Unit VI: Communication Systems

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Department of Electronics &Telecommunication Engineering

COMMUNICATION SYSTEM

CONTENTS

Communication System

Communication is the ***basic process of ex-changing information***. It is what human beings do to convey thoughts, ideas and feelings.

Examples of Communication Systems

- E-mail
- voice Mail
- Fax
- Smart Phone
- instant messaging
- Telecommuting
- Video-conferencing
- Telephony
- Internet
- Global positioning system

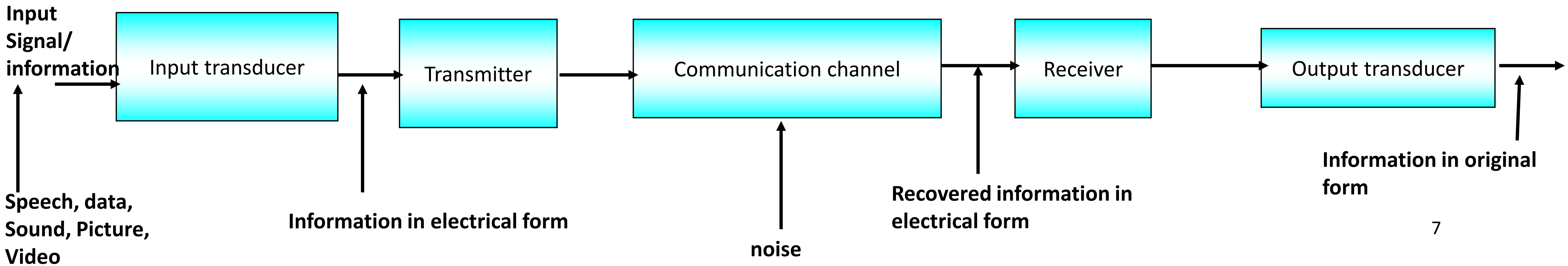
Introduction

Methods of communication:

1. Face to face
2. Signals
3. Written word (letters)
4. Electrical innovations:
   - Telegraph
   - Telephone
   - Radio
   - Television
   - Internet (computer)

Block diagram of an simple communication system

1. Information/ input signal
2. Input transducer
3. Transmitter
4. Communication channel
5. Noise
6. Receiver
7. Output transducer



Types of Communication System

1) **Simplex communication:** Simplex communication refers to communication that occurs *in one direction only.*

   e.g. Commercial radio and television broadcast (not two-way radio such as walkie-talkies)

2) **Duplex :**

   i) Half Duplex: A *half-duplex* (HDX) system provides communication in *both directions, but only one direction at a time* (not simultaneously).An example of a half-duplex system is a two-party system such as a walkie-talkie.

   ii) Full Duplex: A *full-duplex* (FDX), or sometimes double-duplex system, allows communication in both directions, and, unlike half-duplex, allows this to happen simultaneously. Land-line telephone networks are full-duplex.

Types of Communication System

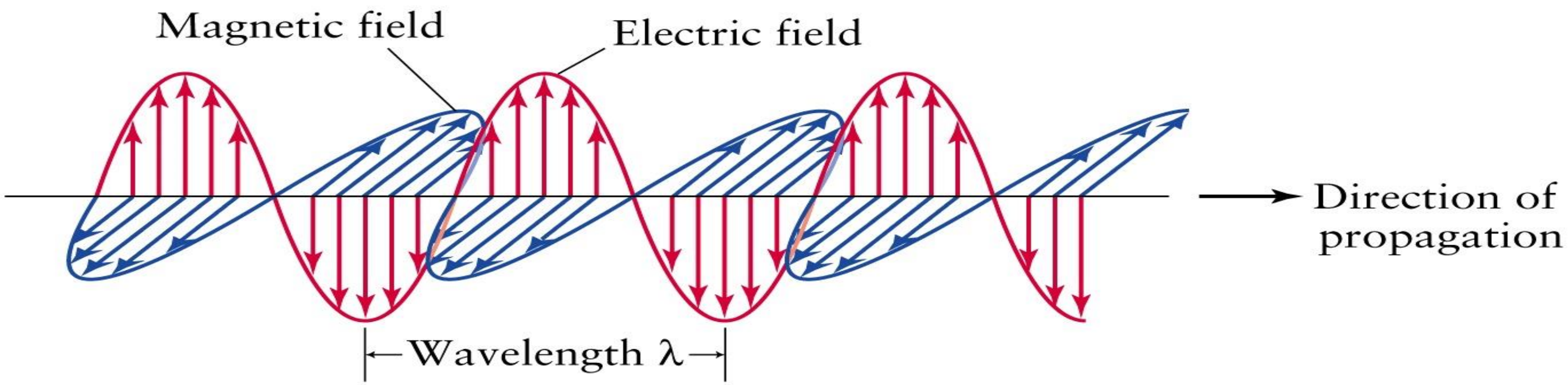
3) **Baseband Signals:** *Putting the original signal directly into the medium* is referred to as baseband transmission. e.g. Telephone.

