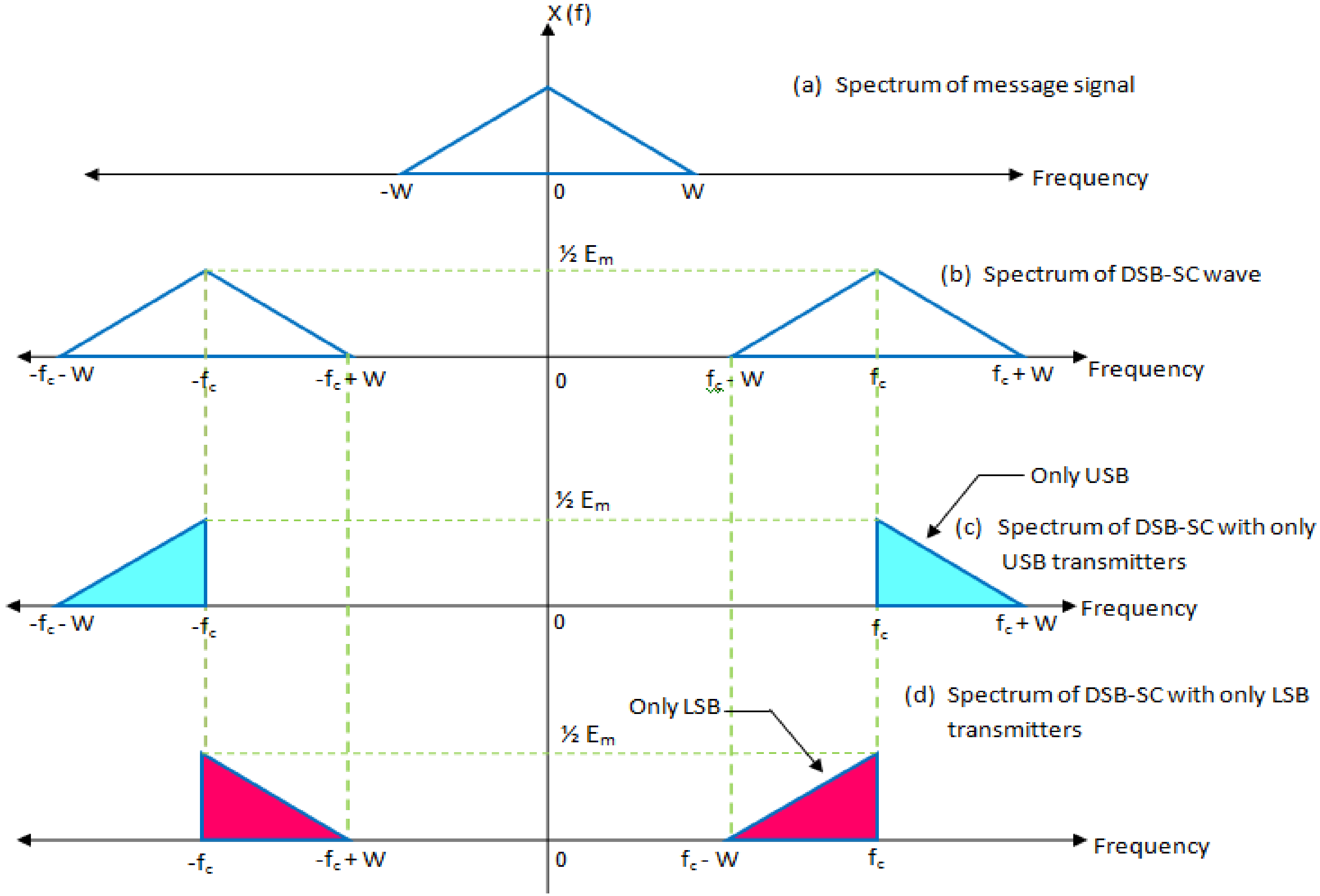
Upper sign (-) → USSB

Lower sign (+) → LSSB

$\hat{m}(t)$ – **Hilbert transform** of *m(t)* ➔ $\hat{m}(t) \equiv m(t) * h(t)$ Where $h(t) = \dfrac{1}{\pi t}$

$H(f) = \Im\left[h(t)\right]$ and $H(f) = \begin{cases} -j, & f > 0 \\ j, & f < 0 \end{cases}$

Hilbert Transform corresponds to a $-90^0$ phase shift


X (f)
(a) Spectrum of message signal
-W
0
W
Frequency
½ Em
(b) Spectrum of DSB-SC wave
-fc - W
-fc
-fc + W
0
fc - W
fc
fc + W
Frequency
Only USB
½ Em
(c) Spectrum of DSB-SC with only USB transmitters
-fc - W
-fc
0
fc
fc + W
Frequency
(d) Spectrum of DSB-SC with only LSB transmitters
Only LSB
½ Em
-fc
-fc + W
0
fc - W
fc
Frequency

# Hilbert transform

a) Let $s_u(t)$ denote the SSB wave obtained by transmitting only the upper sideband, and $\hat{s}_u(t)$ is its Hilbert transform. Show that

$$m(t) = \frac{2}{A_c}[s_u(t)\cos(2\pi f_c t) + \hat{s}_u(t)\sin(2\pi f_c t)]$$

$$\hat{m}(t) = \frac{2}{A_c}[\hat{s}_u(t)\cos(2\pi f_c t) - s_u(t)\sin(2\pi f_c t)]$$

/here $m(t)$ is the message signal, $\hat{m}(t)$ is its Hilbert transform, $f_c$ the carrier frequency, and $A_c$ the arrier amplitude.

b) Show that the corresponding equations in terms of the SSB wave $s_l(t)$ obtained by transmitting only the lower sideband are

$$m(t) = \frac{2}{A_c}[s_l(t)\cos(2\pi f_c t) + \hat{s}_l(t)\sin(2\pi f_c t)]$$

$$\hat{m}(t) = \frac{2}{A_c}[s_l(t)\cos(2\pi f_c t) - \hat{s}_l(t)\sin(2\pi f_c t)]$$

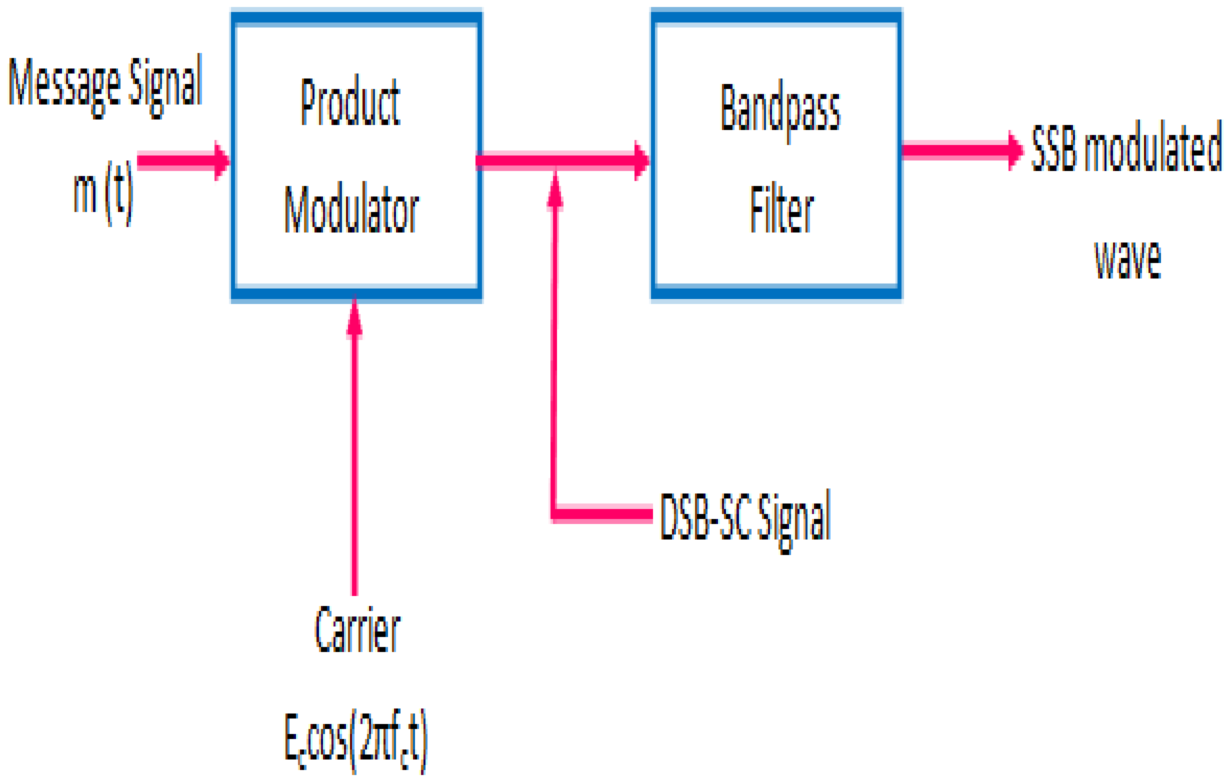
# GENERATION OF SSB- SC

- The modulation process in which only one side band is transmitted and with carrier suppression is called Single sideband suppressed carrier (SSB- SC).
- Modulating Signal $m(t) = Am \cos(2\pi fmt)$ and Carrier Signal $c(t) = Ac \cos(2\pi fct)$
- SSB-SC signal can be generated by passing DSB-SC signal through BPF and DSB-SC signal is generated by multiplying m(t) & c(t).
- $A_{SSB-SC}(t) = AmAc/2 \cos 2\pi(fc+fm)t$

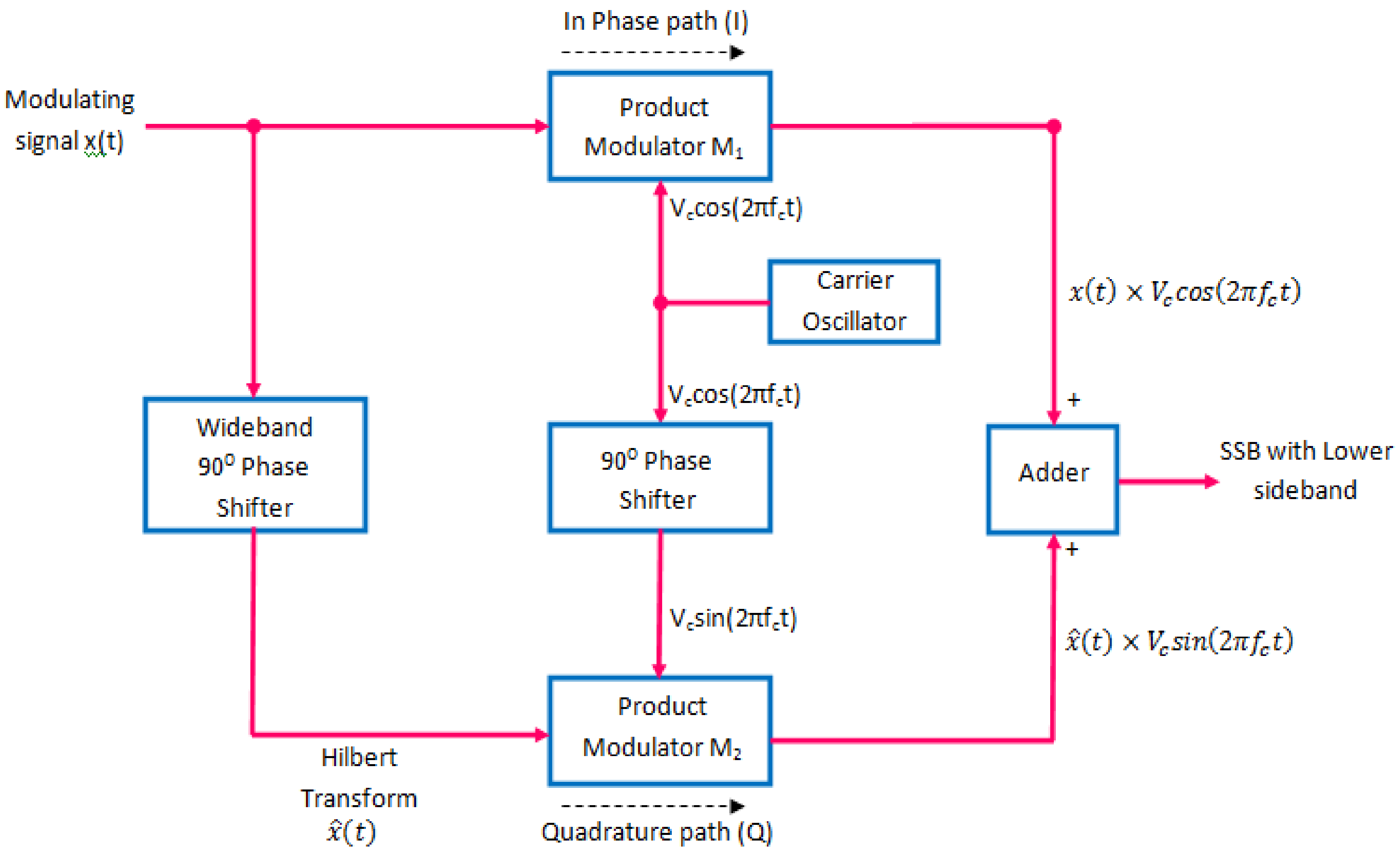
(or)

