ANALOG COMMUNICATION

(AECB12)

B.Tech ECE IV Semester

Prepared By

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CO's	Course outcomes
CO1	Understand the basic concepts of the communication systems and illustrate different amplitude modulation techniques.
CO2	Analyze the time domain and frequency domain description of SSB and VSBSC and compare various amplitude modulation schemes.
CO3	Analyze generation and detection of FM signal and comparison between amplitude and angle modulation schemes.
CO4	Gain the knowledge of different noise sources and evaluate the performance of the communication system in the presence of noise .
CO5	Interpret with different types of receivers and study different pulse modulation and demodulation techniques.

SYLLABUS

Module-I: Amplitude modulation

Module-II: SSB Modulation

Module-III: Angle Modulation

Module-IV: Noise In Analog Communication System

Module-V: Receivers

Module-I:
Amplitude modulation

Course Learning Outcome

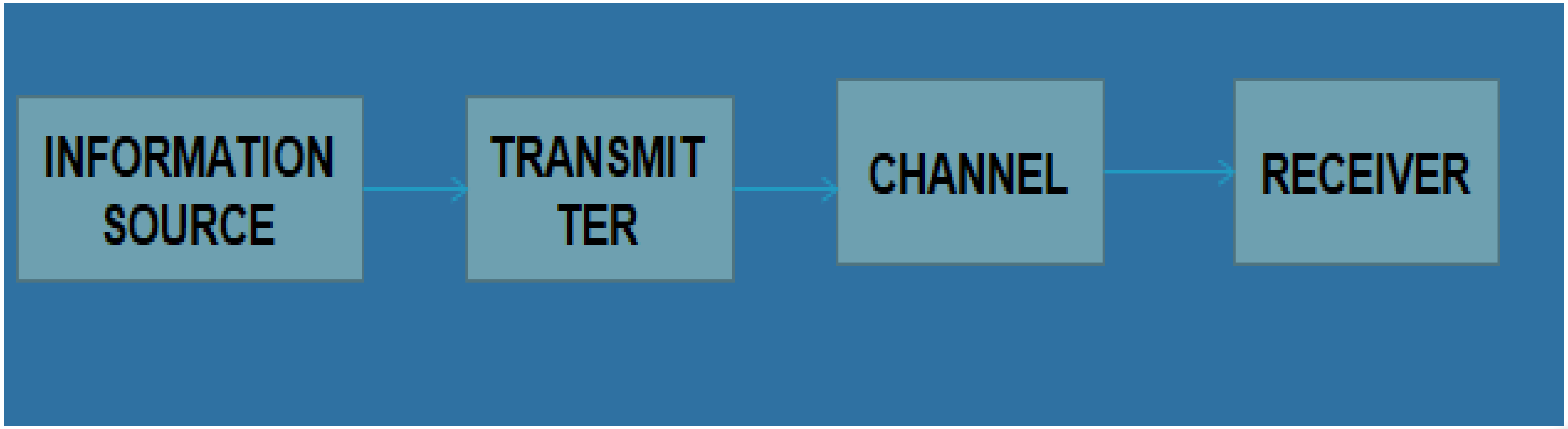
CLOs	Course Learning Outcome
CLO1	Discuss about the basic elements of communication system, importance of modulation and different types of modulation.
CLO2	Understand the time domain, frequency domain description and power relations of amplitude modulation, various techniques of generation and detection of AM.
CLO3	Analyze the time domain, frequency domain description of Double Side Band Suppressed Carrier (DSB SC), various generation techniques and detection techniques of DSB SC, Noise in DSB SC.

AMPLITUDE MODULATION

Introduction to communication system, Need for modulation, Frequency Division Multiplexing , Amplitude Modulation, Definition, Time domain and frequency domain description, single tone modulation, power relations in AM waves, Generation of AM waves, square law Modulator, Switching modulator, Detection of AM Waves; Square law detector, Envelope detector, Double side band suppressed carrier modulators, time domain and frequency domain description, Generation of DSBSC Waves, Balanced Modulators, Ring Modulator, Coherent detection of DSB-SC Modulated waves, COSTAS Loop.

COMMUNICATION

- The transmission of information from source to the destination through a channel or medium is called communication.
- Basic block diagram of a basic communication system:



COMMUNICATION

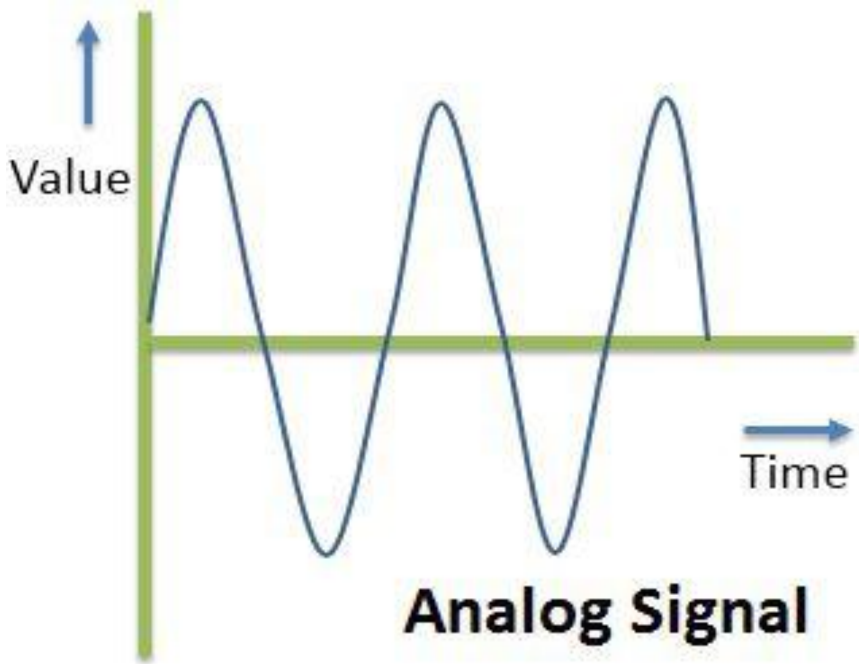
- Source: analog or digital
- Transmitter: transducer, amplifier, modulator, oscillator, power amp., antenna
- Channel: e.g. cable, optical fiber, free space
- Receiver: antenna, amplifier, demodulator, oscillator, power amplifier, transducerDestination : e.g. person, (loud) speaker, computer

SIGNAL

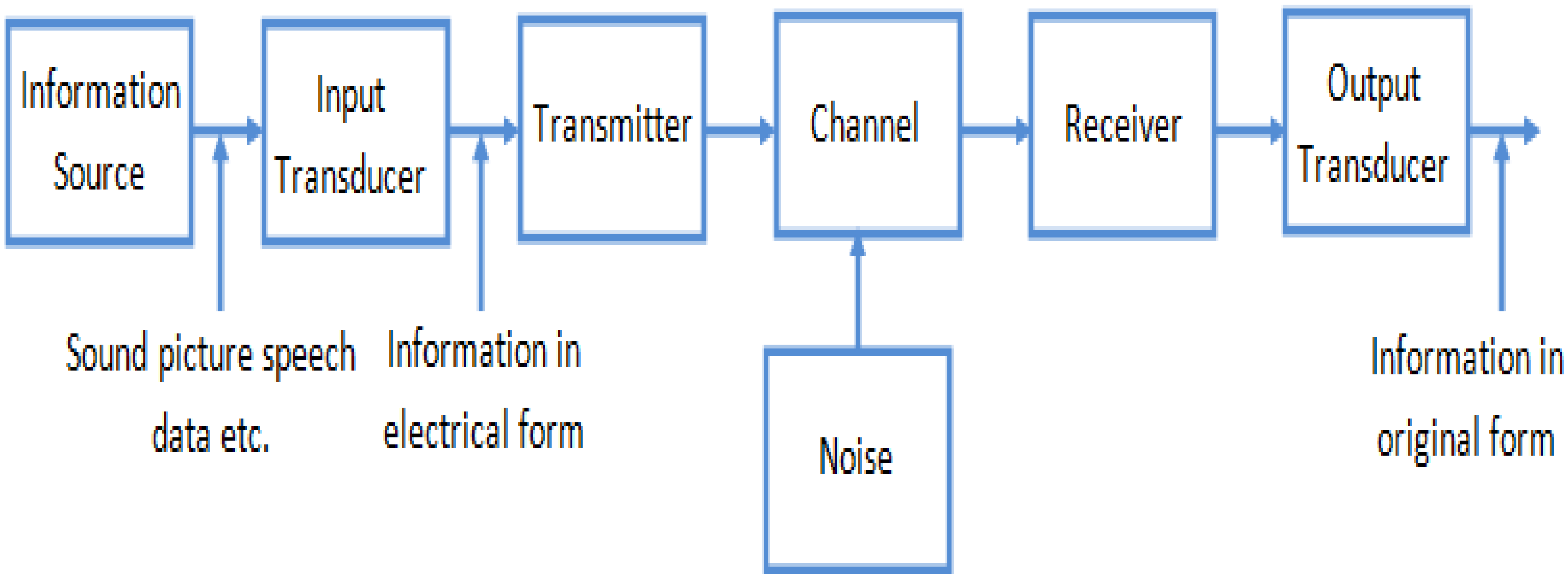
- Any physical quantity that varies with time ,space or any other independent variable.
- Anything that caries information.
- Mathematically it can we describe ,the signal is a function of one or more independent variables.
- Any detectable energy that caries some information.
- convey information or instructions by means of a gesture, action, or sound

ANALOG SIGNAL

❖The signal in which both amplitude and time vary continuously is called analog signal .ex : speech, television signals etc...



ANALOG COMMUNICATION SYSTEM



- In order to become familiar with this communication it is necessary to understand Modulation, noise , transmitters and receivers

MODULATION

- **Modulation** is the process of changing the parameters **or** characteristics(amplitude, frequency, phase) of the carrier signal, in accordance with the instantaneous values of the modulating signal.

- **Need for Modulation**: Baseband signals are incompatible for direct transmission. For such a signal, to travel longer distances, its strength has to be increased by modulating with a high frequency carrier wave, which doesn’t affect the parameters of the modulating signal.

Need for Modulation

1. Reduce the antenna height.
2. Increases the range of Communication.
3. Allows the multiplexing of signals.
4. Adjustments in the bandwidth is allowed.
5. Avoids the mixing of signals.
6. Improved reception quality
7. Narrow banding of signals.

Signals in the Modulation Process

- **Message or Modulating Signal**

The signal which contains a message to be transmitted is called as a **message signal**. It is a baseband signal, which has to undergo the process of modulation, to get transmitted. Hence, it is also called as the **modulating signal**.

- **Carrier Signal**

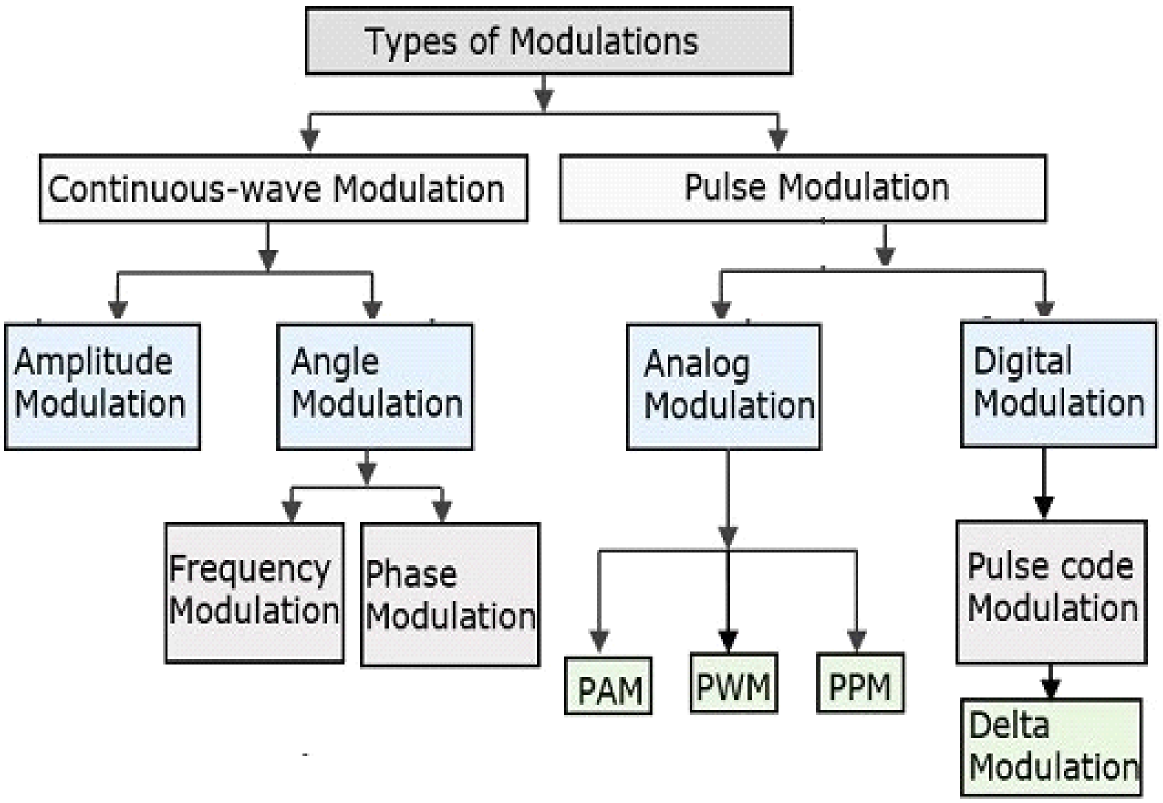
The high frequency signal, which has a certain amplitude, frequency and phase but contains no information, is called as a **carrier signal**. It is an empty signal and is used to carry the signal to the receiver after modulation.

- **Modulated Signal**

The resultant signal after the process of modulation is called as a **modulated signal**. This signal is a combination of modulating signal and carrier signal.

Types of Modulation

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



Continuous-wave Modulation

➢In continuous-wave modulation, a high frequency sine wave is used as a carrier wave. This is further divided into amplitude and angle modulation.

•If the amplitude of the high frequency carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal, then such a technique is called as **Amplitude Modulation**.

•If the angle of the carrier wave is varied, in accordance with the instantaneous value of the modulating signal, then such a technique is called as Angle Modulation. Angle modulation is further divided into frequency modulation and phase modulation.

Continuous-wave Modulation

•If the frequency of the carrier wave is varied, in accordance with the instantaneous value of the modulating signal, then such a technique is called as **Frequency Modulation**.

•If the phase of the high frequency carrier wave is varied in accordance with the instantaneous value of the modulating signal, then such a technique is called as Phase Modulation.

Multiplexing

- **Multiplexing** is the process of combining multiple signals into one signal, shared over a single medium.
- The multiplexing technique divides the communication channel into several logical sub-channels. Each logical sub-channel is dedicated to an individual signal.
- If the analog signals are multiplexed, then it is called as **analog multiplexing**.
- If the digital signals are multiplexed, then it is called as **digital multiplexing**.

Multiplexing

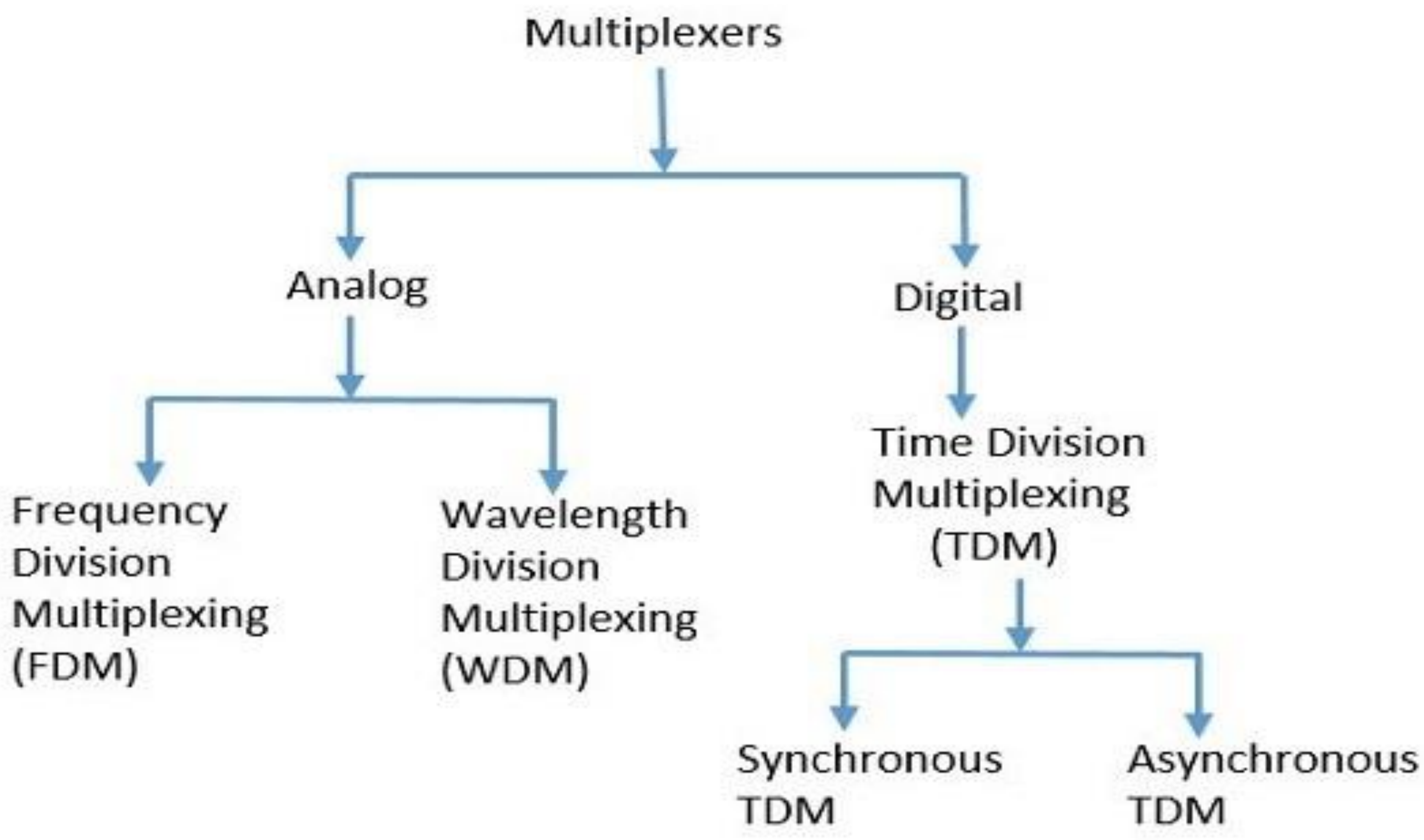
- Multiplexing was first developed in **telephony.**
- In telephony system, number of signals were combined to send through a single cable.
- The process of multiplexing divides a communication channel into several number of logical channels, allotting each one for a different message signal or a data stream to be transferred.
- Multiplexing can be called as **Multiplexer** **or** **MUX.**
- The reverse process, i.e., extracting the number of channels from one, which is done at the receiver is called as de-multiplexing.
- De-multiplexing can be called as **de-multiplexer or DEMUX.**

Multiplexing

The following figure illustrates the concept of MUX and DEMUX

Multiplexing and Demultiplexing

Types of Multiplexers



Frequency Division Multiplexing

❖In analog multiplexing, the most used technique is Frequency Division Multiplexing (FDM).

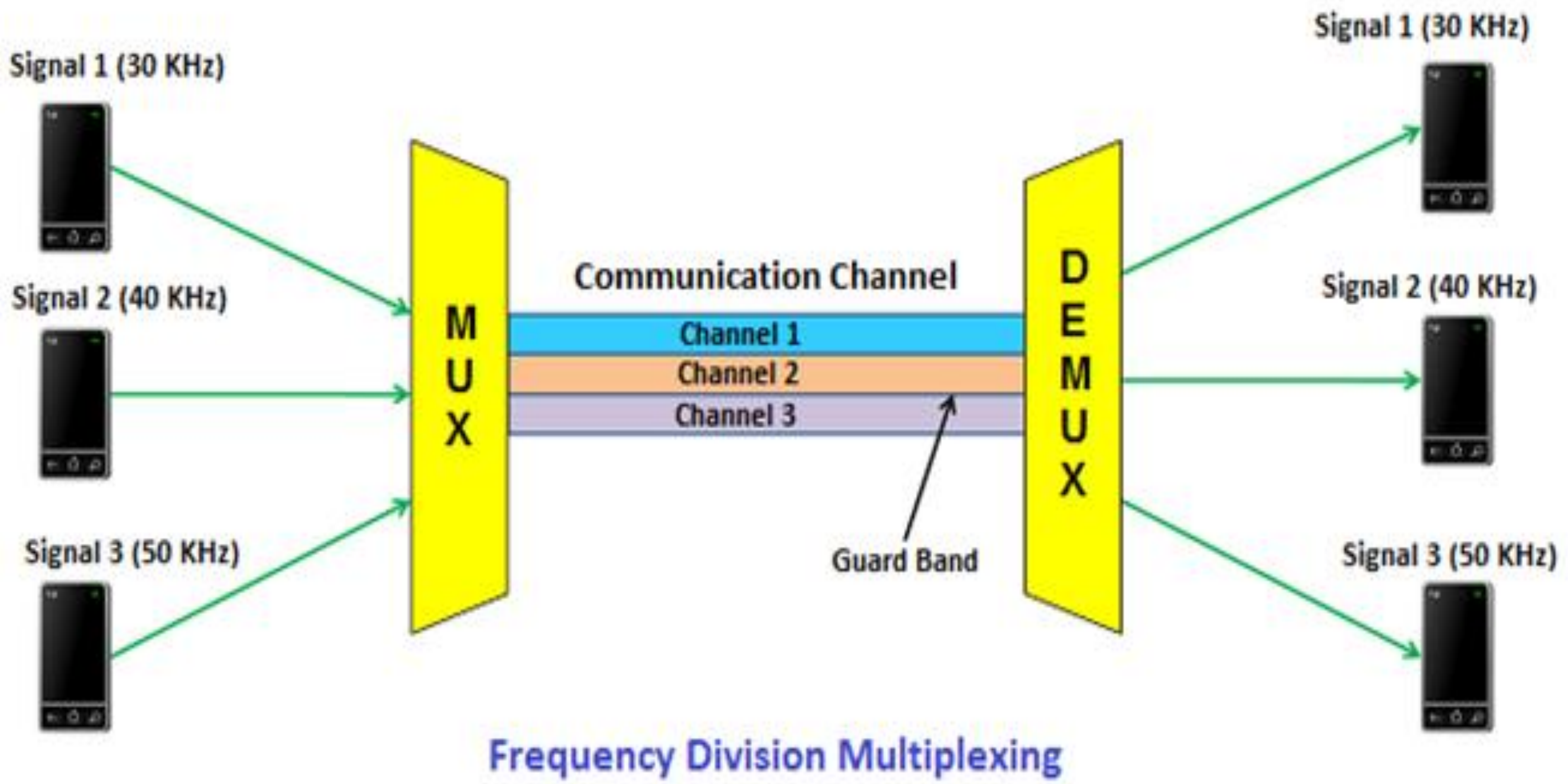
❖This technique uses various frequencies to combine streams of data, for sending them on a communication medium, as a single signal.

❖**Example** – A traditional television transmitter, which sends a number of channels through a single cable uses FDM.

Frequency Division Multiplexing

- We use this technique extensively in TV and radio transmission.
- This technique combines multiple signals into one signal and transmitted over the communication channel.
- Frequency division multiplexing is also known as FDM.
- In this technique, the bandwidth of the communication channel should be greater than the combined bandwidth of individual signals.

Frequency Division Multiplexing



Frequency Division Multiplexing

- The frequency division multiplexing divides the bandwidth of a channel into several logical sub-channels.
- Each logical sub-channel is allotted for a different signal frequency.
- The individual signals are filtered and then modulated (frequency is shifted), in order to fit exactly into logical sub-channels.
- Each logical sub-channel (individual signal frequency) is allotted to each user. In other words, each user owns a sub-channel.

Frequency Division Multiplexing

- Each logical sub-channel is separated by an unused bandwidth called **Guard Band**.
- Guard Band are used to prevent overlapping of signals.
- In other words, there exists a frequency gap between two adjacent signals to prevent signal overlapping.
- A guard band is a narrow frequency range that separates two signal frequencies.

Guard Band

➢ What does Guard Band mean?

- A guard band is a narrow frequency range that separates two ranges of wider frequency.
- This ensures that simultaneously used communication channels do not experience interference.

Advantages of Frequency Division Multiplexing

Advantages:

✓It transmits multiple signals simultaneously.

✓In frequency division multiplexing, the demodulation process is easy.

✓It does not need Synchronization between transmitter and receiver.

Disadvantages:

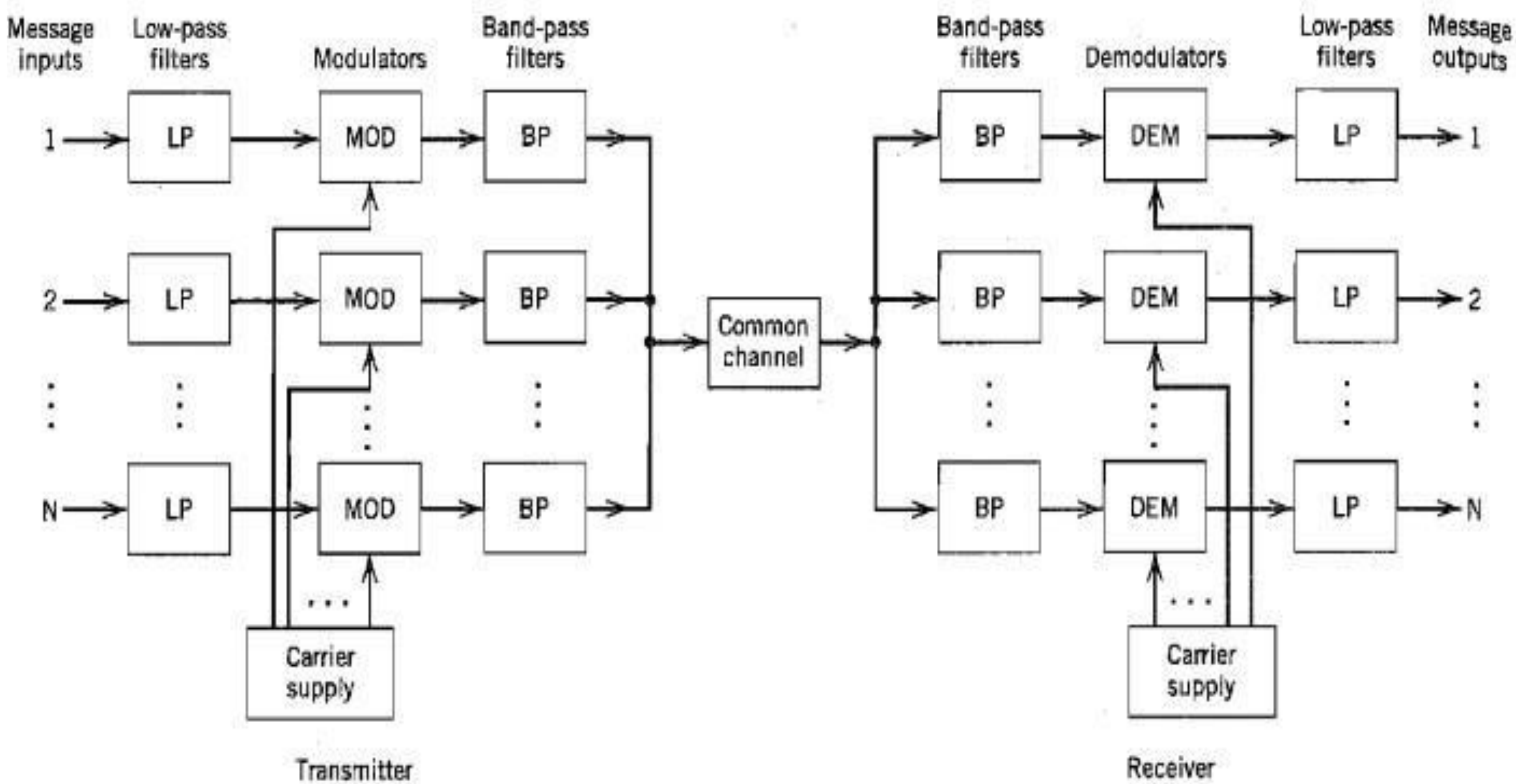
❖It needs a large bandwidth communication channel.

Applications of Frequency Division Multiplexing

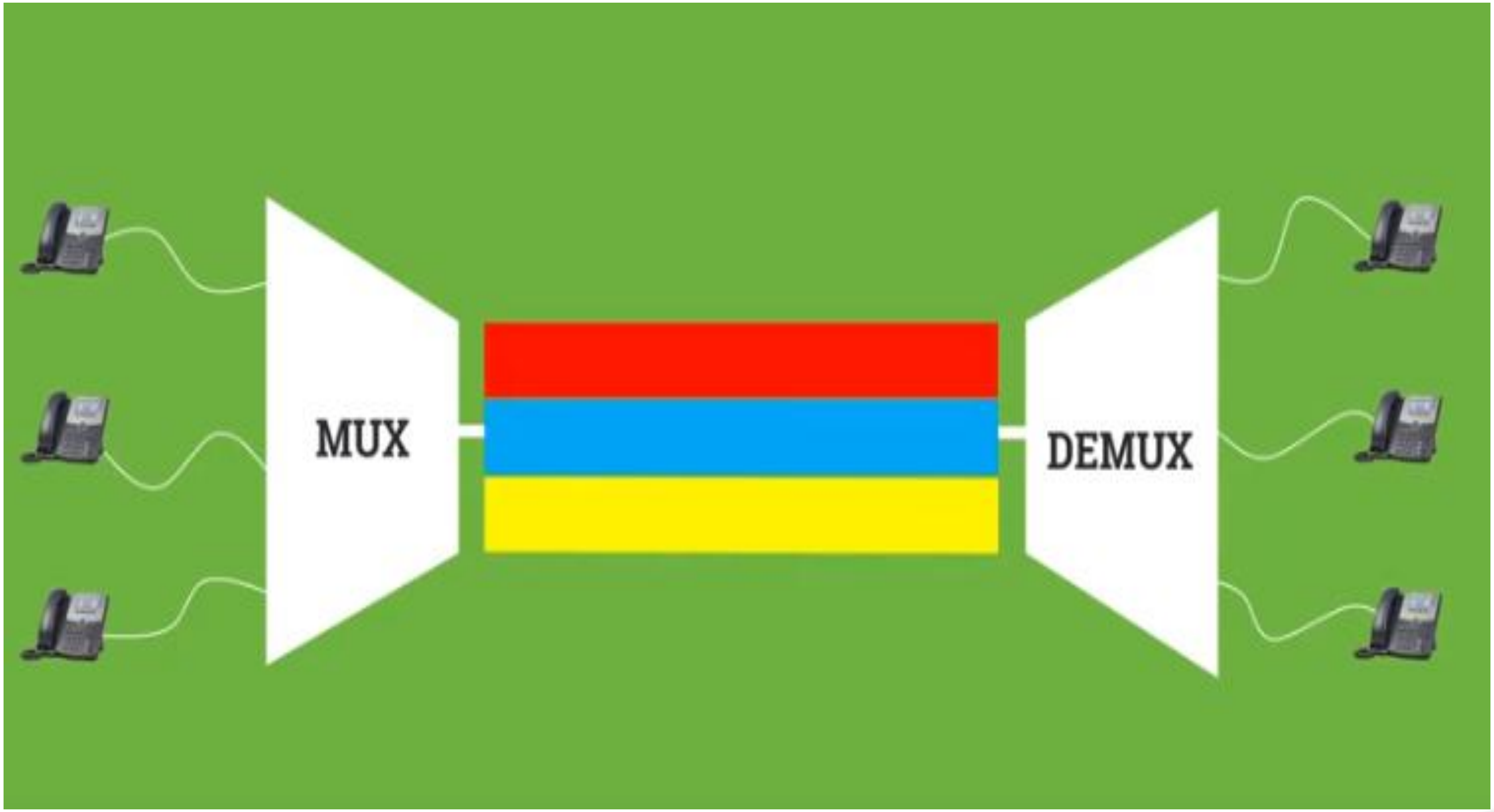
Applications:

- Frequency division multiplexing is used for FM and AM radio broadcasting.
- It is used in first generation cellular telephone.
- It is used in television broadcasting.