4) **Broadband Signals:** There are many instances when the baseband signals are incompatible with the media. To transmit baseband signal modulation technique must be used. *Technique using modulation is called as broadband*.

5) **Multiplexing:** Transmitting *two or more signal simultaneously* over the *single channel*.

The Electromagnetic Spectrum

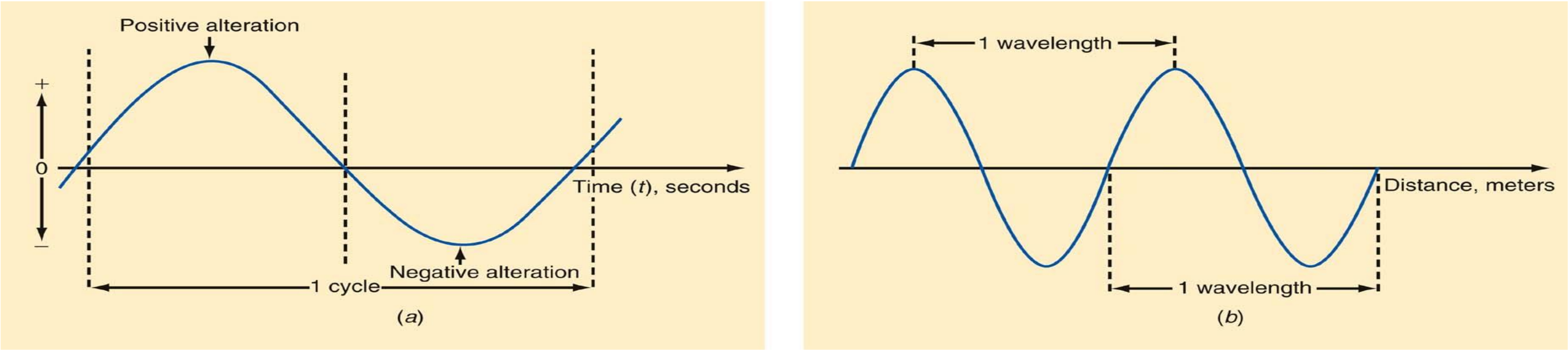
- ✓Instead of using wires, free space can be used. The *information is converted into electronic signal* which radiate into space.
- ✓Such signals consist of both electric and magnetic field. So these called *ELECTROMAGNETIC* signals. Also called Radio Frequency (RF) waves.



The Electromagnetic Spectrum

- The range of electromagnetic signals encompassing all frequencies is referred to as the **electromagnetic spectrum.**

ELECTROMAGNETIC SPECTRUM



Frequency and wavelength (a) One cycle (b) One wavelength

ELECTROMAGNETIC SPECTRUM

Frequency and wavelength

Wavelength (λ) = speed of light ÷ frequency

Speed of light = 3×10^8 meters/second

Therefore:

$$\lambda = 3 \times 10^8 / f$$

Example:

What is the wavelength if the frequency is 4MHz?