$$A_{SSB-SC}(t) = AmAc/2 \cos 2\pi(fc-fm)t$$

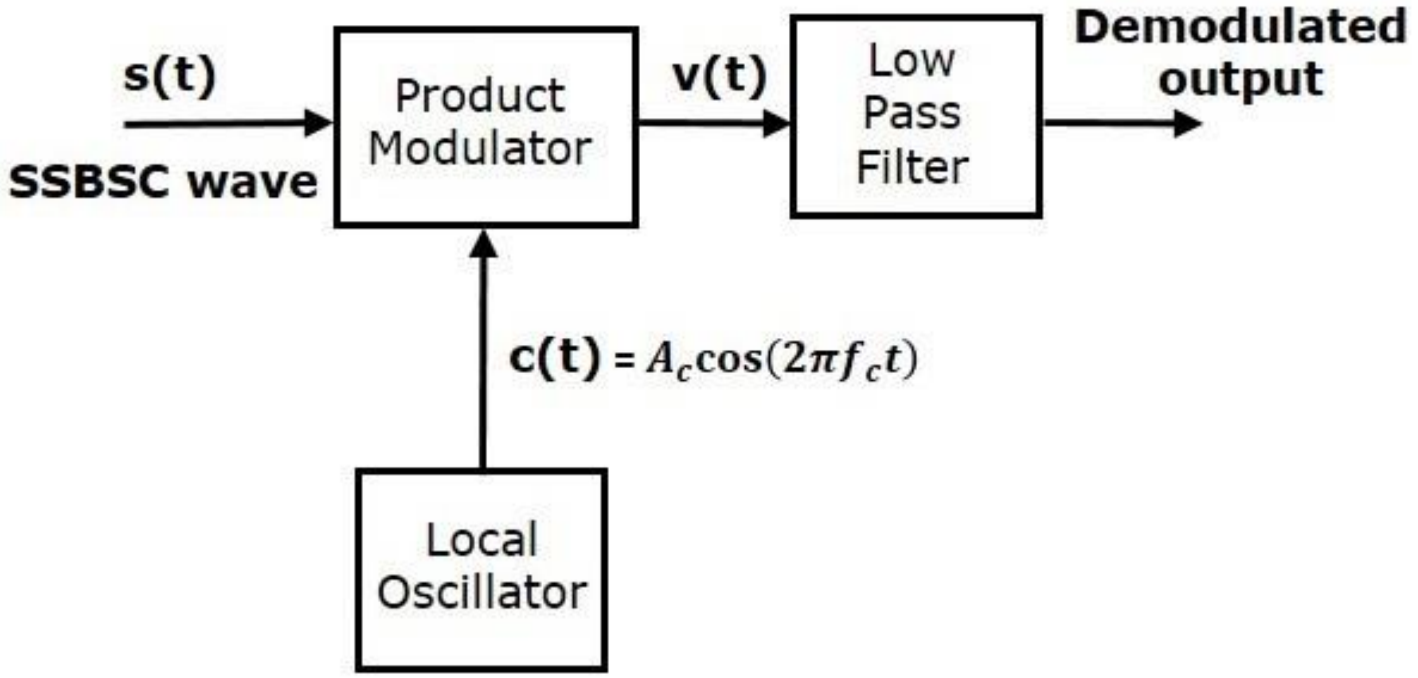
# FREQUENCY DISCRIMINATION



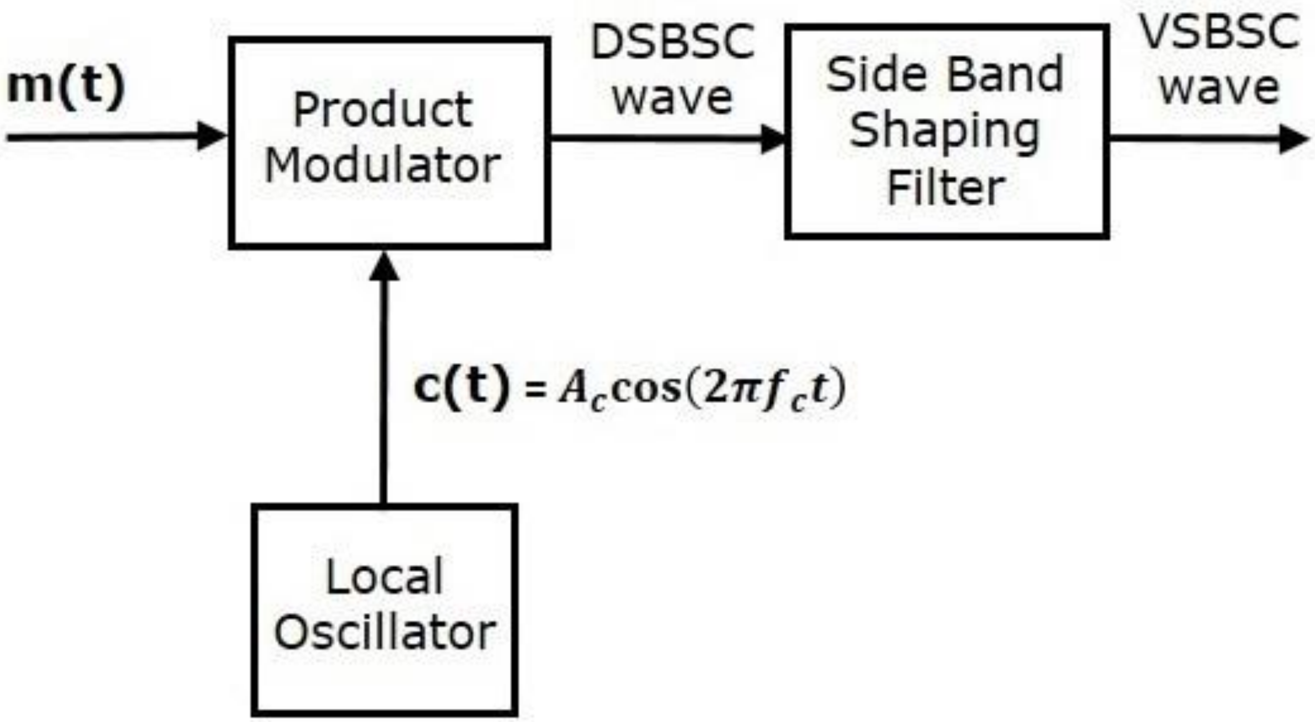
# PHASE DISCRIMINATION



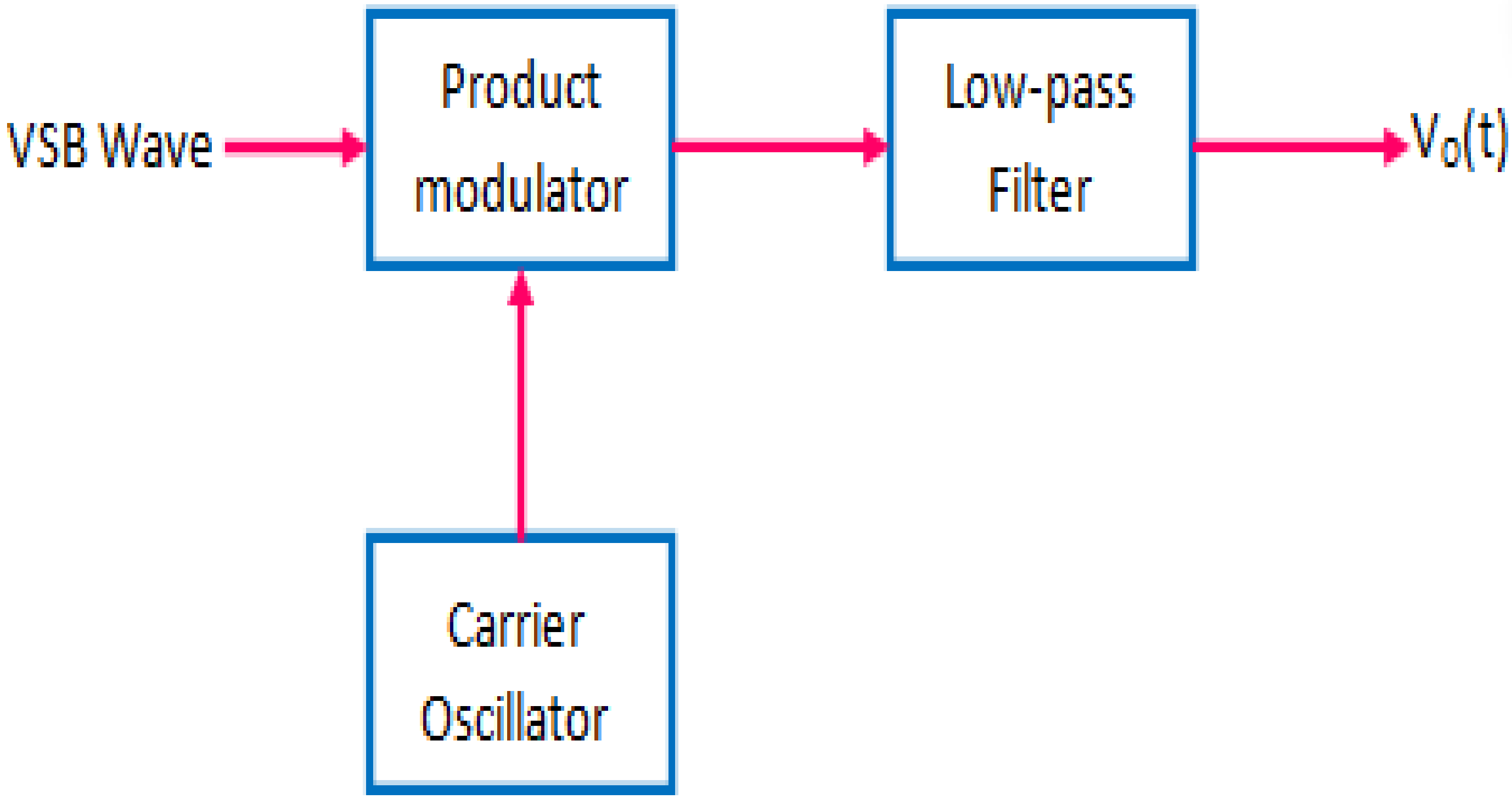
# DEMODULATION OF SSB WAVE



# INTRODUCTION TO VSB MODULATION



# VSB DEMODULATION



# COMPARISION OF VARIOUS 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 | Moderate | Maximum | Moderate |
| Number of modulating inputs | 1 | 1 | 1 | 2 |
| Applications | Radio broadcasting | Radio broadcasting | Point to point mobile communication | TV |

# REFERENCES


- https://www.electronics-notes.com/articles/radio/modulation/am-diode-detector-demodulator.php
- https://www.youtube.com/watch?v=OC451cdFLoQ
- https://en.wikipedia.org/wiki/Single-sideband_modulation
- https://www.tutorialspoint.com/analog_communication/analog_communication_vsbsc_modulation.htm
- https://www.tutorialspoint.com/analog_communication/analog_communication_numerical_problems_2.htm

**SIDDARTHA INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(Autonomous)**
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)
(NAAC Accredited Institution with 'A' Grade)
SIDDHARTH NAGAR, NARAYANAVANAM ROAD, PUTTUR – 517 583
CHITTOOR DIST., A.P., INDIA

# Unit – 3
# Angle Modulation

**Prepared**
**By**
**Dr.B.SAROJA Ph.D(Professor)**
**S.ROJA M.Tech(Assistant Professor)**

# COURSE OBJECTIVES

- Students are able to study the fundamental concepts of the analog communication system.
- Students are able to analyze various analog modulation and demodulation techniques.
- Students are able to know the working of various transmitters and receivers.
- Students are able to understand the influence of noise on the performance of analog communicationsystems, and to acquire the knowledge about information and capacity.

# COURSE OUTCOMES

- ➢ Describe the fundamentals of Analog Communication Systems
- ➢Express the concept of various Analog Modulation schemes and Multiplexing.
- ➢Compute various parameters of continuous and pulse wave modulation Techniques.
- ➢Analyze various continuous and pulse wave modulation and Demodulation Schemes.
- ➢Estimate the performance of Analog Communication System in the presence of noise.
- ➢Identify different Radio receivers and understand the concept of coding schemes in Information theory.

# CONTENTS

- Concept of angle modulation
- Frequency modulation
- Narrow band frequency modulation (NBFM)
- Wide band FM (WBFM)
- Generation of FM waves
- Indirect method
- Direct method
- Demodulation of FM
- Phase modulation
- Pre-emphasis& De-emphasis filters
- FM Transmitter

# CONCEPT OF ANGLE MODULATION

- Angle modulation is a process of varying angle of the carrier in accordance with the instantaneous values of modulating signal.

- Angle can be varied by varying frequency or phase.

- Angle modulation is of 2 types.

  Frequency Modulation

  Phase Modulation

# FREQUENCY MODULATION

➢ The process of varying frequency of the carrier in accordance with the instantaneous values of the modulating signal.

**Relation between angle and frequency :**

Consider carrier signal $c(t) = A_c \cos(w_c t + \varphi)$

$= A_c \cos(2\pi f_c t + \varphi)$

Where, $W_c$ = Carrier frequency

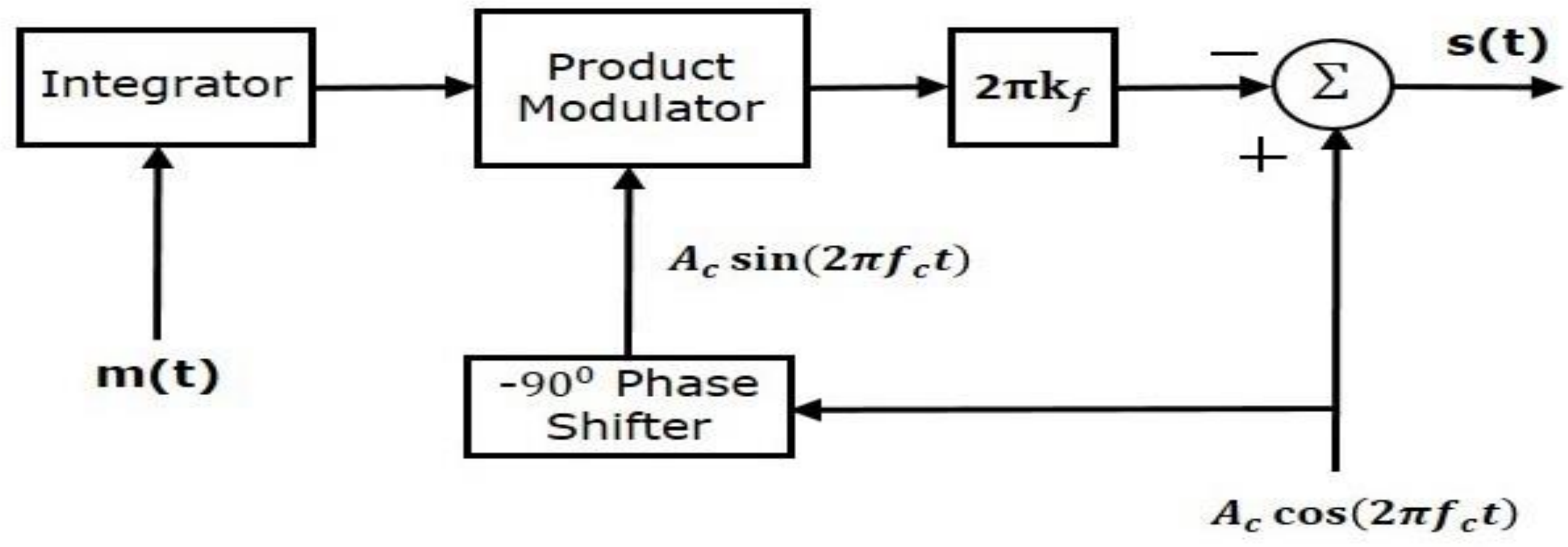
$\varphi$ = Phase

$C(t) = A_c \cos[\psi(t)]$, where, $\psi(t) = w_c t + \varphi$

$$\frac{d}{dt}\psi(t) = w_c$$

i.e Frequency can be obtained by derivating angle and angle can be obtained by integrating frequency.

# FREQUENCY MODULATION




Frequency modulated signal can be written as,

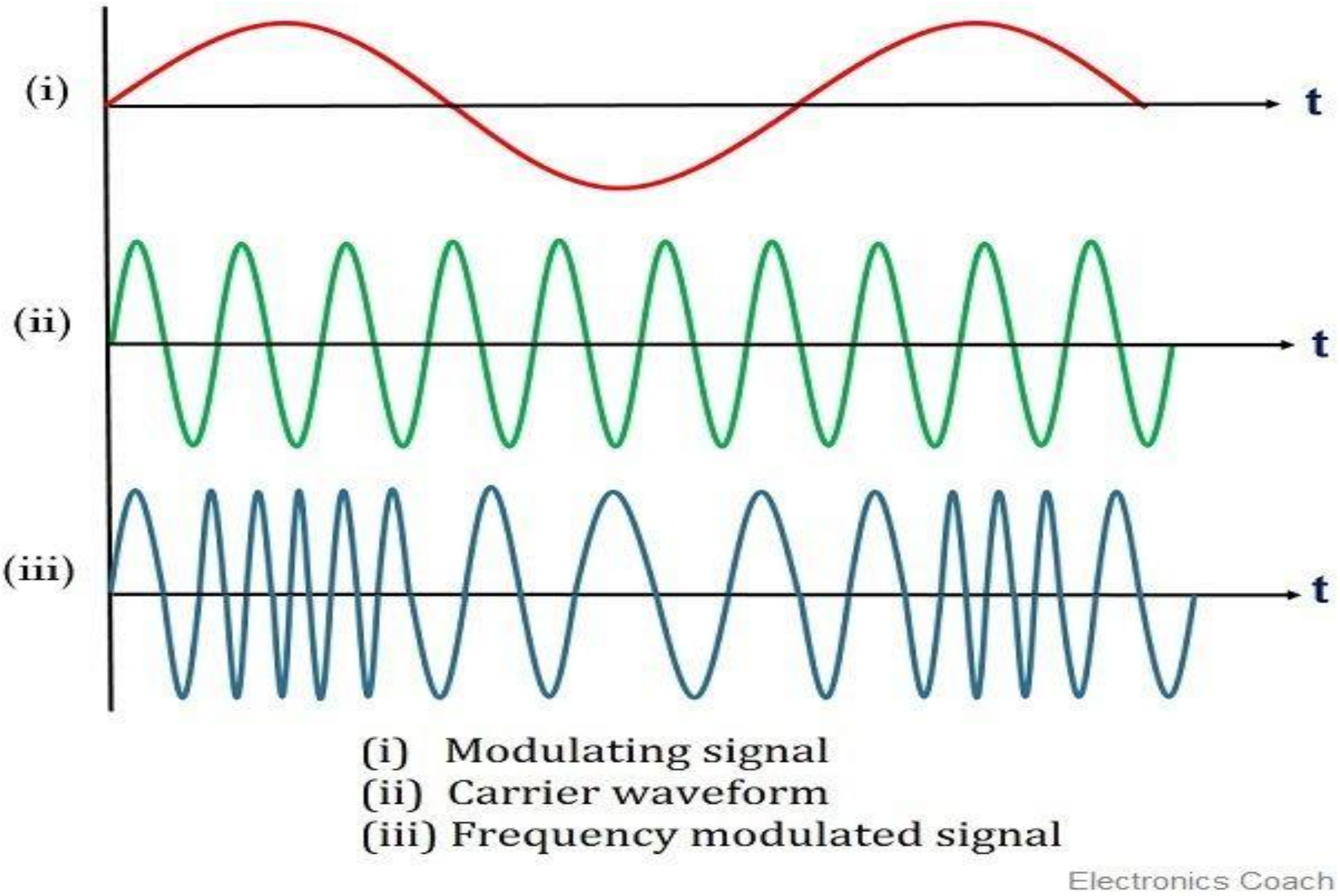
$$A_{FM}(t) = Ac\ Cos\ [\psi_{i(}t)] = Ac\ Cos\ [w_c t + k_f \int m(t)dt]$$

**Frequency Deviation in FM:**

The instantaneous frequency, $wi = w_c + k_f\ m(t)$

$$= w_c + \Delta w$$

# FM WAVEFORMS



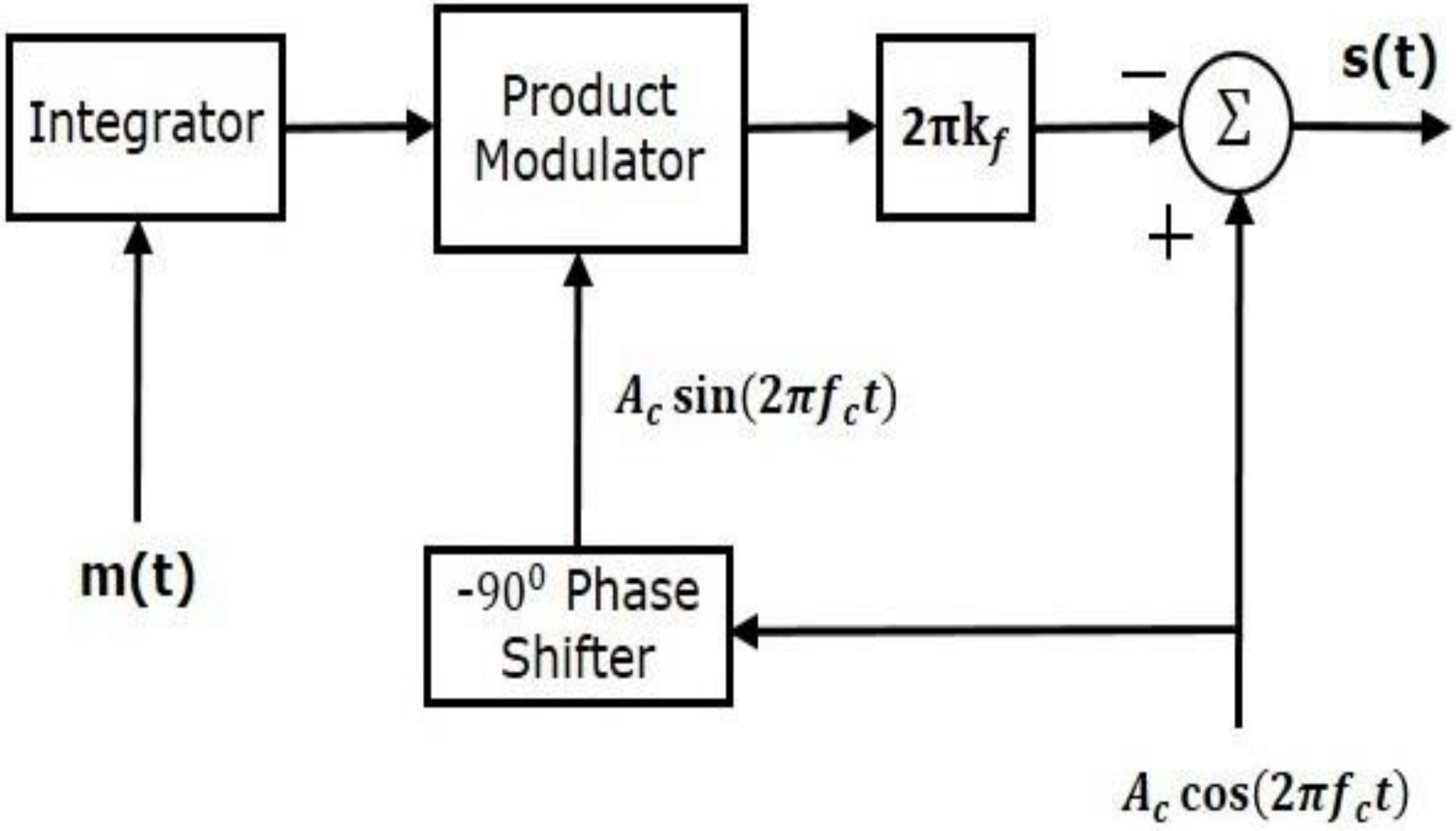
# Types of Frequency Modulation

FM (Frequency Modulation)

Narrowband FM (NBFM)  Wideband FM (WBFM)

[When modulation index is small][When modulation index is large]

# NARROW BAND FM



We know that the standard equation of FM wave is

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt\right)$$

$$\Rightarrow s(t) = A_c \cos(2\pi f_c t) \cos(2\pi k_f \int m(t)\, dt) -$$
$$A_c \sin(2\pi f_c t) \sin(2\pi k_f \int m(t)\, dt)$$

For NBFM,

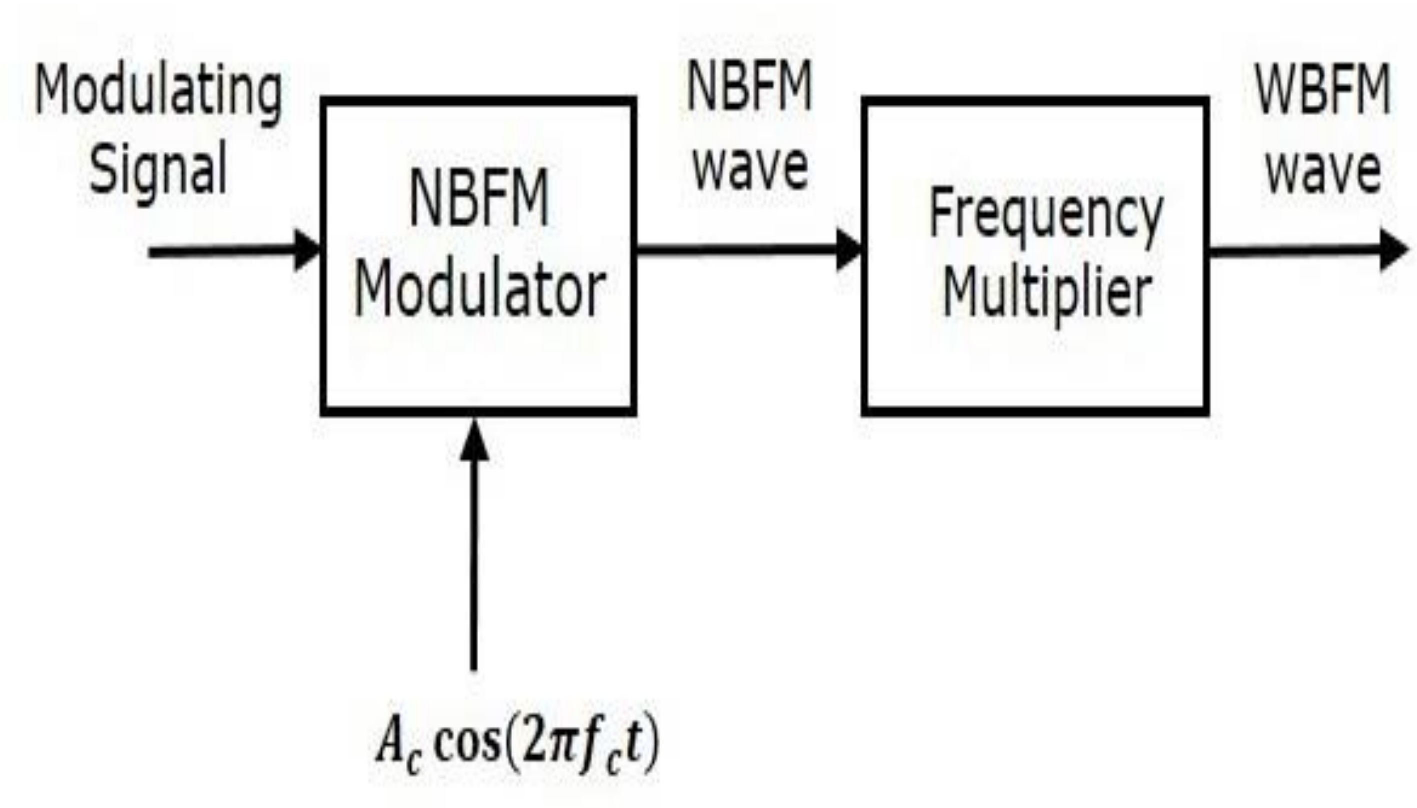
$$\left|2\pi k_f \int m(t)\, dt\right| << 1$$

We know that $\cos\theta \approx 1$ and $\sin\theta \approx 1$ when $\theta$ is very small.