Frequency Division Multiplexing



Frequency Division Multiplexing



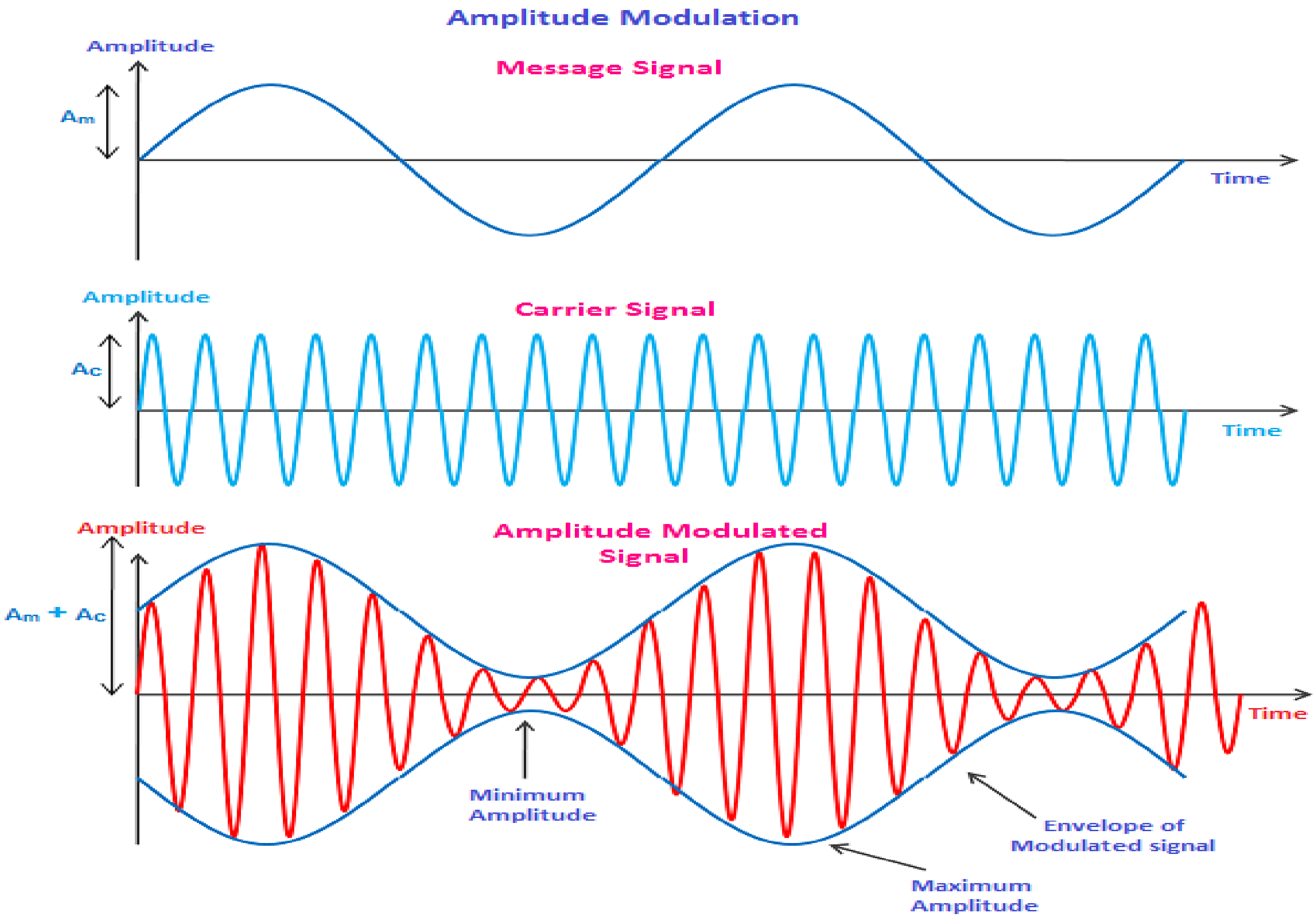
Amplitude Modulation

❖**The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal is called amplitude modulation.**

❖Which means, the amplitude of the carrier signal which contains no information varies as per the amplitude of the signal, at each instant, which contains information.

❖The carrier amplitude varied linearly by the modulating signal which usually consists of a range of audio frequencies. The frequency of the carrier is not affected

Amplitude Modulation



Mathematical Expressions

Time-domain Representation of the Waves:

Let the modulating signal be,

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

and the carrier signal be,

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

Where,

- **Am** and **Ac** are the amplitude of the modulating signal and the carrier signal respectively.
- **fm** and **fc** are the frequency of the modulating signal and the carrier signal respectively.

Time-domain Representation of the Waves:

Then, the equation of Amplitude Modulated wave will be,

$$\boxed{S(t)_{AM} = A_c\left[1 + K_a\, m(t)\right]\cos(2\pi f_c t)}$$

Where K_a = constant and is called as Amplitude sensitivity.

Eqn (3) can also be written as

$$\boxed{S(t)_{AM} = A_c \cos(2\pi f_c t) + A_c K_a\, m(t) \cos 2\pi f_c t} \rightarrow (4)$$

Modulation Index

➢The carrier wave, after being modulated, if the modulated level is calculated, then it is called as **Modulation Index** or **Modulation Depth**.

➢It states the level of modulation that a carrier wave undergoes.

$$s_{AM}(t) = A_c\left[1 + k_a A_m \cos(2\pi f_m t)\right]\cos(2\pi f_c t)$$

$$= A_c\left[1 + \mu \cos(2\pi f_m t)\right]\cos(2\pi f_c t)$$

$$\mu = \frac{A_m}{A_c}$$

➢Where, **μ** is Modulation index and it is equal to the ratio of **Am** and **Ac**,

$$\mu = \frac{A_m}{A_c}$$

➢we can calculate the value of modulation index by using the above formula, when the amplitudes of the message and carrier signals are known.

➢Let **Amax** and **Amin** be the maximum and minimum amplitudes of the modulated wave.

➢We will get the **maximum amplitude** of the modulated wave, when , $\cos(2\pi f_m t)$ is 1.

$$\Rightarrow A_{\max} = A_c + A_m$$

Modulation Index

- We will get the **minimum amplitude** of the modulated wave, when, $\cos(2\pi f_m t)$ is -1.

$$\Rightarrow A_{\min} = A_c - A_m$$

Add both Equations,

$$A_{\max} + A_{\min} = A_c + A_m + A_c - A_m = 2A_c$$

$$\Rightarrow A_c = \frac{A_{\max} + A_{\min}}{2}$$

Subtract both Equations,

$$A_{\max} - A_{\min} = A_c + A_m - (A_c - A_m) = 2A_m$$

$$\Rightarrow A_m = \frac{A_{\max} - A_{\min}}{2}$$

Modulation Index

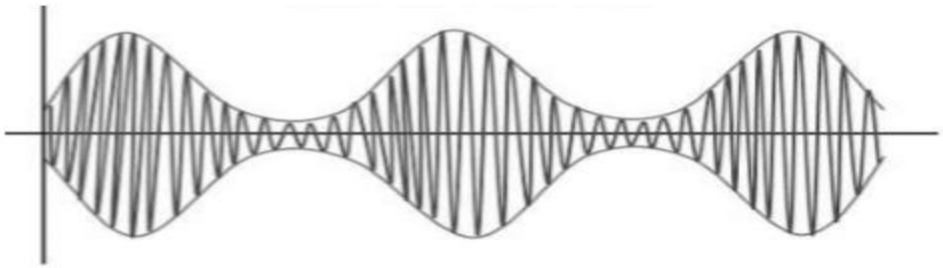
$$\frac{A_m}{A_c} = \frac{(A_{max} - A_{min})/2}{(A_{max} + A_{min})/2}$$

$$\Rightarrow \mu = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$$

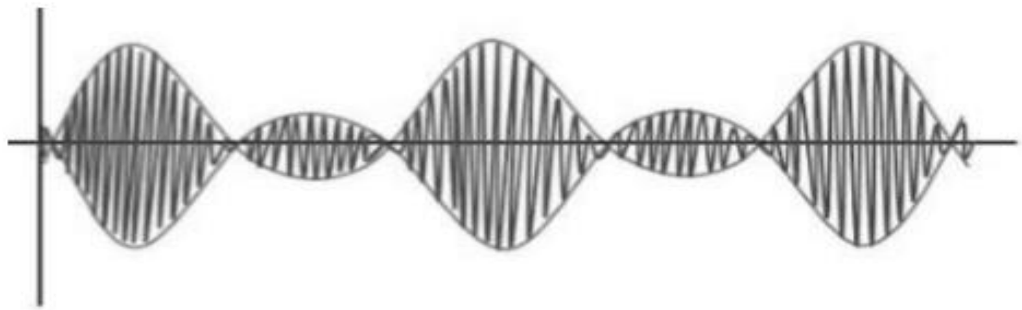
- The **modulation index** or modulation **depth** is often denoted in percentage called as **Percentage of Modulation.** We will get the **percentage of modulation**, just by multiplying the modulation index value with **100.**

Under Modulation

Under-Modulated wave



Over-Modulated wave



Power Calculations of AM Wave

- 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.

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

Power Calculations of AM Wave

- We can use the above formula to calculate the power of AM wave, when the carrier power and the modulation index are known.
- If the modulation index $\mu=1\mu=1$ then the power of AM wave is equal to 1.5 times the carrier power.
- So, the power required for transmitting an AM wave is 1.5 times the carrier power for a perfect modulation.

SINGLE TONE MODULATION

- Single Tone modulation is "a modulation in which the modulation is carried out by a single frequency (tone) signal".
- The toned (single frequency) modulating signal consists of only one frequency component and this signal is modulated with a carrier signal.
- Consider a toned (single frequency) modulating signal,

$$x(t) = V_m \cos \omega_m t$$

SINGLE TONE MODULATION

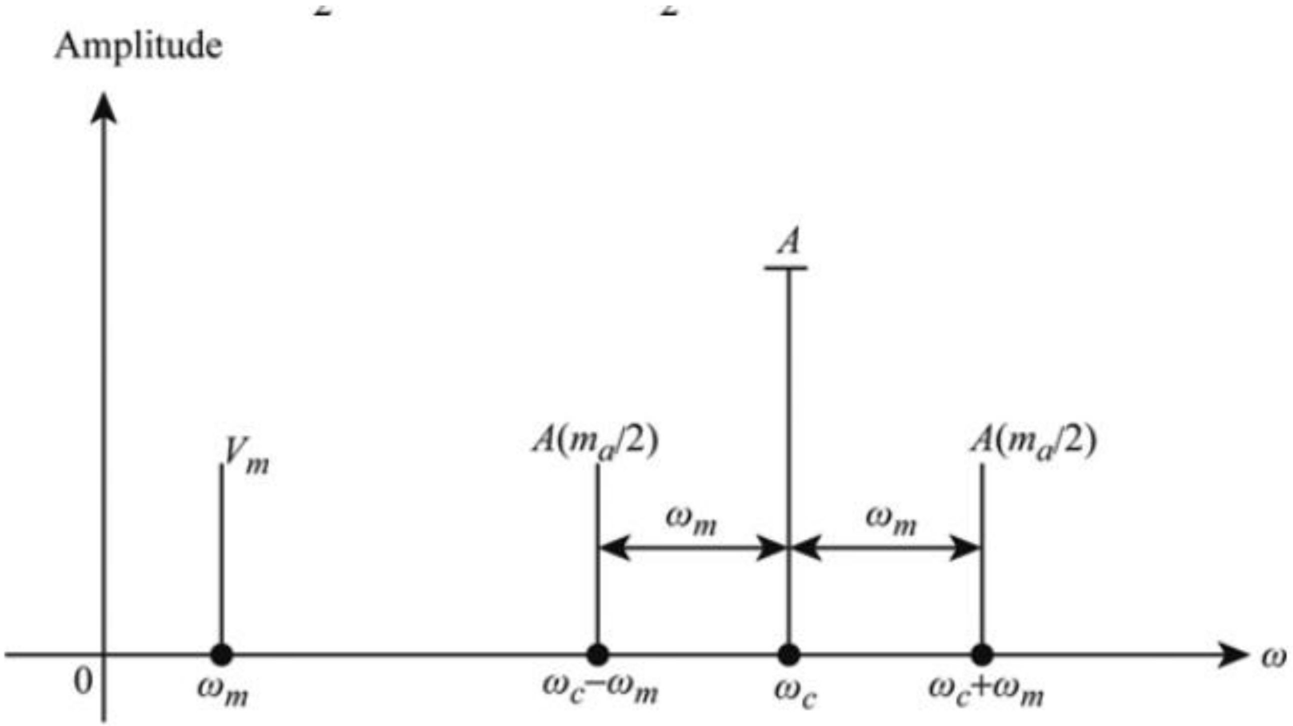
- Here, V_m is maximum amplitude of modulating signal, and ω_m is frequency of modulating signal
- Consider a carrier signal,

$$c(t) = A\cos\omega_c t \qquad \text{......} (2)$$

- Here, A is maximum amplitude of carrier signal, and ω_c is frequency of carrier signal.
- Consider the general equation for amplitude modulation signal.

$$s(t) = \left[A + x(t)\right]\cos\omega_c t \qquad \text{......} (3)$$

SINGLE TONE MODULATION

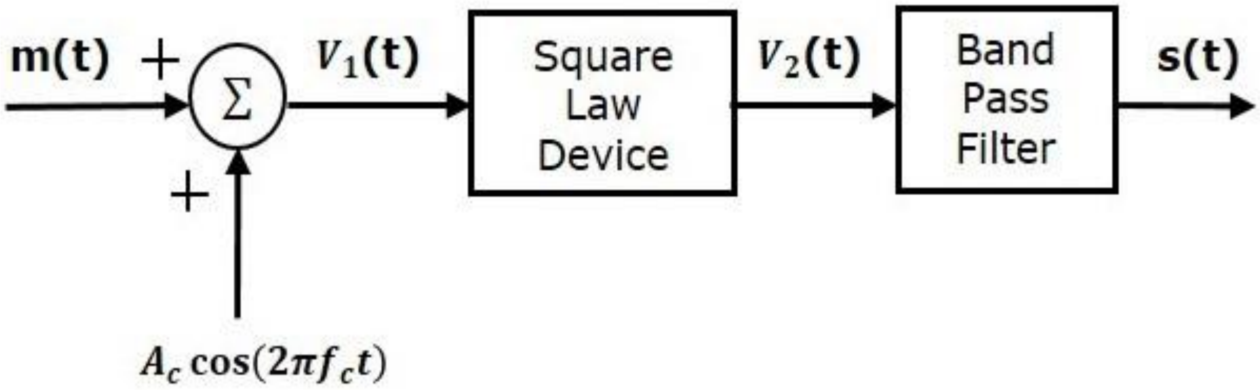


There are two modulators to generate AM signal .They are,

1. Square law modulator
2. Switching modulator.

Square Law Modulator

Following is the block diagram of the square law modulator



Square Law Modulator

- Let the modulating and carrier signals be denoted as m(t) and A cos(2πfct).
- These two signals are applied as inputs to the summer (adder) block.
- This summer block produces an output, which is the addition of the modulating and the carrier signal.
- Mathematically, we can write it as

$$V_1 t = m(t) + A_c \cos(2\pi f_c t)$$

Square Law Modulator

•This signal V1(t) is applied as an input to a nonlinear device like diode.

•The characteristics of the diode are closely related to square law.

$$V_2 t = k_1 V_1(t) + k_2 V_1^2(t)$$

•Where, k1and k2 are constants.

•Substitute V1(t) in above Equation 1 ,we will get

$$V_2(t) = k_1 \left[m(t) + A_c \cos(2\pi f_c t)\right] + k_2 \left[m(t) + A_c \cos(2\pi f_c t)\right]^2$$

Square Law Modulator

$$\Rightarrow V_2(t) = k_1 m(t) + k_1 A_c \cos(2\pi f_c t) + k_2 m^2(t) +$$

$$k_2 A_c^2 \cos^2(2\pi f_c t) + 2k_2 m(t) A_c \cos(2\pi f_c t)$$

$$\Rightarrow V_2(t) = k_1 m(t) + k_2 m^2(t) + k_2 A_c^2 \cos^2(2\pi f_c t) +$$

$$k_1 A_c \left[1 + \left(\frac{2k_2}{k_1}\right) m(t)\right] \cos(2\pi f_c t)$$

Square Law Modulator

- The last term of the above equation represents the desired AM wave and the first three terms of the above equation are unwanted.
- So, with the help of band pass filter, we can pass only AM wave and eliminate the first three terms.
- Therefore, the output of square law modulator is,

$$s(t) = k_1 A_c \left[1 + \left(\frac{2k_2}{k_1}\right) m(t)\right] \cos(2\pi f_c t)$$

Square Law Modulator

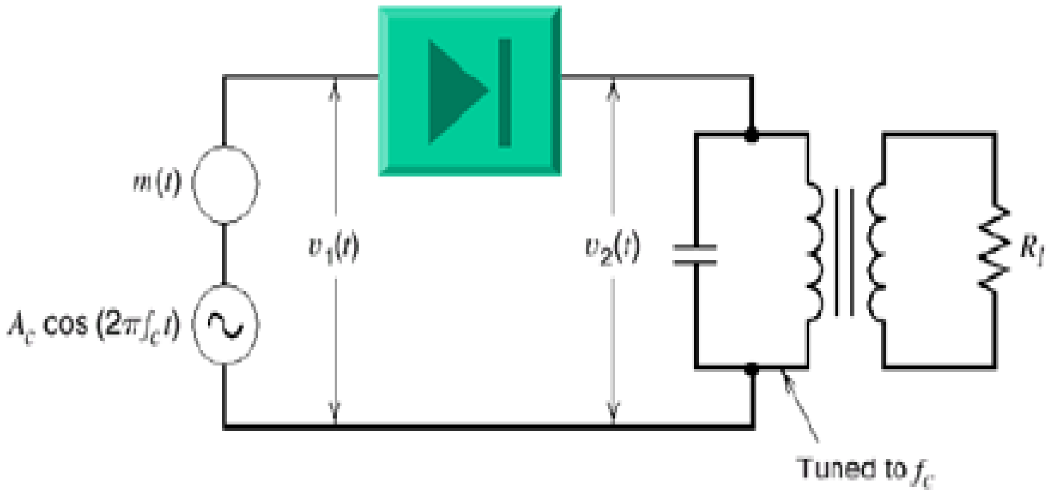
- The standard equation of AM wave is

$$s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)$$

- Where, **K_a** is the amplitude sensitivity.
- By comparing the output of the square law modulator with the standard equation of AM wave, we will get the scaling factor as **k_1** and the amplitude sensitivity **K_a** as **$2k_2/k_1$**

Switching Modulator

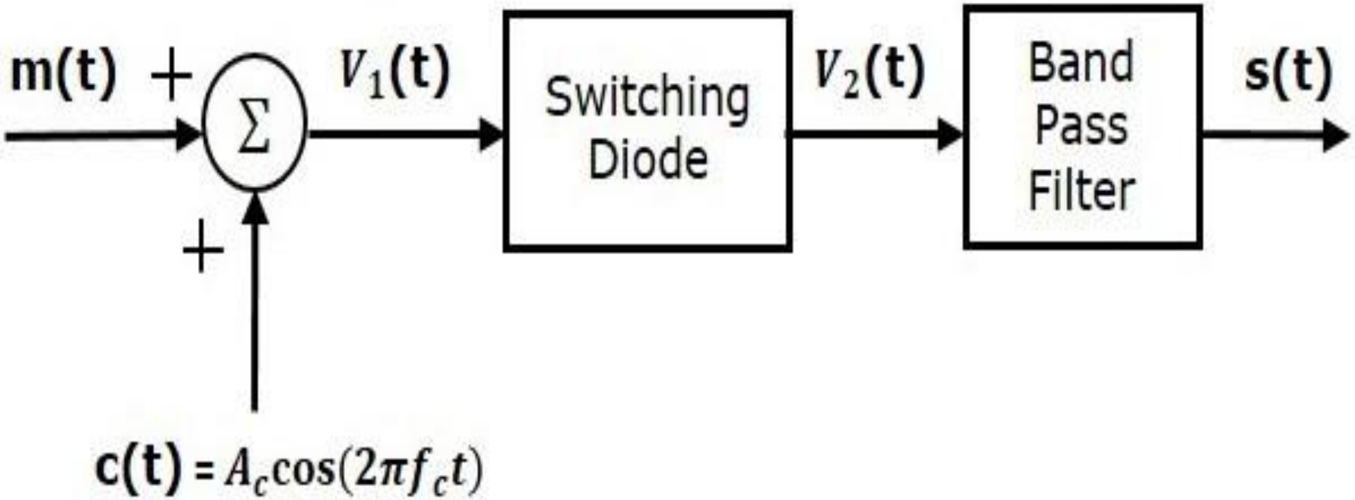
➢Following is the block diagram of switching modulator.



➢Switching modulator is similar to the square law modulator.

➢The only difference is that in the square law modulator, the diode is operated in a **non-linear mode**, whereas, in the switching modulator, the diode has to operate as an **ideal switch**.

Switching Modulator



•Let the modulating and carrier signals be denoted as

$$m(t) \quad \text{and} \quad c(t) = A_c \cos(2\pi f_c t)$$

Switching Modulator

- These two signals are applied as inputs to the summer (adder) block.
- Summer block produces an output, which is the addition of modulating and carrier signals. Mathematically, we can write it as

$$V_1(t) = m(t) + c(t) = m(t) + A_c \cos(2\pi f_c t)$$

- This signal V1(t) is applied as an input of diode.
- Assume, the magnitude of the modulating signal is very small when compared to the amplitude of carrier signal Ac.
- So, the diode's **ON** and **OFF** action is controlled by carrier signal c(t).

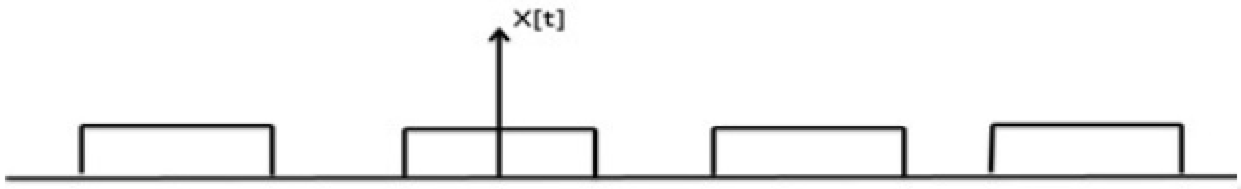
Switching Modulator

- This means, the diode will be forward biased when c(t)>0 and it will be reverse biased when c(t)<0.
- Therefore, the output of the diode is,

$$V_2(t) = \begin{cases} V_1(t) & if \quad c(t) > 0 \\ 0 & if \quad c(t) < 0 \end{cases}$$

- We can approximate this as

$$V_2(t) = V_1(t)\,x(t)$$



Detection of AM Waves

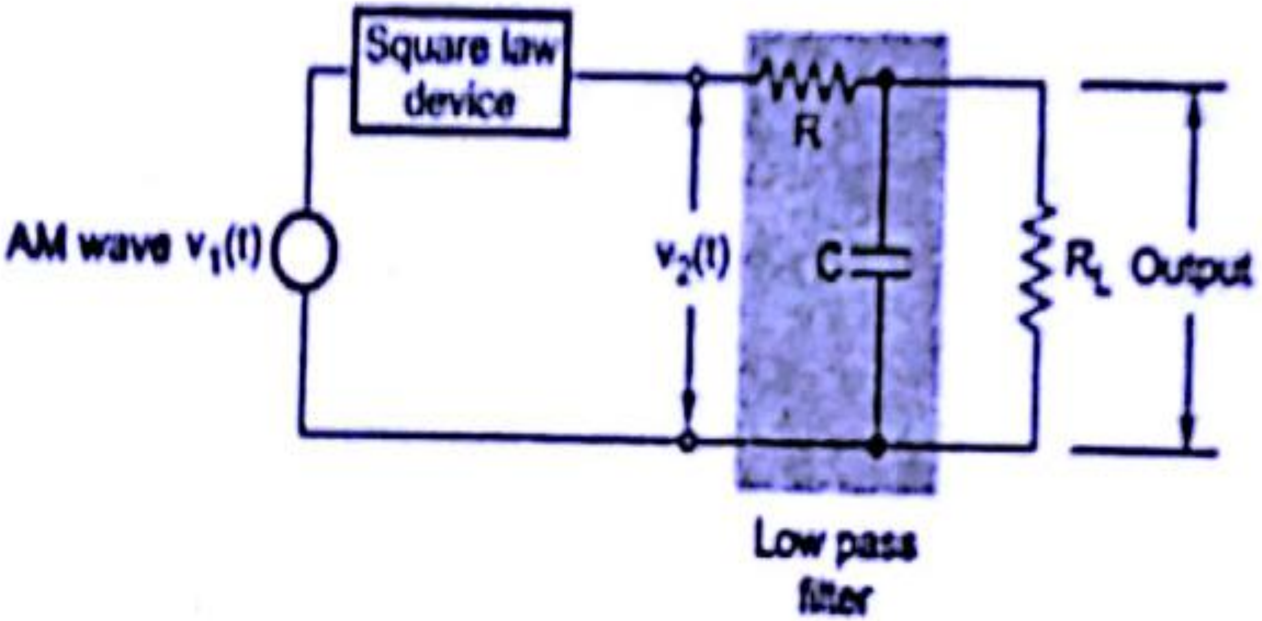
- The process of extracting an original message signal from the modulated wave is known as **detection** or **demodulation**.
- The circuit, which demodulates the modulated wave is known as the **demodulator**.
- The following demodulators (detectors) are used for demodulating AM wave.

1. Square Law Demodulator
2. Envelope Detector

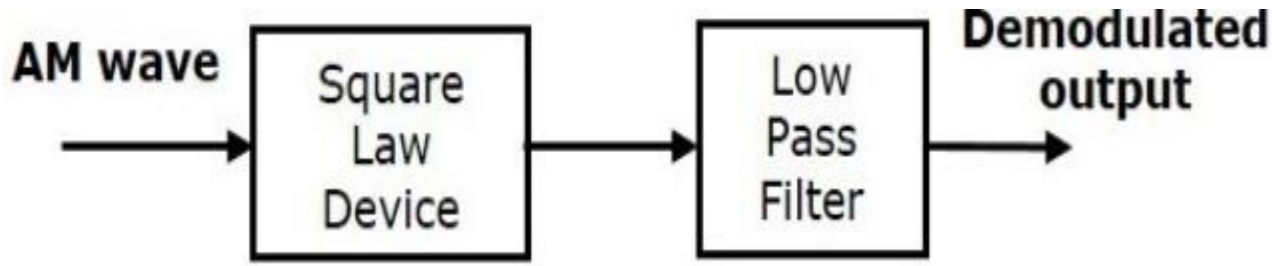
Square Law Detector

➢Square law demodulator is used to demodulate low level AM wave.

➢Following is the block diagram of the **square law demodulator**.



Square Law Detector



•This demodulator contains a square law device and low pass filter.

•The AM wave V1(t) is applied as an input to this demodulator.