$$\lambda = 3 \times 10^8 / 4 \text{ MHz}$$

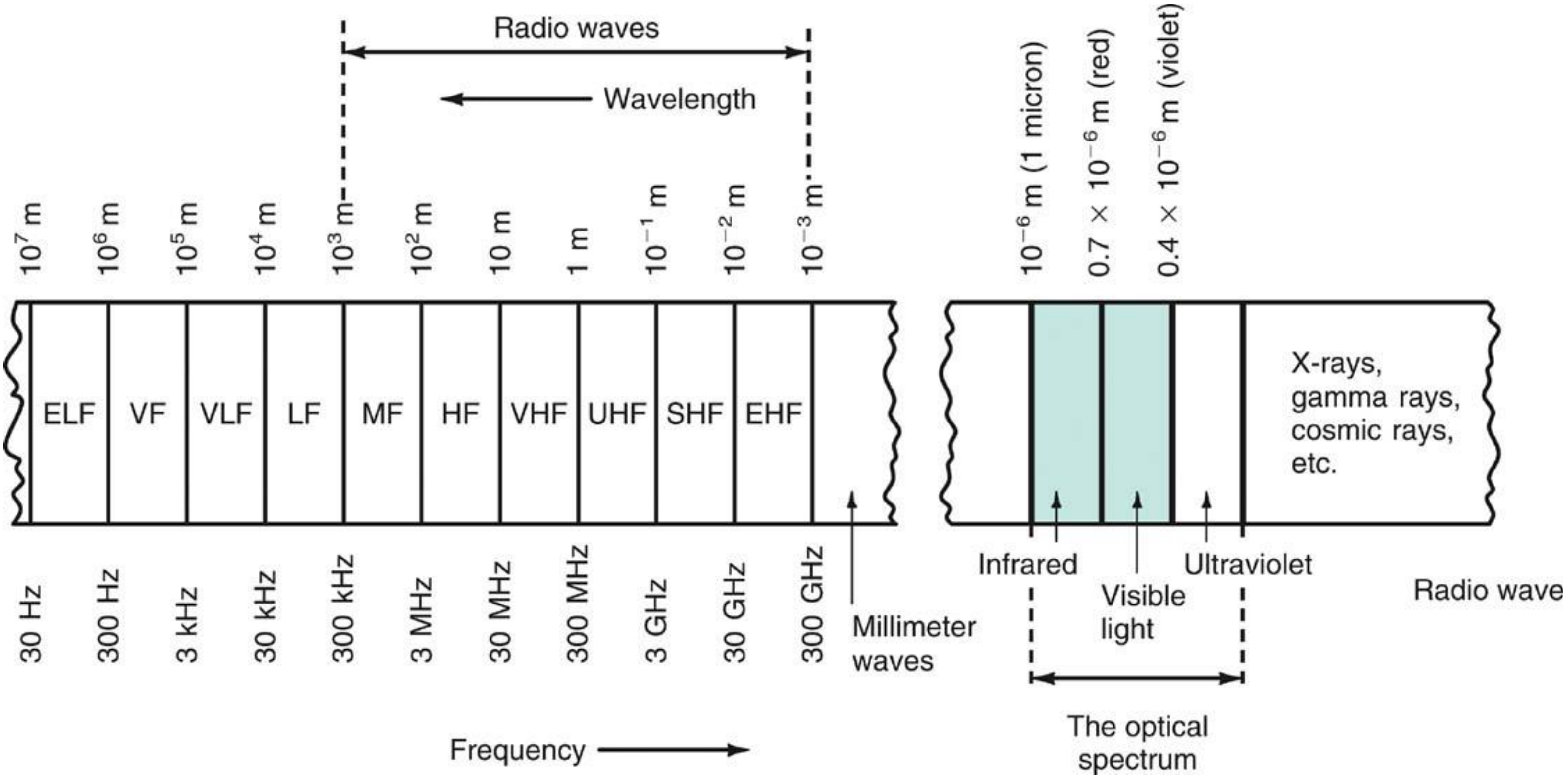
$$= 75 \text{ meters (m)}$$

Bandwidth

- Bandwidth is the difference *between the upper and lower frequency* range of the signal or the equipment operating range.
- It is typically measured in hertz, and may sometimes refer to passband bandwidth, sometimes to baseband bandwidth.
- When upper frequency is F2 and Lower Frequency is F1. Then bandwidth is calculated as