By using the above relations, we will get the **NBFM equation** as

$$s(t) = A_c \cos(2\pi f_c t) - A_c \sin(2\pi f_c t) 2\pi k_f \int m(t)\, dt$$

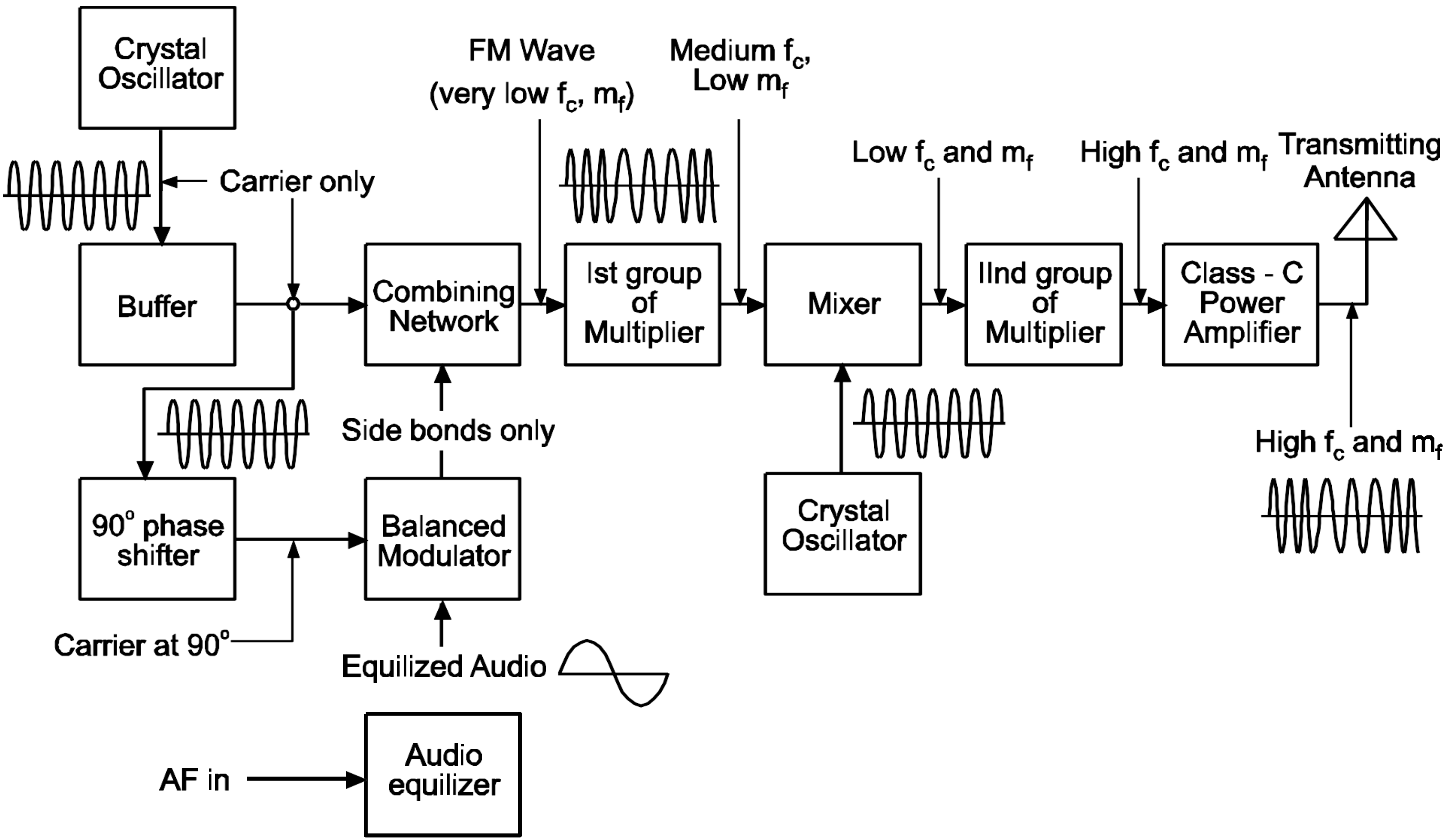
# WIDE BAND FM


Modulating Signal
NBFM Modulator
NBFM wave
Frequency Multiplier
WBFM wave
$A_c \cos(2\pi f_c t)$