•The standard form of AM wave is

$$V_1(t) = A_c\left[1 + k_a m(t)\right]\cos(2\pi f_c t) \qquad \text{(Equation 1)}$$

Square Law Detector

- We know that the mathematical relationship between the input and the output of square law device is

$$V_2(t) = k_1 V_1(t) + k_2 V_1^2(t)$$ (Equation 2)

- Substitute V1(t) in Equation 1

$$V_2(t) = k_1\left(A_c[1 + k_a m(t)]\cos(2\pi f_c t)\right) + k_2\left(A_c[1 + k_a m(t)]\cos(2\pi f_c t)\right)^2$$

$$\Rightarrow V_2(t) = k_1 A_c \cos(2\pi f_c t) + k_1 A_c k_a m(t)\cos(2\pi f_c t) +$$

$$k_2 A_c^2 \left[1 + K_a^2 m^2(t) + 2k_a m(t)\right]\left(\frac{1+\cos(4\pi f_c t)}{2}\right)$$

Square Law Detector

$$\Rightarrow V_2(t) = k_1 A_c \cos(2\pi f_c t) + k_1 A_c k_a m(t) \cos(2\pi f_c t) + \frac{K_2 A_c^{\ 2}}{2} +$$

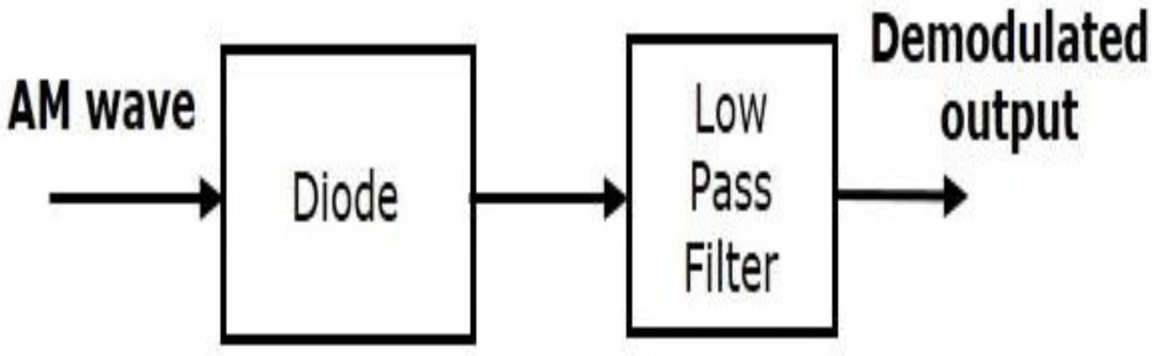
$$\frac{K_2 A_c^{\ 2}}{2} \cos(4\pi f_c t) + \frac{k_2 A_c^{\ 2} k_a^{\ 2} m^2(t)}{2} + \frac{k_2 A_c^{\ 2} k_a^{\ 2} m^2(t)}{2} \cos(4\pi f_c t) +$$

$$k_2 A_c^{\ 2} k_a m(t) + k_2 A_c^{\ 2} k_a m(t) \cos(4\pi f_c t)$$

- In the above equation, the term $k_2 A_c^{\ 2} k_a m(t)$ is the scaled version of the message signal.
- It can be extracted by passing the above signal through a low pass filter and the DC component $\frac{k_2 A_c^{\ 2}}{2}$ can be eliminated with the help of a coupling capacitor.

Envelope Detector

- Envelope detector is used to detect (demodulate) high level AM wave. Following is the block diagram of the envelope detector.



- This envelope detector consists of a diode and low pass filter.
- Here, the diode is the main detecting element. Hence, the envelope detector is also called as the diode detector.
- The low pass filter contains a parallel combination of the resistor and the capacitor.

Envelope Detector

- The AM wave s(t)s(t) is applied as an input to this detector.

We know the standard form of AM wave is

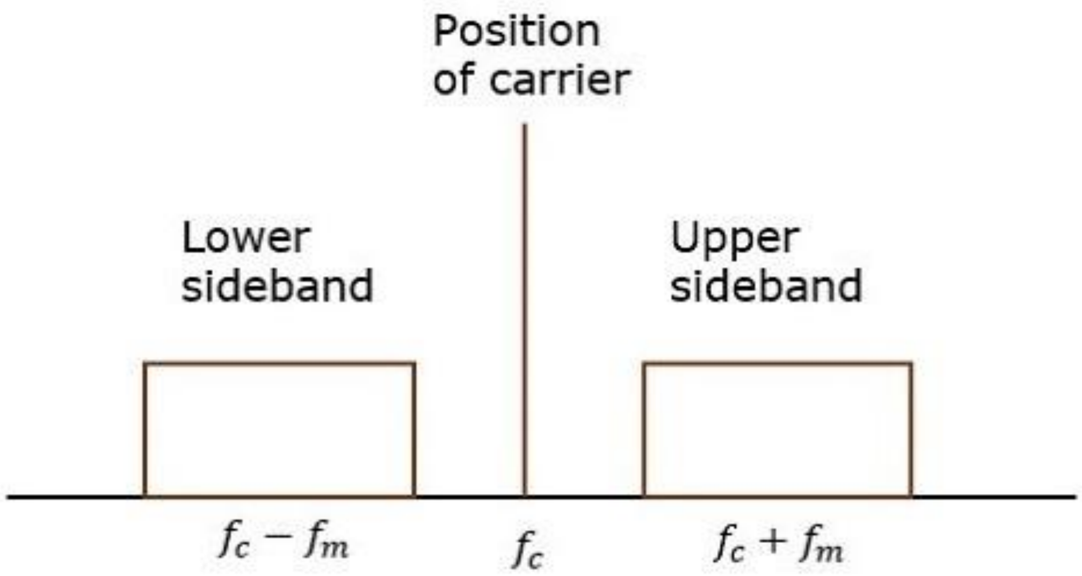
$$s\left(t\right)=A_c\left[1+k_a m\left(t\right)\right]\cos(2\pi f_c t)$$

- In the positive half cycle of AM wave, the diode conducts and the capacitor charges to the peak value of AM wave.
- When the value of AM wave is less than this value, the diode will be reverse biased.
- Thus, the capacitor will discharge through resistor R till the next positive half cycle of AM wave.
- When the value of AM wave is greater than the capacitor voltage, the diode conducts and the process will be repeated.

Double Sideband Suppressed Carrier

- In the process of Amplitude Modulation, the modulated wave consists of the **carrier wave** and **two sidebands**. The modulated wave has the information only in the sidebands.
- **Sideband** is nothing but a band of frequencies, containing power, which are the lower and higher frequencies of the carrier frequency.
- The transmission of a signal, which contains a carrier along with two sidebands can be termed as **Double Sideband Full Carrier** system or simply **DSBFC**. It is plotted as shown in the following figure.

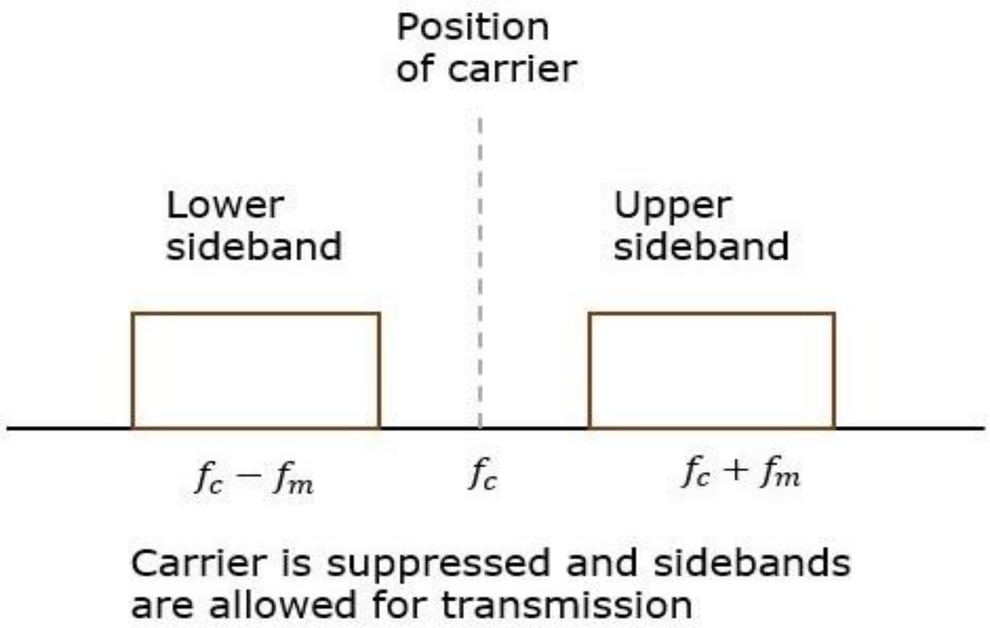
Double Sideband Full Carrier DSBFC



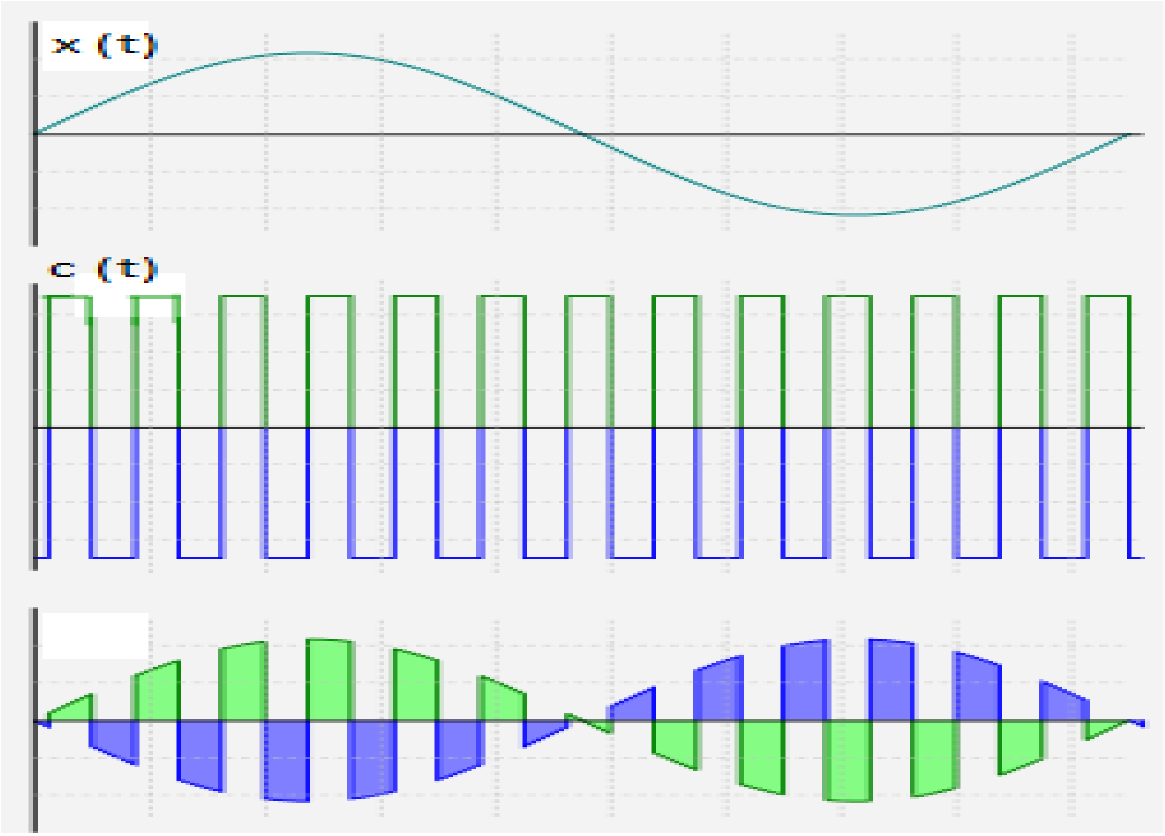
- However, such a transmission is inefficient. Because, two-thirds of the power is being wasted in the carrier, which carries no information.

Double Sideband Suppressed Carrier

➢If this carrier is suppressed and the saved power is distributed to the two sidebands, then such a process is called as **Double Sideband Suppressed Carrier** system or simply **DSBSC**. It is plotted as shown in the following figure.



Double Sideband Suppressed Carrier



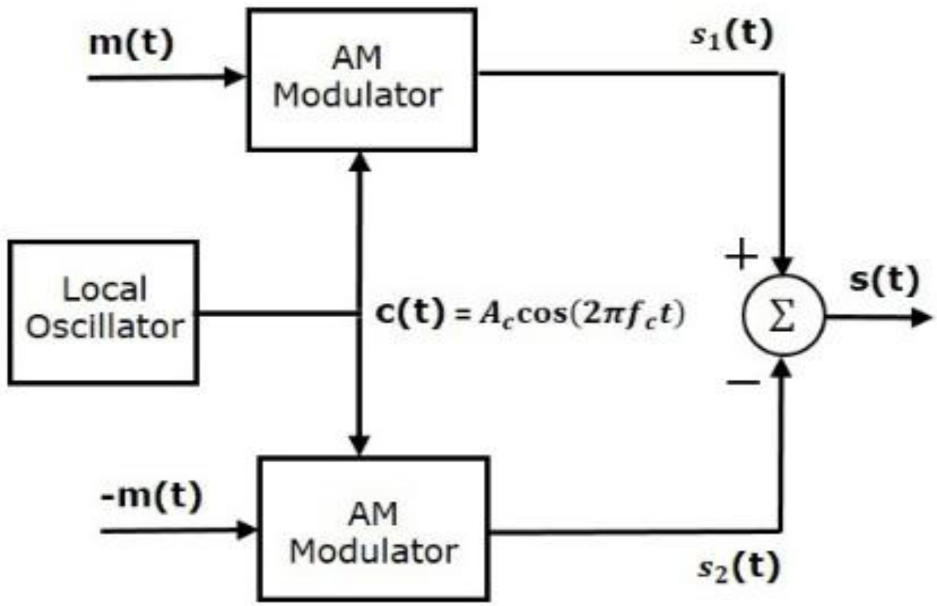
D1 , D2 ON   D3 , D4 ON

DSB-SC Signal at primary of T_2

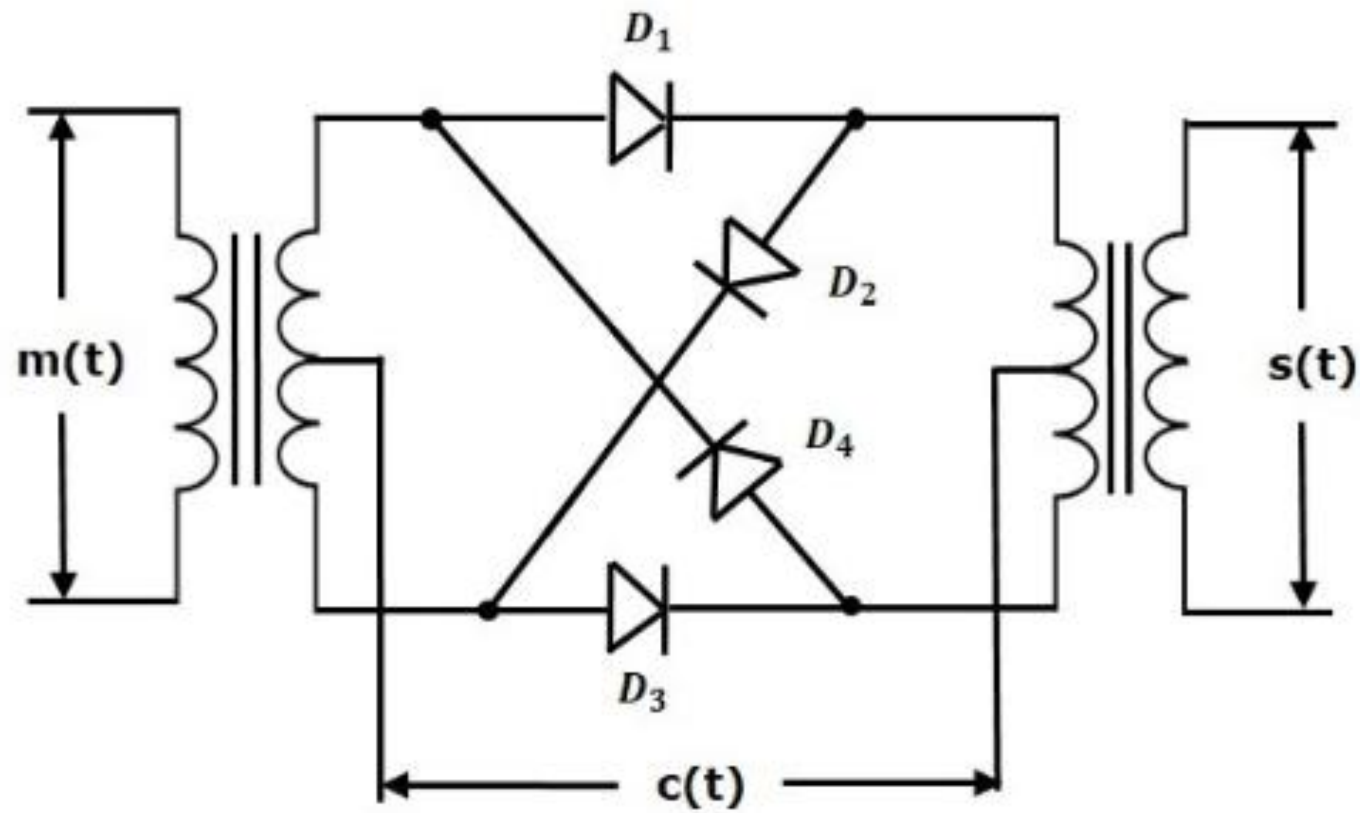
The following two modulators generate DSBSC wave.

- Balanced modulator
- Ring modulator

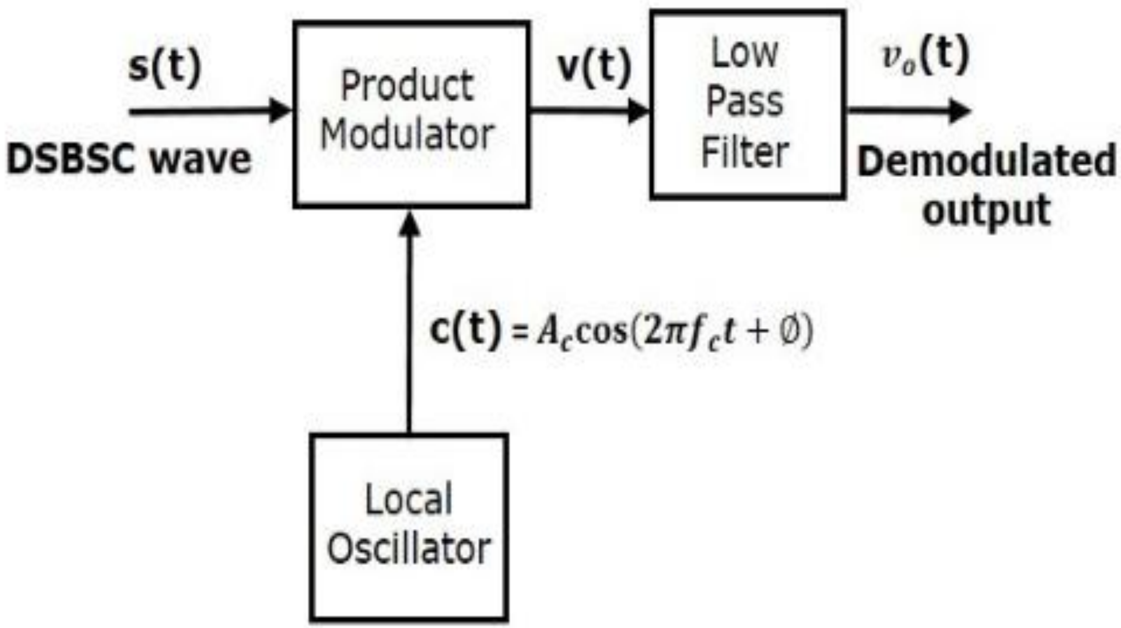
Balanced Modulator



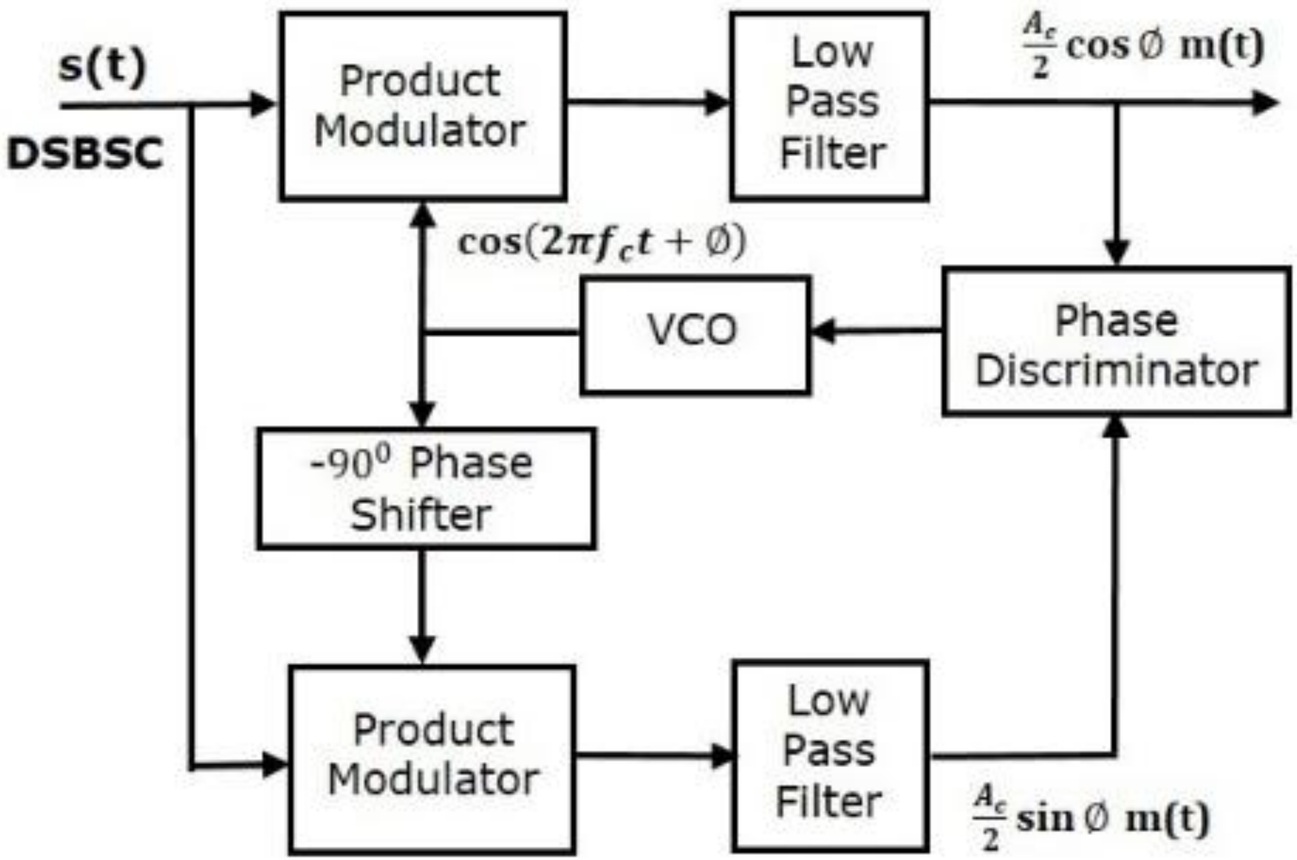
•Ring modulator



Coherent Detector



Costas Loop


s(t)
DSBSC
Product Modulator
Low Pass Filter
$\frac{A_c}{2}\cos\emptyset\ m(t)$
$\cos(2\pi f_c t+\emptyset)$
VCO
Phase Discriminator
-90^0 Phase Shifter
Product Modulator
Low Pass Filter
$\frac{A_c}{2}\sin\emptyset\ m(t)$

SSB-SC and VSB

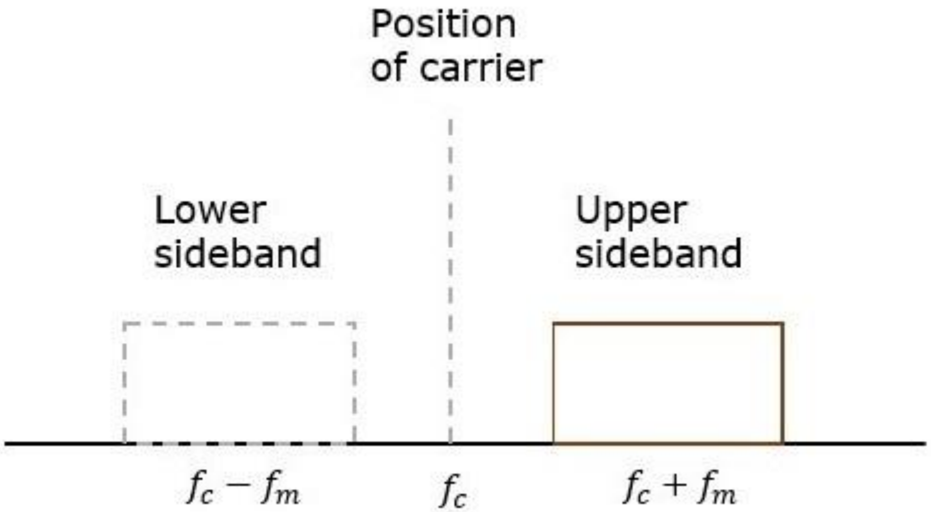
MODULE -2 -SSB-SC and VSB

- Frequency domain description, frequency discrimination method for generation of amplitude modulation single side band modulated wave; time domain description; Phase discrimination method for generating amplitude modulation single side band modulated waves; Demodulation of single side band waves.
- Noise in single side band suppressed carrier; Vestigial side band modulation: Frequency description, generation of vestigial side band modulated wave; Time domain description; Envelope detection of a vestigial side band modulation wave pulse carrier; Comparison of amplitude modulation techniques; applications of different amplitude modulation systems.

Course Learning Outcome

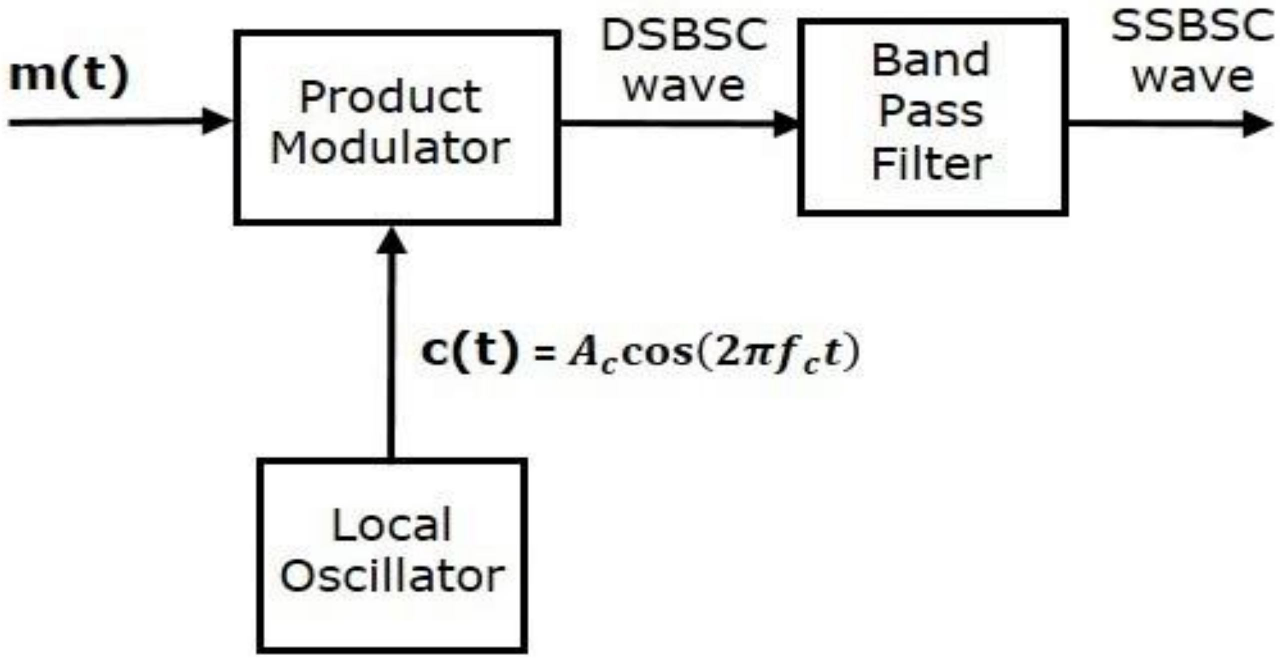
CLOs	Course Learning Outcome
CLO4	Understand the time domain, frequency domain description of amplitude modulation single side band modulated wave, various techniques of generation and detection of SSB, Noise in SSB SC.
CLO5	Understand the time domain, frequency domain description of amplitude modulation single side band modulated wave, various techniques of generation and detection of SSB, Noise in SSB SC.
CLO6	Discuss the comparison of different amplitude modulation techniques and applications of various amplitude systems.

MODULE -2 -SSB-SC and VSB

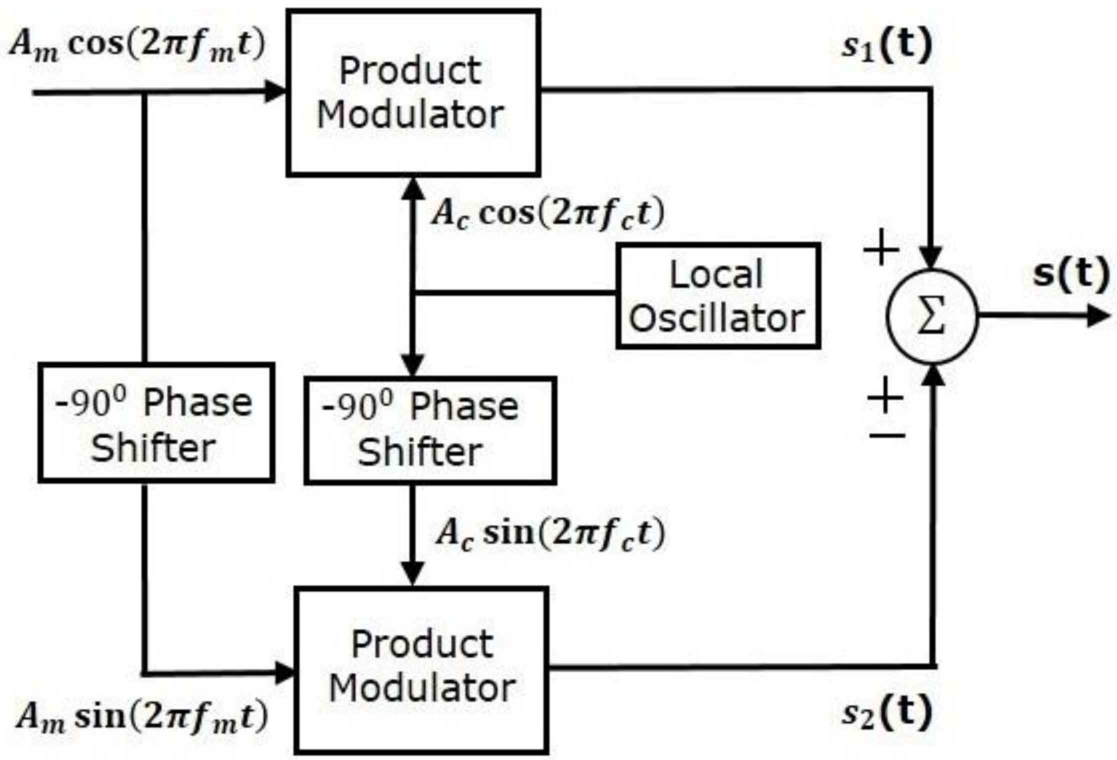


Carrier and a sideband are suppressed and a single sideband is allowed for transmission

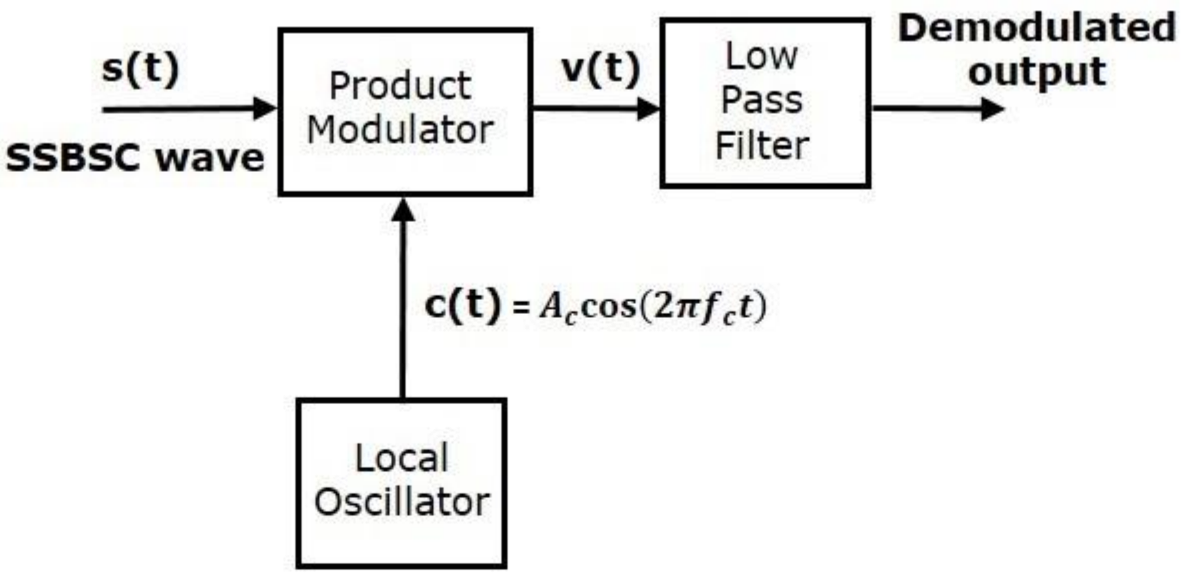
Frequency Discrimination Method



Phase Discrimination Method



Coherent Detector For SSB



TIME DOMAIN DESCRIPTION OF SSB

Mathematical Expression

Let the modulating signal be,

$$\mathbf{m(t) = A_m \cos (2\pi f_m t)}$$

carrier signal

$$\mathbf{c(t) = A_c \cos (2\pi f_c t)}$$

As we have discussed the similar expression in DSB-SC modulation.