$$BW=F2-F1$$

The IEEE Electromagnetic Spectrum

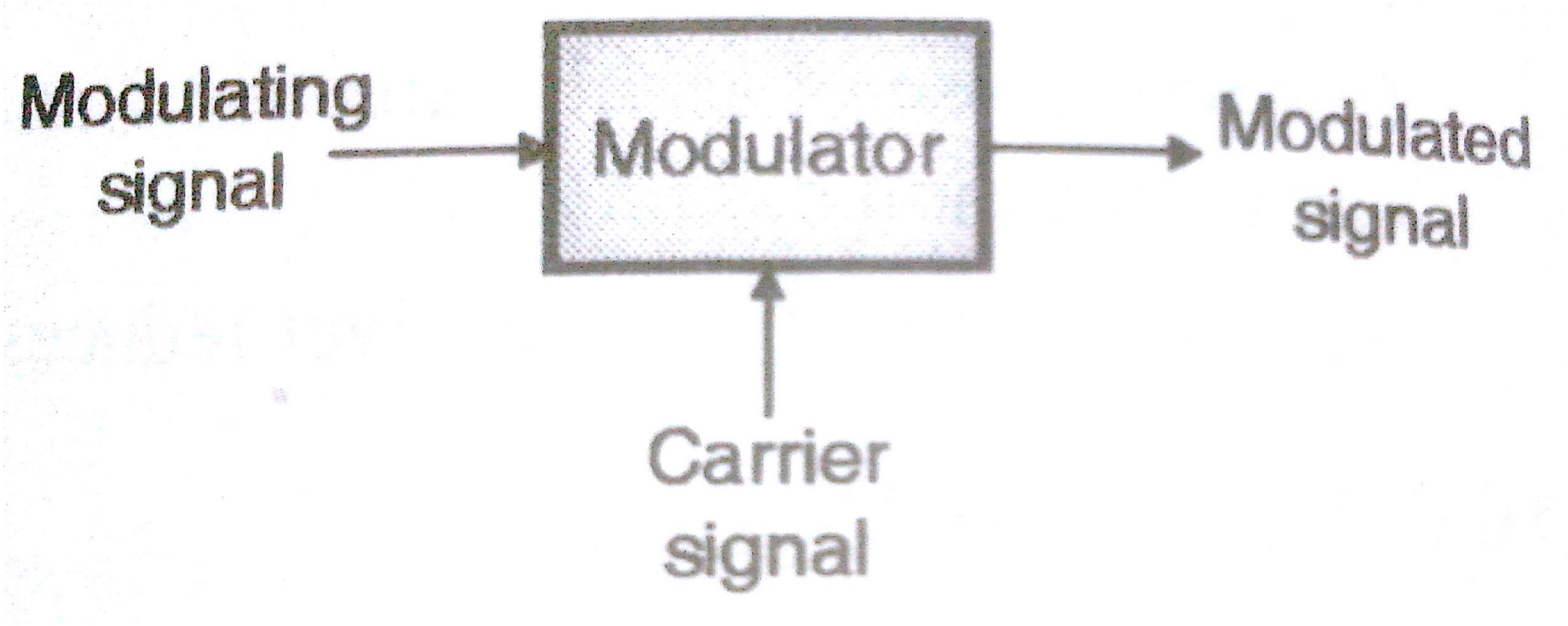


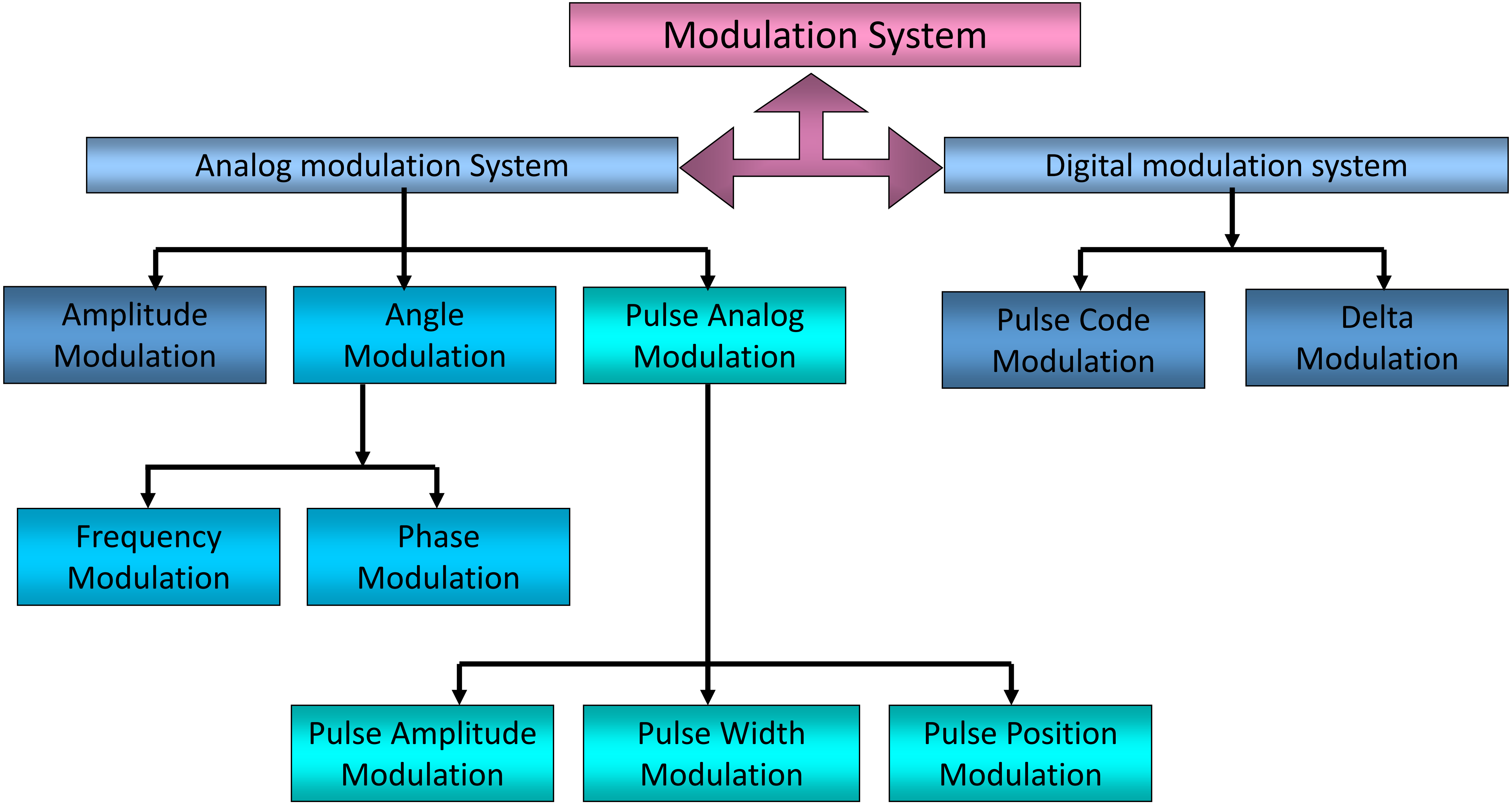
Name	Frequency	Wavelength	Applications
Extremely low frequency (ELF)	30-300Hz	10^7 to 10^6 m	Power transmission
Voice frequency (VF)	300Hz- 3000Hz	10^6 to 10^5 m	Audio Applications
Very Low frequency (VLF)	3 – 30kHz	10^5 to 10^4 m	Submarine communication, Navy, military communication
Low frequency (LF)	30-300kHz	10^4 to 10^3 m	Aeronautical, Marine applications
Medium frequency (MF)	300kHz-3MHz	10^3 to 10^2 m	AM radio broadcast, Marine communication
High frequency (HF)	3 – 30 MHz	10^2 to 10m	Shortwave transmission
Very High frequency(VHF)	30 – 300MHz	10 to 1m	TV, FM broadcasting