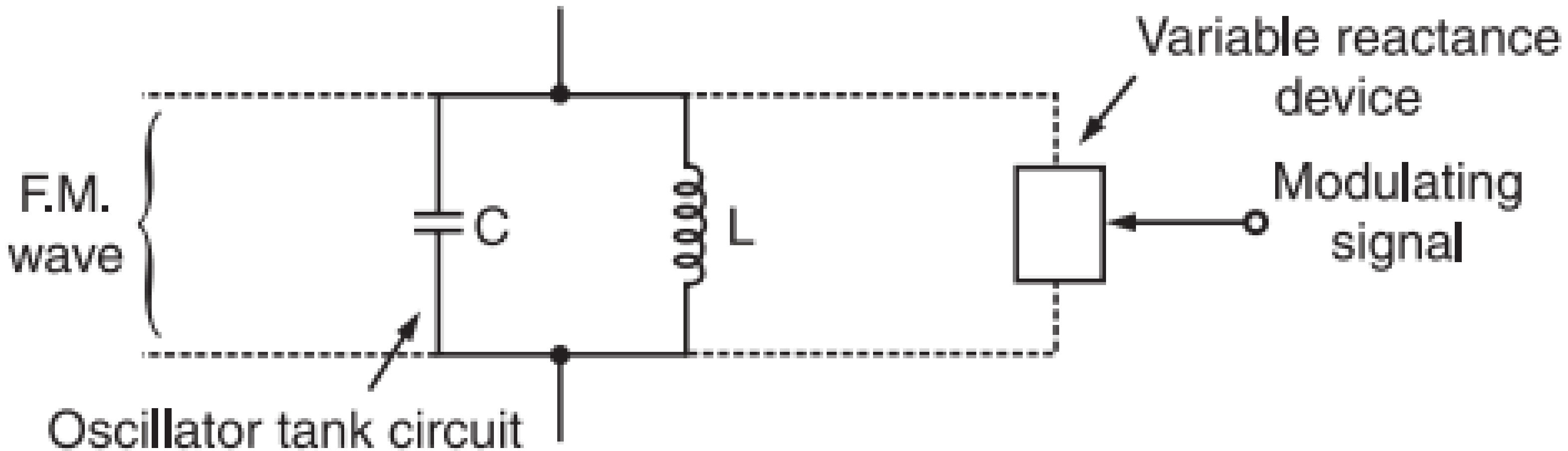
# Generation of FM waves

- Indirect Method Of FM
- Direct Method Of FM

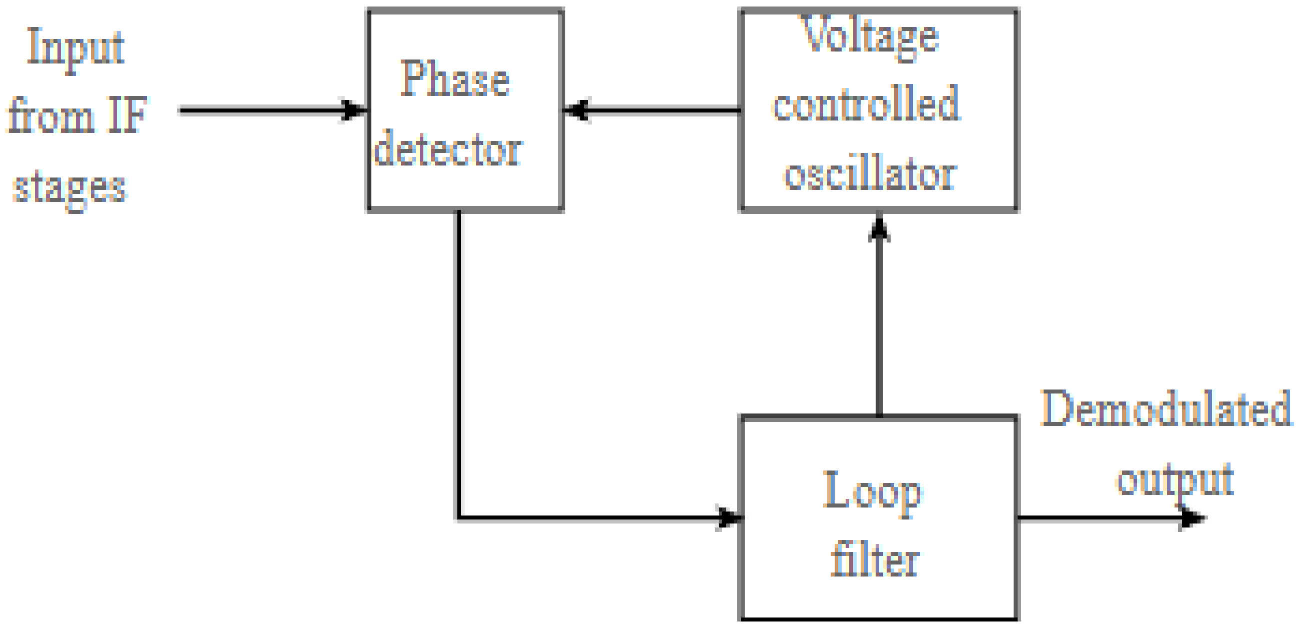
# INDIRECT METHOD OF FM



# DIRECT METHOD OF FM

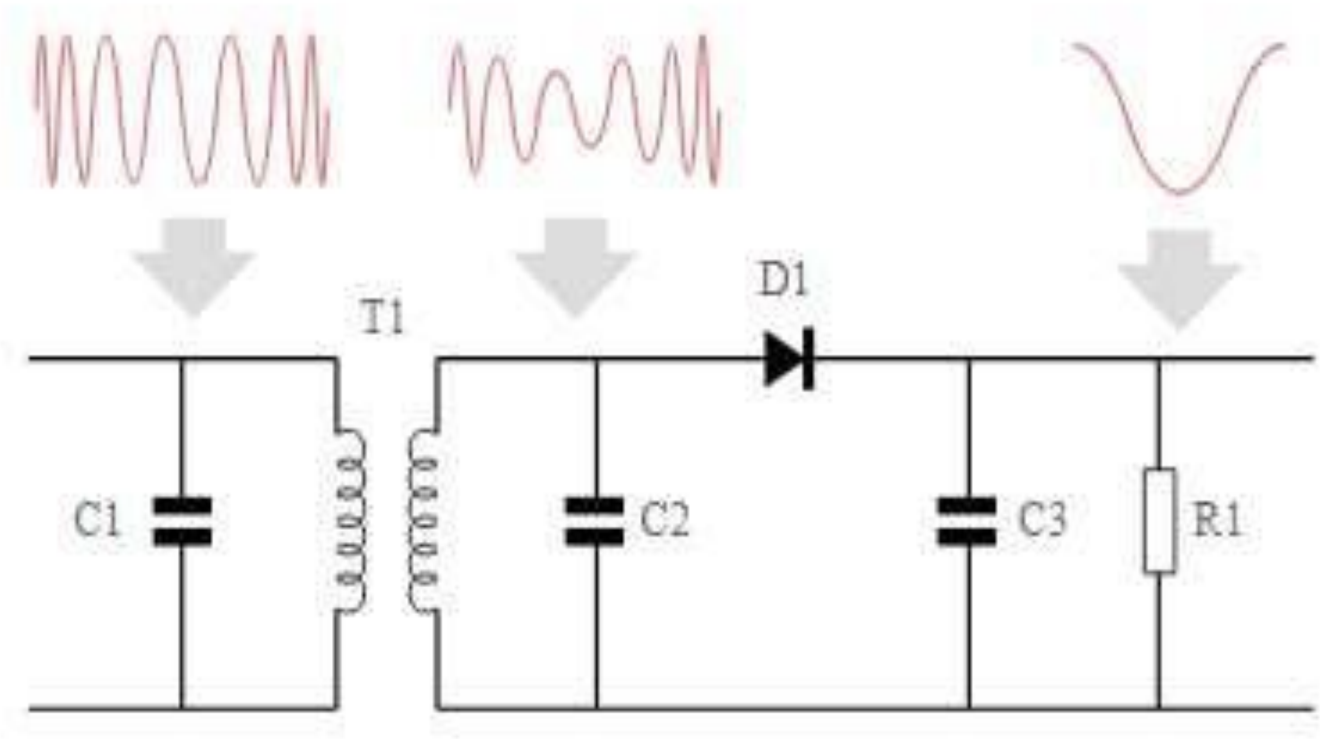


# FM DEMODULATION



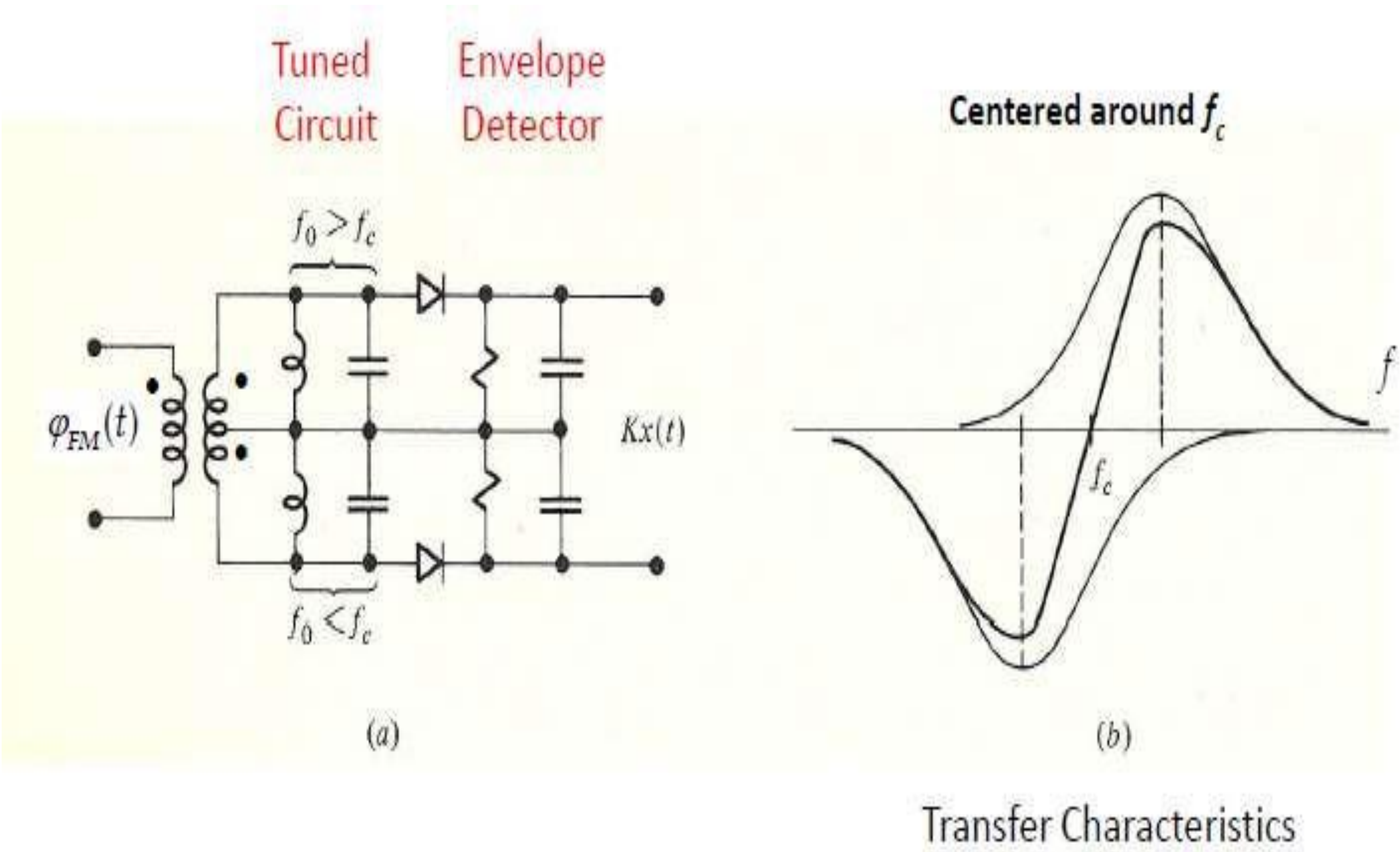

PLL Phase locked Loop FM demodulator

# SLOPE DEMODULATOR

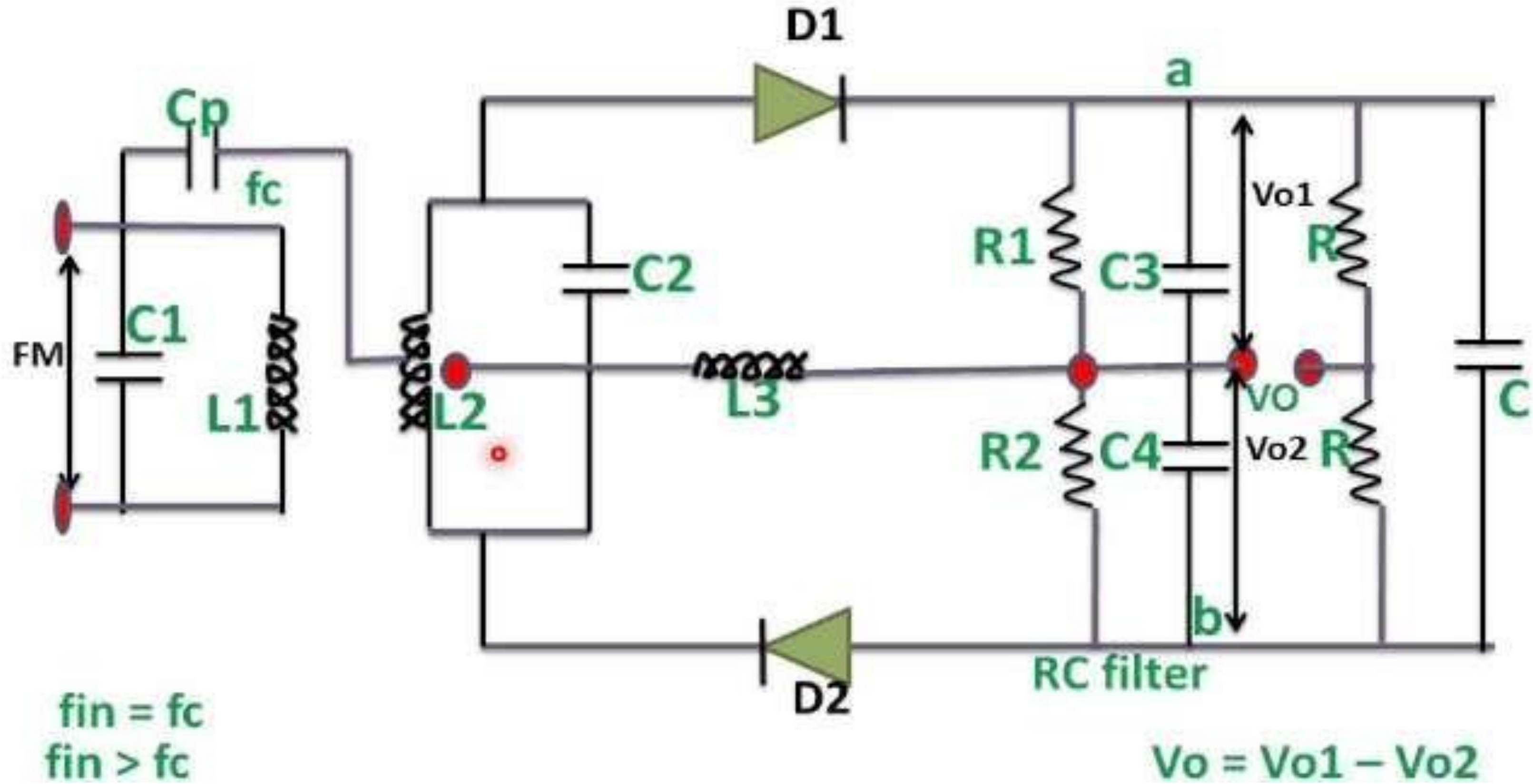



FM slope detector circuit showing the signal waveforms

# Foster Seeley Demodulator



# RATIO DEMODULATOR



# PHASE MODULATION

- Phase modulation is another type of angle modulation in which the phase of the carrier wave is changed according to the amplitude (magnitude) of the message (modulating) signal.

The carrier signal is given as

$$\mathbf{c(t) = V_C \sin(\omega_c t + \varphi)}$$

So, the phase modulated wave will be

$$\mathbf{s(t) = V_C \sin(\omega_c t + \varphi_m \sin \omega_m t)}$$

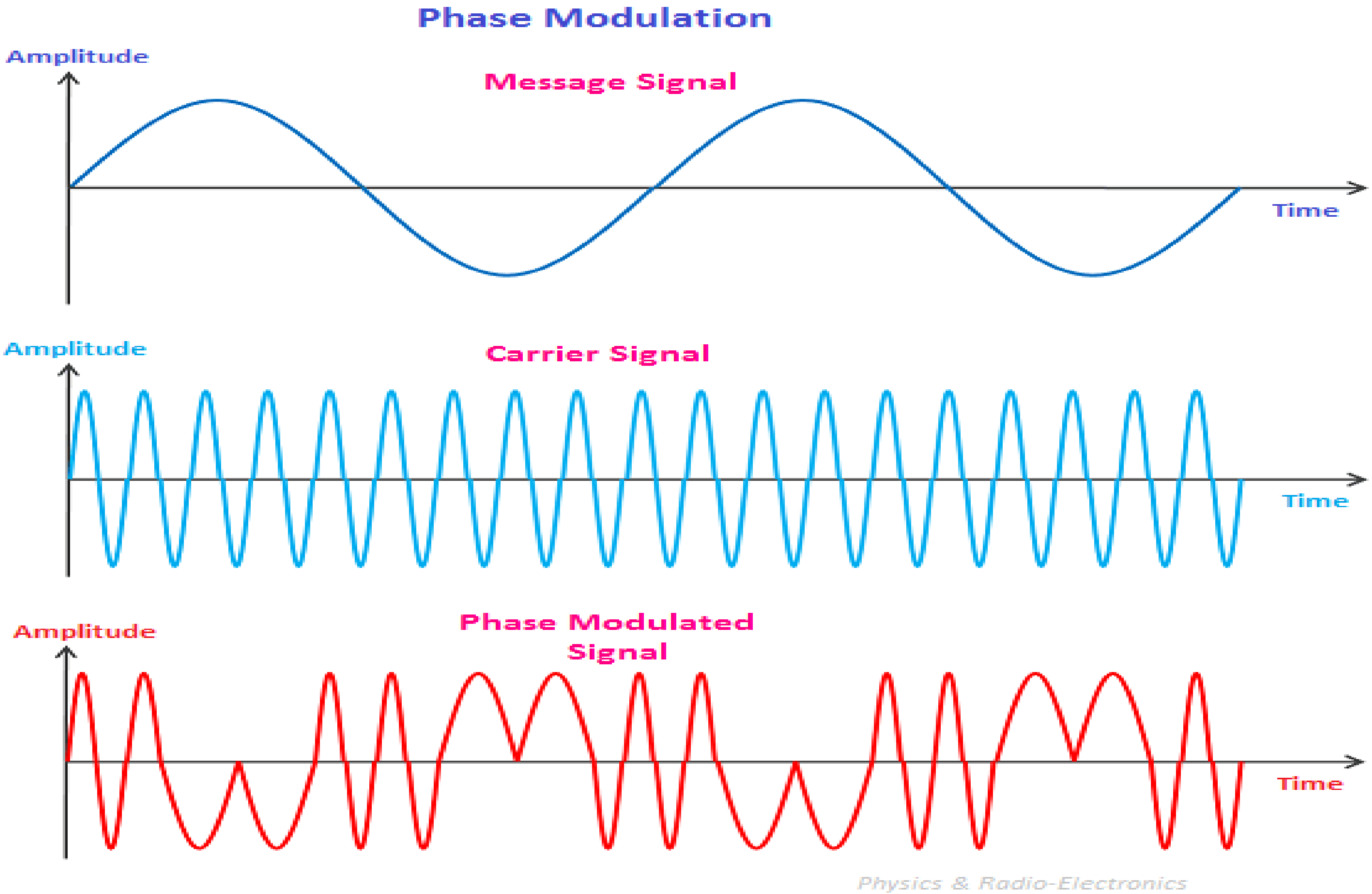
$$\mathbf{s(t) = V_C \sin(\omega_c t + m_p \sin \omega_m t)}$$

: $\varphi_m = m_p$ = modulation index

wave is given as

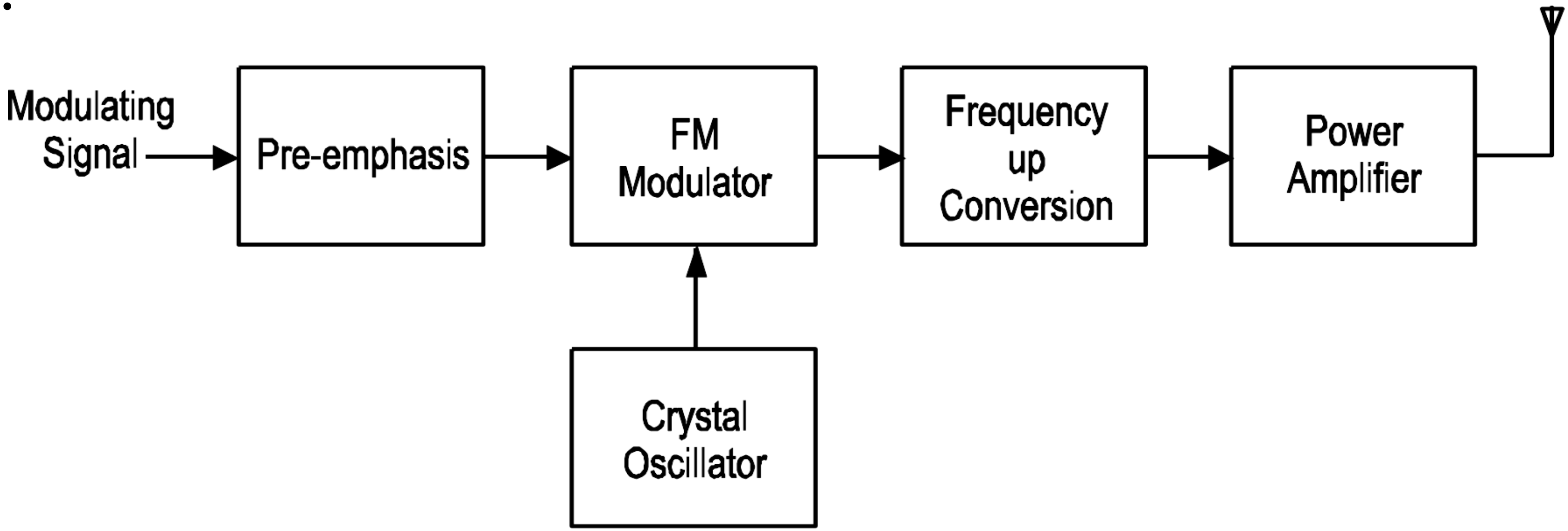
$$\mathbf{m_p = K_p V_m}$$

# PM WAVEFORMS



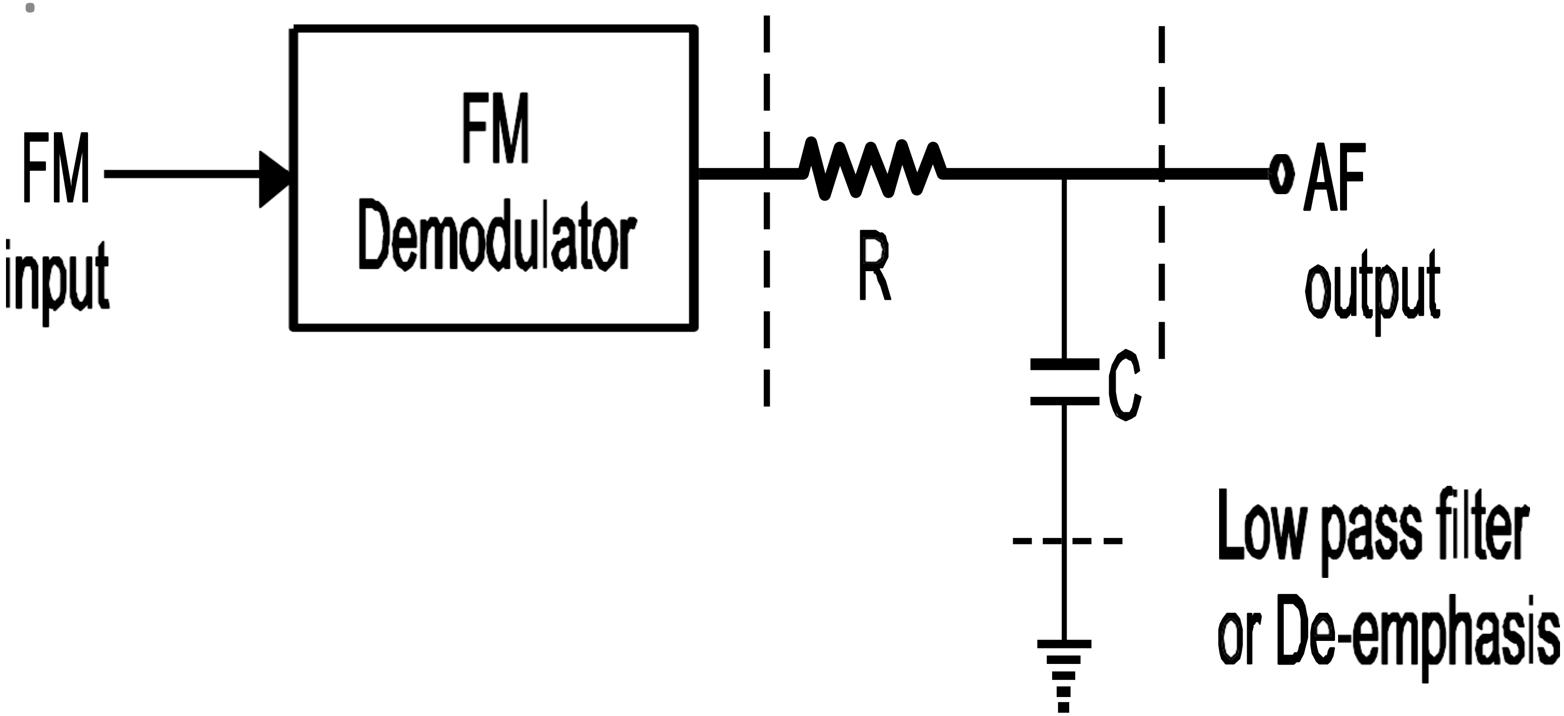
# PRE-EMPHASIS

•

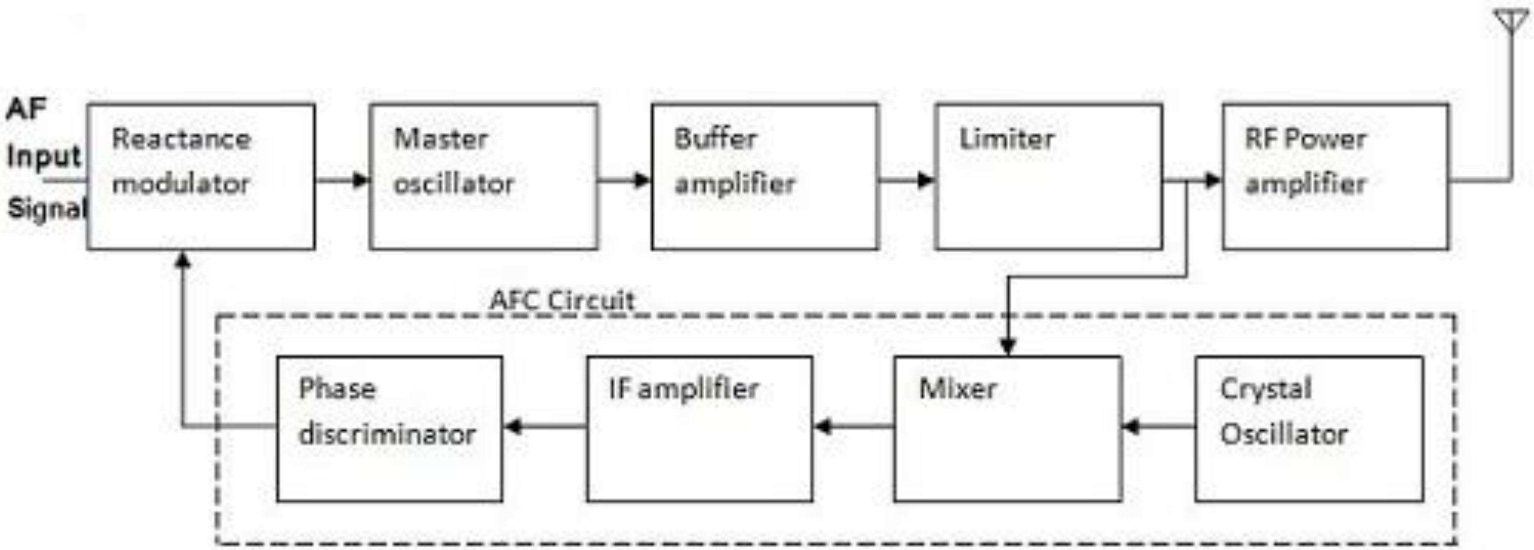


# DE-EMPHASIS

•


FM
input
FM
Demodulator
R
C
AF
output
Low pass filter
or De-emphasis

# FM TRANSMITTER



# REFERENCES


- https://en.wikipedia.org/wiki/Frequency_modulation
- https://en.wikipedia.org/wiki/Phase_modulation
- https://www.daenotes.com/electronics/communication-system/pre-emphasis-and-de-emphasis
- https://www.etechnog.com/2019/10/fm-transmitter-block-diagram-working.html

**SIDDARTHA INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(Autonomous)**
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)
(NAAC Accredited Institution with 'A' Grade)
SIDDHARTH NAGAR, NARAYANAVANAM ROAD, PUTTUR – 517 583
CHITTOOR DIST., A.P., INDIA

# Unit-4
# Radio Receivers & Noise

**Prepared**
**By**
**Dr.B.SAROJA Ph.D(Professor)**
**S.ROJA M.Tech(Assistant Professor)**

# COURSE OBJECTIVES

- Students are able to study the fundamental concepts of the analog communication system.
- Students are able to analyze various analog modulation and demodulation techniques.
- Students are able to know the working of various transmitters and receivers.
- Students are able to understand the influence of noise on the performance of analog communicationsystems, and to acquire the knowledge about information and capacity.

# COURSE OUTCOMES

- ➢ Describe the fundamentals of Analog Communication Systems
- ➢Express the concept of various Analog Modulation schemes and Multiplexing.
- ➢Compute various parameters of continuous and pulse wave modulation Techniques.
- ➢Analyze various continuous and pulse wave modulation and Demodulation Schemes.
- ➢Estimate the performance of Analog Communication System in the presence of noise.
- ➢Identify different Radio receivers and understand the concept of coding schemes in Information theory.

# CONTENTS

- Introduction to radio receivers
- Parameters
- Superheterodyne AM Receiver.
- Superheterodyne FM Receiver
- Review of noise
- Noise sources
- Noise figure
- Performance analysis of AM
- Performance analysis of DSB-SC
- Performance analysis of SSB-SC

# Introduction to radio receivers

- In radio communications, a radio receiver (receiver or simply radio) is an electronic device that receives radio waves and converts the information carried by them to a usable form.

- **Types of Receivers:**The TRF(Tuned radio frequency) receiver and super heterodyne receiver are the two main configuration of the receivers, they have real practical or commercial significance.
- Most of the present day receivers use superheterodyne configuration.
- But the TRF receivers are simple and easy to understand.