So, here we can write,

It is a combination of 2 sidebands,

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

$$: \frac{A_m\ A_c}{2} \cos\left[2\pi\left(f_c + f_m\right) t\right] = \text{Upper sideband}$$

$$\frac{A_m\ A_c}{2} \cos\left[2\pi\left(f_c - f_m\right) t\right] = \text{Lower sideband}$$

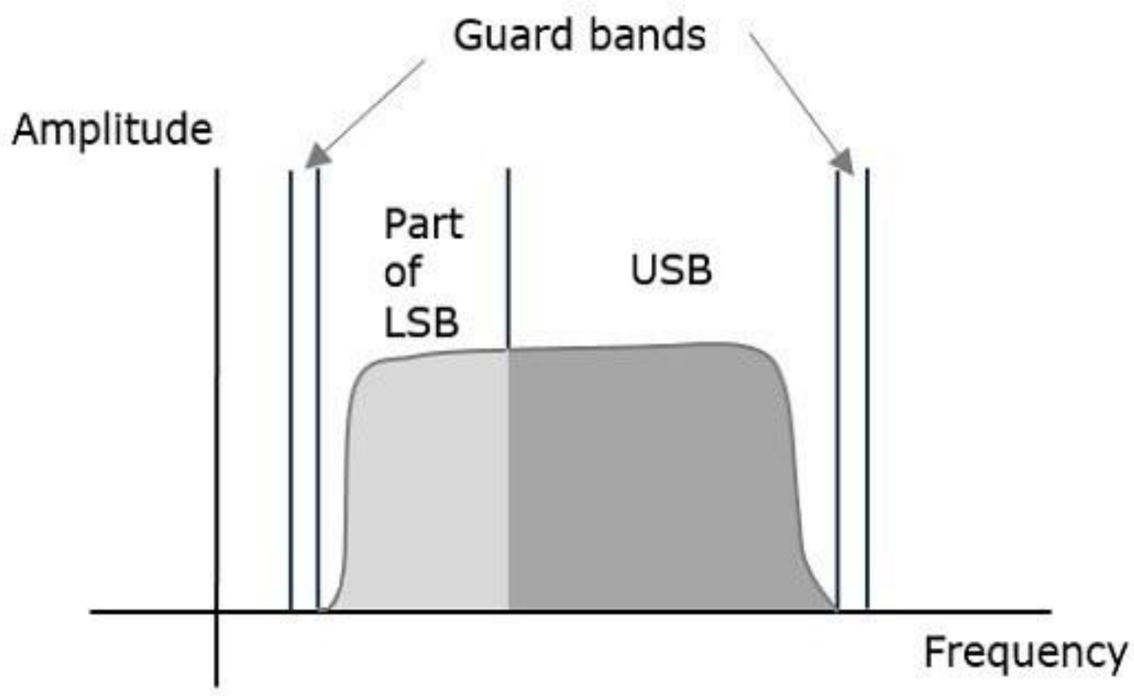
However, we know that the **DSB-SC** amplitude modulated wave requires a bandwidth of $\mathbf{2f_m}$. But, due to the presence of single sideband in SSB modulation, the bandwidth requirement is reduced to half. Hence, bandwidth in case of **SSB-SC** amplitude modulation wave is $\mathbf{f_m}$.

$$: \frac{A_m A_c}{2} \cos[2\pi (f_c + f_m) t] = \text{Upper sideband}$$

$$\frac{A_m A_c}{2} \cos[2\pi (f_c - f_m) t] = \text{Lower sideband}$$

However, we know that the **DSB-SC** amplitude modulated wave requires a bandwidth of $\mathbf{2f_m}$. But, due to the presence of single sideband in SSB modulation, the bandwidth requirement is reduced to half. Hence, bandwidth in case of **SSB-SC** amplitude modulation wave is $\mathbf{f_m}$.

VSBSC MODULATION



VSBSC MODULATION

- Vestigial sideband is a type of Amplitude modulation in which one side band is completely passed along with trace or tail or vestige of the other side band.
- VSB is a compromise between SSB and DSBSC modulation. In SSB, we send only one side band, the Bandwidth required to send SSB wave is w.
- SSB is not appropriate way of modulation when the message signal contains significant components at extremely low frequencies. To overcome this VSB is used.

Transmission Bandwidth

- The transmission bandwidth of VSB modulated wave is represented as,
- B=(fm+ fv) Hz
- **f_m** = Message bandwidth
- **f_v** = Width of the vestigial sideband

VSB Modulation – Advantages

- Highly efficient.
- Reduction in bandwidth.
- Filter design is easy as high accuracy is not needed.

VSB Modulation – Disadvantages

- Bandwidth when compared to SSB is greater.
- Demodulation is complex.

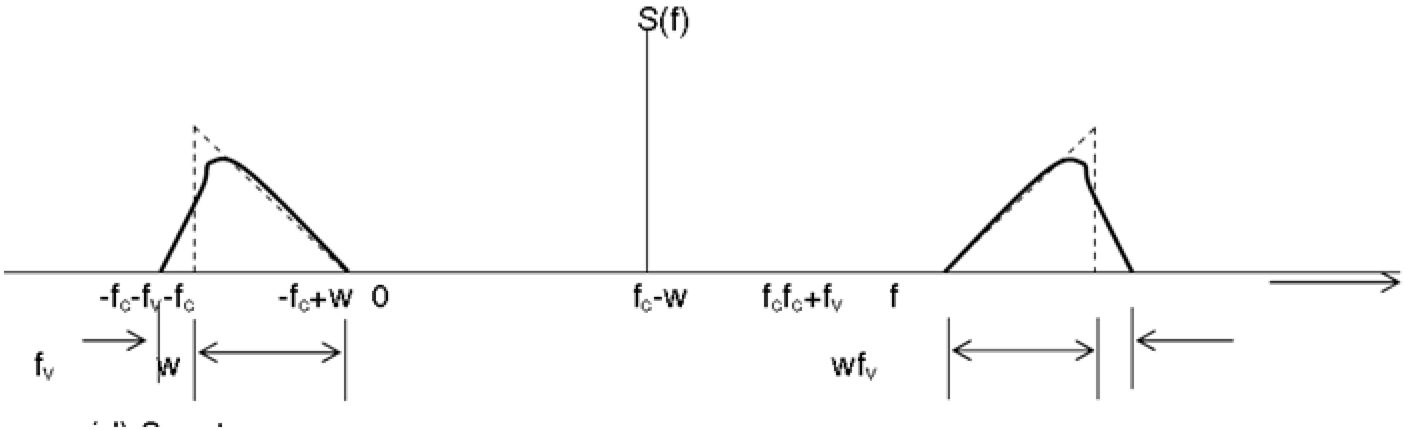
VSB Modulation – Application

- The most prominent and standard application of VSB is for the transmission of **television signals**. Also, this is the most convenient and efficient technique when bandwidth usage is considered.

Frequency Domain Description

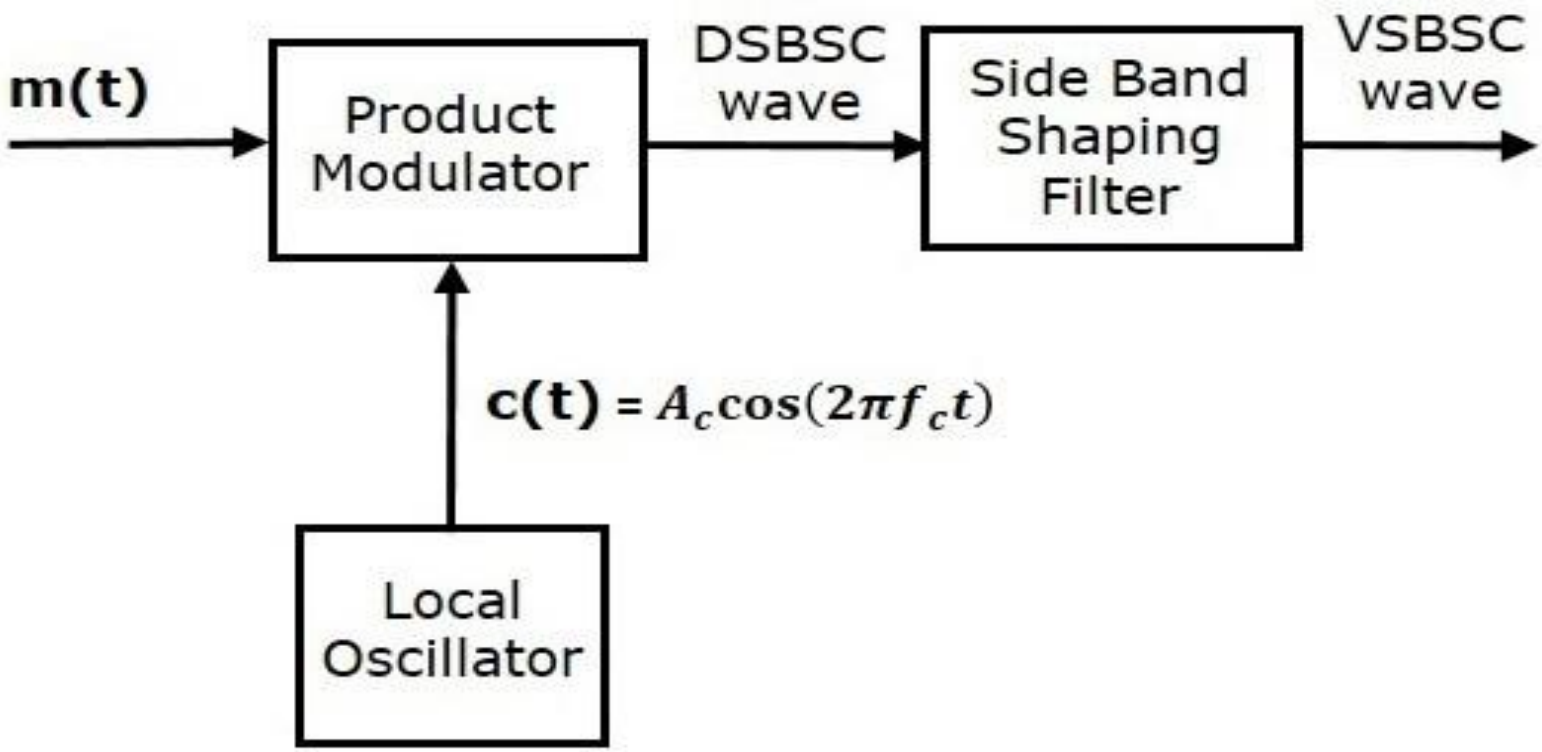
- Assume that the Lower side band is modified into the vestigial side band.
- The vestige of the lower sideband compensates for the amount removed from the upper sideband.
- The bandwidth required to send VSB wave is $B = w+f_v$
- Where Fv is vestigial side band .
- The vestige of the Upper sideband compensates for the amount removed from the Lower sideband.
- The bandwidth required to send VSB wave is B = w+fv, where fv is the width of the vestigial side band.

Frequency Domain Description



•Therefore, VSB has the virtue of conserving bandwidth almost as efficiently as SSB modulation, while retaining the excellent low-frequency base band characteristics of DSBSC and it is standard for the transmission of TV signals.

Generation of VSBSC



Generation of VSBSC

- Both of the sidebands are not essential for the transmission, as it is a waste. But a single band if transmitted, hints to loss of information. Therefore, this technique has evolved.
- Vestigial Sideband Modulation or VSB Modulation is the procedure where a part of the signal called as vestige is modulated, along with one sideband. A VSB signal can be plotted as shown in the resulting figure.

Generation of VSBSC

- Sideways with the upper sideband, a part of the lower sideband is also being transmitted in this method. A guard band of very minor width is laid on either side of VSB in order to avoid the interferences. VSB modulation is mostly used in television transmissions.

Transmission Bandwidth

The transmission bandwidth of VSB modulated wave is represented as

– $B=(fm+fv)Hz$

Where,

$\mathbf{f_m}$ = Message bandwidth

fv = Width of the vestigial sideband

Generation of VSBSC

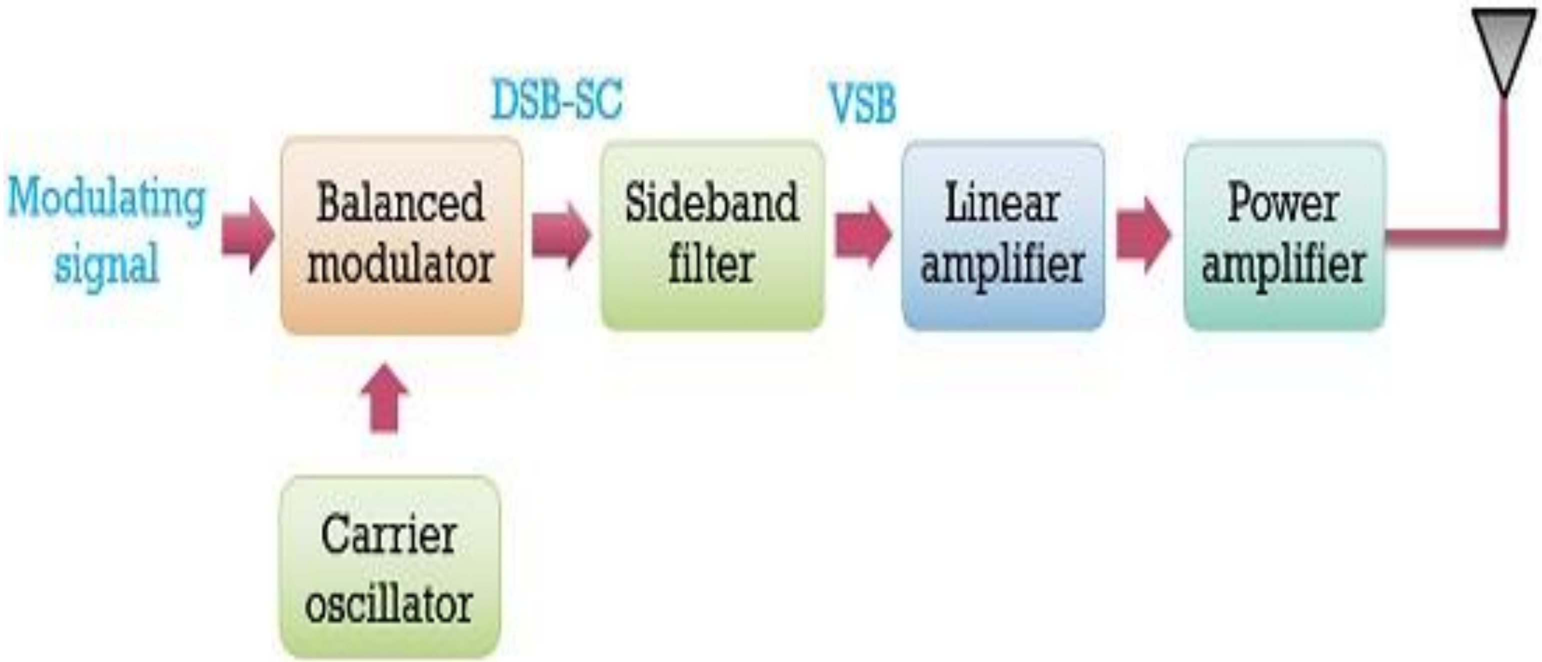
- VSB Modulation **– Advantages**
- Highly efficient.
- Reduction in bandwidth.
- Filter design is easy as high accuracy is not needed.
- The transmission of low frequency components is possible, without difficulty.
- Possesses good phase characteristics.
- VSB Modulation – **Disadvantages**
- Bandwidth when compared to SSB is greater.
- Demodulation is complex.

Generation of VSBSC

VSB Modulation – **Application**

- The most noticeable and standard application of VSB is for the transmission of television signals. Likewise, this is the supreme suitable and capable technique when bandwidth usage is considered.
- From 1.25 MHz of lower sideband band, 0.75 MHz vestige is transmitted and rest is suppressed. This basically simplifies the filtering requirements.
- Hence, by this, we can reduce the bandwidth requirement to 6 MHz from 9MHz

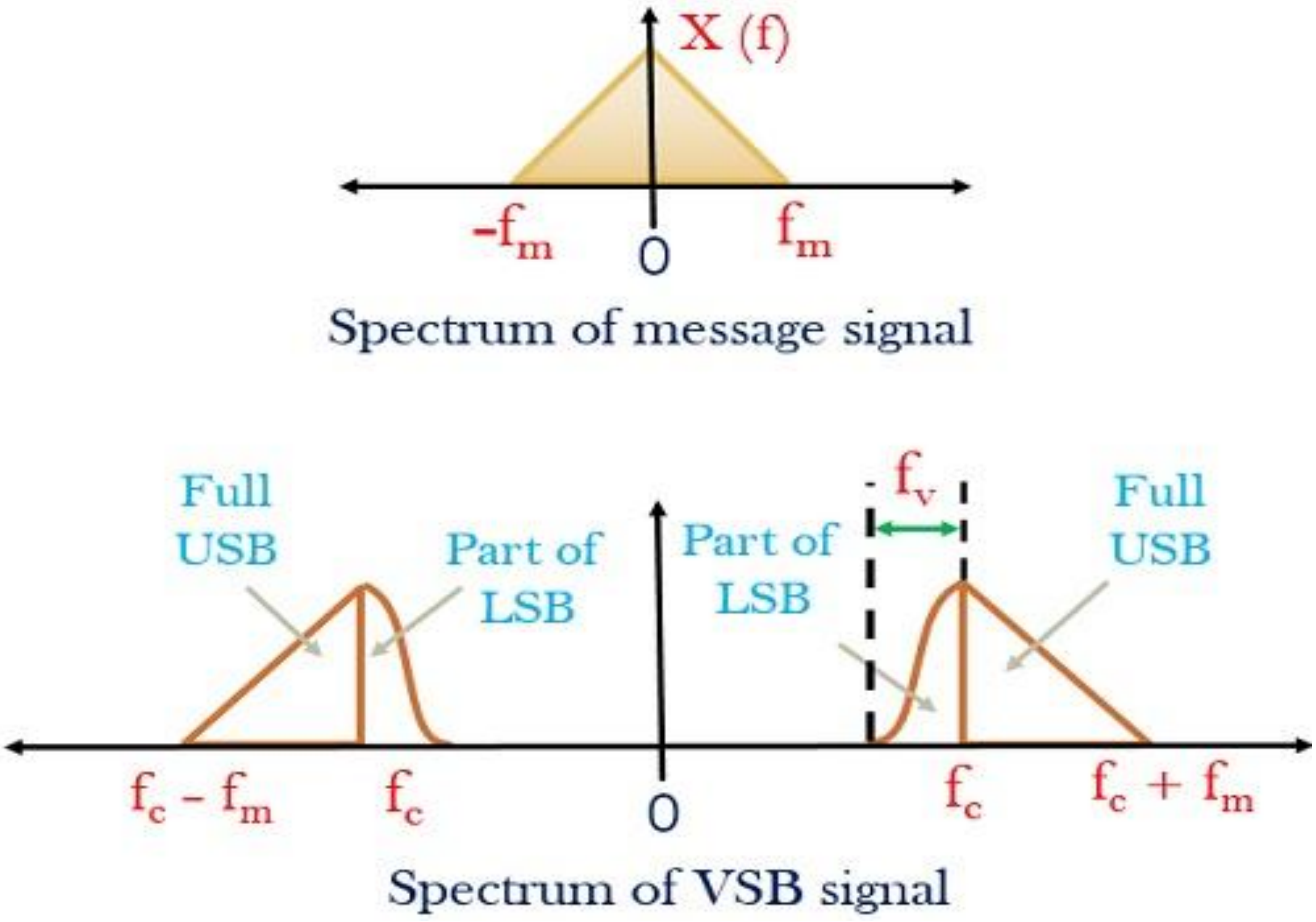
Generation of VSBSC



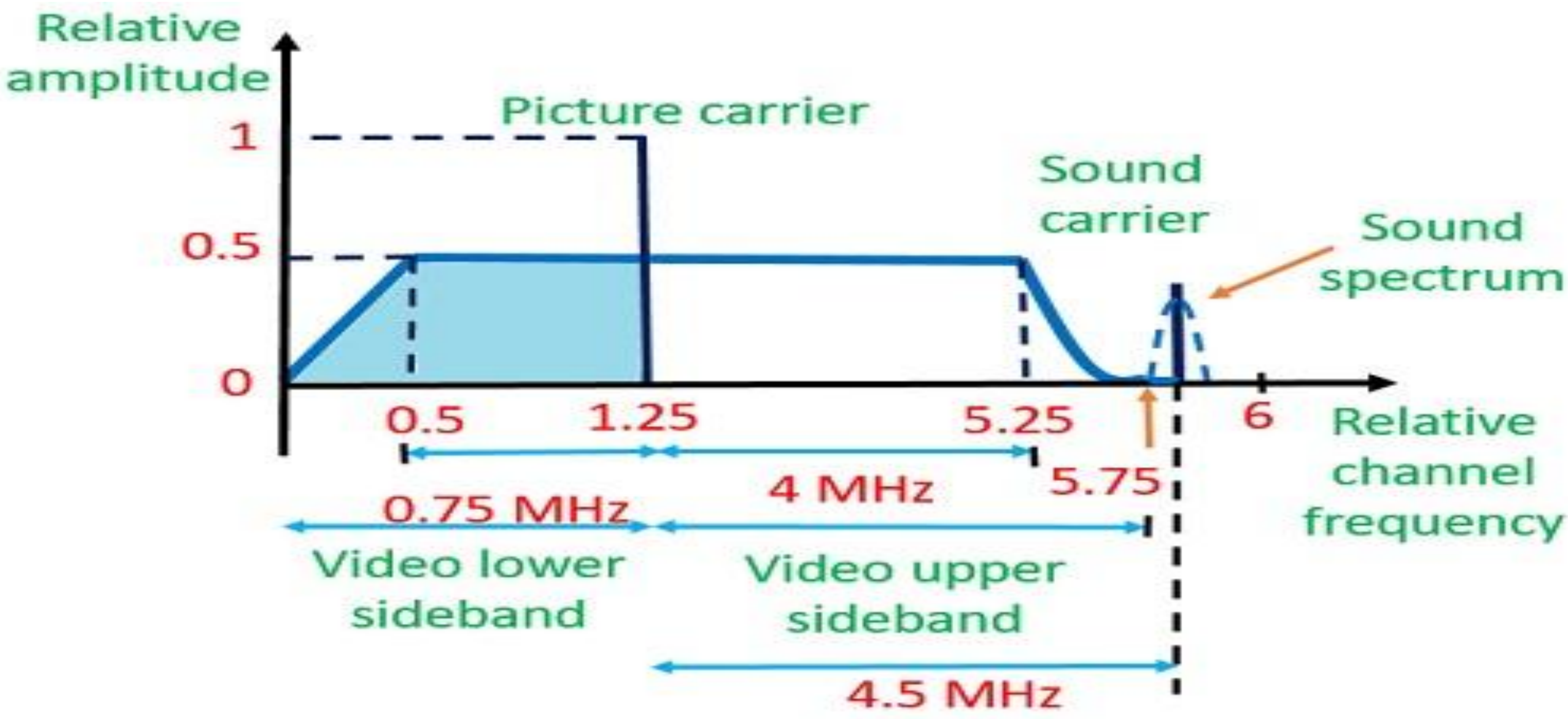
VSB signal generation and transmission

Electronics Coach

Generation of VSBSC



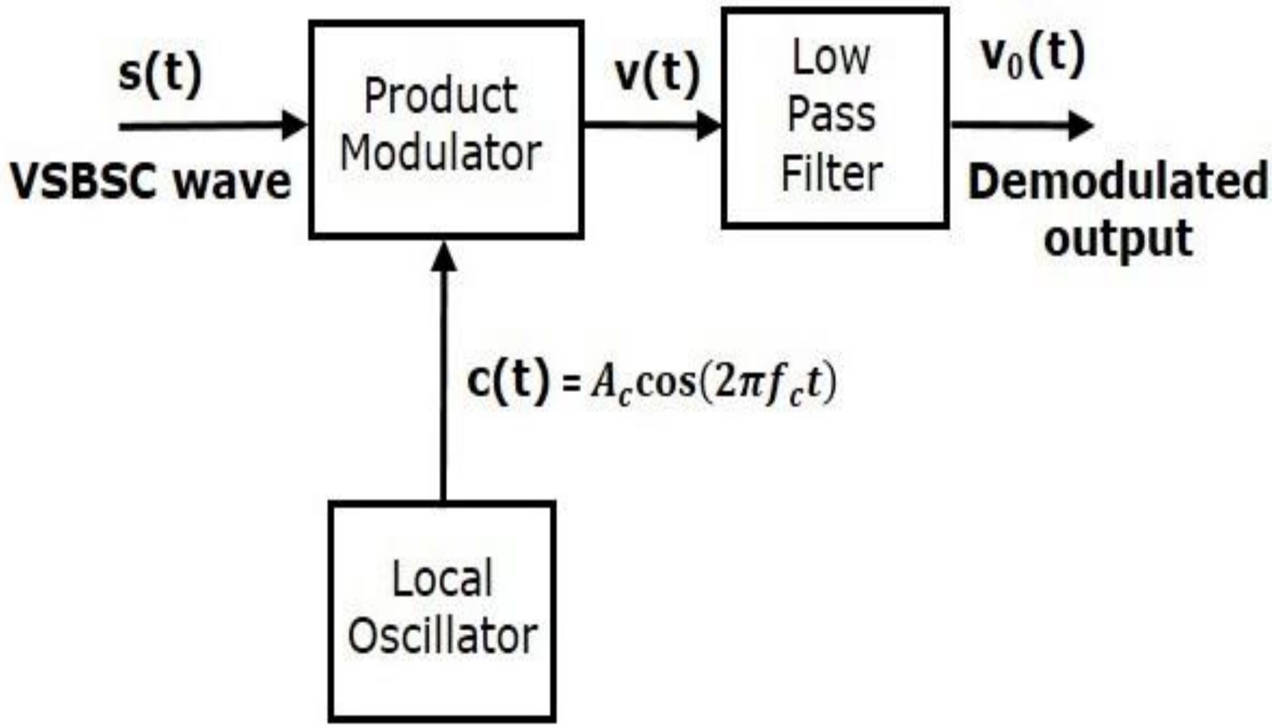
Generation of VSBSC



Spectrum of transmitted TV signal using VSB transmission

Electronics Coach

Demodulation of VSBSC



Comparison of AM

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

ANGLE MODULATION

MODULE -III

Basic concepts, Frequency Modulation: Single tone frequency modulation, Spectrum Analysis of Sinusoidal FM Wave, Narrow band FM, Wide band FM, Constant Average Power, Transmission bandwidth of FM Wave - Generation of FM Waves, Direct FM, Detection of FM Waves: Balanced Frequency discriminator, Zero crossing detector, Phase locked loop, Comparison of FM and AM.

Course Learning Outcome

CLOs	Course Learning Outcome
CLO7	Analyze the basic concepts of Frequency modulation like single tone , spectrum analysis of frequency modulated wave and transmission bandwidth of FM.
CLO8	Understand the concepts of narrow band frequency modulation, wide band frequency modulation and pre emphasis and de emphasis circuits in FM.
CLO9	Discuss the generation of frequency modulation waves by direct method and indirect method and detection methods like balanced frequency discriminator, foster seeley discriminator, phase locked loop etc.

ANGLE MODULATION

Angle modulation : Angle modulation is the process by which the angle (frequency or phase) of the carrier signal is changed in accordance with the instantaneous amplitude of modulating or message signal.

classified into two types such as

Frequency modulation (FM)

Phase modulation (PM)

ANGLE MODULATION

Angle modulation is Used for :

Commercial radio broadcasting

Television sound transmission

Two way mobile radio

Cellular radio

Microwave and satellite communication system

FM MODULATION

In FM the carrier amplitude remains constant, the carrier frequency varies with the amplitude of modulating signal.

The amount of change in carrier frequency produced by the modulating signal is known as ***frequency deviation.***

PHASE MODULATION(PM)

PHASE MODULATION(PM)

The process by which changing the phase of carrier signal in accordance with the instantaneous of message signal. The amplitude remains constant after the modulation process.