Name	Frequency	Wavelength	Applications
Ultra high frequency (UHF)	300MHz – 3GHz	1 to 10^{-1}m	Cellular phone, UHF TV channels
Super High frequency (SHF)	3GHz – 30 GHz	10^{-1} to 10^{-2}m	Satellite and radar communication
Extremely High frequency (EHF)	30 - 300GHz	10^{-2} to 10^{-3}m	Satellite and specialized radar
Infrared	30 – 430 THz	0.7 to 10μm	Night vision goggles
Visible light	375 – 750 THz	0.4 to 0.8 μm	Light bulbs

Modulation

- Modulation is the process of modifying the characteristics of one signal in accordance with some characteristics of another signal.
- The *information signal is called the modulating signal*, with any shape.
- The *higher frequency signal which is being modulated is called carrier signal*, which is may be cosine wave or sine wave.


Modulating signal
Modulator
Modulated signal
Carrier signal


Modulation System
Analog modulation System
Digital modulation system
Amplitude Modulation
Angle Modulation
Pulse Analog Modulation
Pulse Code Modulation
Delta Modulation
Frequency Modulation
Phase Modulation
Pulse Amplitude Modulation
Pulse Width Modulation
Pulse Position Modulation

Types of modulation

Depending on which parameter carrier types of modulation are

(1) Amplitude modulation(AM):

Amplitude of carrier is varied in proportion with the instantaneous amplitude of information /modulating signal keeping its frequency & phase constant.

(2) Frequency modulation (FM):

Frequency of carrier is varied in proportion with the instantaneous Frequency of base band signal keeping its amplitude & phase constant.

(3) Phase modulation(PM):

Phase of the carrier is modified in proportion with instantaneous phase of base band signal keeping amplitude & frequency constant.

Need For Modulation

- **Reduces the antenna heights**
- **Avoids mixing of signals.**
- **Increases range of communication.**
- **Improves quality of reception.**
- **Allow adjustment in the Bandwidth**
- **Allows multiplexing of signals.**

1. Reduce the Height of Antenna:

The height of antenna required for transmission and reception of radio waves in radio transmission is function of wavelength (λ) the frequency (f).

$$\lambda = c/f$$

C=Velocity of light = 3×10^8

For transmitting baseband signal with f= 15 Khz.
Height of Antenna (H) = λ /4 = c/(4×f) = (3×10^8) /(4×15×10^3) = 5000 meter (unthinkable and unpractical)

let us consider modulated signal of 1 Mhz
Height of Antenna (H) = λ /4 = c/(4×f) = (3×10^8) /(4×1×10^6) = 75 meter
Practical and can be installed.