# PARAMETERS

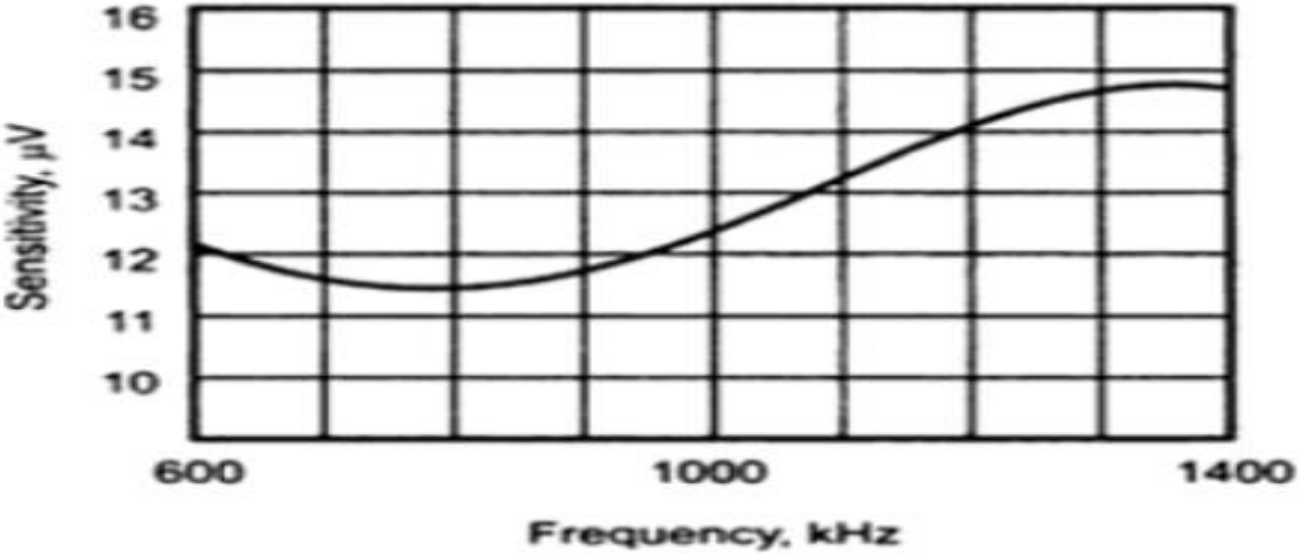
1.Sensitivity

2.Selectivity

3.Fidelity

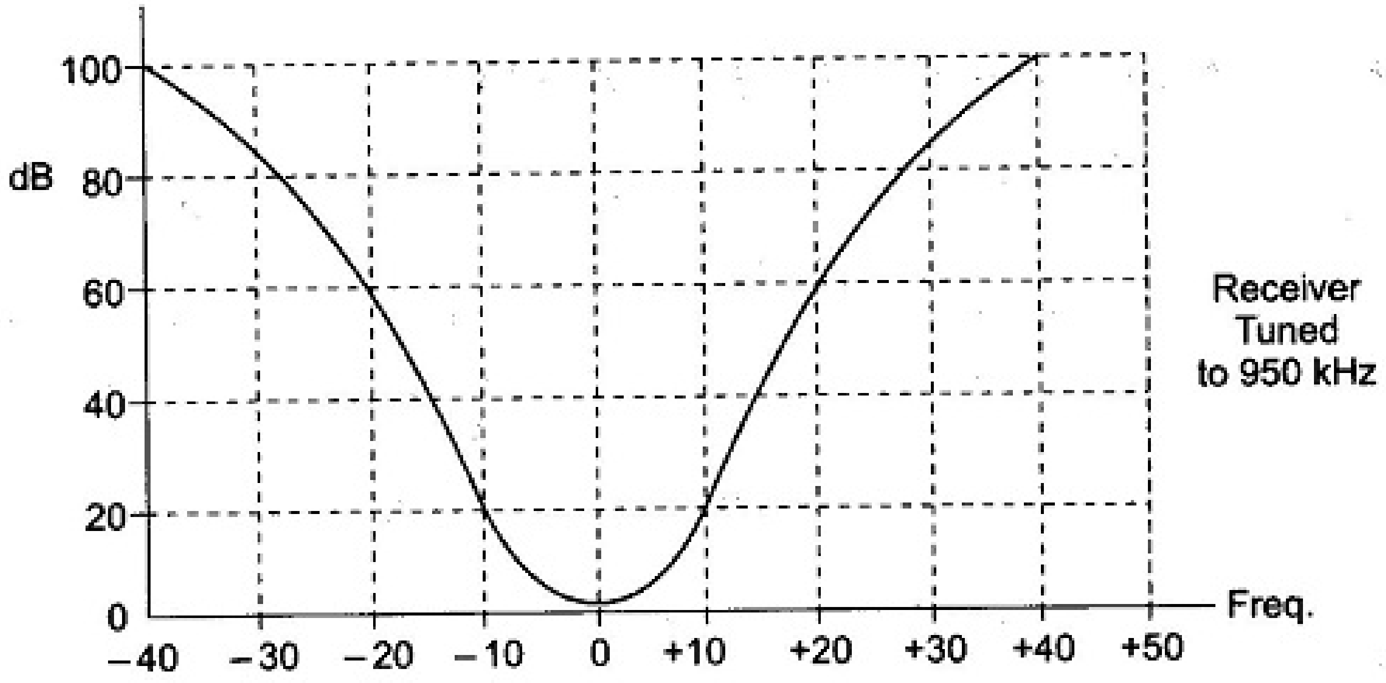
## 1.Sensitivity:

It is defined as the ability of a receiver to amplify weak signals.



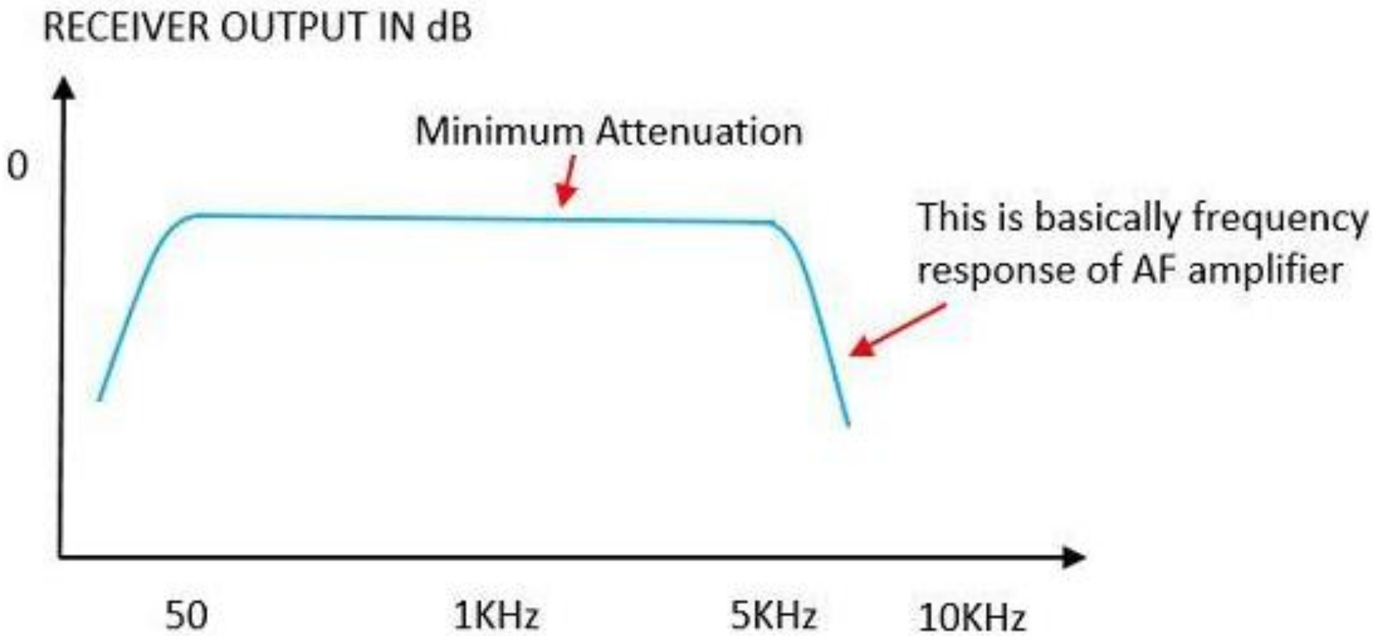
## 2.selectivity:

It is the ability of a receiver to select a signal of a desired frequency while reject all others.

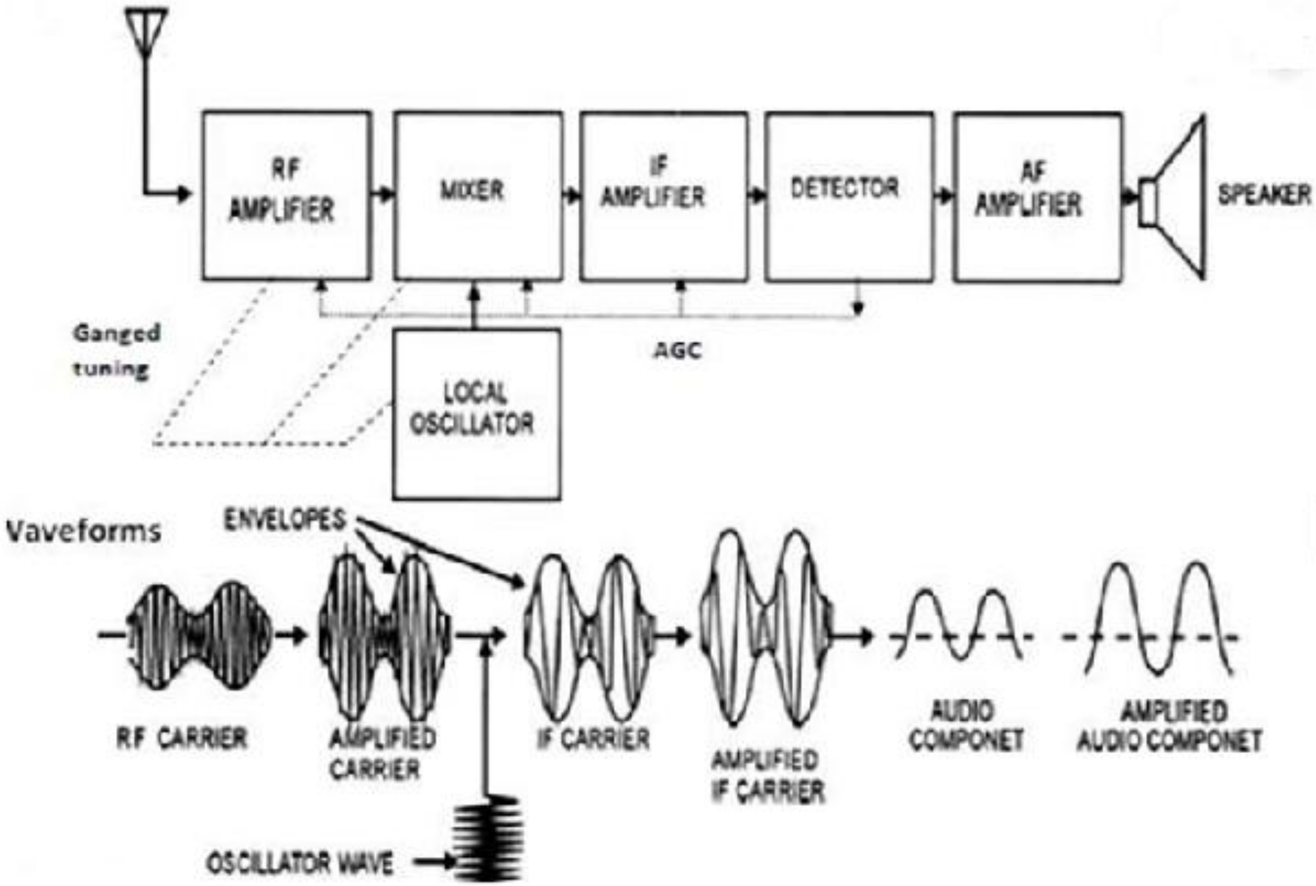


## 3.Fidelity:

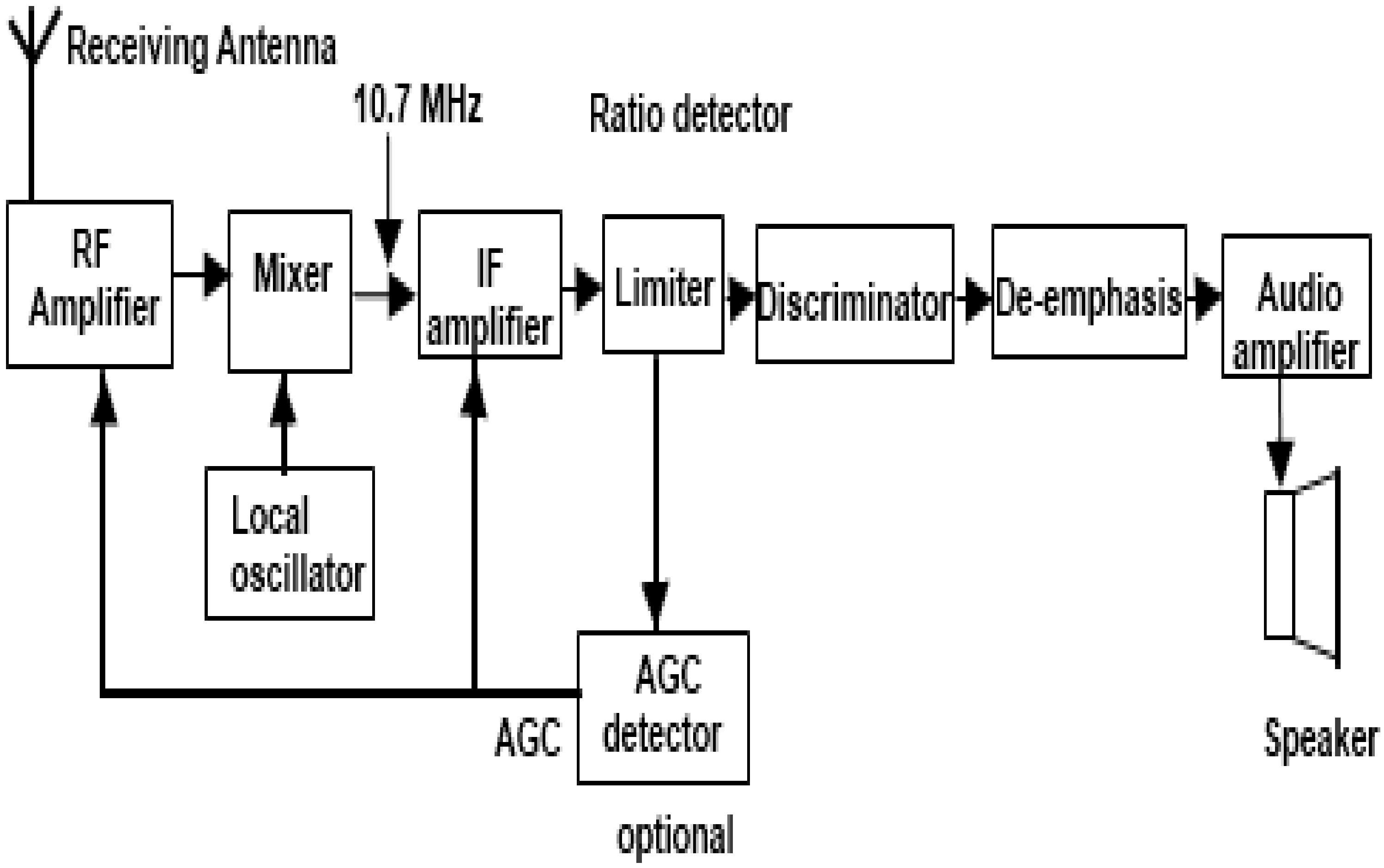
It is the ability of a receiver to reproduce all the modulating frequencies equally.



# SUPERHETERODYNE AM RECEIVER



# SUPERHETERODYNE FM RECEIVER



# REVIEW OF NOISE

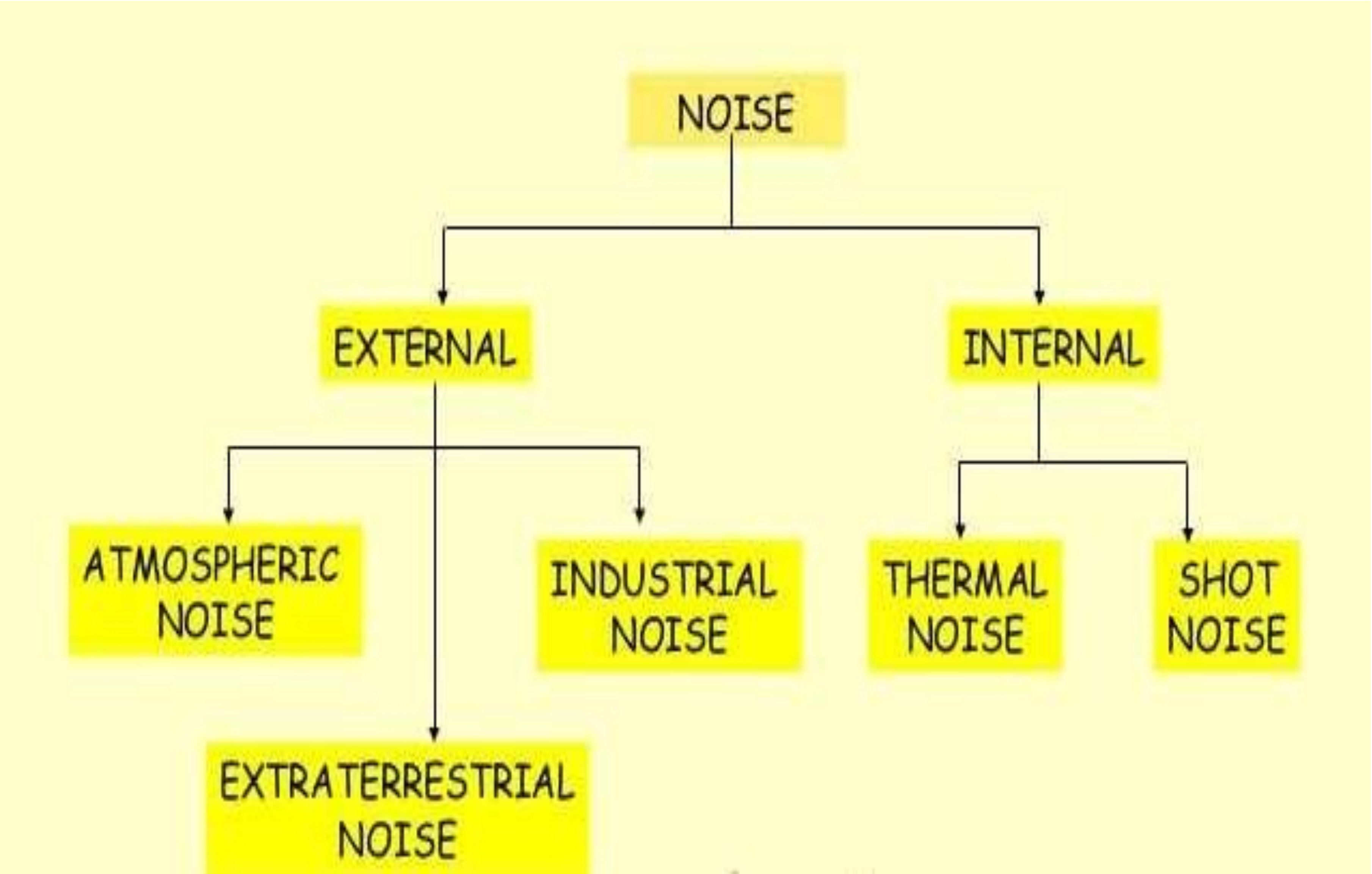
- It is an unwanted signal which tends to interfere with the modulating signal.