Mathematical analysis:

$$\mathbf{M\ (t) = A[\cos wct + k\,p\,m\,(t)]}$$

where A is a constant, wc is the carrier frequency, m(t) is the message signal, and kp is a parameter that specifies how much change in the angle occurs for every unit of change of m(t).

PHASE MODULATION (PM)

Where = phase angle of carrier signal. It is changed in accordance with the amplitude of the message signal;

i.e.

$$\theta = KV_m(t) = KV_m \cos\omega_m t$$

After phase modulation the instantaneous voltage will be or

$$v_{pm}(t) = V_C \cos(\omega_C t + KV_m \cos\omega_m t)$$

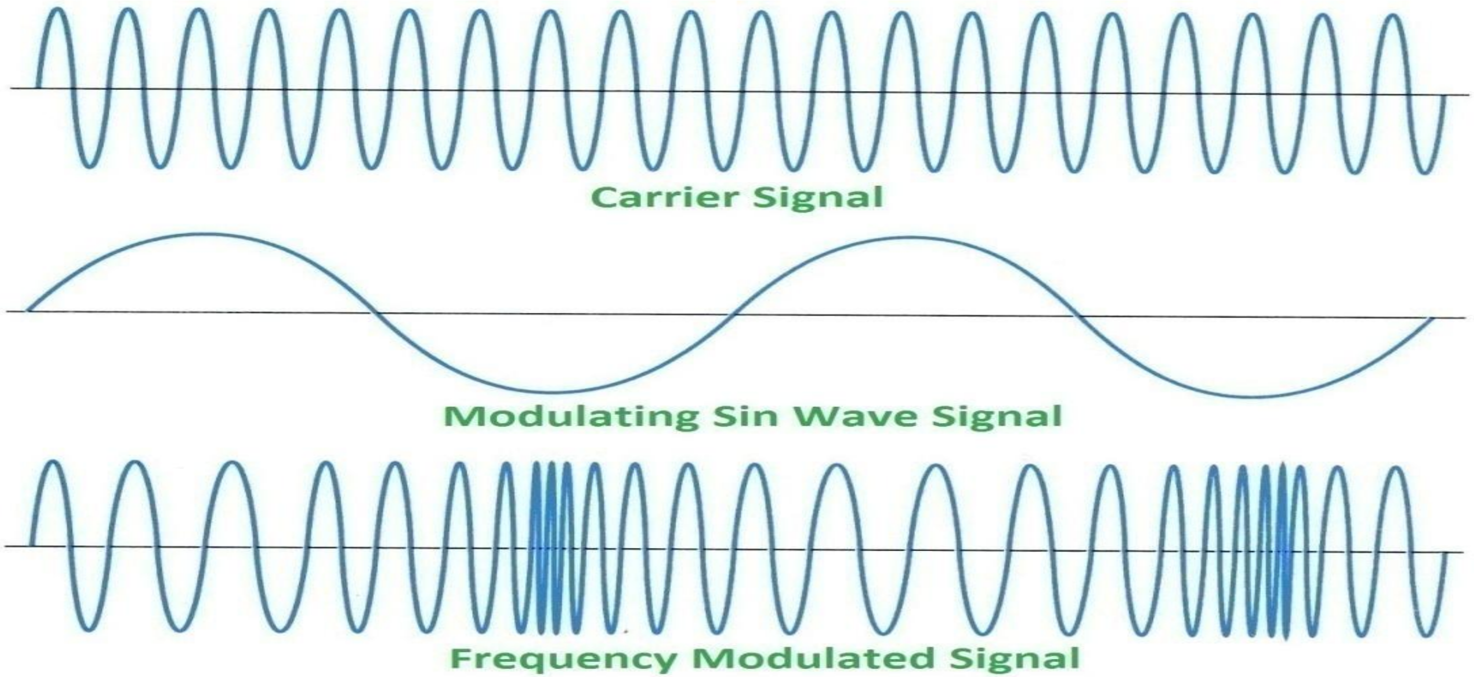
$$v_{pm}(t) = V_C \cos(\omega_C t + m_p \cos\omega_m t)$$

Where m_p = Modulation index of phase modulation

K is a constant and called deviation sensitivities of the phase

- A process where the frequency of the carrier wave varies with the magnitude variations of the modulating or audio signal.

- The amplitude of the carrier wave is kept constant.



Mathematical analysis:
Let message signal:

$$v_m(t) = V_m \cos \varpi_m t$$

And carrier signal:

$$v_c(t) = V_c \cos[\varpi_c t + \theta]$$

FREQUENCY MODULATION

During the process of frequency modulations the frequency of carrier signal is changed in accordance with the instantaneous amplitude of message signal .Therefore the frequency of carrier after modulation is written as

$$\omega_i = \omega_c + K_1 v_m(t) = \omega_C + K_1 V_m \cos\omega_m t$$

To find the instantaneous phase angle of modulated signal, integrate equation above w.r.t. ***t***

$$\phi_i = \int \omega_i dt = \int \left(\omega_C + K_1 V_m \cos\omega_m t\right) dt = \omega_C t + \frac{K_1 V_m}{\omega_m} \sin\omega_m t$$

Thus, we get the FM wave as:

$$v_{FM}(t) = Vc\cos\phi_1 = V_C\cos(\omega_C t + \frac{K_1 V_m}{\omega_m}\sin\omega_m t)$$

$$v_{FM}(t) = V_C\cos(\omega_C t + m_f \sin\omega_m t)$$

Where modulation index for FM is given by

$$m_f = \frac{K_1 V_m}{\omega_m}$$

Frequency deviation:

Δf is the relative placement of carrier frequency (Hz) w.r.t its unmodulated value. Given as

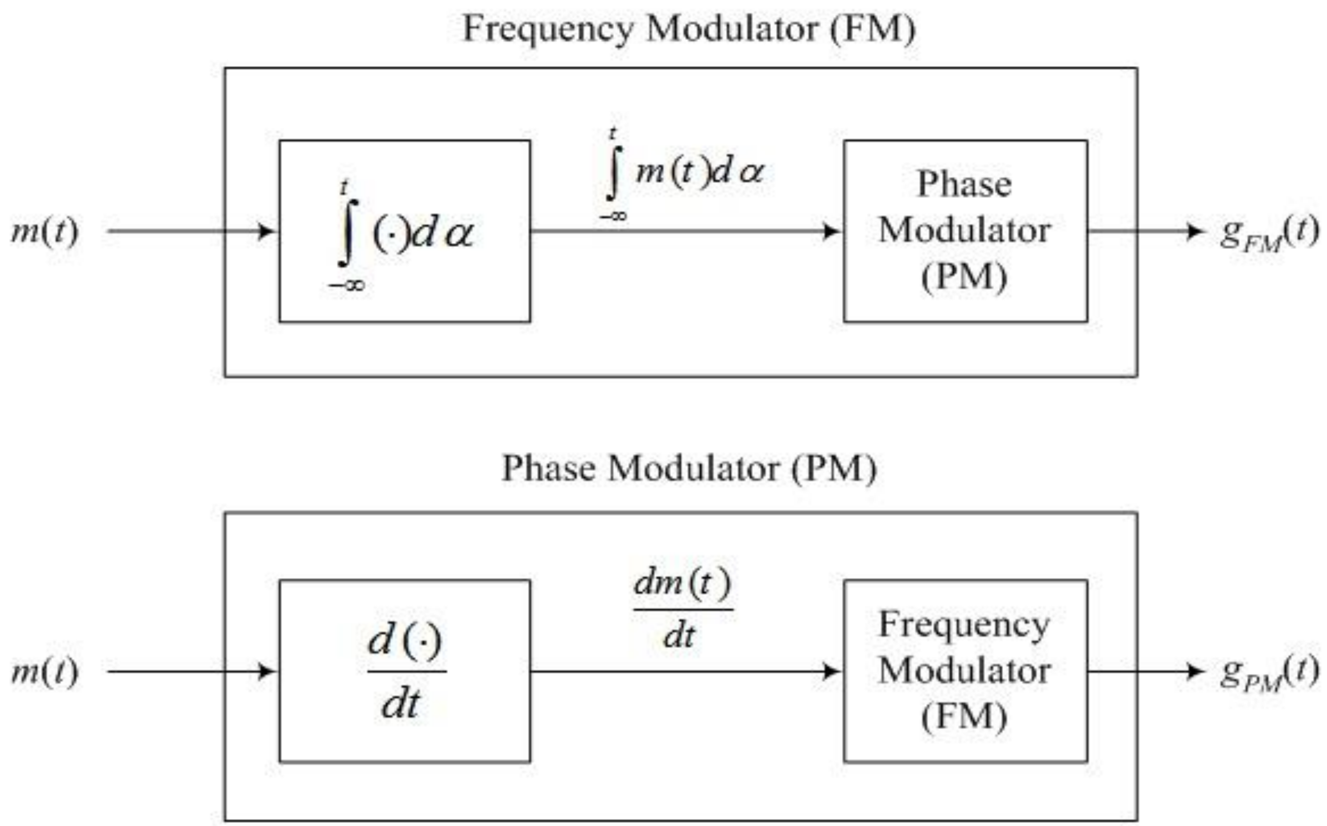
$$\omega_{max} = \omega_C + K_1 V_m$$

$$\omega_{min} = \omega_C - K_1 V_m$$

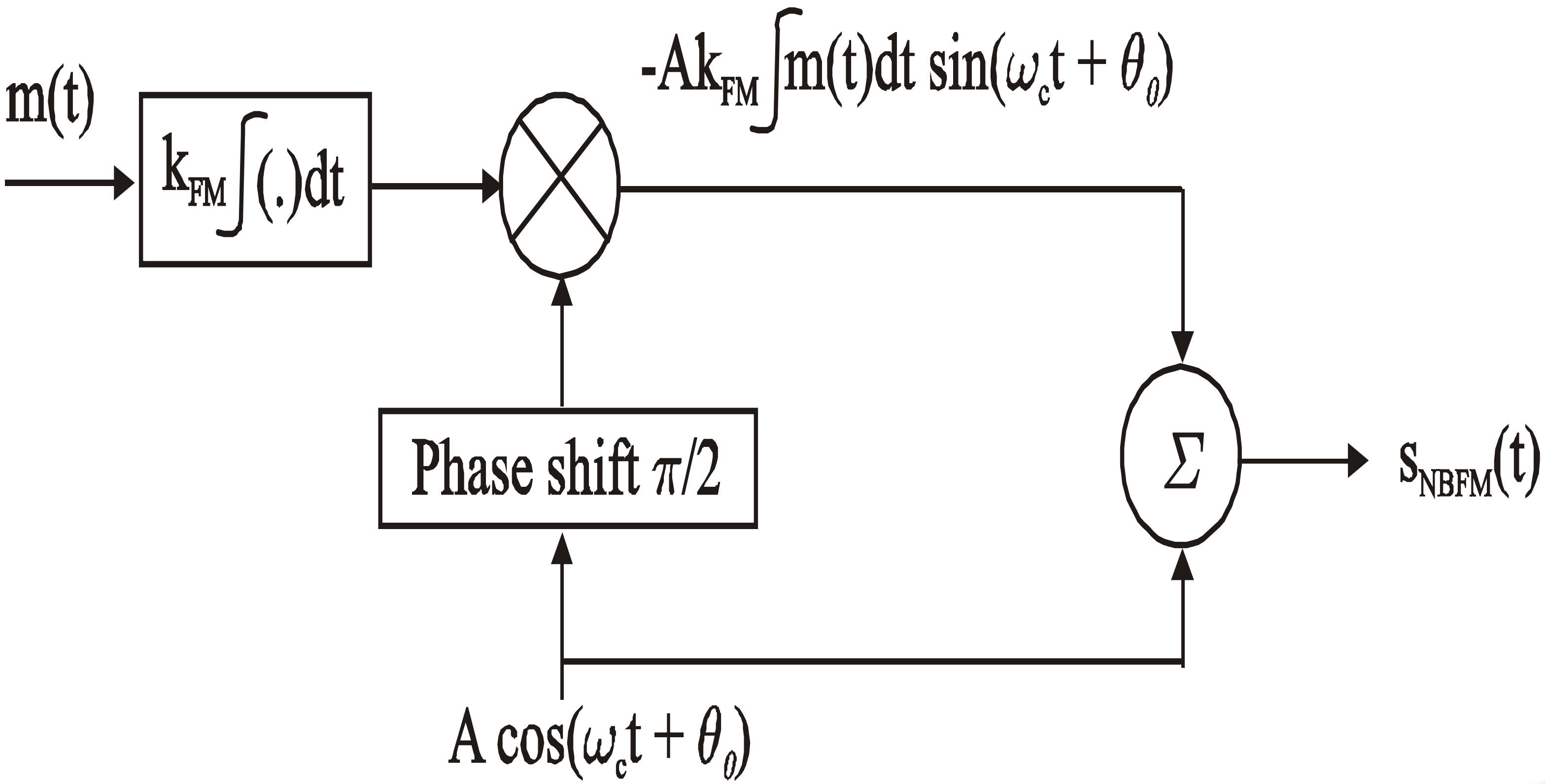
$$\omega_d = \omega_{max} - \omega_C = \omega_C - \omega_{min} = K_1 V_m$$

$$\Delta f = \frac{\omega_d}{2\pi} = \frac{K_1 V_m}{2\pi}$$

Relation between FM and PM



NARROW BAND FM



FM Bandwidth

Estimation of transmission b/w;
Assume m_f is large and n is approximate $m_f + 2$;
Thus

B_{fm}=2(m_f + 2)f_m

$$2\left(\frac{\Delta f}{f_m} + 2\right) f_m$$

$$B_{fm} = 2(\Delta f + f_m)........(1)$$

(1) is called Carson's rule

SINGLE-TONE FM

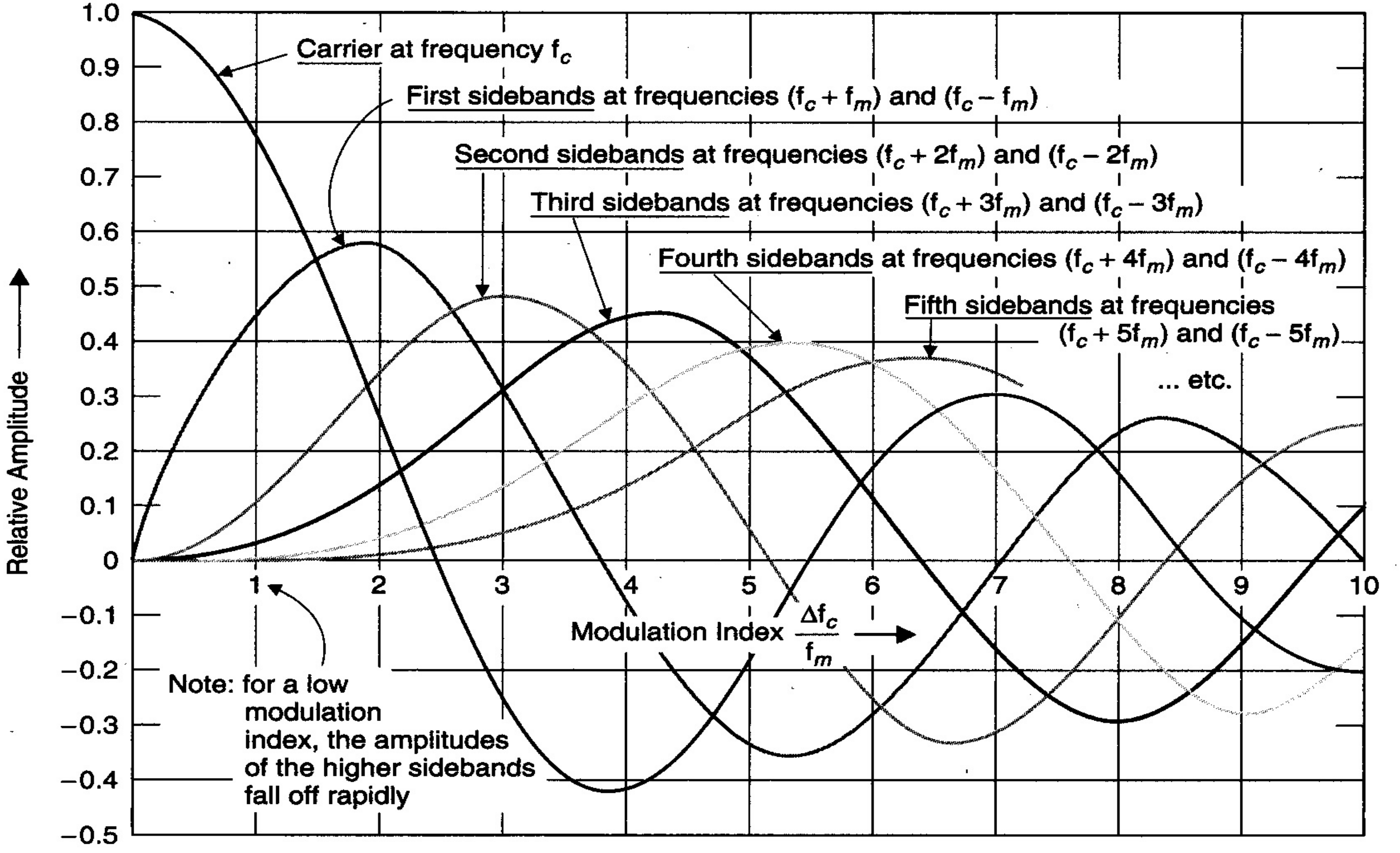
$$v(t)_{FM} = V_C\{J_0(m_f)\cos\omega_C t + J_1(m_f)\cos\left[(\omega_C+\omega_m)t+\frac{\pi}{2}\right] - J_1(m_f)\cos\left[(\omega_C-\omega_m)t-\frac{\pi}{2}\right]$$

$$+J_2(m_f)\cos[(\omega_C+2\omega_m)t] + J_2(m_f)\cos[(\omega_C-2\omega_m)t] + \ldots J_n(m_f)\ldots\}$$

$$J_n(m_f) = \left(\frac{m_f}{2}\right)^n\left[\frac{1}{n} - \frac{(m_f/2)^2}{1!(n+1)!} + \frac{(m_f/2)^4}{2!(n+2)!} - \ldots\right]$$

N = number of the side frequency
M_f = modulation index

SINGLE-TONE FM



FM Generation

The frequency modulated signals can be generated in 2 ways:

i) Direct method of FM:

It requires a VCO whose oscillation frequency has linear dependence on applied voltage.

Advantage: large frequency deviation

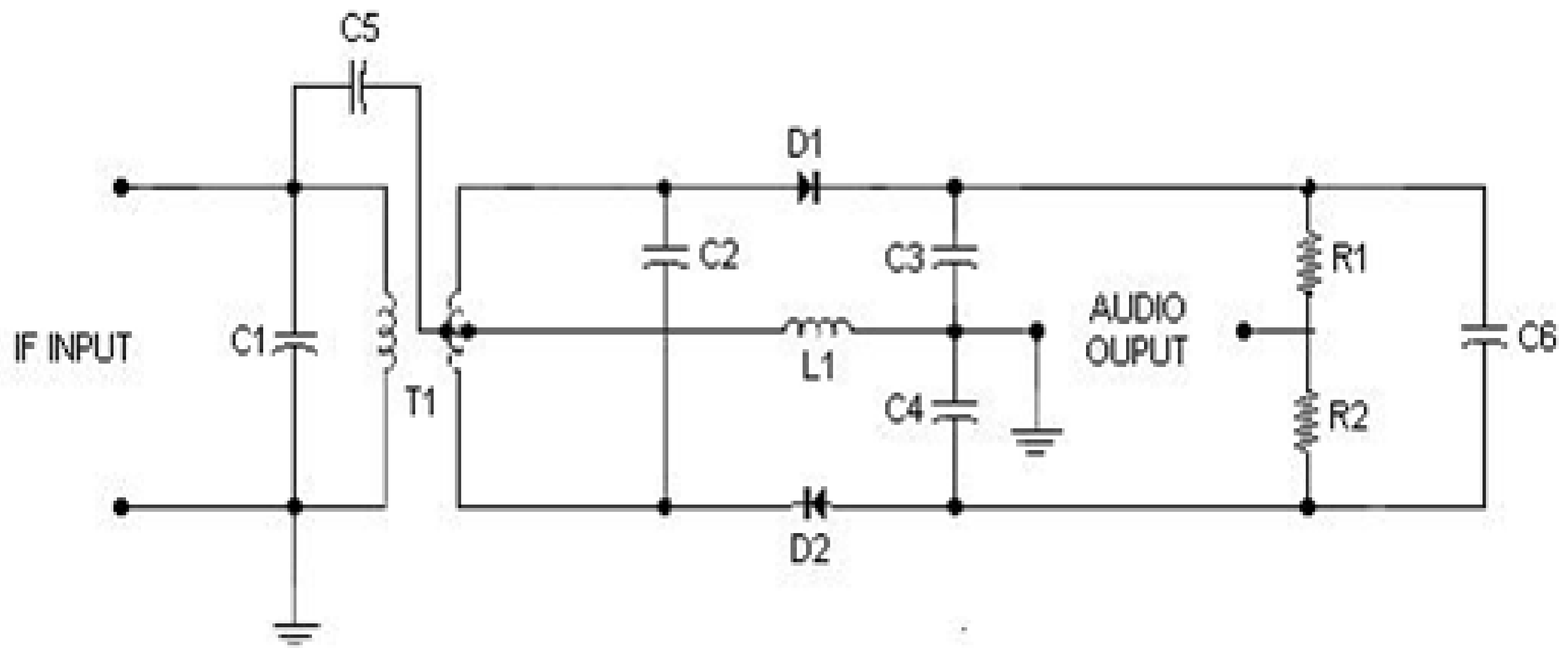
Disadvantage: the carrier frequency tends to drift and must be stabilized.

Ex: Varactor diode

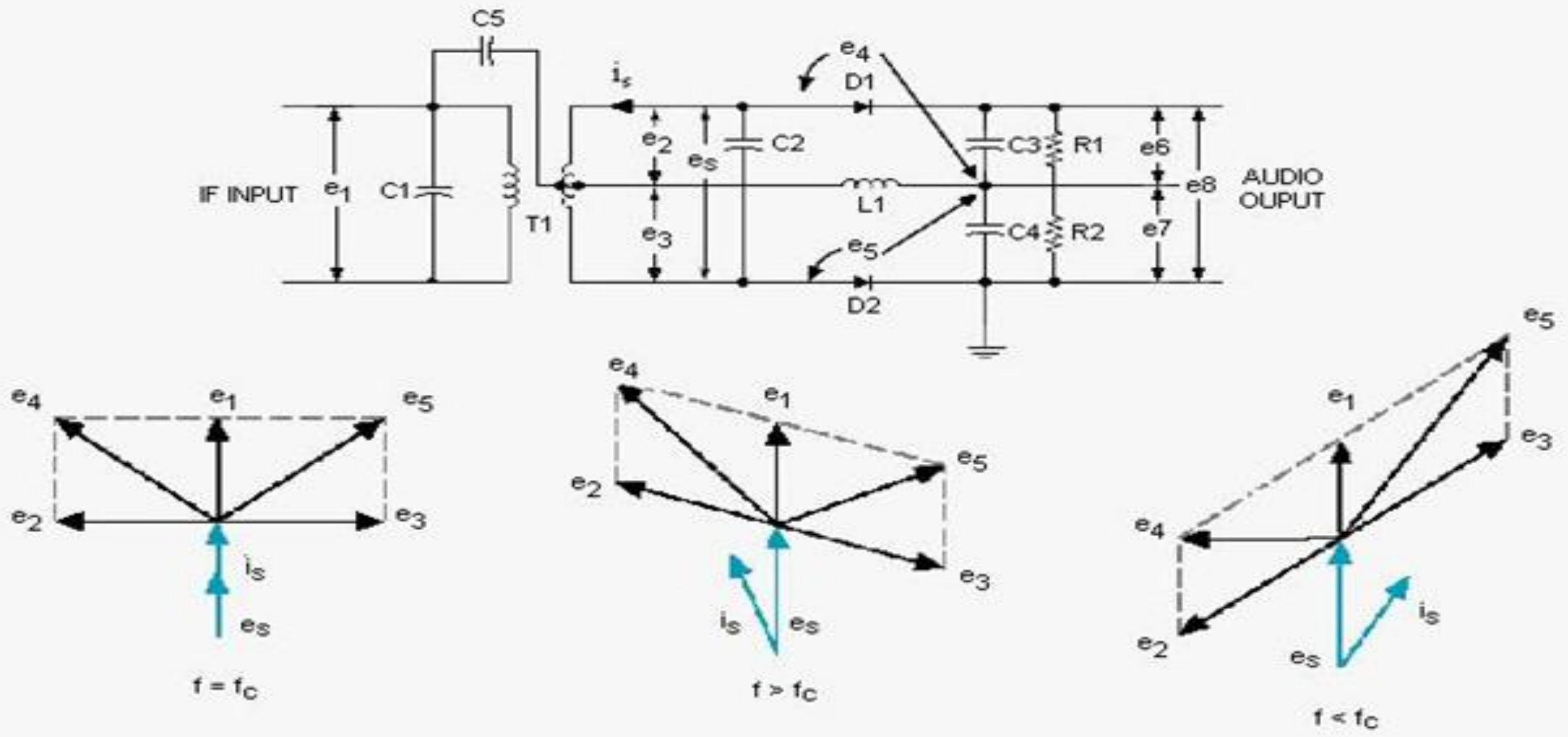
Foster Seley Detector

- The Foster-Seely Discriminator is a widely used FM detector.
- The detector consists of a special center-tapped IF transformer feeding two diodes. The schematic looks very much like a full wave DC rectifier circuit.
- Because the input transformer is tuned to the IF frequency, the output of the discriminator is zero when there is no deviation of the carrier
- both halves of the center tapped transformer are balanced. As the FM signal swings in frequency above and below the carrier frequency,
- the balance between the two halves of the center-tapped secondary are destroyed and there is an output voltage proportional to the frequency deviation.

DEMODULATION OF FM WAVES



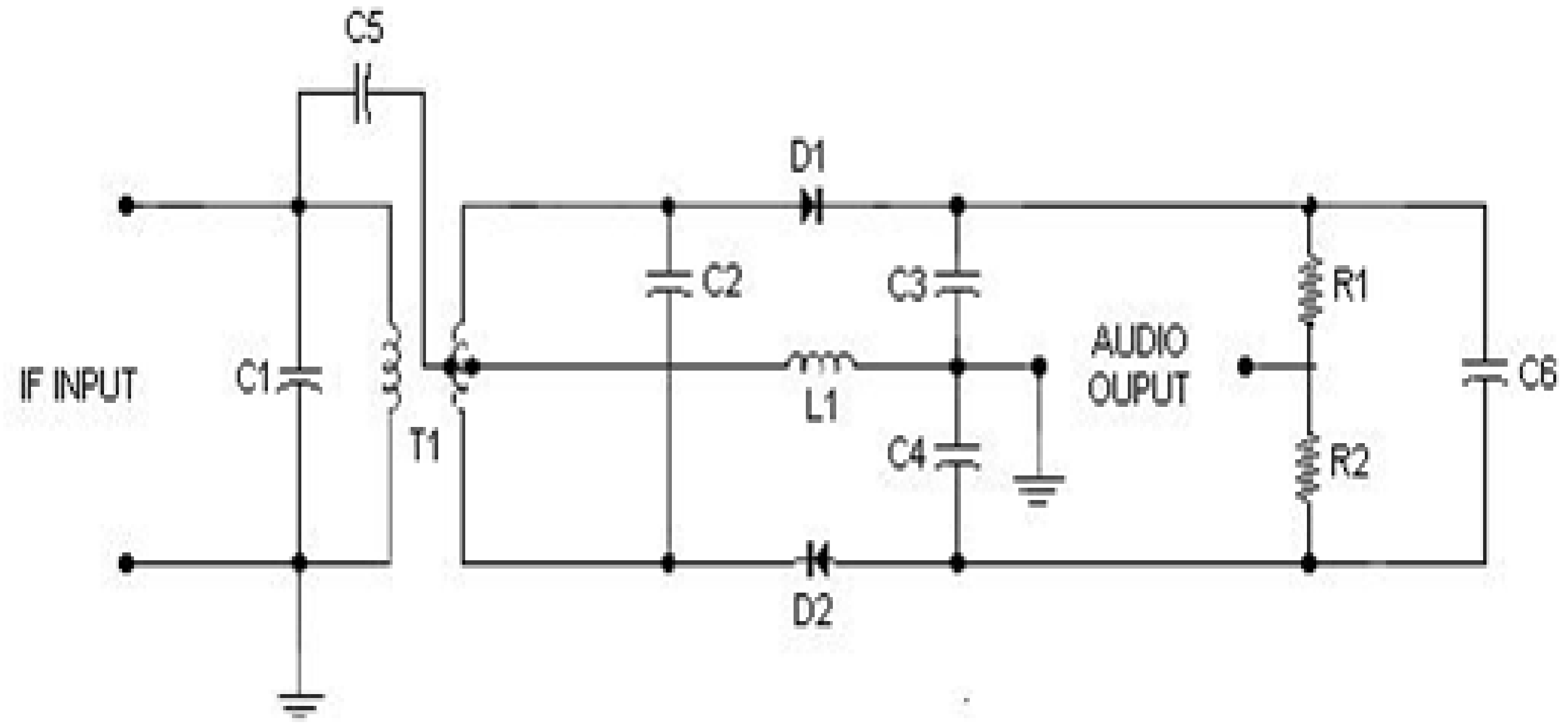
DEMODULATION OF FM WAVES



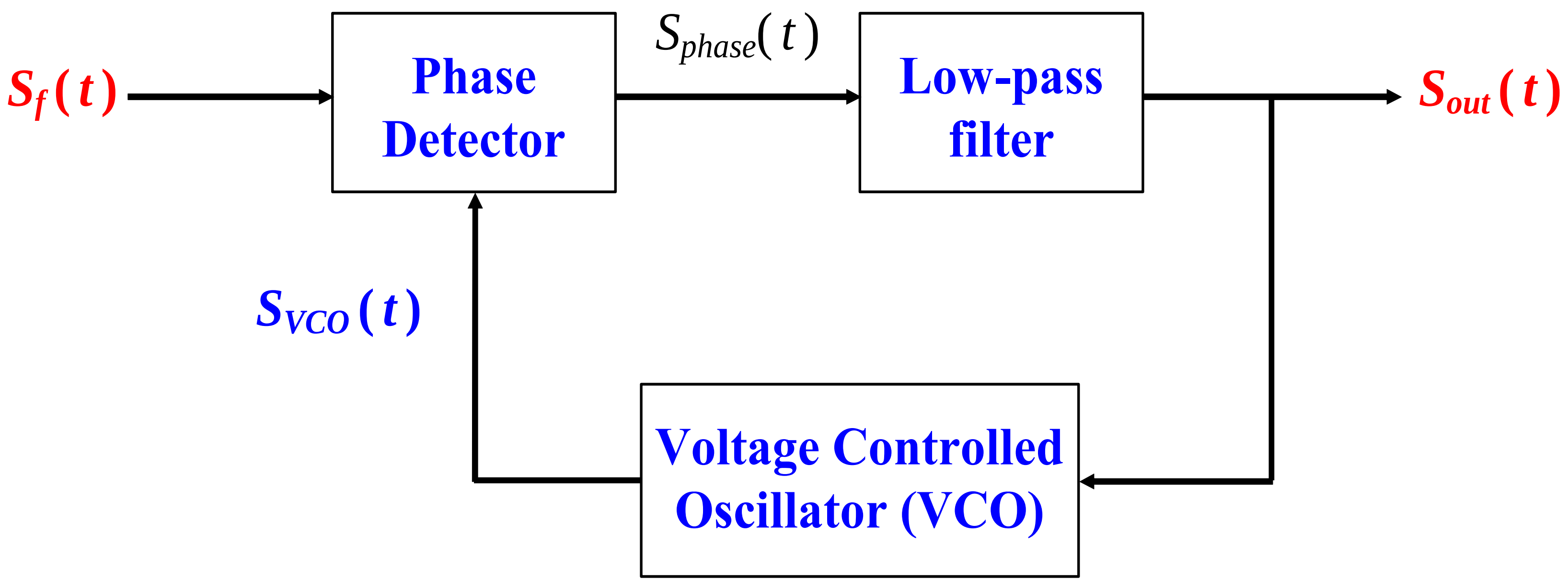
Ratio Detector :

- The ratio detector is a variant of the discriminator.
- The circuit is similar to the discriminator, but in a ratio detector, the diodes conduct in opposite directions. Also, the output is not taken across the diodes, but between the sum of the diode voltages and the center tap.
- The output across the diodes is connected to a large capacitor, which eliminates AM noise in the ratio detector output.
- The operation of the ratio detector is very similar to the discriminator, but the output is only 50% of the output of a discriminator for the same input signal.