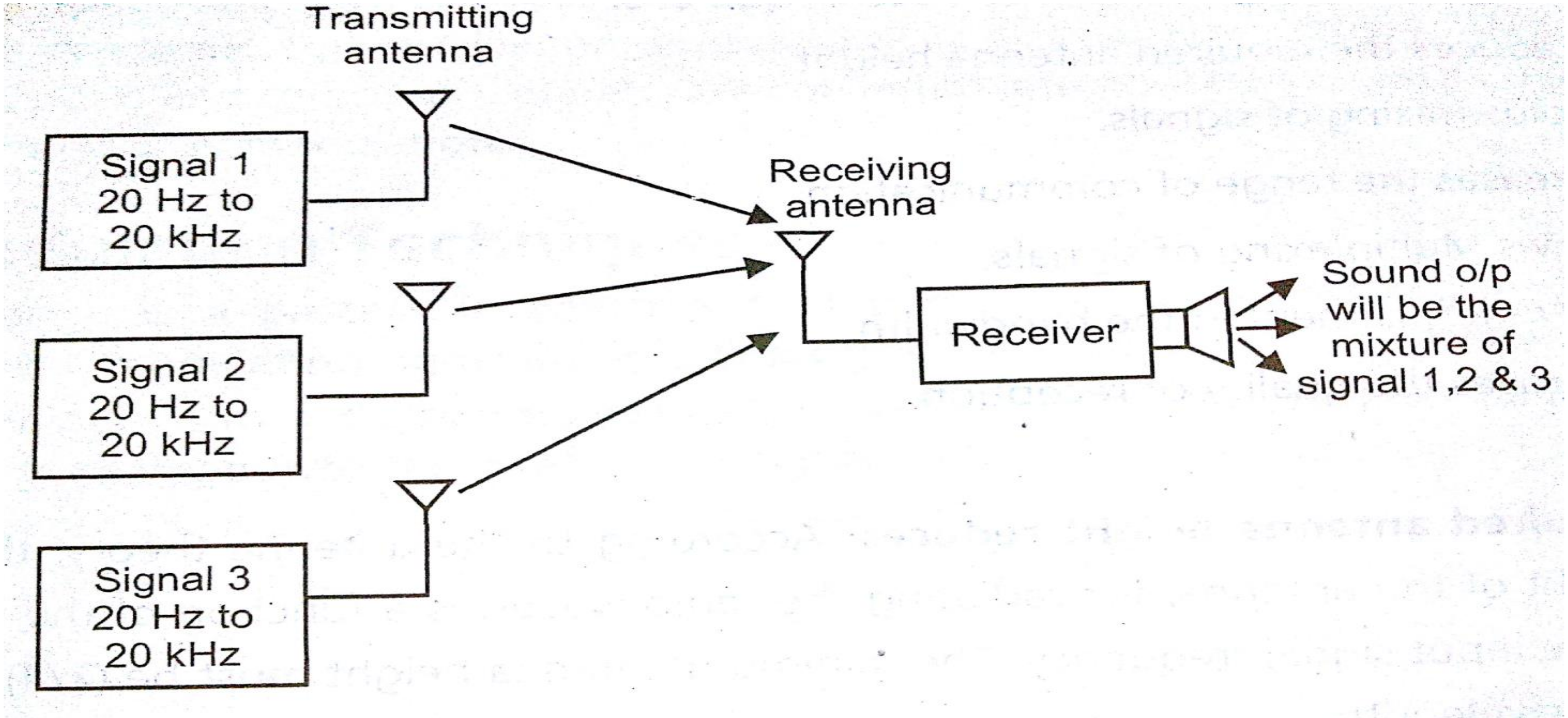
2. Avoids Mixing of Signal:

i. All sound signals are connected within the range of 20 Hz to 20 KHz.

ii. The transmission of baseband signals from various source causes the mixing of signal and then difficult to separate at the receiver.