**Types of noise**:

Noise is basically divided into

- External Noise
- Internal Noise

# NOISE SOURCES



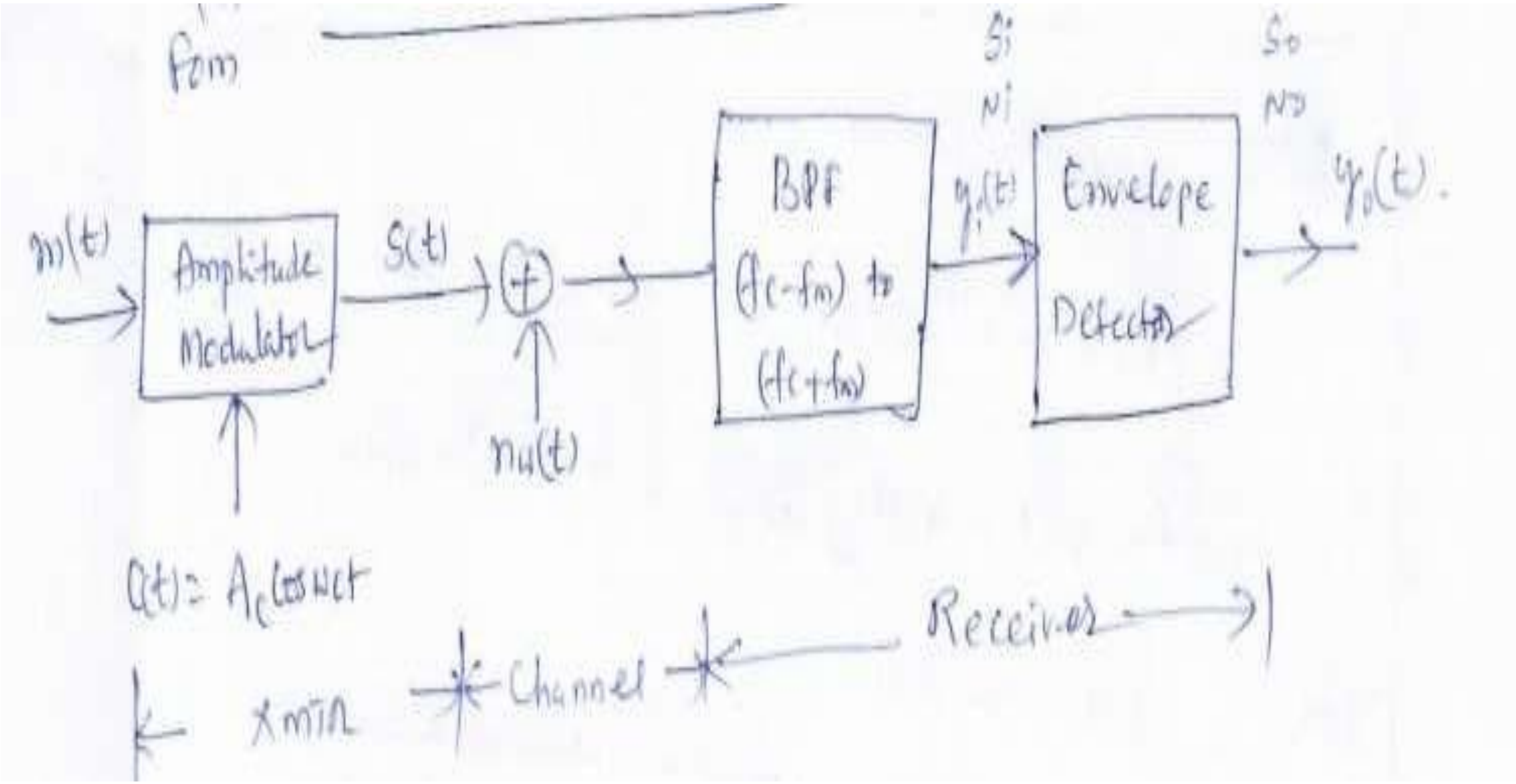
# NOISE FIGURE

- It is the ratio of output and input noise of an amplifier or network.
- It is expressed as, Fn= $\frac{KT_0BG + \Delta N}{KT_0BG}$

Where,

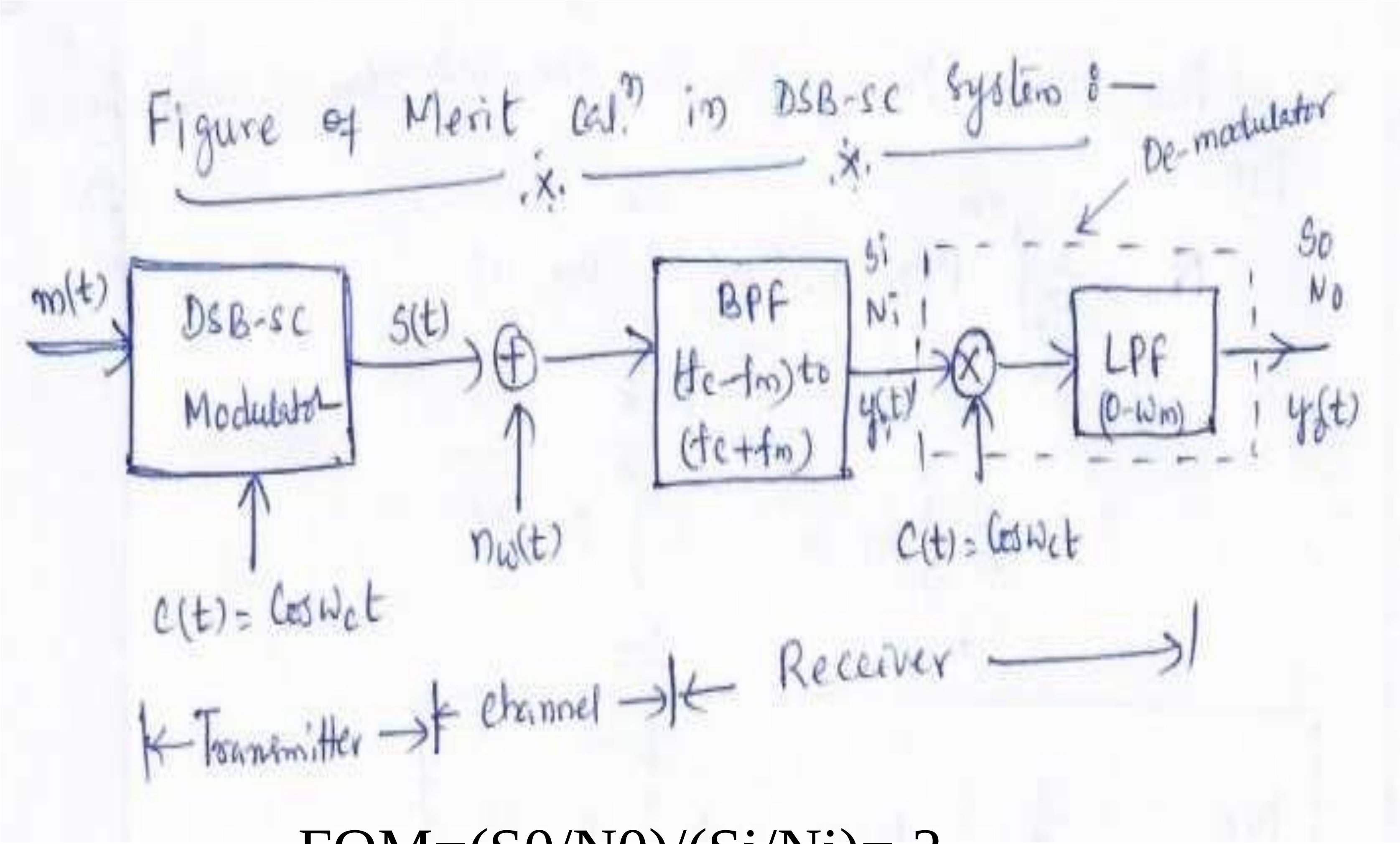
$\Delta$ N = Noise added by the network or amplifier.
G = gain of an network or amplifier

# S/N RATIO OF AM



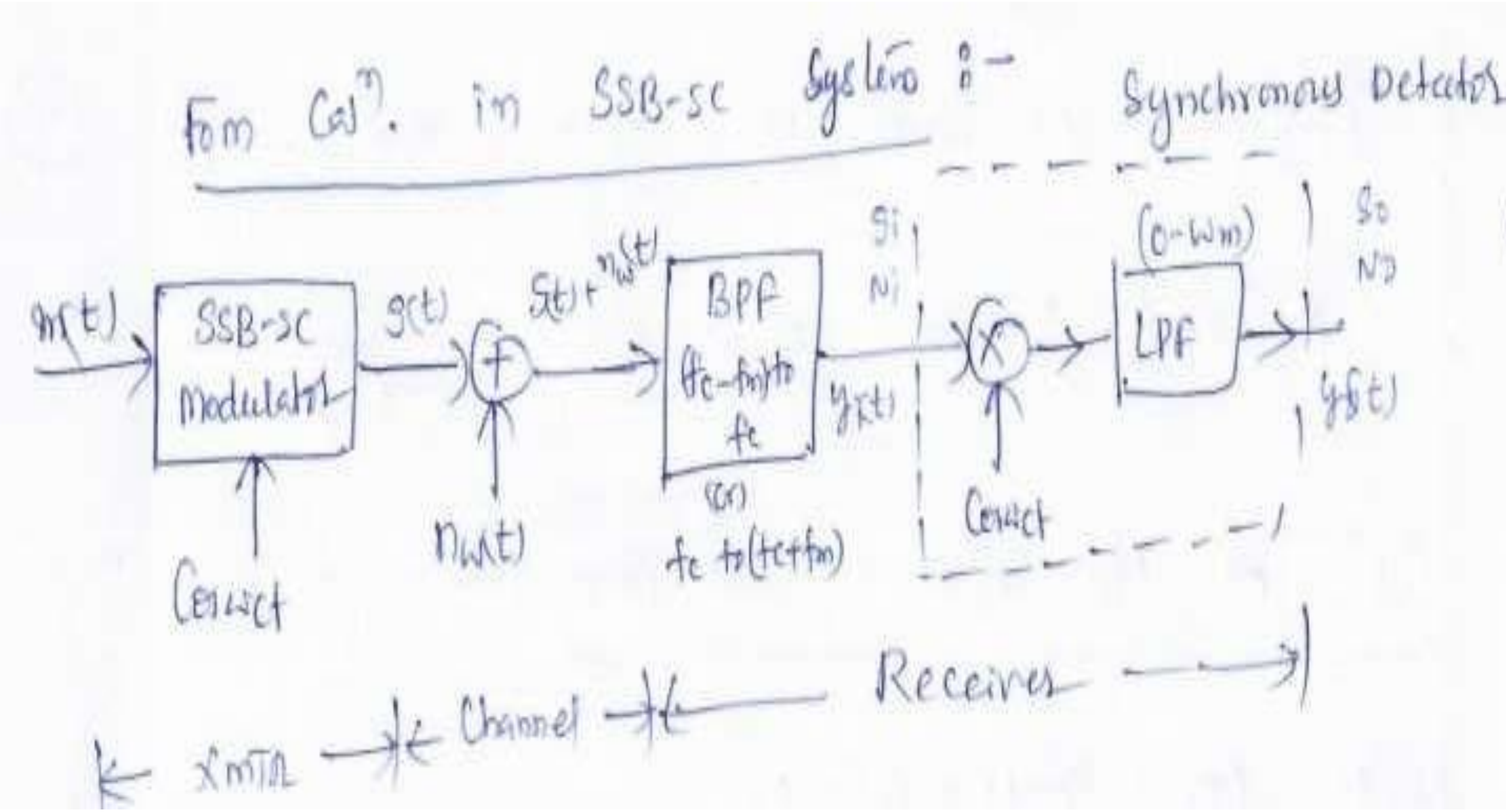

FOM= 2

# S/N RATIO OF DSBSC




FOM=(S0/N0)/(Si/Ni)= 2

# S/N RATIO OF SSBSC




FOM= (S0/N0)/(Si/Ni)= 1

# REFERENCES


- https://mrcet.com/downloads/digital_notes/ECE/III%20Year/ANALOG%20COMMUNICATIONS-18.pdf
- https://electronicsdesk.com/noise-in-communication-system.html
- https://www.youtube.com/watch?v=WT1Y97riAQQ
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4098065/
- https://ccrma.stanford.edu/~jos/sasp/Filtered_White_Noise.html

**SIDDARTHA INSTITUTE OF SCIENCE AND TECHNOLOGY**
**(Autonomous)**
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)
(NAAC Accredited Institution with 'A' Grade)
SIDDHARTH NAGAR, NARAYANAVANAM ROAD, PUTTUR – 517 583
CHITTOOR DIST., A.P., INDIA

# Unit – 5

# Analog Pulse Modulation Schemes And Information Theory

**Prepared**
**By**
**Dr.B.SAROJA Ph.D(Professor)**
**S.ROJA M.Tech(Assistant Professor)**

# COURSE OBJECTIVES

- Students are able to study the fundamental concepts of the analog communication system.
- Students are able to analyze various analog modulation and demodulation techniques.
- Students are able to know the working of various transmitters and receivers.
- Students are able to understand the influence of noise on the performance of analog communication systems, and to acquire the knowledge about information and capacity.

# COURSE OUTCOMES

- Describe the fundamentals of Analog Communication Systems
- Express the concept of various Analog Modulation schemes and Multiplexing.
- Compute various parameters of continuous and pulse wave modulation Techniques.
- Analyze various continuous and pulse wave modulation and Demodulation Schemes.
- Estimate the performance of Analog Communication System in the presence of noise.
- Identify different Radio receivers and understand the concept of coding schemes in Information theory.

# CONTENTS

- Pulse amplitude modulation (PAM) & demodulation
- Transmission bandwidth
- Pulse-Time Modulation
- Pulse Duration modulation and demodulation
- Pulse Position modulation and demodulation
- Multiplexing Techniques FDM, TDM.
- Introduction to information theory
- Entropy
- Mutual information
- Channel capacity theorem
- Shannon-Fano encoding algorithm

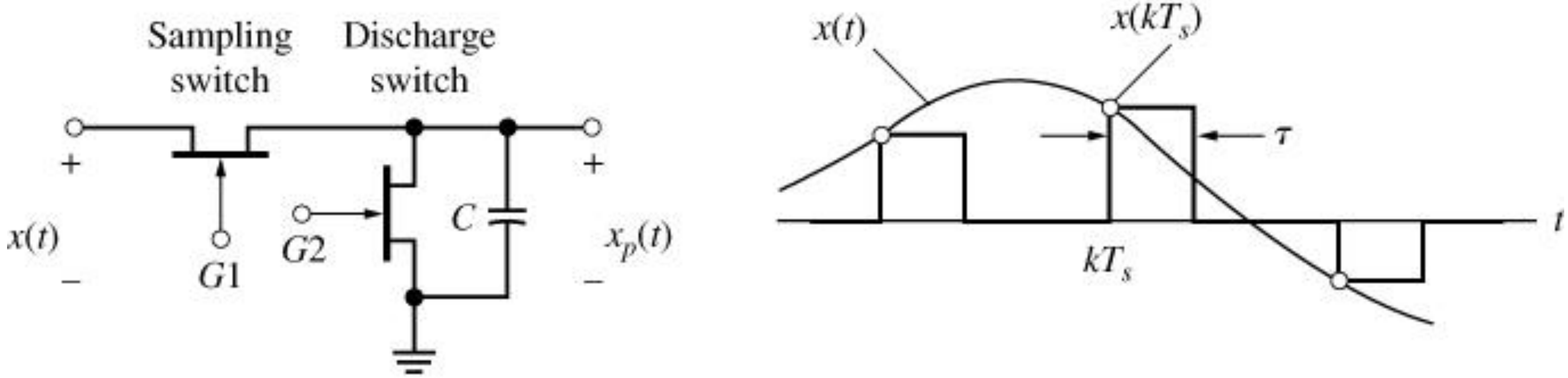
# PULSE MODULATION

- The process of transmitting the signals in the form of pulses by using some special techniques.

- There are two types of pulse modulation systems,
  - Pulse Amplitude Modulation
  - Pulse Time Modulation

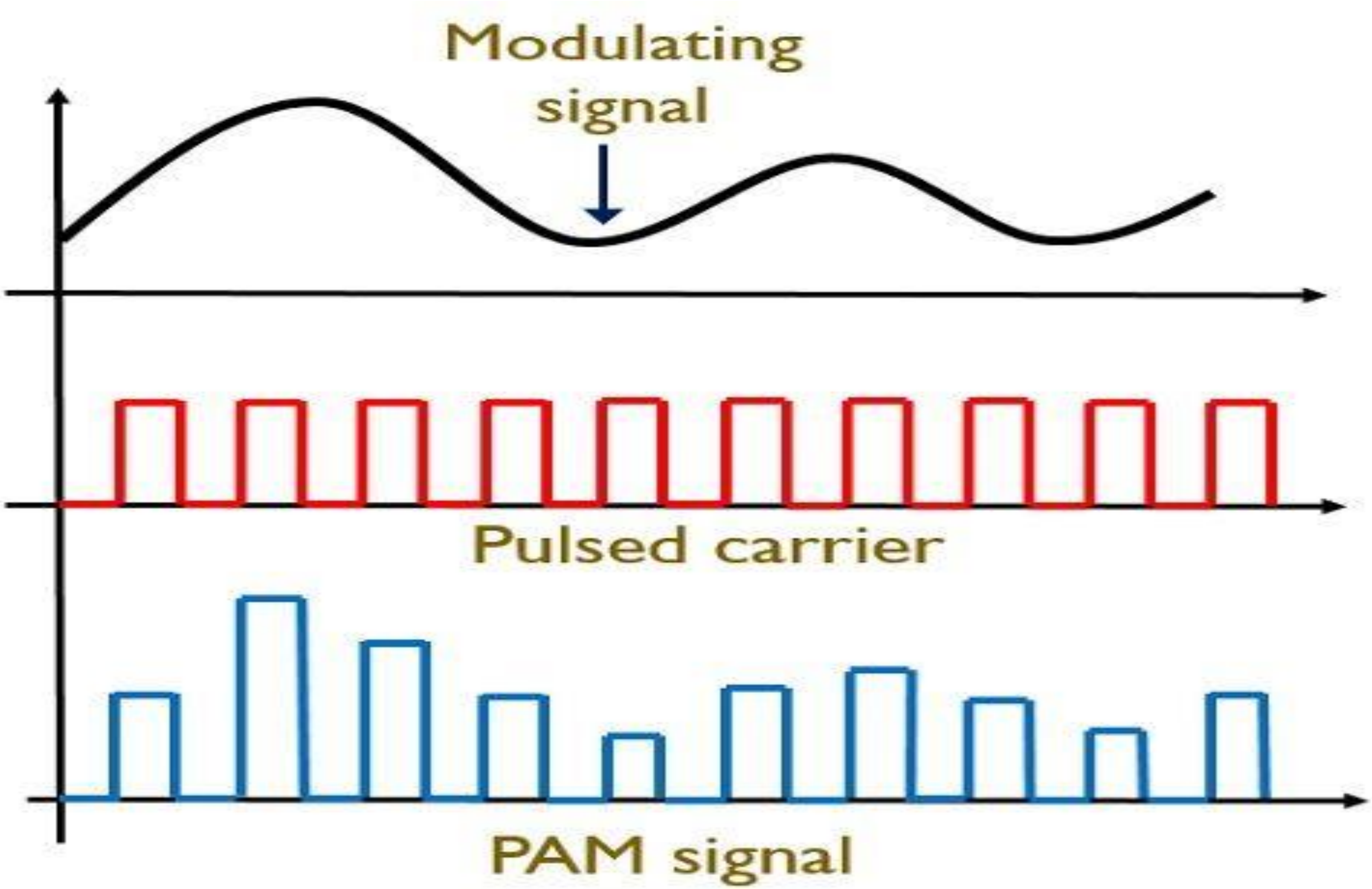
- Pulse time modulation is further divided into,
  - Pulse Width Modulation
  - Pulse Position Modulation