DEMODULATION OF FM WAVES



DEMODULATION OF FM WAVES



$$S_f(t) = A_f \cdot \cos[\omega_c t + \phi(t)]$$

$$S_{VCO}(t) = A_{VCO} \cdot \sin[\omega_0 t + \phi_0(t)]$$

PREEMPHASIS AND DEEMPHASIS

- In FM, the noise increases linearly with frequency. By this, the higher frequency components of message signal are badly affected by the noise.
- To solve this problem, we can use a preemphasis filter of transfer function Hp(ƒ) at the transmitter to boost the higher frequency components before modulation.
- Similarly, at the receiver, the deemphasis filter of transfer function Hd(ƒ)can be used after demodulator to attenuate the higher frequency components thereby restoring the original message signal.

PREEMPHASIS AND DEEMPHASIS

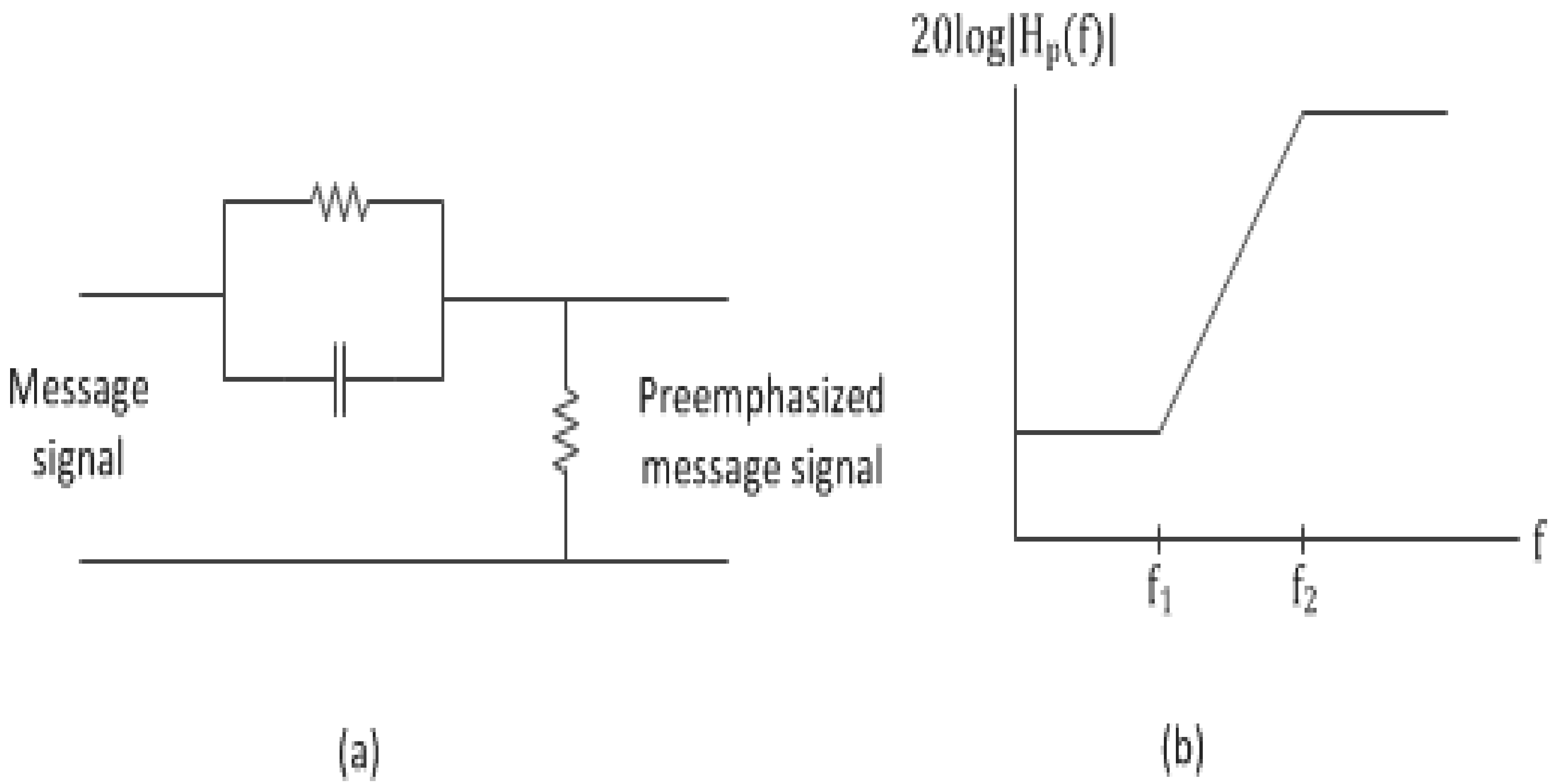


Figure ;(a) Preemphasis network. (b) Frequency response of preemphasis network.

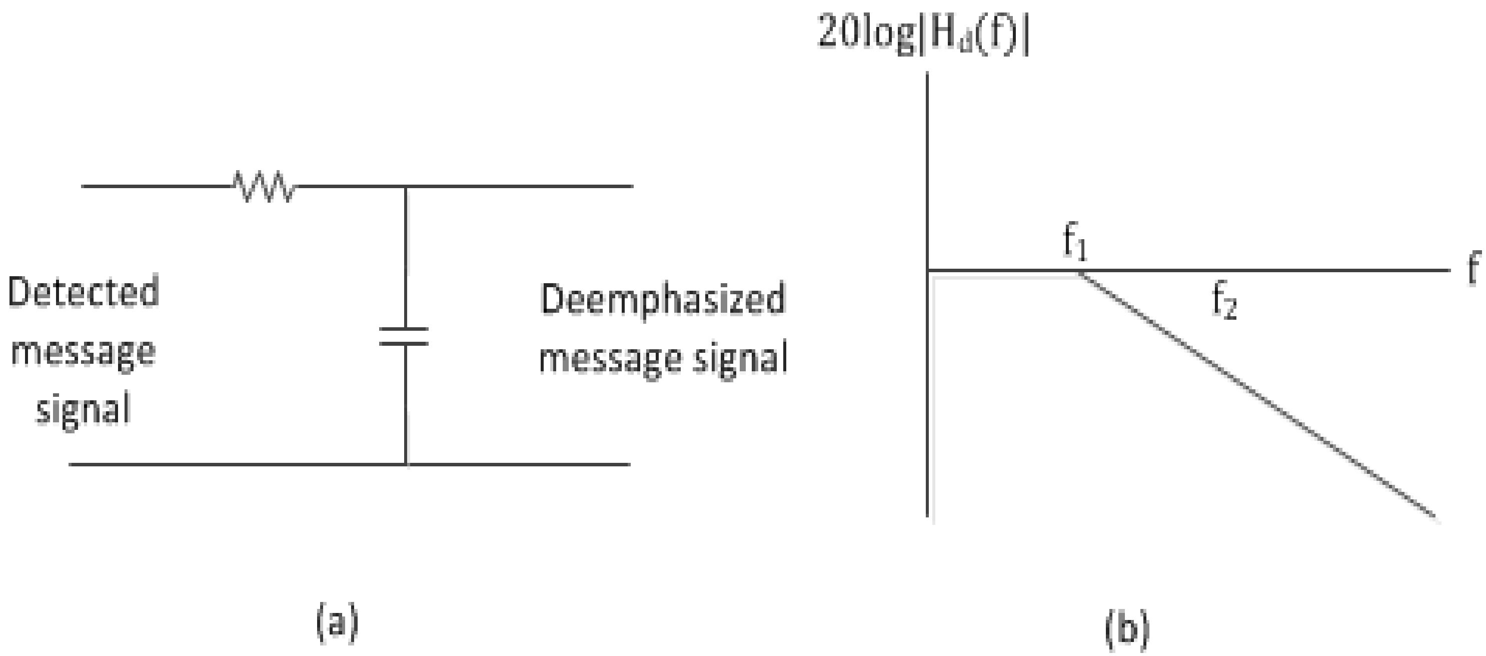


Figure (a) Deemphasis network. (b) Frequency response of Deemphasis network.

Comparison of AM and FM:

Table 1 - Comparison of AM, FM, and Digital Encoding Techniques			
Parameter	AM	FM	Digital
Signal-to-Noise Ratio	Low-to-Moderate	Moderate-High	High
Performance vs. Attenuation	Sensitive	Tolerant	Invariant
Transmitter Cost	Moderate-High	Moderate	High
Receiver Cost	Moderate	Moderate-High	High
Receiver Gain Adjustment	Often Required	Not Required	Not Required
Installation	Adjustments Requires	No Adjustments Required	No Adjustments Required
Multichannel Capabilities	Require High Linearity Optics	Fewer Channels	Good
Performance Over Time	Moderate	Excellent	Excellent
Environmental Factors	Moderate	Excellent	Excellent

NOISE IN ANALOG COMMUNICATION SYSTEM

NOISE IN ANALOG COMMUNICATION SYSTEM

Types of Noise: Resistive (Thermal) Noise Source, Shot noise, Extraterrestrial Noise, Arbitrary Noise Sources, White Noise, Narrowband Noise- In phase and quadrature phase components and its Properties, Modeling of Noise Sources, Average Noise Bandwidth, Effective Noise Temperature, Average Noise Figures, Average Noise Figure of cascaded networks. Noise in DSB and SSB System Noise in AM System, Noise in Angle Modulation System, Noise Triangle in Angle Modulation System, Pre-emphasis and de-emphasis.

Course Learning Outcome

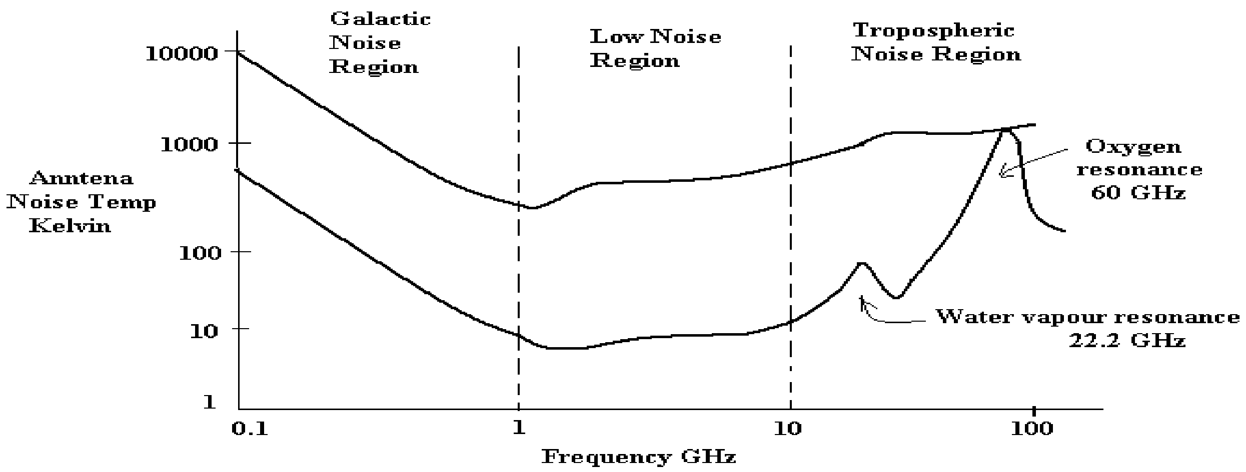
CLOs	Course Learning Outcome
CLO10	Discuss the different types of Noises and noise source, Narrowband Noise In phase and quadrature phase components and its Properties.
CLO11	Analyze the Noise in DSB and SSB System, Noise in AM System, Noise in Angle Modulation System, Pre-emphasis and de-emphasis circuits.

Introduction of Noise

- Noise is a general term which is used to describe an unwanted signal which affects a wanted signal. These unwanted signals arise from a variety of sources which may be considered in one of two main categories:-
  - Interference, usually from a human source (man made)
  - Naturally occurring random noise
- Interference
- Interference arises for example, from other communication systems (cross talk), 50 Hz supplies (hum) and harmonics, switched mode power supplies, thyristor circuits, ignition (car spark plugs) motors … etc.

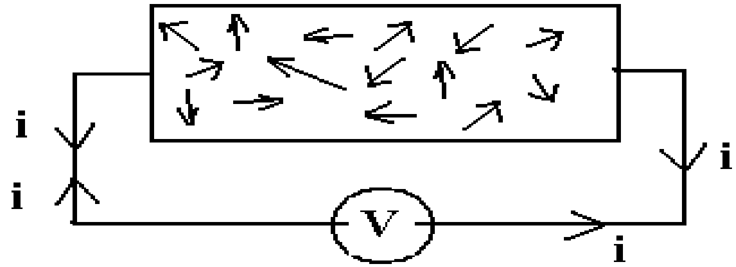
Thermal Noise (Johnson Noise)

- Naturally occurring external noise sources include atmosphere disturbance (e.g. electric storms, lighting, ionospheric effect etc), so called ‘Sky Noise’ or Cosmic noise which includes noise from galaxy, solar noise and ‘hot spot’ due to oxygen and water vapor resonance in the earth’s atmospher**e.**



Thermal Noise (Johnson Noise)

- This type of noise is generated by all resistances (e.g. a resistor, semiconductor, the resistance of a resonant circuit, i.e. the real part of the impedance, cable etc).



•Experimental results (by Johnson) and theoretical studies (by Nyquist) give the mean square noise voltage as

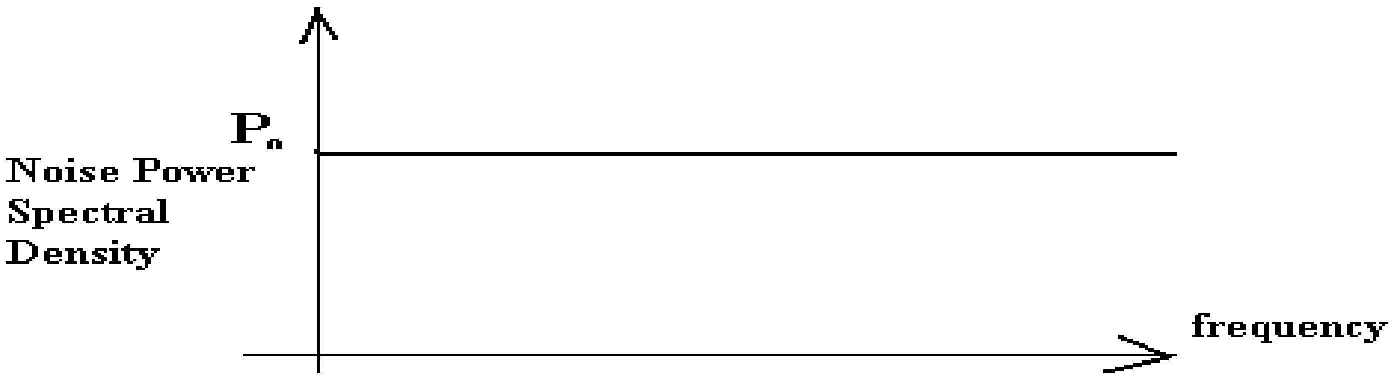
$$V = 4kTBR \ (volt^2)$$

Thermal Noise (Johnson Noise) (Cont’d)

The law relating noise power, N, to the temperature and bandwidth is

N = k TB watts

Thermal noise is often referred to as ‘white noise’ because it has a uniform ‘spectral density’.



Uniform Noise Power Spectral Density

Shot noise

•Shot noise was originally used to describe noise due to random fluctuations in electron emission from cathodes in vacuum tubes (called shot noise by analogy with lead shot).

•Shot noise also occurs in semiconductors due to the liberation of charge
carriers.

•For *pn* junctions the mean square shot noise current is

$$I_n^2 = 2(I_{DC} + 2I_o)q_e B \quad (amps)^2$$

•Where

•is the direct current as the pn junction (amps) is the reverse saturation current (amps)

•is the electron charge = 1.6 x 10-19 coulombs

•B is the effective noise bandwidth (Hz)

•Shot noise is found to have a uniform spectral density as for thermal noise

Low Frequency or Flicker Noise

➢ Active devices, integrated circuit, diodes, transistors etc also exhibits a low frequency noise, which is frequency dependent (i.e. non uniform) known as flicker noise or 'one – over – f' noise.

Excess Resistor Noise

Thermal noise in resistors does not vary with frequency, as previously noted, by many resistors also generates as additional frequency dependent noise referred to as excess noise.

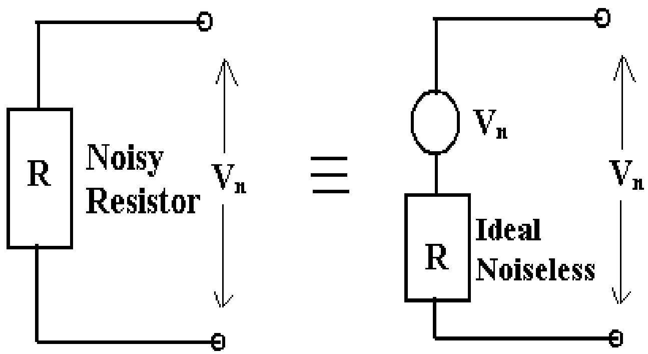
Burst Noise or Popcorn Noise

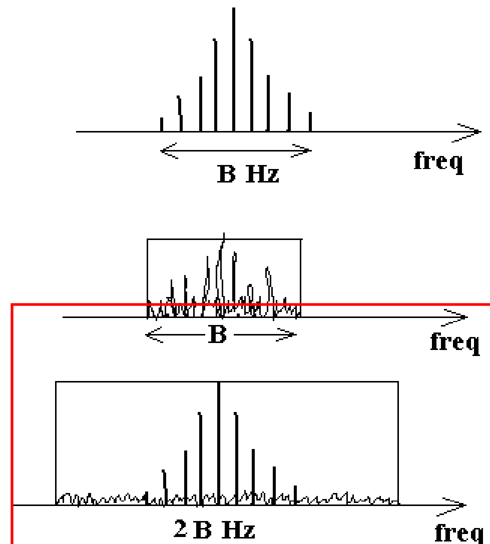
Some semiconductors also produce burst or popcorn noise with a

spectral density which is proportional to $\left(\frac{1}{f}\right)^2$

Thermal Noise (Johnson noise)

This thermal noise may be represented by an equivalent circuit as shown below





A) System BW = B Hz

N= Constant B (watts) = KB

B) System BW

N= Constant 2B (watts) = K2B

Analysis of Noise In Communication Systems (Cont'd)

Resistors in Series

Assume that R_1 at temperature T_1 and R_2 at temperature T_2, then

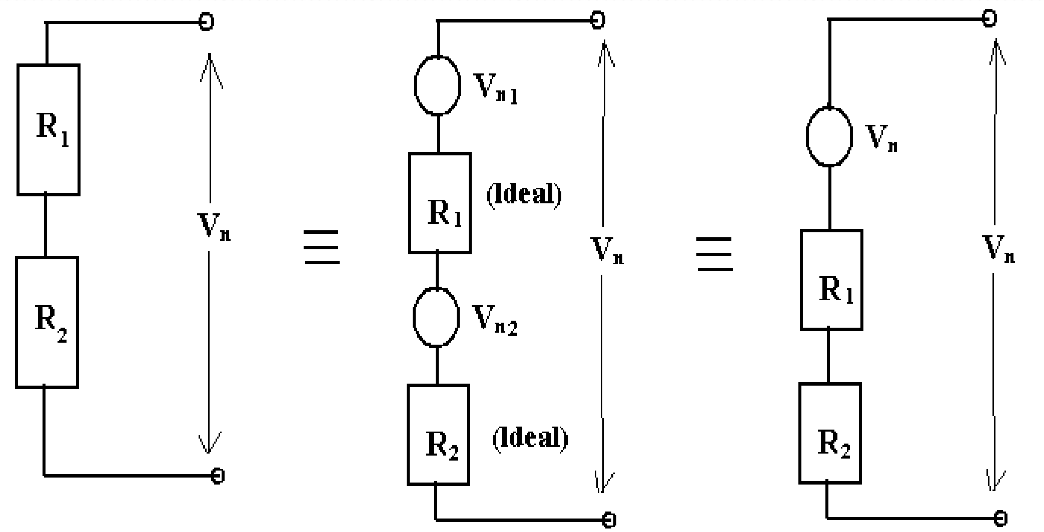
$$\overline{V_n^2} = \overline{V_{n1}^2} + \overline{V_{n2}^2}$$

$$\overline{V_{n1}^2} = 4kT_1BR_1$$

$$\overline{V_{n2}^2} = 4kT_2BR_2$$

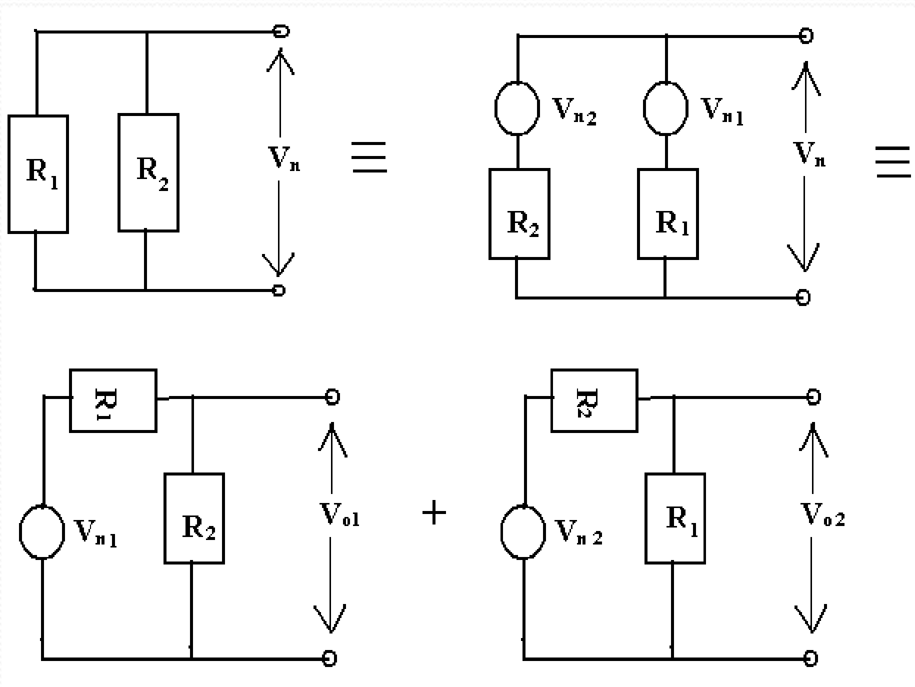
$$\therefore \overline{V_n^2} = 4kB(T_1R_1 + T_2R_2)$$

$$\overline{V_n^2} = 4kTB(R_1 + R_2)$$



i.e. The resistor in series at same temperature behave as a single resistor

Resistance in Parallel



$$V_{o1} = V_{n1}\frac{R_2}{R_1 + R_2} \qquad V_{o2} = V\frac{R_1}{\;_1 \quad _2}$$

$$\overline{V_n^2} = \overline{V_{o1}^2} + \overline{V_{o2}^2}$$

$$\overline{V_n^2} = \frac{4kB}{(R_1 + R_2)^2}\left[R_2^2 T_1 R_1 + R_1^2 T_2 R_2\right] \times \left(\frac{R_1 R_2}{R_1 R_2}\right)$$

$$\overline{V_n^2} = \frac{4kBR_2R_1(T_1R_2 + T_2 R)}{(R_1 + R_2)^2}$$

$$\overline{V_n^2} = 4kTB\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

Signal to Noise

The signal to noise ratio is given by

$$\frac{S}{N} = \frac{Signal\,Power}{Noise\,Power}$$

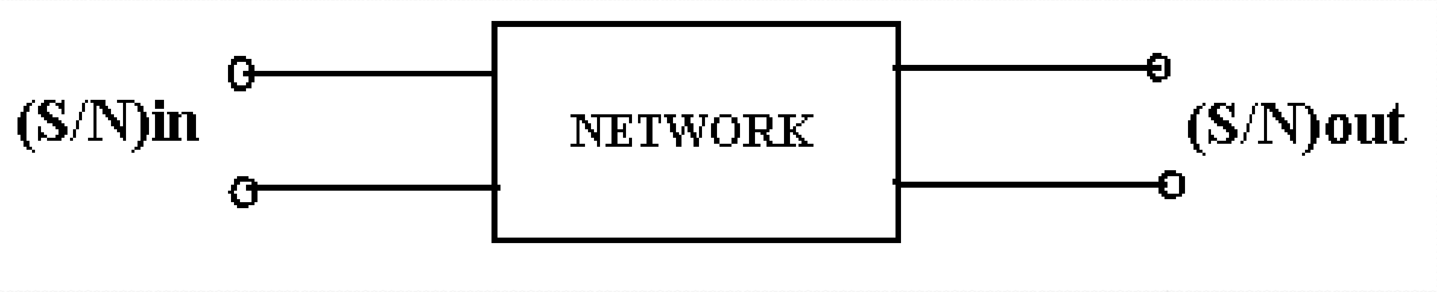
The signal to noise in dB is expressed by

$$\left(\frac{S}{N}\right)_{dB} = 10\log_{10}\left(\frac{S}{N}\right)$$

$$\left(\frac{S}{N}\right)_{dB} = S_{dBm} - N_{dBm}$$ for S and N measured in mW.

Noise Factor- Noise Figure

Consider the network shown below,



Noise Factor- Noise Figure

•The amount of noise added by the network is embodied in the Noise Factor F, which is defined by

$$\text{Noise factor } F = \frac{\left(S/N\right)_{IN}}{\left(S/N\right)_{OUT}}$$

•F equals to 1 for noiseless network and in general F > 1. The noise figure in the noise factor quoted in dB

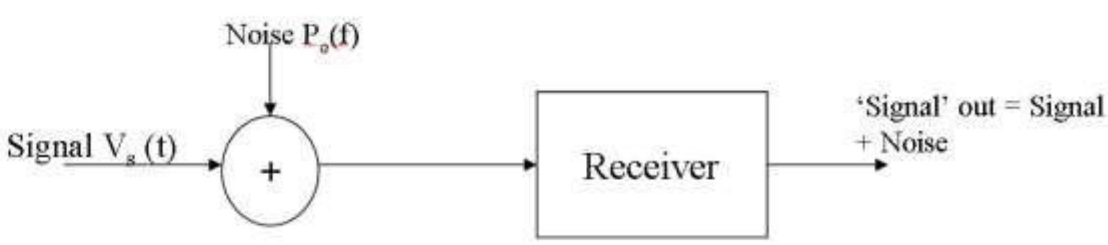
i.e. Noise Figure F dB = 10 log10 F $F \geq 0$ dB

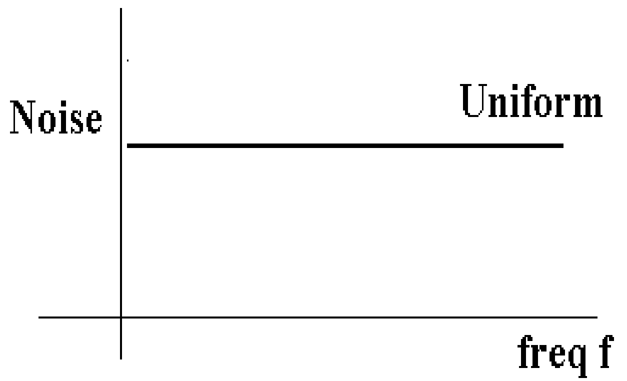
•The noise figure / factor is the measure of how much a network degrades the (S/N)IN, the lower the value of F, the better the network.

Additive White Gaussian Noise

Additive

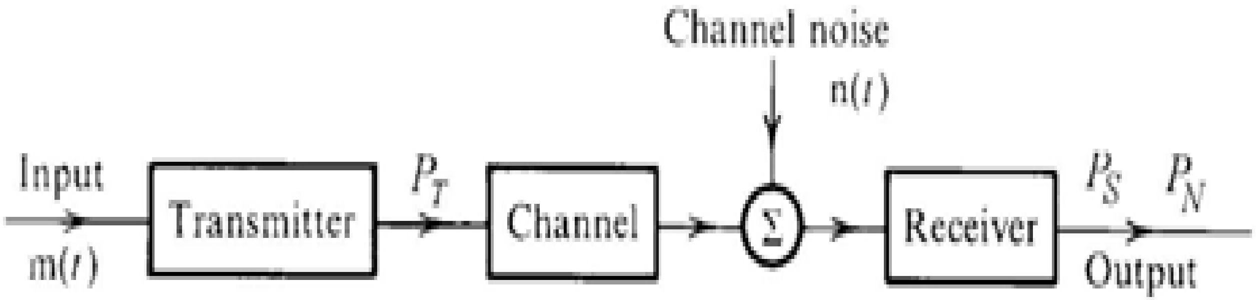
Noise is usually additive in that it adds to the information bearing signal. A model of the received signal with additive noise is shown below





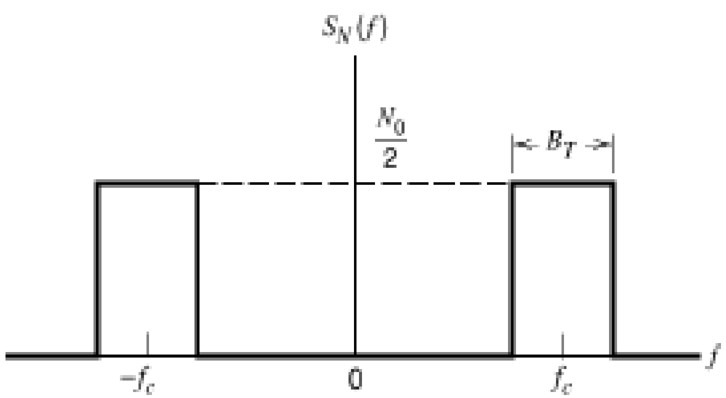
White noise = $p_o(f)$=Constant

Noise in Analog Communication Systems



Model of an analog communication system

Noise PSD: B_T is the bandwidth,
$N_0/2$ is the double-sided noise PSD



NOISE IN DSB-SC SYSTEM

Demodulate the received signal by first multiplying r(t) by a locally generated sinusoid cos(2∏fct + ϴ), where ϴ is the phase of the sinusoid. Then passing the product signal through an ideal low pass filter having a bandwidth W.

The multiplication of r(t) with cos(2πfct + ϕ) yields

$$
\begin{aligned}
& r(t)\cos(2\pi f_c t+\phi) \\
& \quad = u(t)\cos(2\pi f_c t+\phi)+n(t)\cos(2\pi f_c t+\phi) \\
& \quad = A_c m(t)\cos(2\pi f_c t)\cos(2\pi f_c t+\phi) \\
& \qquad + n_c(t)\cos(2\pi f_c t)\cos(2\pi f_c t+\phi)-n_s(t)\sin(2\pi f_c t)\cos(2\pi f_c t+\phi) \\
& \quad = \tfrac{1}{2}A_c m(t)\cos(\phi)+\tfrac{1}{2}A_c m(t)\cos(4\pi f_c t+\phi) \\
& \qquad + \tfrac{1}{2}\left[n_c(t)\cos(\phi)+n_s(t)\sin(\phi)\right]+\tfrac{1}{2}\left[n_c(t)\cos(4\pi f_c t+\phi)-n_s(t)\sin(4\pi f_c t+\phi)\right]
\end{aligned}
$$

NOISE IN AM Cont…

➢The amplitude of the noise varies randomly at these frequencies. The change in amplitude can actually modulate the signal and be picked up in the AM system. As a result, AM systems are very sensitive to random noise

DSB AM signal : $u(t) = A_c[1 + am_n(t)]\cos(2\pi f_c t)$

Received signal at the input to the demodulator

$$
\begin{aligned}
r(t) &= A_c[1 + am_n(t)]\cos(2\pi f_c t) + n(t) \\
&= A_c[1 + am_n(t)]\cos(2\pi f_c t) + n_c(t)\cos(2\pi f_c t) - n_s(t)\sin(2\pi f_c t) \\
&= \left[A_c[1 + am_n(t)] + n_c(t)\right]\cos(2\pi f_c t) - n_s(t)\sin(2\pi f_c t)
\end{aligned}
$$

Where *a* is the modulation index,

mn(t) is normalized so that its minimum value is *-1*

If a synchronous demodulator is employed, the situation is basically similar to the DSB case, except that we have 1 + amn(t) instead of m(t).

$$y(t) = \tfrac{1}{2}\left[A_c a m_n(t) + n_c(t)\right]$$

Noise in Angle Modulated Systems

➢Like AM, noise performance of angle modulated systems is characterized by parameter γ

$$\gamma_{FM} = \frac{3}{2}\beta^2$$

If it is compared with AM

$$\frac{\gamma_{FM}}{\gamma_{AM}} = \frac{1}{2}\left(\frac{\omega_{FM}}{\omega_{AM}}\right)^2$$

- Note: if bandwidth ratio is increased by a factor 2.Then YFM/YAM increases by a factor 4
- This exchange of bandwidth and noise performance is an important feature of FM

RECEIVERS

Receiver Types -Tuned radio frequency receiver, Superhetrodyne receiver, RF section and Characteristics - Frequency changing and tracking, Intermediate frequency, AGC, FM Receiver, Comparison with AM Receiver, Amplitude limiting. Pulse Modulation: Types of Pulse modulation, PAM (Single polarity, double polarity) PWM: Generation and demodulation of PWM, PPM, Generation and demodulation of PPM, Time Division Multiplexing.

Course Learning Outcome

CLOs	Course Learning Outcome
CLO12	Discuss the concept of receivers in communication system and receiver types like tuned radio frequency receiver and super heterodyne receiver.
CLO13	Analyze the characteristics of the receiver like sensitivity, selectivity, image frequency rejection ratio, choice of intermediate frequency and fidelity.
CLO14	Understand the different Pulse analog modulation techniques
CLO15	Acquire the knowledge and develop capability to succeed national and international level competitive examinations.

Requirements of a Receiver

- AM receiver receives AM wave and demodulates it by using the envelope detector. Similarly, FM receiver receives FM wave and demodulates it by using the Frequency Discrimination method. Following are the requirements of both AM and FM receiver.
- It should be cost-effective.
- It should receive the corresponding modulated waves.
- The receiver should be able to tune and amplify the desired station.
- It should have an ability to reject the unwanted stations.

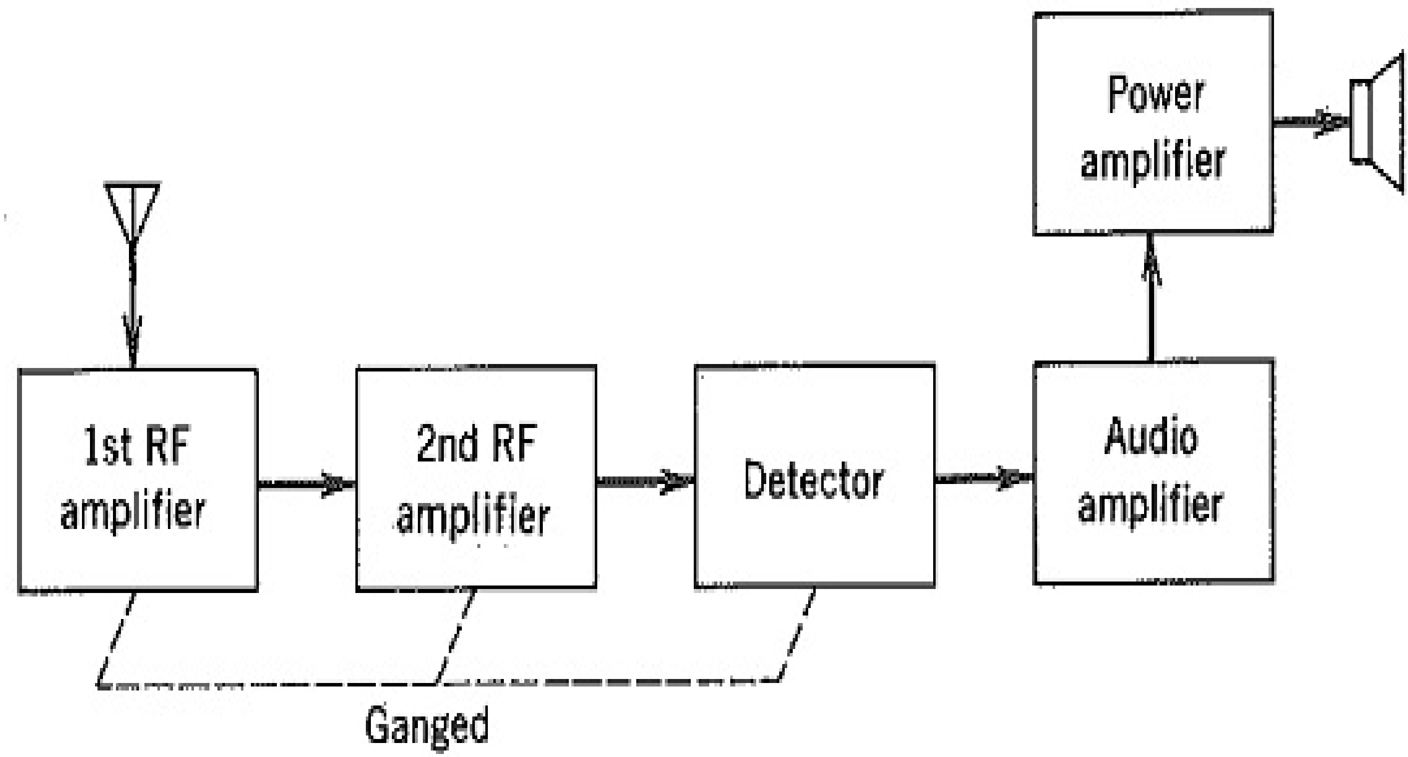
Types of Receivers:

- **Tuned radio frequency(TRF)**
- Regenerative receiver
- Super regenerative receiver
- **Super heterodyne receiver**
- Direct conversion receiver
- Many of these different types of radio receiver are in widespread use today. Each type of radio has its own characteristics that lend its use to particular applications.

Tuned Radio Frequency Receiver(TRF)

- The tuned radio frequency receiver is one in which the tuning or selectivity is provided at the radio frequency stages.
- Tuning is provided by a tuned coil / capacitor combination, and then the signal is presented to a simple crystal or diode detector where the amplitude modulated signal is recovered.
- The tuned radio frequency receiver was used in the early days of wireless technology but it is rarely used today as other techniques offering much better performance are available.

Tuned Radio Frequency Receiver(TRF)



Tuned Radio Frequency Receiver(TRF)

Operation:

- TRF receiver consists of two or three stages of RF amplifiers, detector, audio amplifier and power amplifier.
- The RF amplifier stages placed between the antenna and detector are used to increase the strength of the received signal before it is applied to the detector.
- These RF amplifiers are tuned to fix frequency, amplify the desired band of frequencies. Therefore they provide amplification for selected band of frequencies and rejection for all others.

Tuned Radio Frequency Receiver(TRF)

- As selection and amplification process is carried out in two or three stages and each stage must amplify the same band of frequencies, the ganged tuning is provided.
- The amplified signal is then demodulated using detector to recover the modulating signal.
- The recovered signal is amplified further by the audio amplifier followed by power amplifier which provides sufficient gain to operate a loud speaker.

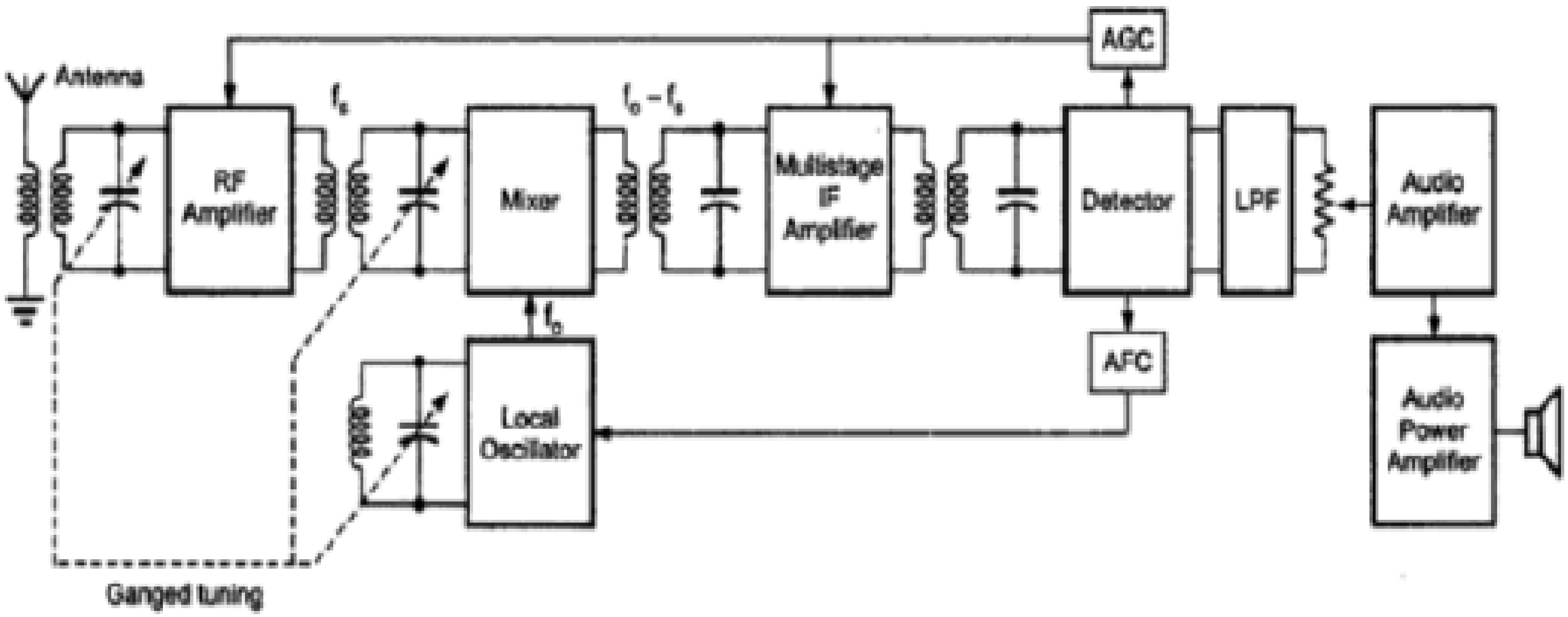
Super heterodyne Receiver:

•The basic concept and theory behind the super heterodyne radio involves the process of mixing.

•This enables signals to be translated from one frequency to another.

•The input frequency is often referred to as the RF input, whilst the locally generated oscillator signal is referred to as the local oscillator, and the output frequency is called the intermediate frequency as it is between the RF and audio frequencies.

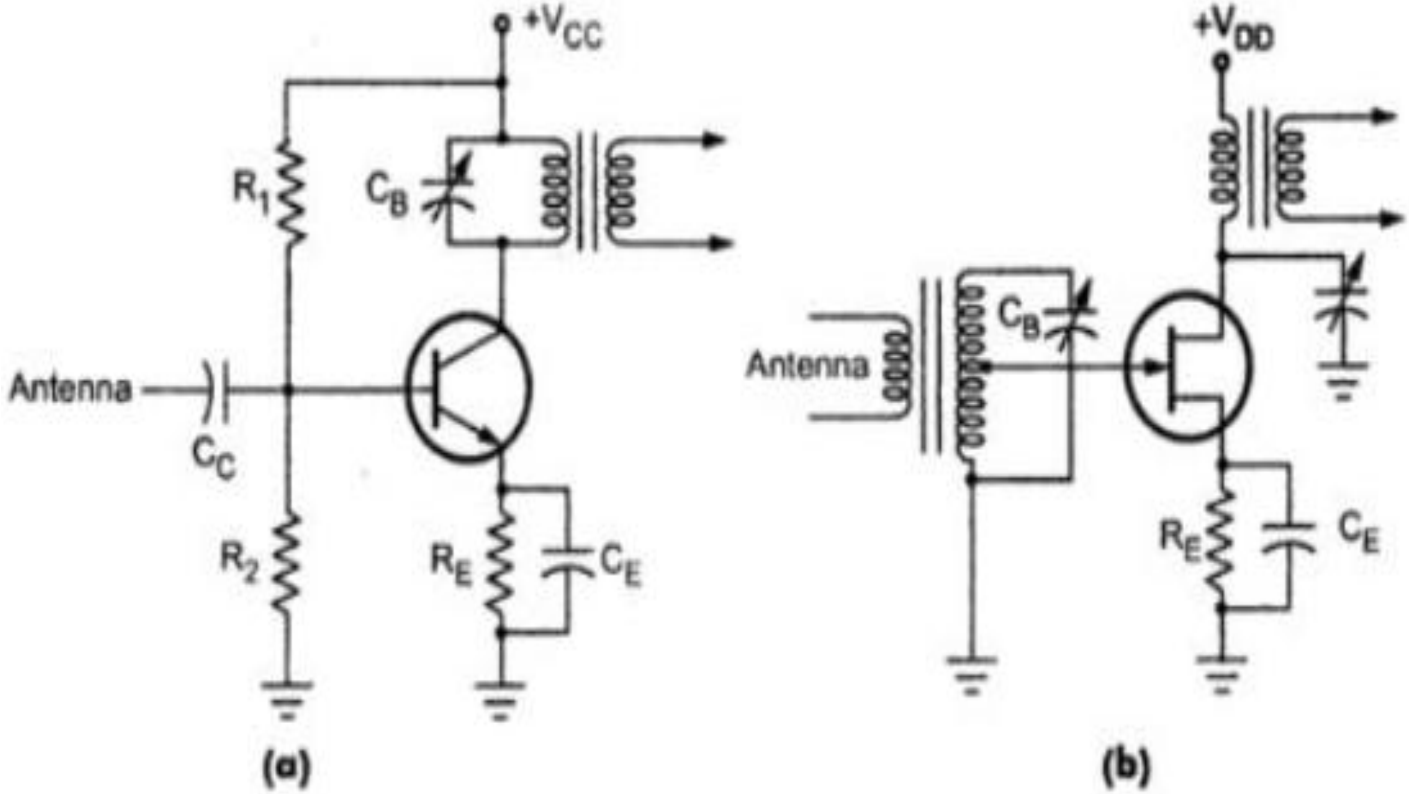
Super heterodyne Receiver:



RF Tuner Section:

- The amplitude modulated wave received by the antenna is first passed to the **tuner circuit** through a transformer.
- The tuner circuit is nothing but a LC circuit, which is also called as **resonant** or **tank circuit**. It selects the frequency, desired by the AM receiver.
- It also tunes the local oscillator and the RF filter at the same time.

RF section and Characteristics



Mixer or Frequency Changer or Converter:

•Real-life mixers produce a variety of other undesired outputs, including noise and they may also suffer overload when very strong signals are present.

•Although very basic non-linear devices can actually perform a basic RF mixing or multiplication process, the performance will be far from the ideal, and where good receiver performance is required, the specification of the RF mixer must be match this expectation.

•The basic process of RF mixing or multiplication where the incoming RF signal and a local oscillator are mixed or multiplied together to produce signals at the sum and difference frequencies is key to the whole operation of the super heterodyne receiver.

MIXER

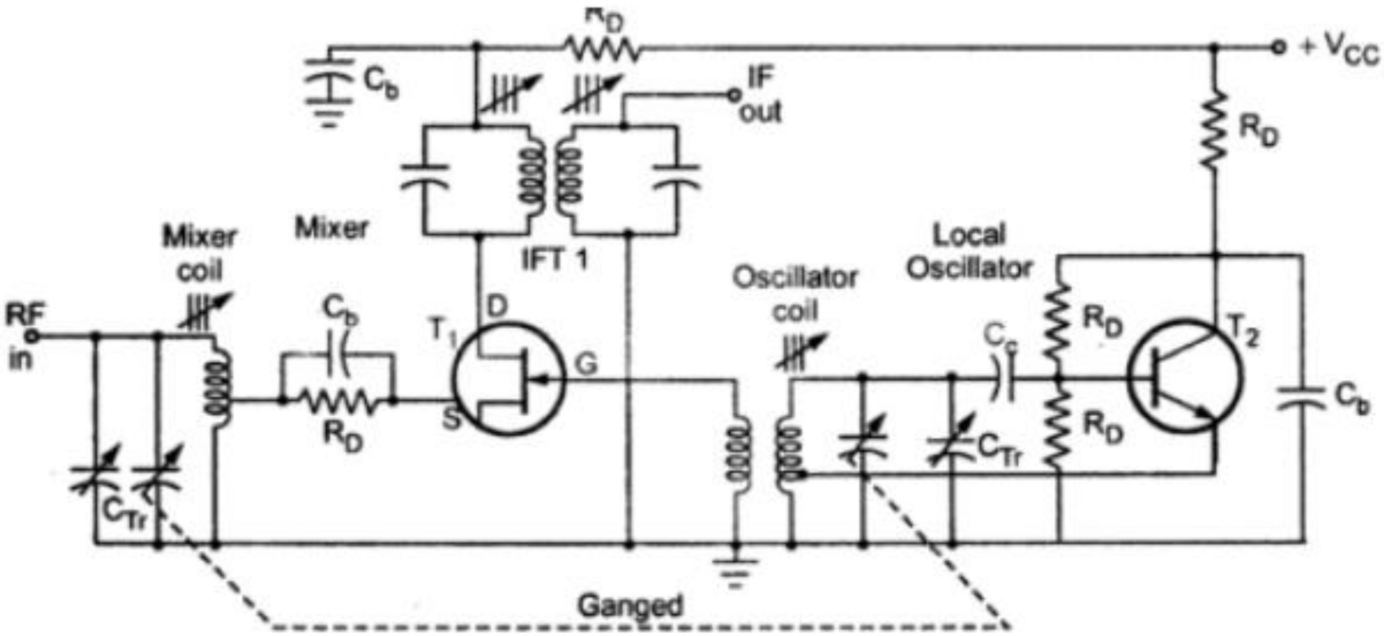
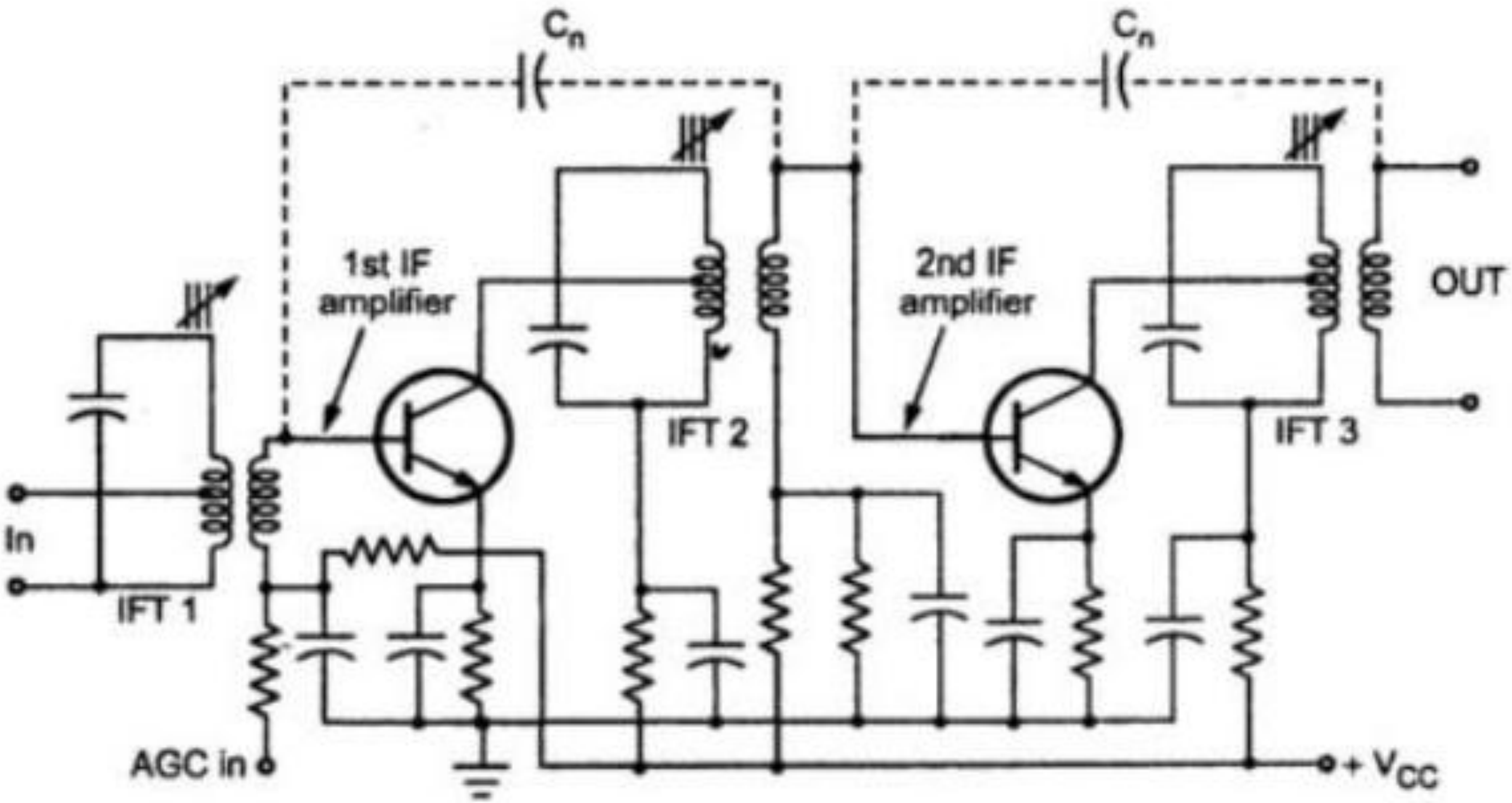


Fig. Separately Excited Mixer

Tracking

- Super heterodyne receiver has number of tunable circuits which must all be tuned correctly if any given station is to be received.
- The ganged tuning is employed which mechanically couples all tuning circuits so that only one tuning control is required. Usually there are three tuned circuits: Antenna or RF tuned circuit, Mixer tuned circuit and local oscillator tuned circuit.
- The process of tuning circuit to get the desired output is called Tracking. Tracking error will result in incorrect frequency being fed to the IF amplifier and these must be avoided.
- To avoid tracking errors,ganged capacitors with identical sections are used.

Intermediate frequency



Automatic Gain Control, AGC:

- An automatic gain control is incorporated into most super heterodyne radios. Its function is to reduce the gain for strong signals so that the audio level is maintained for amplitude sensitive forms of modulation, and also to prevent overloading.
- It is a system in which the overall gain of a radio receiver is varied automatically with the variations in the strength of the receiver signal to maintain the output substantially constant.
- When the average signal level increases, the size of the AGC bias increases and the gain is deceased.