# PULSE AMPLITUDE MODULATION(PAM)

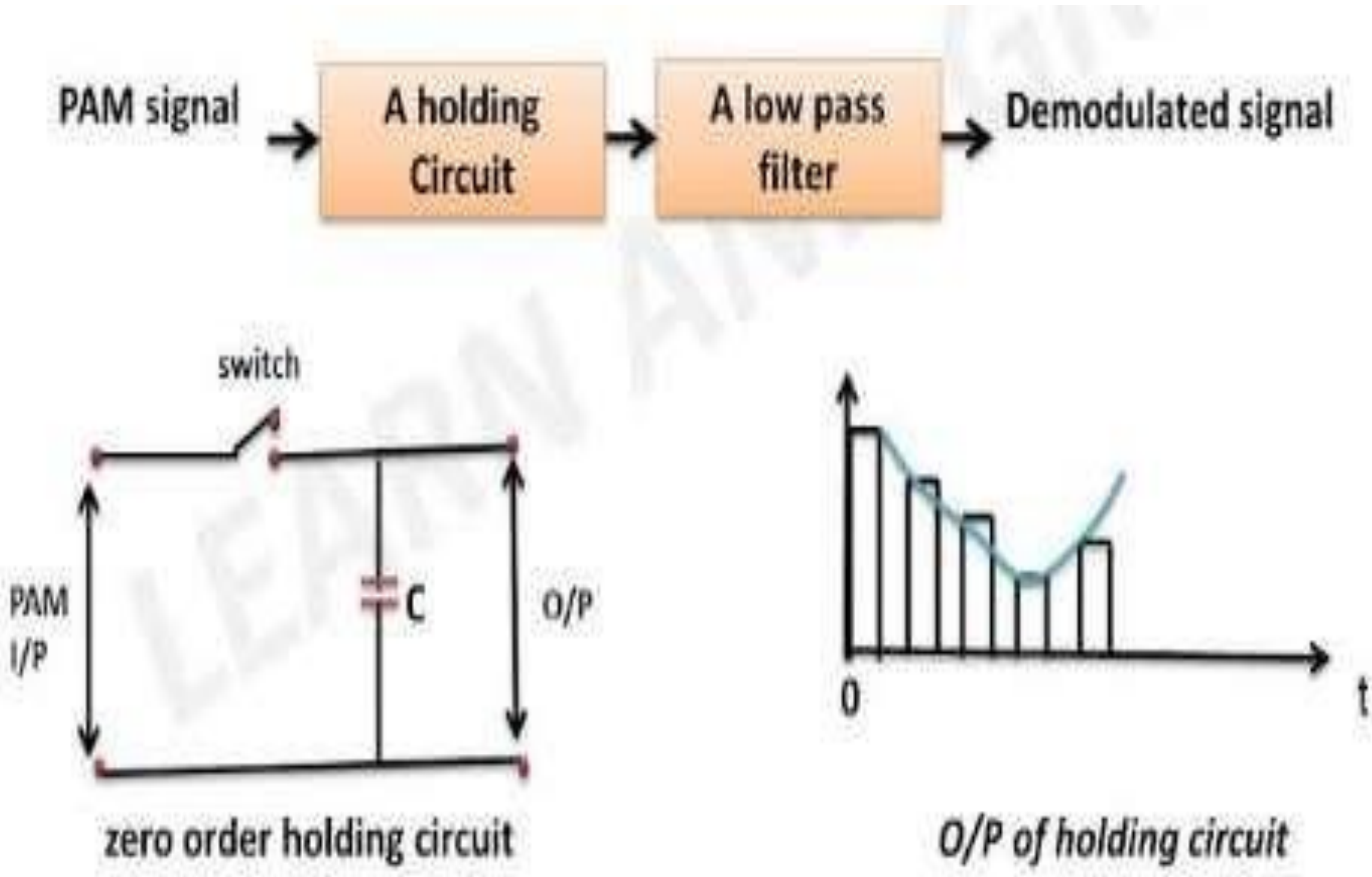



(a) (b)

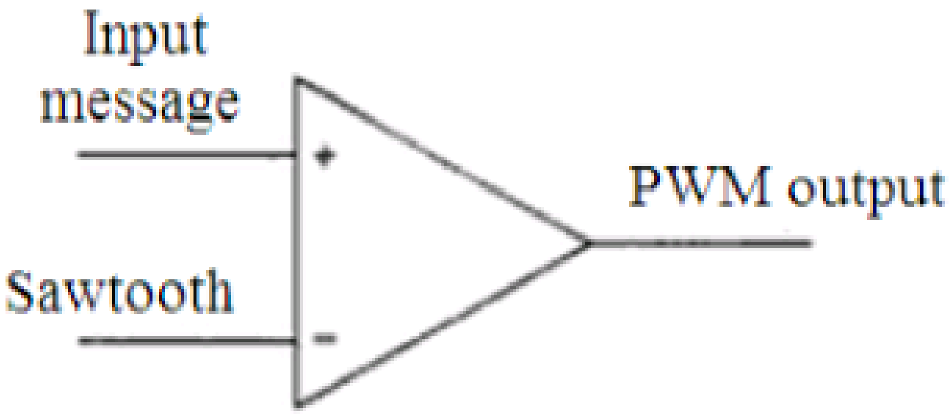
# WAVEFORMS



# DEMODULATION OF PAM

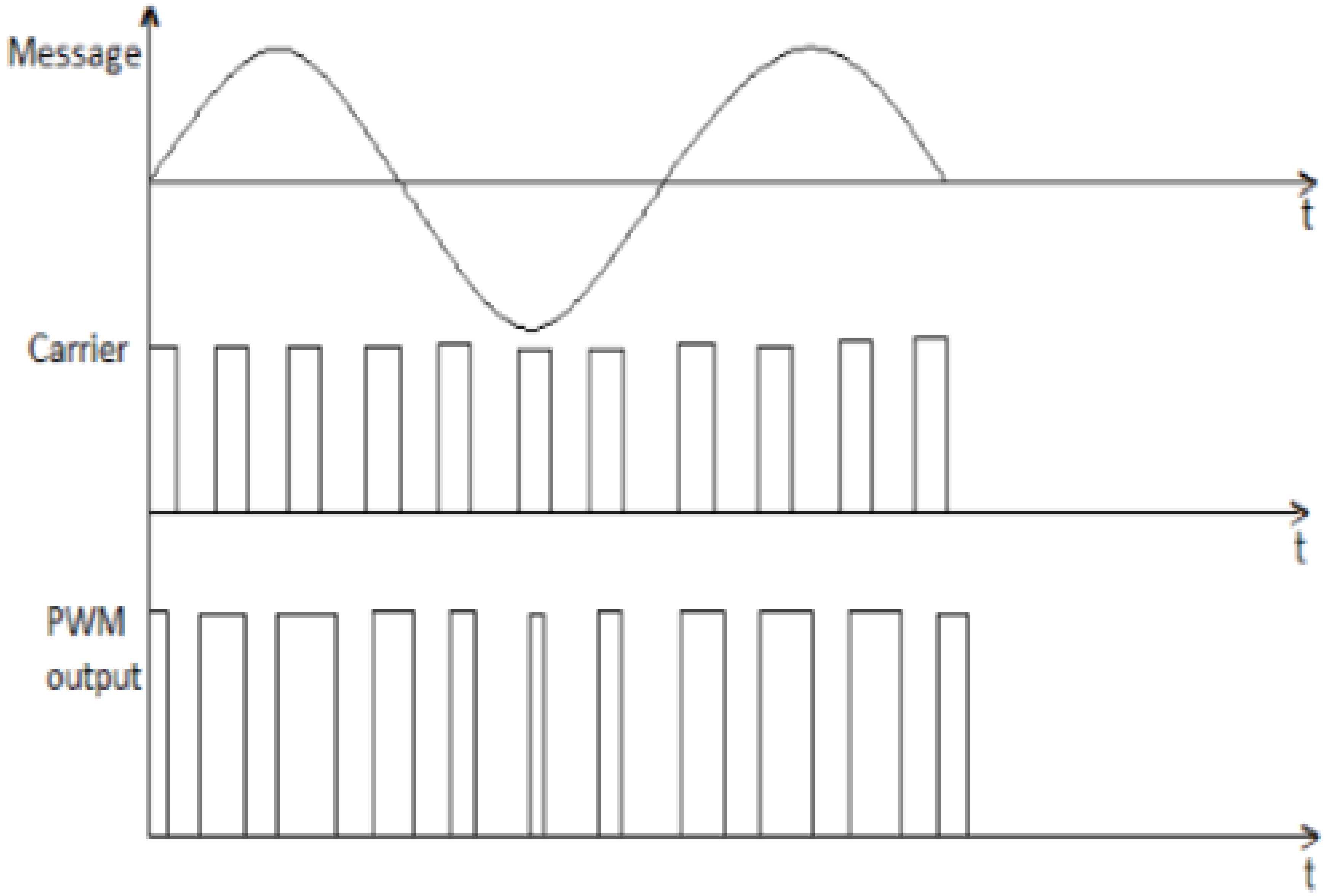


# PULSE WIDTH MODULATION(PWM)

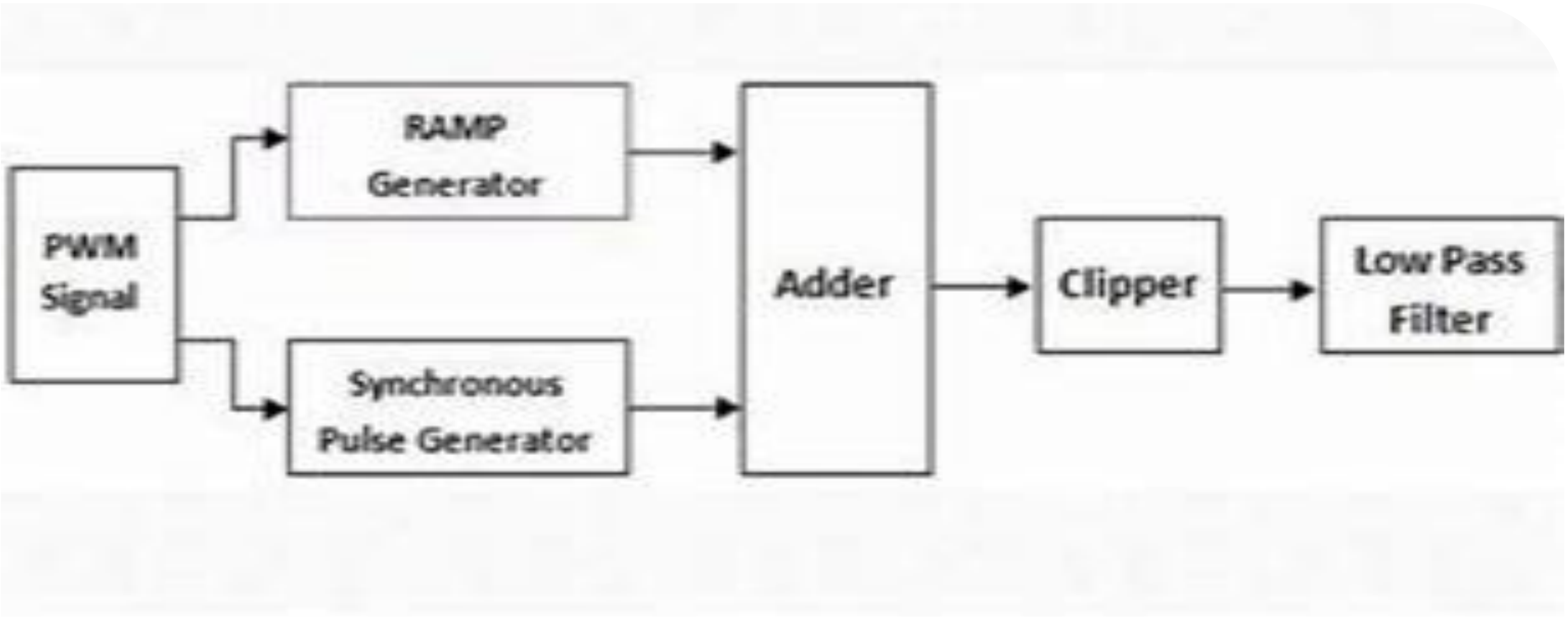



PWM signal can be generated by using a comparator, where modulating signal and sawtooth signal form the input of the comparator. It is the simplest method for PWM generation.