Simple AGC

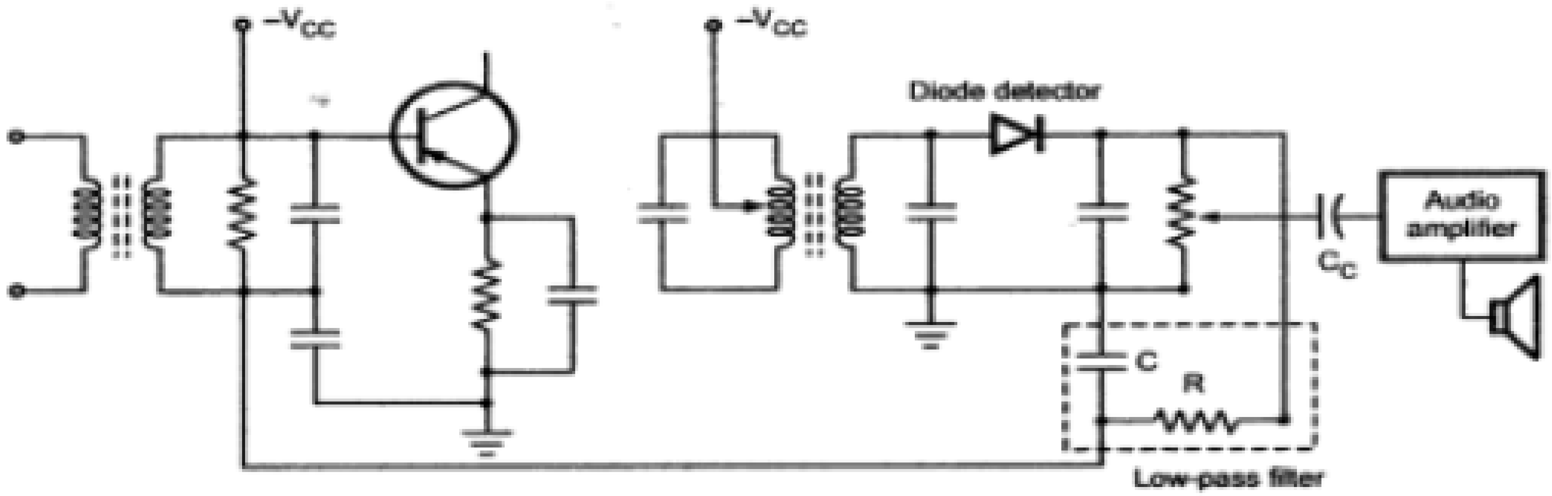
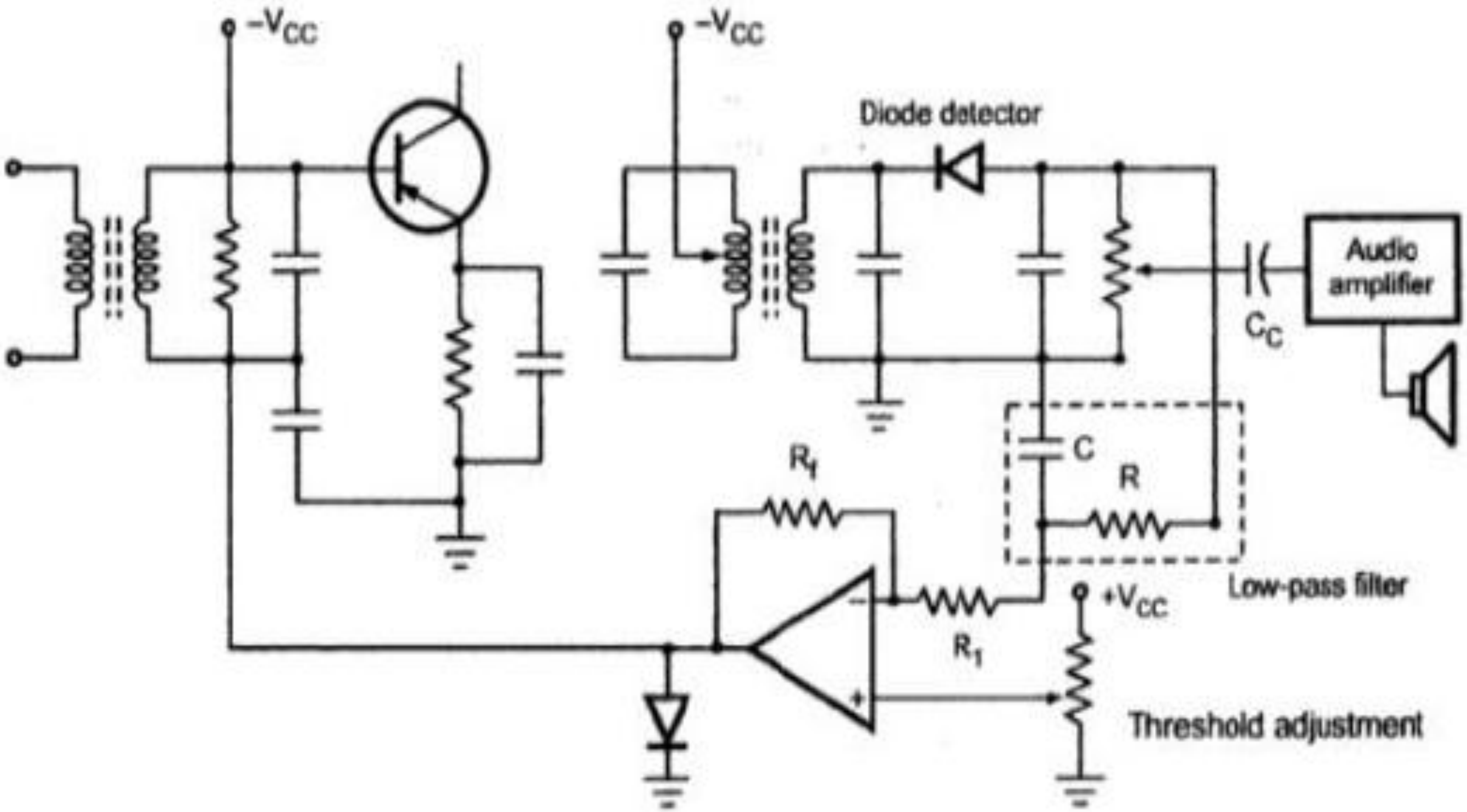


Fig. Simple AGC circuit

Delayed AGC



–V_CC
–V_CC
Diode detector
Audio amplifier
C_C
C
R
R_f
R_1
Low-pass filter
+V_CC
Threshold adjustment

Comparison with AM FM Receivers

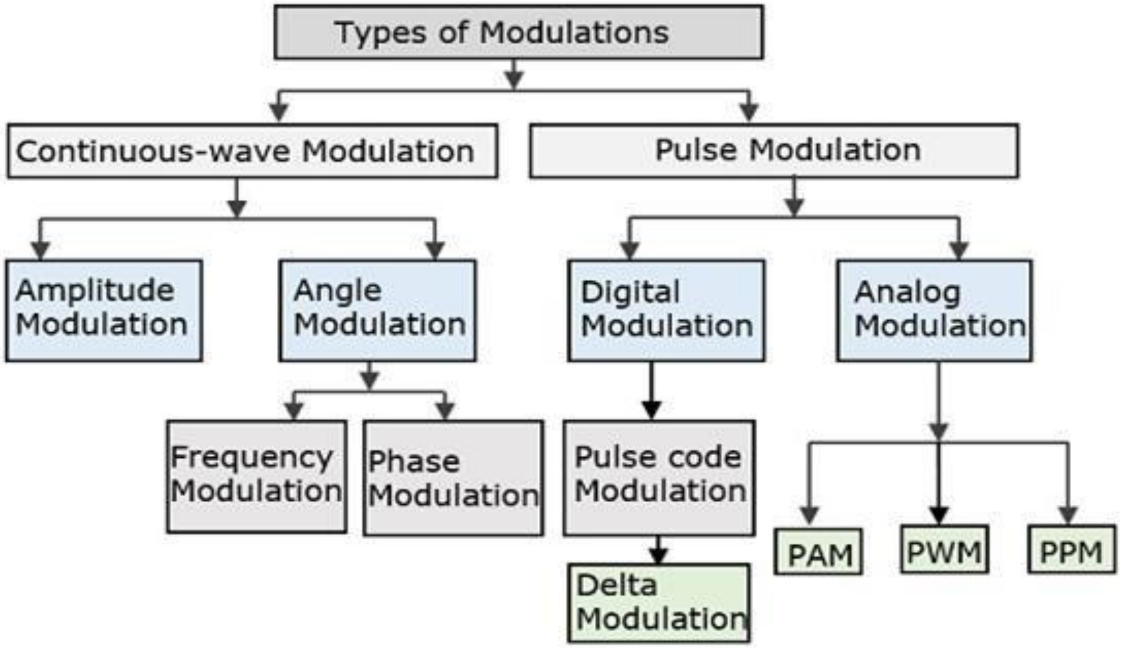
	AM	FM
Stands for	AM stands for Amplitude Modulation	FM stands for Frequency Modulation
Origin	AM method of audio transmission was first successfully carried out in the mid 1870s.	FM radio was developed in the United states in the 1930s, mainly by Edwin Armstrong.
Modulating differences	In AM, a radio wave known as the "carrier" or "carrier wave" is modulated in amplitude by the signal that is to be transmitted. The frequency and phase remain the same.	In FM, a radio wave known as the "carrier" or "carrier wave" is modulated in frequency by the signal that is to be transmitted. The amplitude and phase remain the same.

Comparison with AM FM Receivers

	AM	FM
Bandwidth Requirements	Twice the highest modulating frequency. In AM radio broadcasting, the modulating signal has bandwidth of 15kHz, and hence the bandwidth of an amplitude-modulated signal is 30kHz.	Twice the sum of the modulating signal frequency and the frequency deviation. If the frequency deviation is 75kHz and the modulating signal frequency is 15kHz, the bandwidth required is 180kHz.
Zero crossing in modulated signal	Equidistant	Not equidistant
Complexity	Transmitter and receiver are simple but syncronization is needed in case of SSBSC AM carrier.	Tranmitter and reciver are more complex as variation of modulating signal has to beconverted and detected from corresponding variation in frequencies.(i.e. voltage to frequency and frequency to voltage conversion has to be done).

PULSE MODULATION

- In Pulse modulation, a periodic sequence of rectangular pulses, is used as a carrier wave.
- It is divided into analog and digital modulation.



Analog Pulse Modulation

In **Analog modulation** ,

➢If the **amplitude**, **duration** or **position** of a pulse is varied in accordance with the instantaneous values of the baseband modulating signal, then such a technique is called as

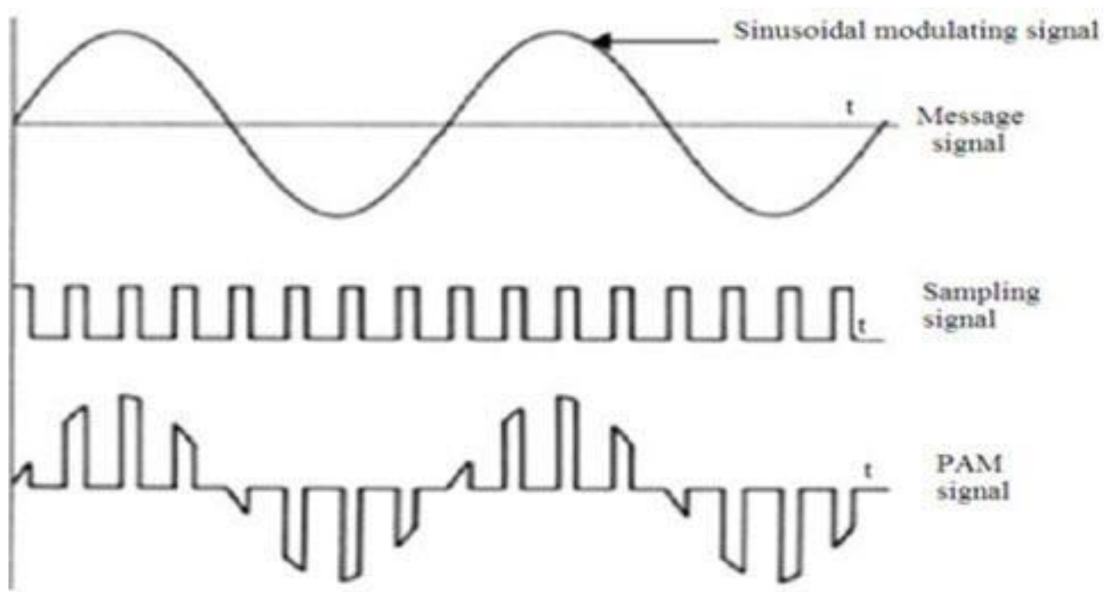
- **Pulse Amplitude Modulation (PAM)** or
- **Pulse Duration/Width Modulation (PDM/PWM)**, or
- **Pulse Position Modulation (PPM)**.

Digital modulation

- In **Digital Modulation**, the modulation technique used is **Pulse Code Modulation (PCM)** where the analog signal is converted into digital form of 1s and 0s.
- This is further developed as **Delta Modulation (DM)**,

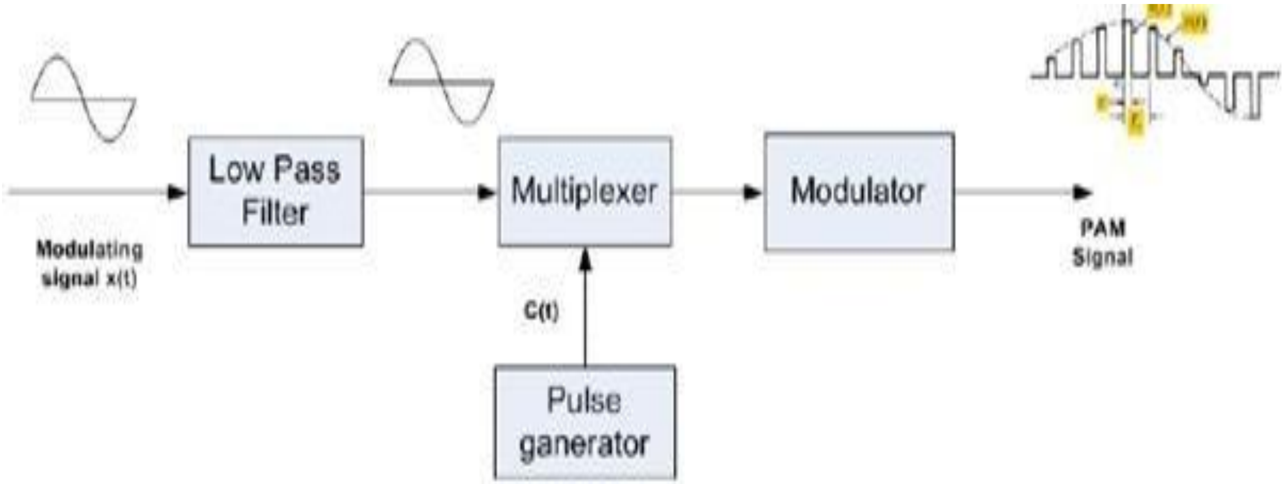
PULSE AMPLITUDE MODULATION (PAM)

- In PAM, Amplitude of the pulse carrier varies in accordance to the instantaneous amplitude of the message signal.



PAM GENERATION

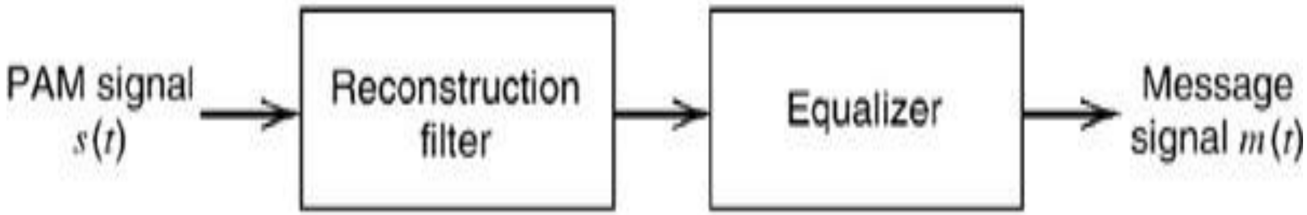
Block schematic of PAM generator



•LPF is used to avoid aliasing effect, during sampling process i.e band limiting is necessary

•LPF removes all frequency components which are higher than f_m , this is known as band limiting .

PAM Demodulation



•The original Modulating signal can be detected from natural PAM by passing through LPF.

•The LPF with cut-off frequency equal to f_m and it removes high frequency ripples and recovers original modulating signal.

•The Equalizer compensates for aperture effect(Difference b/w input signal and
sampled values).

- Single polarity PAM is a situation where a suitable fixed DC bias is added to the signal to ensure that all the pulses are positive.
- Double polarity PAM is a situation where the pulses are both positive and negative.

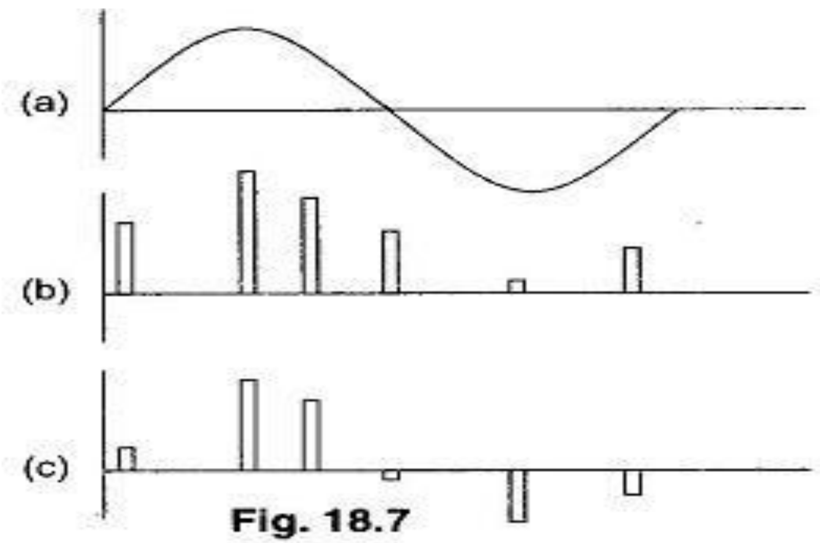


Fig. 18.7

Pulse Amplitude Modualtion (a) Signal
(b) Single Polarity PAM (c) Double Polarity PAM

GENERATION OF PWM

- In Pulse Width Modulation (**PWM**) or Pulse Duration Modulation (**PDM**) or Pulse Time Modulation (**PTM**) technique, the **width** or the **duration** or the **time** of the pulse carrier varies in accordance to the instantaneous amplitude of the message signal.
- The width of the pulse varies and the amplitude of the signal remains constant.
- Amplitude limiters are used to make the amplitude of the signal constant. These

circuits clip off the amplitude to a desired level, and hence the noise is limited.

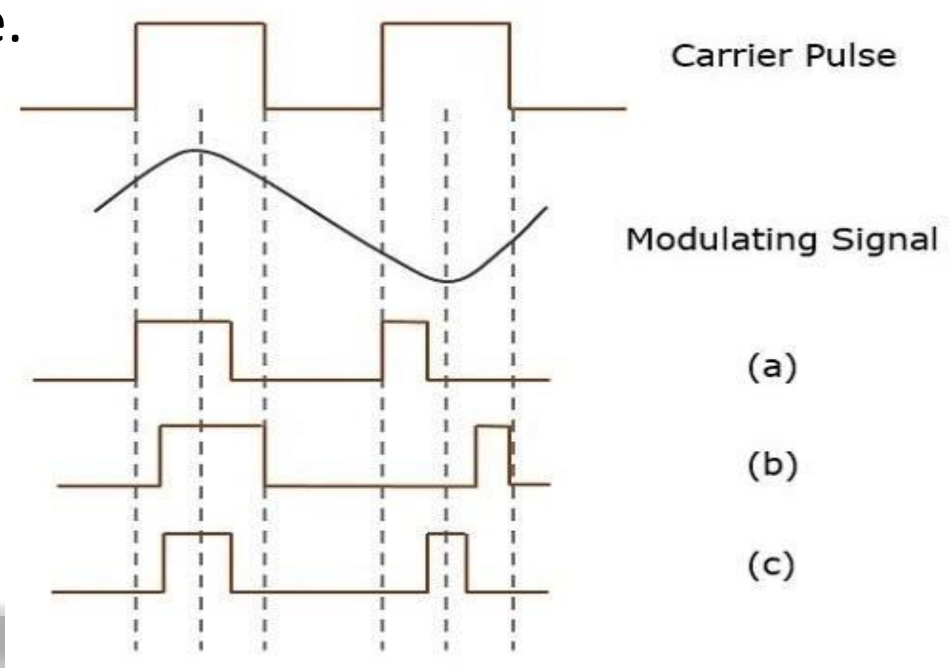
PWM GENERATION cont...

There are three variations of PWM.

a)Leading edge of pulse is held constant and change in pulse width is measured w.r.t leading edge.

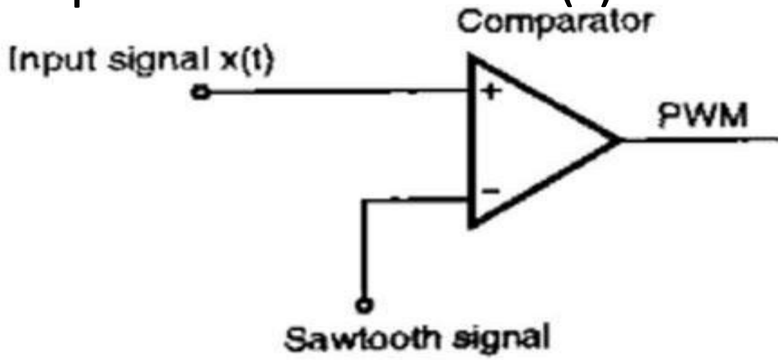
b)Trailing edge is held constant .

c)Centre of the pulse is held constant and pulse width changes on either side of centre of pulse.

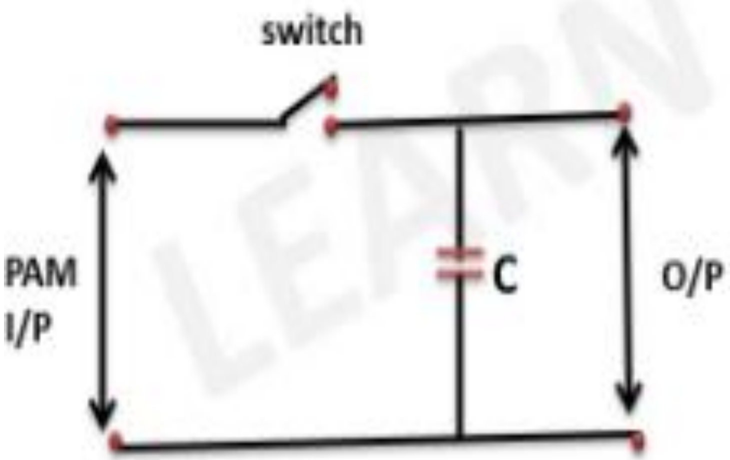


PWM GENERATION cont...

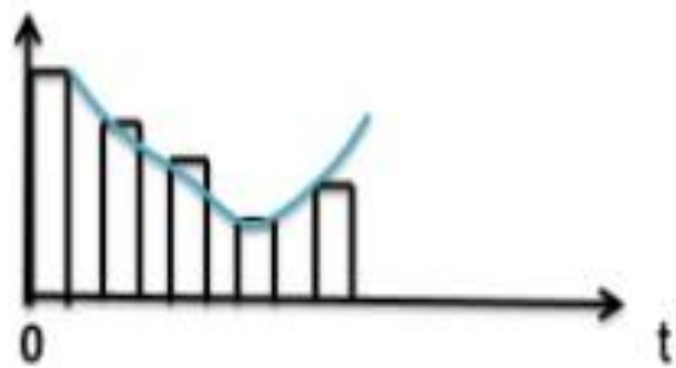
•It consists of sawtooth wave generator, comparator.
•sawtooth generator generates sawtooth signal which is used as sampling signal.
•Comparator compares the amplitude of modulating signal m(t) and amplitude of
sawtooth signal.
•Output of the comparator is high as long as the amplitude of m(t) is greater than that of sawtooth signal.
•The duration for which comparator o/p remains high is directly proportional to the m(t).



DEMODULATION OF PWM



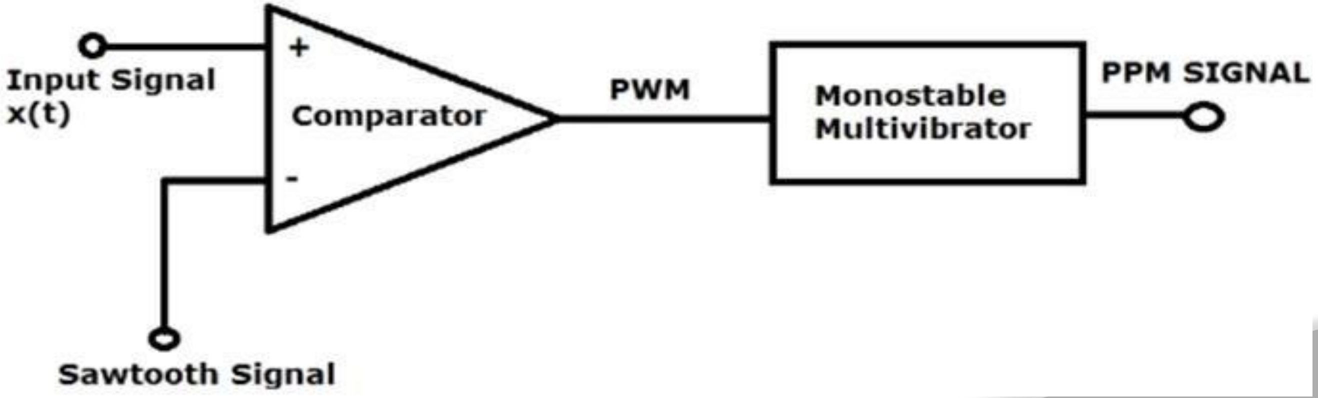
zero order holding circuit



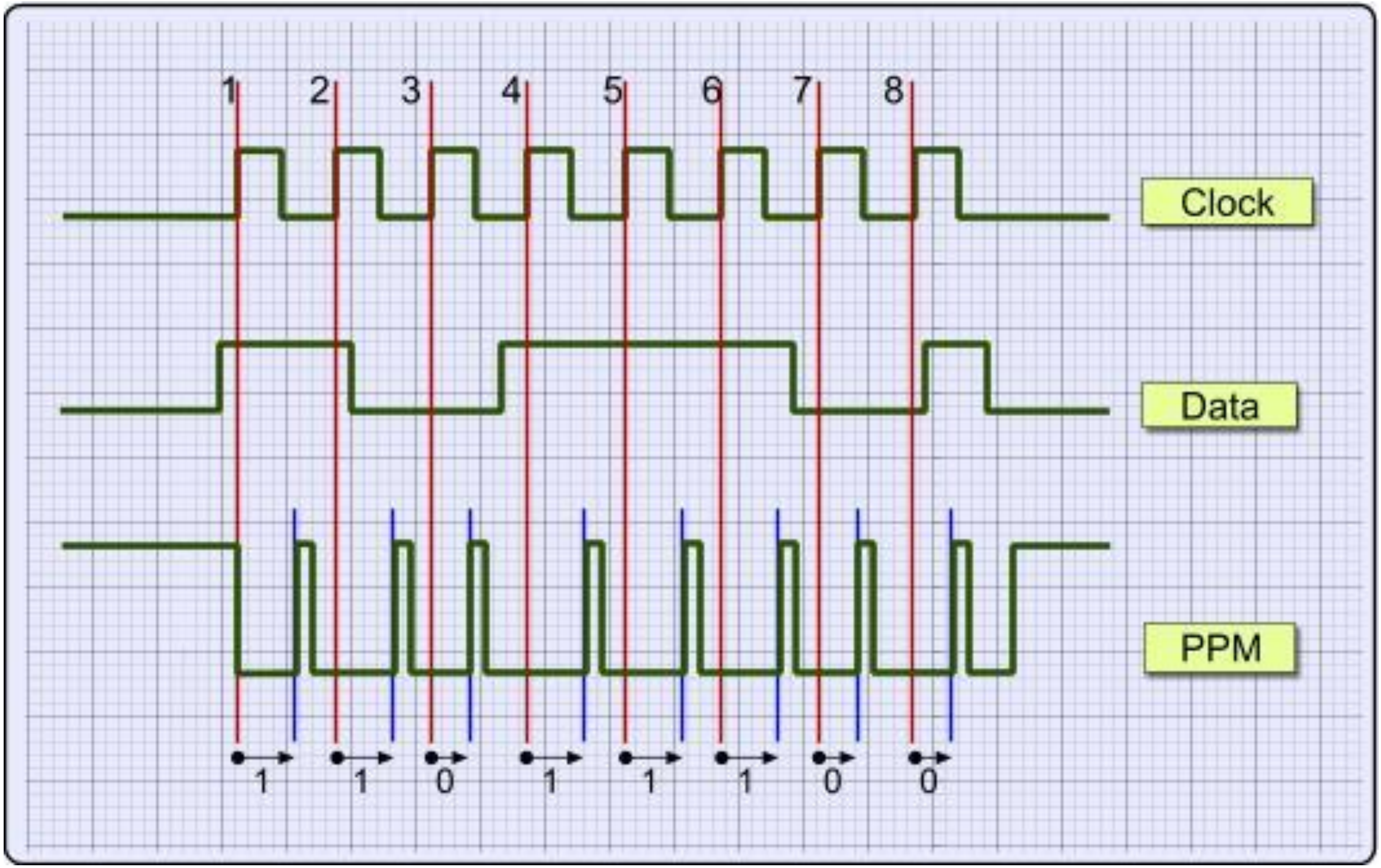
O/P of holding circuit

- In PPM, Amplitude and width of the pulse are kept constant, while position of each pulse with reference to position of reference pulse is changed according to the m(t).
- PPM is obtained from PWM.
- Each Trailing edge of PWM pulse is a starting point of PPM.
- Position of the pulse is 1:1 proportional to the width of PWM and m(t).

Generation of PPM:



PPM Cont...

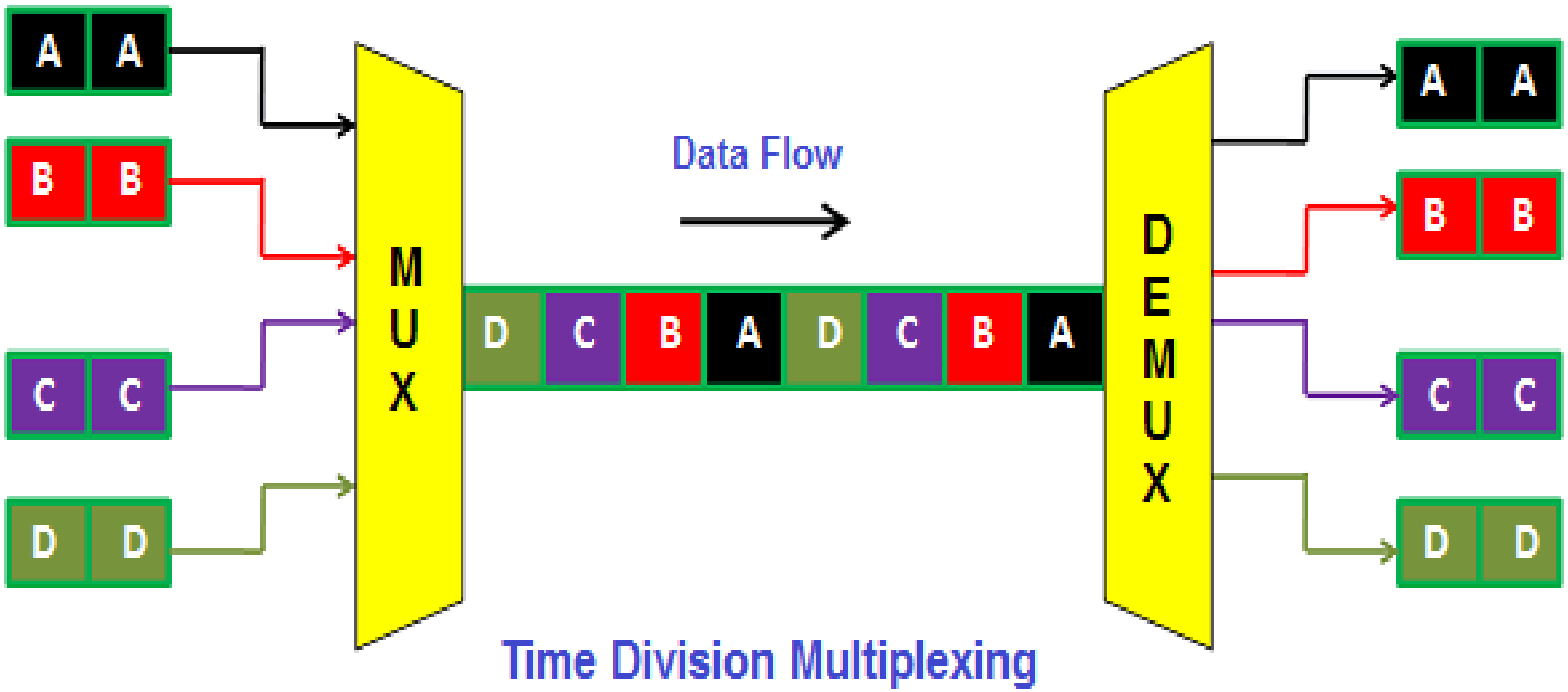


PPM Demodulation Cont...

COMPARE PAM PWM PPM

PAM	PWM	PPM
Amplitude is varied	Width is varied	Position is varied
Bandwidth depends on the width of the pulse	Bandwidth depends on the rise time of the pulse	Bandwidth depends on the rise time of the pulse
Instantaneous transmitter power varies with the amplitude of the pulses	Instantaneous transmitter power varies with the amplitude and width of the pulses	Instantaneous transmitter power remains constant with the width of the pulses
System complexity is high	System complexity is low	System complexity is low
Noise interference is high	Noise interference is low	Noise interference is low
It is similar to amplitude modulation	It is similar to frequency modulation	It is similar to phase modulation

TIME DIVISION MULTIPLEXING AND DEMULTIPLEXING



TIME DIVISION MULTIPLEXING AND DEMULTIPLEXING