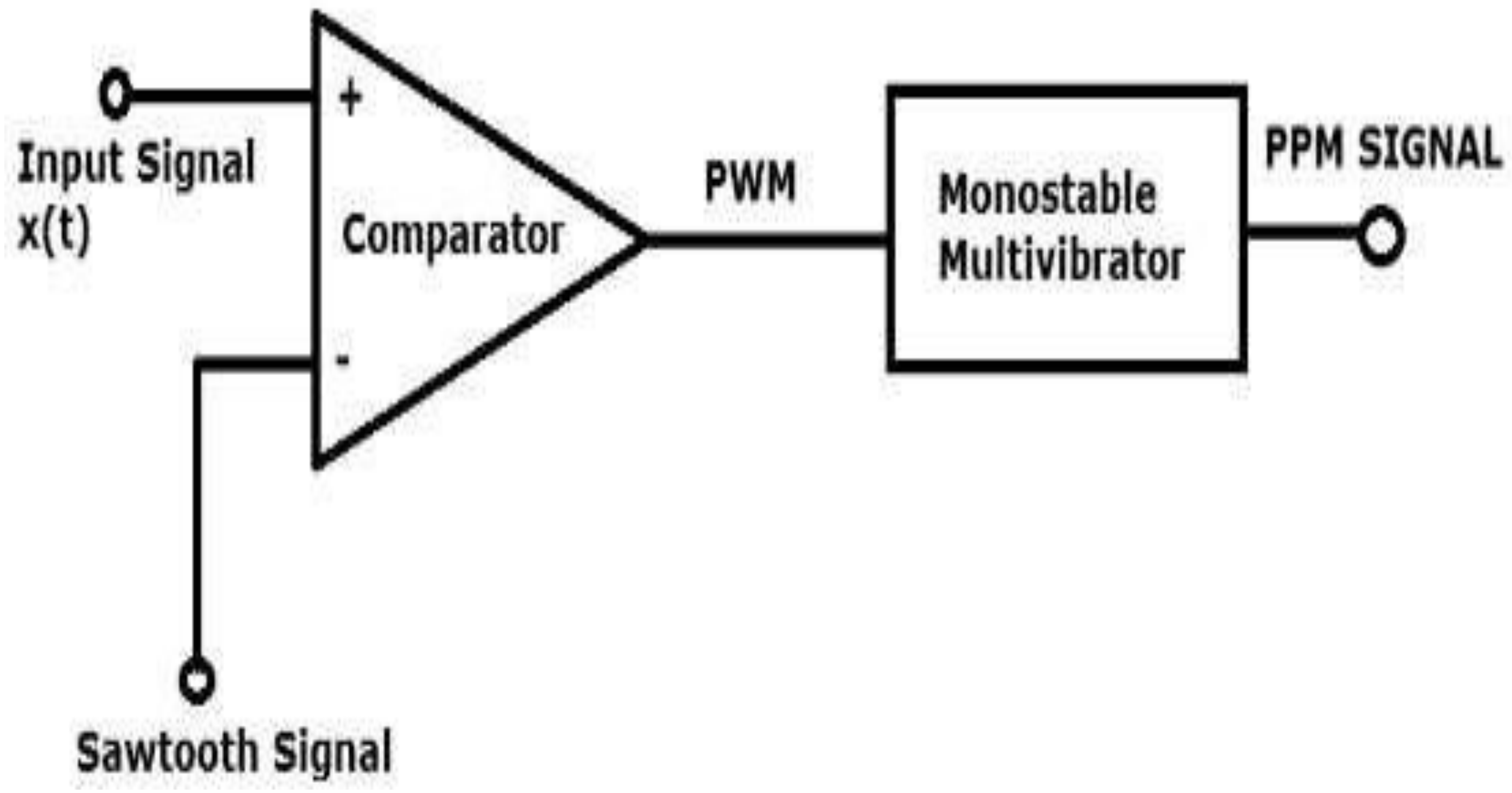
# WAVEFORMS



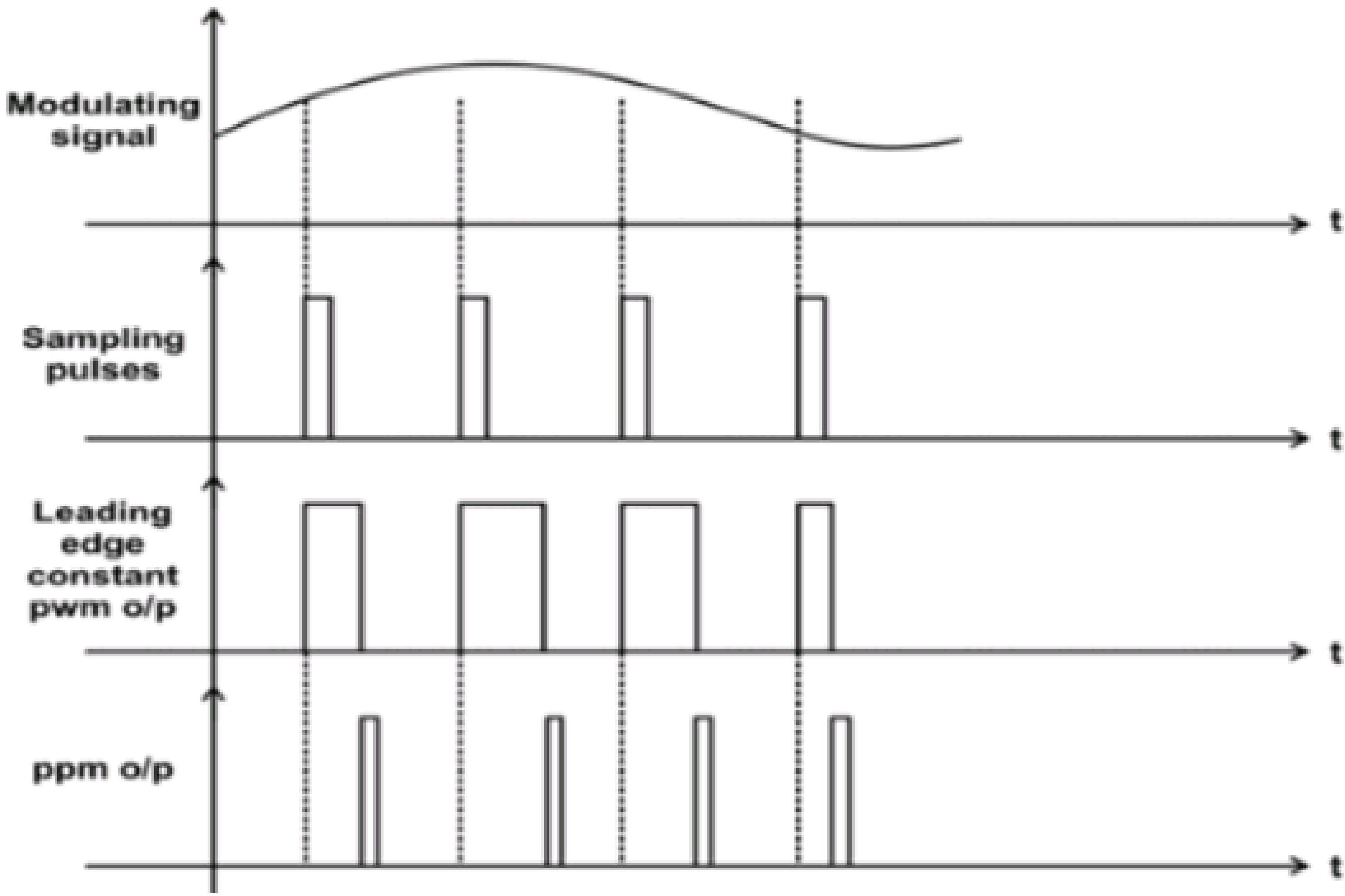
# DETECTION OF PWM



# PULSE POSITION MODULATION(PPM)

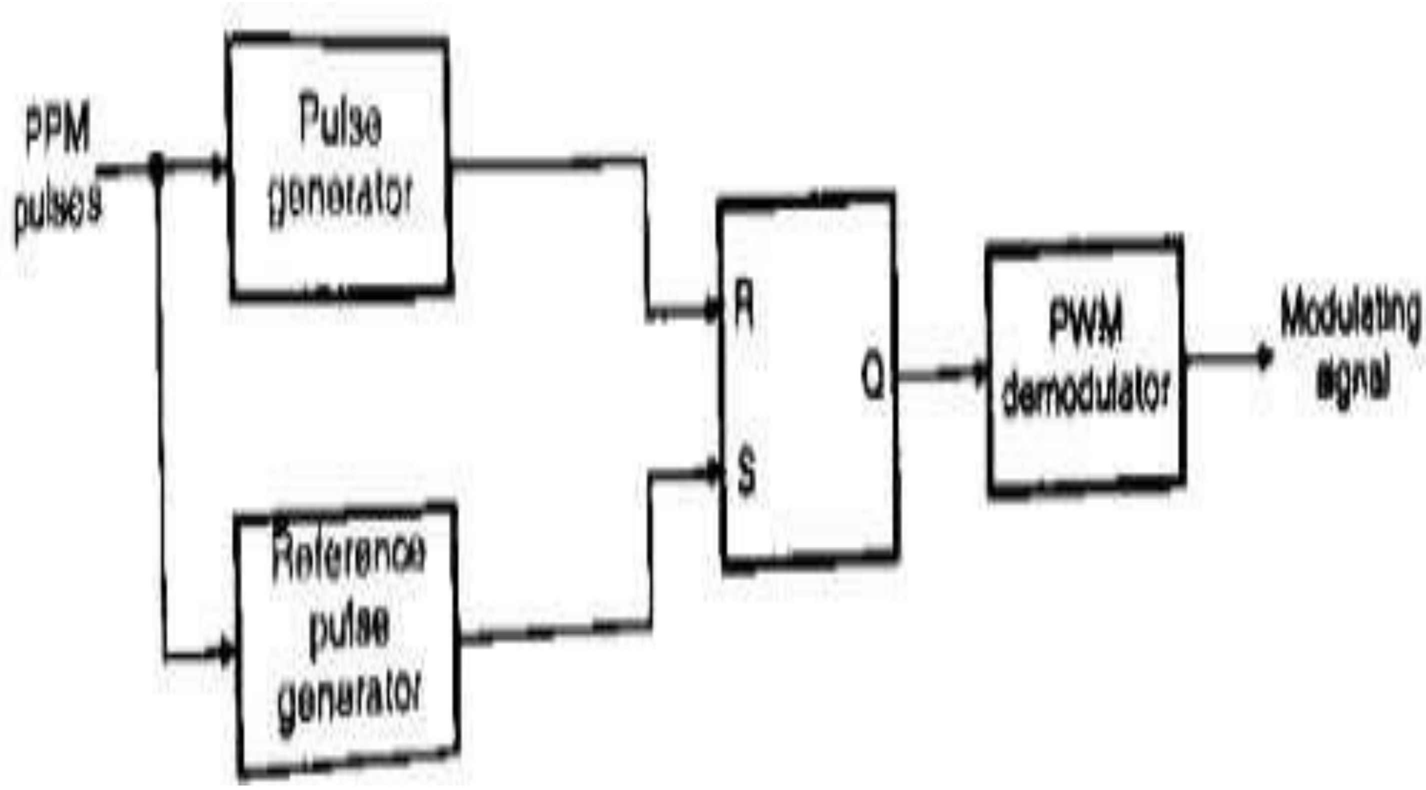


# WAVEFORMS



Modulating signal
t
Sampling pulses
t
Leading edge constant pwm o/p
t
ppm o/p
t

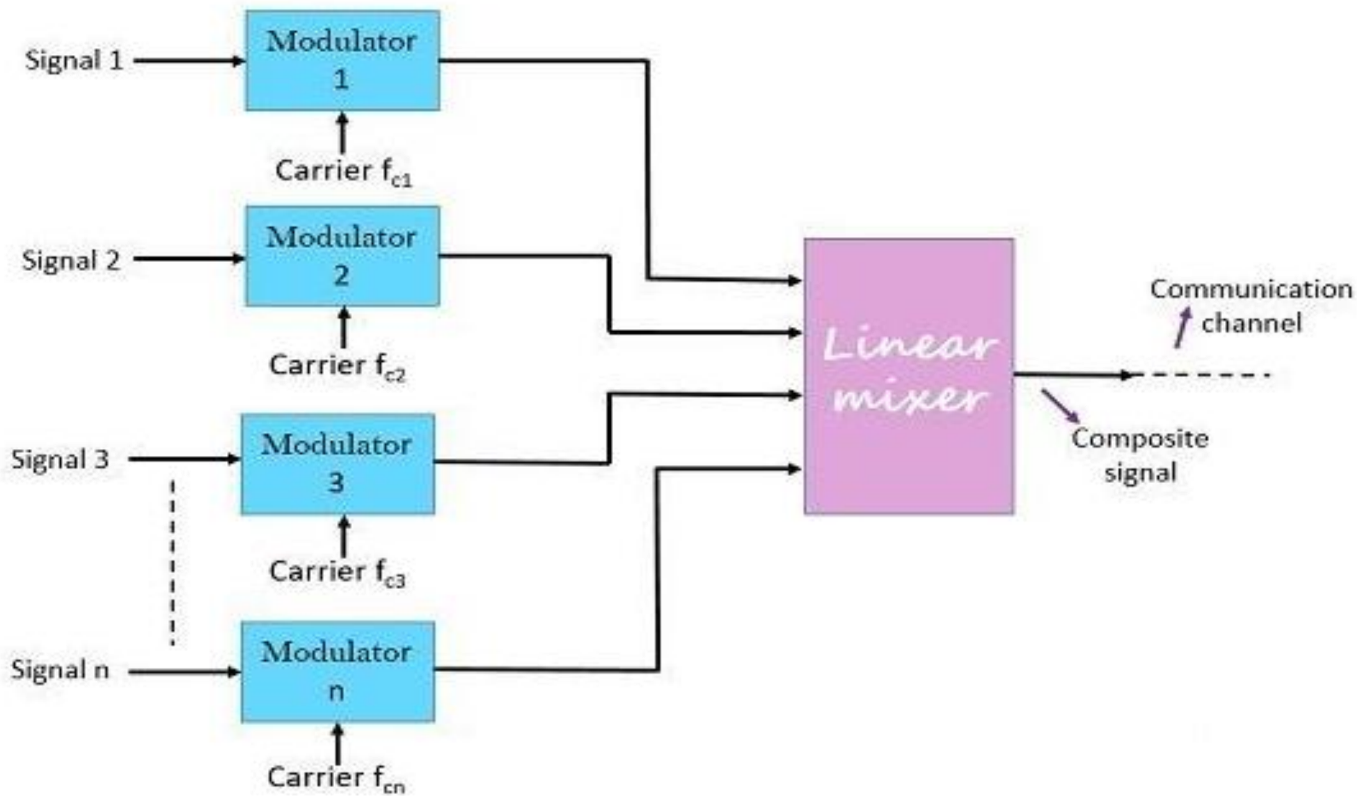
# DETECTION OF PPM



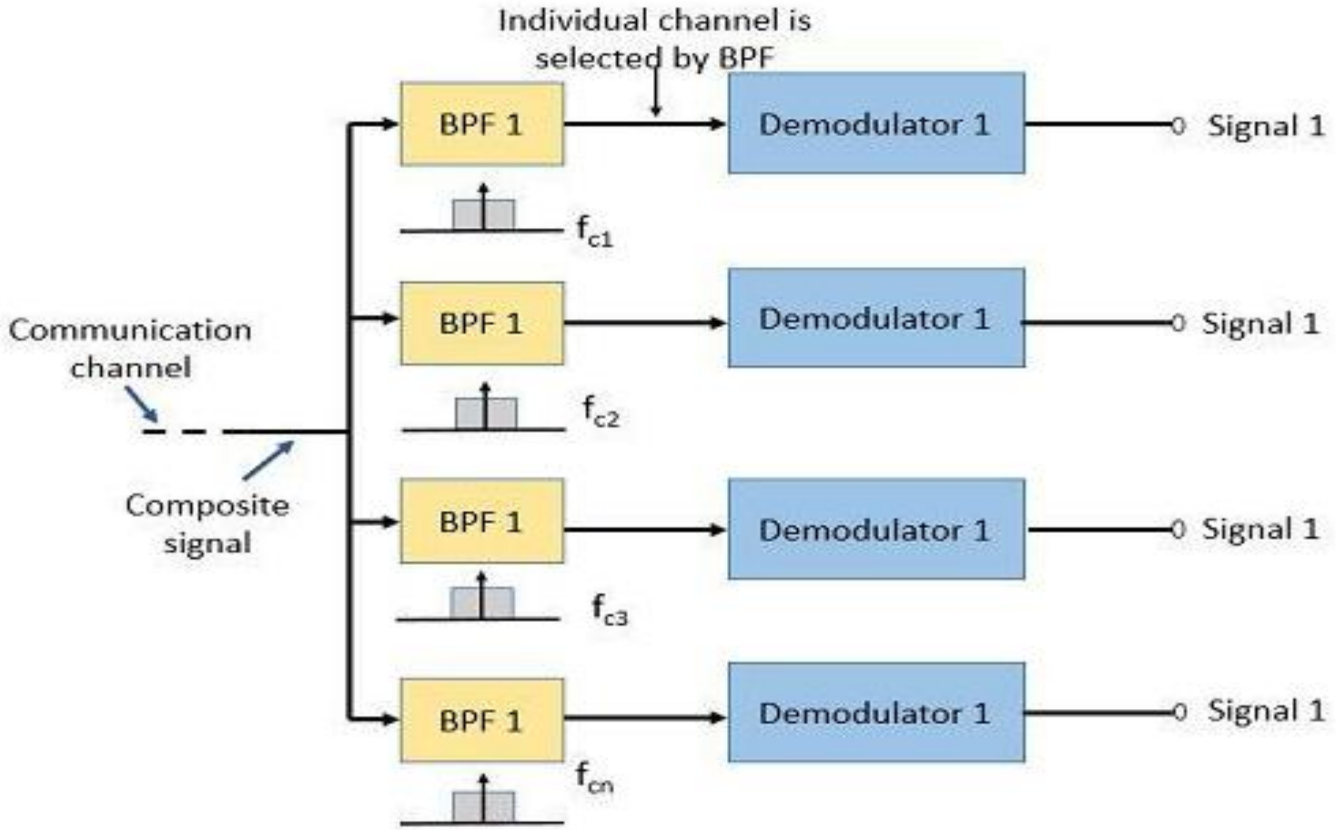
# Comparison of PAM,PWM,PPM

| PAM | PWM | PPM |
|---|---|---|
| Amplitude of pulse is proportional to amplitude of modulating signal. | Width of pulse is proportional to amplitude of modulating signal. | Relative position of pulse is proportional to amplitude of modulating signal. |
| Band width of transmitting channel depends on width of pulse. | Band width of transmitting channel depends on rise time of the pulse. | Band width of transmitting channel depends on rise time of the pulse. |
| Instantaneous power of transmitter varies. | Instantaneous power of transmitter varies. | Instantaneous power remains constant. |
| Noise interference is high. | Noise interference is minimum. | Noise interference is minimum. |
| Complex system. | Simple to implement. | Simple to implement. |
| Similar to A.M. | Similar to F.M. | Similar to P.M. |

# FDM Multiplexing



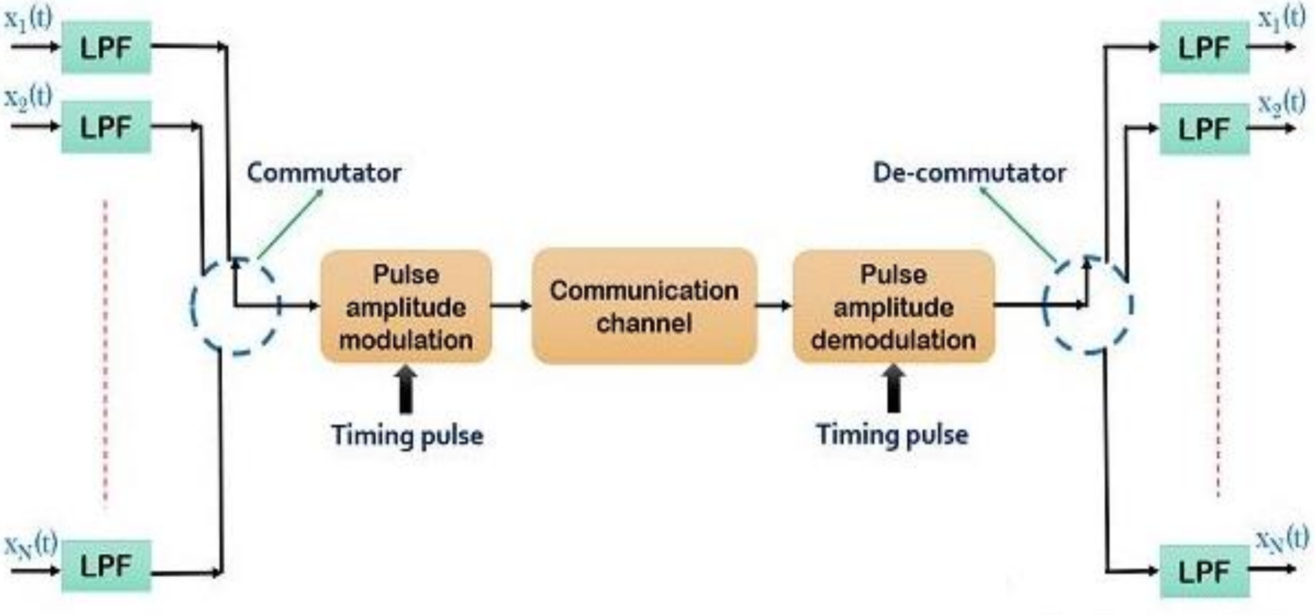
# FDM Demultiplexing



# Time Division Multiplexing (TDM)

- Time division multiplexing shares a circuit among two or more terminals by having them take turns, dividing the circuit “vertically.”
- Time on the circuit is allocated even when data are not transmitted, so that some capacity is wasted when a terminal is idle.
- Time division multiplexing is generally more efficient and less expensive to maintain than frequency division multiplexing, because it does not need guard bands.

# Time Division Multiplexing (TDM)



# INFORMATION THEORY

- Information is defined as a sequence of letters, alphabets, symbols which carries a message with specific meaning.

  **Source of Information**:

The sources of information can be divided into 2 types.

  - Analog Information sources
  - Digital information sources

- Analog information sources produce continuous amplitude continuous time electrical waveforms.
- The unit of information is bit.

# ENTROPY

- Entropy is defined as the average amount of information conveyed by a message. It is denoted by H.

$$H(X) = \sum_{K=1}^{M} Pk \log \frac{1}{Pk}$$

**Properties of Entropy:**

1.Entropy is always non negative i.e H(x) ≥ 0.

2.Entropy is zero when probability of all symbols is zero except probability one symbol is one.

3.Entropy is maximum when probability occurrence of all symbols is equal

i.e H(x) = $log_2 M$

# MUTUAL INFORMATION

- $I(X; Y)$ of a channel is equal to difference between initial uncertainty and final uncertainty.
- $I(X;Y)$ = Initial uncertainty – final uncertainty.
- $I(X;Y) = H(X) - H(X/Y)$ bits/symbol

  Where, $H(X)$ - entropy of the source and

  $H(X/Y)$ - Conditional Entropy.
- **Properties of mutual information:**

1. $I(X;Y) = I(Y;X)$
2. $I(X;Y)>=0$
3. $I(X;Y) = H(X) - H(X/Y)$
4. $I(X;Y)) = H(X)+H(Y)-H(X,Y)$.

# CHANNEL CAPACITY THEOREM

- Shannon- Hartley theorem states that the capacity of Gaussian channel having bandwidth 'W' is given as,

$$C = W \log 2 \left[1 + \frac{S}{N}\right] bits/sec$$

Where, W= Channel bandwidth

S = Average signal power

N = Average noise power

# SHANNON FANO ALGORITHM

- Shannon Fano coding is source encoding technique which is used to remove the redundancy (repeated information). The following steps are involved

1. For a given list of symbols, develop a corresponding list of probabilities or frequency counts so that each symbol's relative frequency of occurrence is known.
2. Sort the lists of symbols according to frequency, with the most frequently occurring symbols at the left and the least common at the right.
3. Divide the list into two parts, with the total frequency counts of the left part being as close to the total of the right as possible.

4. The left part of the list is assigned the binary digit 0, and the right part is assigned the digit 1. This means that the codes for the symbols in the first part will all start with 0, and the codes in the second part will all start with 1.
5. Recursively apply the steps 3 and 4 to each of the two halves, subdividing groups and adding bits to the codes until each symbol has become a corresponding code leaf on the tree.

# SHANNON-FANO CODING

**Ques:-** Apply Shannon-Fano Coding for following message

$[X] : [x_1 \quad x_2 \quad x_3 \quad x_4 \quad x_5 \quad x_6]$

$[P] : [0.30 \quad 0.25 \quad 0.15 \quad 0.12 \quad 0.08 \quad 0.10]$

Take $m=2$

| [X] | [P] | Stage 1 | Stage 2 | Stage 3 | Codeword | Length |
|---|---|---|---|---|---|---|
| $x_1$ | 0.30 | 0 | 0 | | 00 | 2 |
| $x_2$ | 0.25 | 0 | 1 | | 01 | 2 |
| $x_3$ | 0.15 | 1 | 0 | 0 | 100 | 3 |
| $x_4$ | 0.12 | 1 | 0 | 1 | 101 | 3 |
| $x_6$ | 0.10 | 1 | 1 | 0 | 110 | 3 |
| $x_5$ | 0.08 | 1 | 1 | 1 | 111 | 3 |

(Group sums noted: 0.55, 0.45, 0.27, 0.18)

$$H(x) = \sum_{i=1}^{6} P_i n_i$$

$$= (0.30)\log_2\frac{1}{(0.30)} + (0.25)\log_2\frac{1}{(0.25)} + (0.15)\log_2\frac{1}{(0.15)} + (0.12)\log_2\frac{1}{(0.12)} + (0.10)\log_2\frac{1}{(0.10)} + (0.08)\log_2\frac{1}{(0.08)}$$

$$= \underline{2.418 \text{ Bits}}$$

$$L_{avg} = \sum_{i=1}^{6} P_i \,(\text{length})$$

$$= (0.30\times 2) + (0.25\times 2) + (0.15\times 3) + (0.12\times 3) + (0.10\times 3) + (0.08\times 3)$$

$$= \underline{2.45 \text{ Bits}}$$

$$(\eta)\text{ Efficiency} = \frac{H(x)}{L_{avg}} = \frac{2.418}{2.45} = 0.9869.$$

**98%**

Redundancy

$$R = 1 - \eta$$
$$= 1 - 0.9869$$
$$= 0.0131$$

# REFERENCES


- https://www.tutorialspoint.com/analog_communication/analog_communication_multiplexing.htm
- https://www.tutorialspoint.com/analog_communication/analog_communication_sampling.htm
- https://www.scesasaram.in/wp-content/uploads/2020/04/EEE_6_ICS_6.1__Analog-Pulse-Modulation.pdf
- https://www.youtube.com/watch?v=2XjqS1clY_E
- https://www.slideshare.net/sanjeev2419/pulse-modulation-121168648