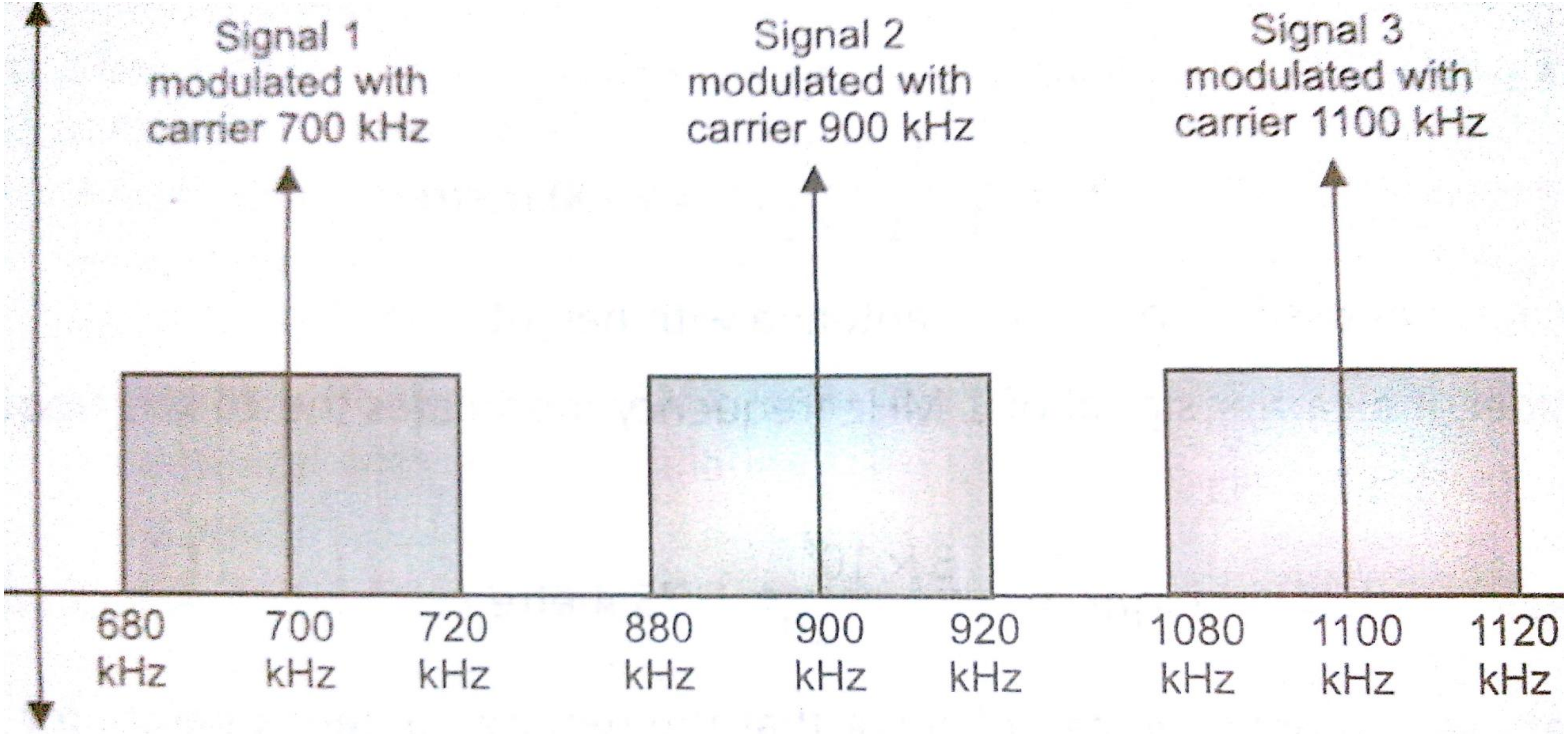
iii. Therefore modulating different signal by different carrier frequency avoid mixing of signal.

2. Avoids mixing of signals



Baseband communication for three sound signals

2. Avoids mixing of signals



Modulation avoids mixing of signals

3.Increase the range of communication:

i. The base band signal is low frequency signal which , when transmitted, can not travel long distance .

ii. Modulation effectively increase the frequency of the signal to be radiated and thus the distance over which signals can be transmitted faithfully.

iii. Hence modulation increases the range of communication

4. Allows multiplexing of signals:

i. Multiplexing means transmission of two or more signals simultaneously over single channel.

i. Modulation permits multiplexing of signals.

ii. Therefore many TV channels can use the same frequency range, without getting mixed with each other.

5. Allow adjustment in the Bandwidth:

i. Signal to noise ratio (SNR) in the receiver is function of signal bandwidth

ii. Bandwidth of a modulated signal can be changed to improve the signal to noise ratio (SNR).

iii. Bandwidth of a modulated signal may be made smaller or larger than the original signal.

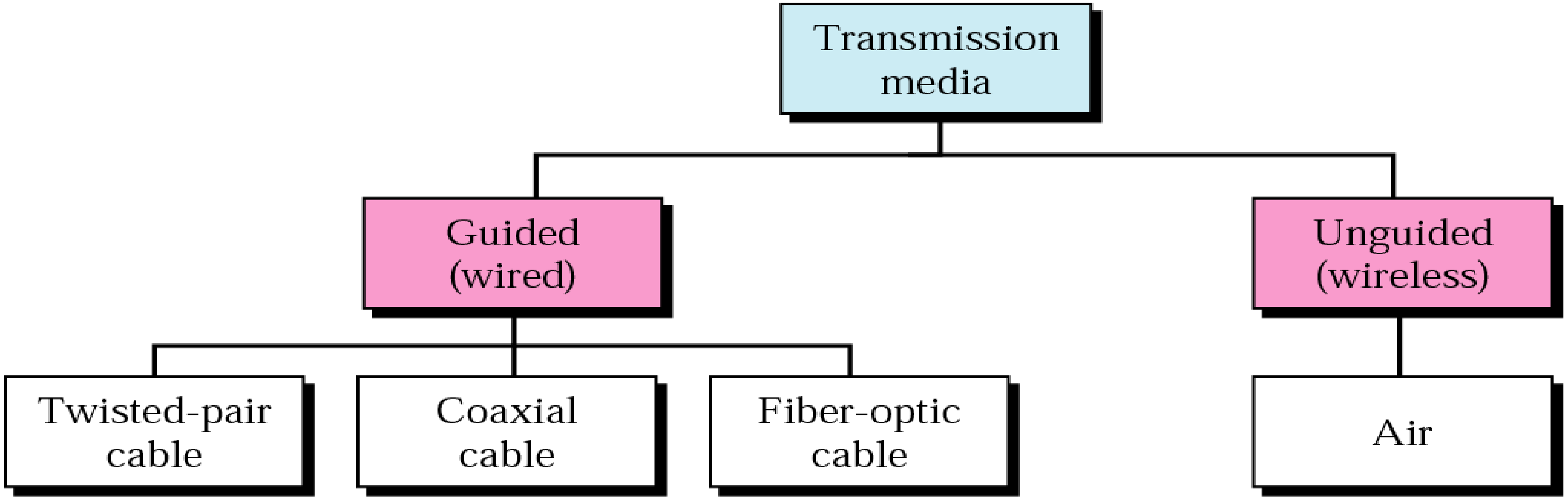
6.Improve quality of reception:

i. Frequency Modulation(FM) & Pulse Code Modulation (PCM) techniques are proven to have high Signal to Noise Ratio(SNR).

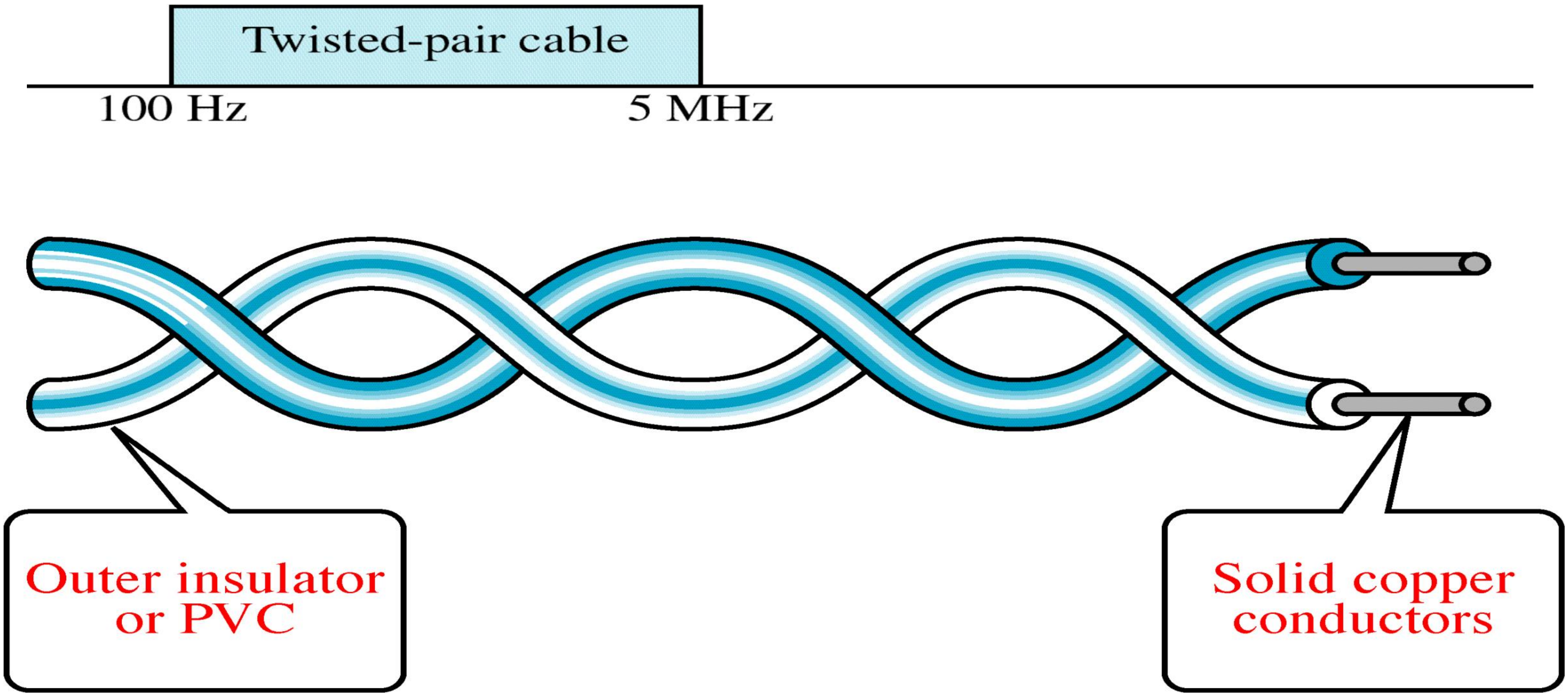
ii. FM and PCM reduce the effect of noise to great extent and improve quality of reception.

Transmission Media

Classes of transmission media



Twisted pair cable



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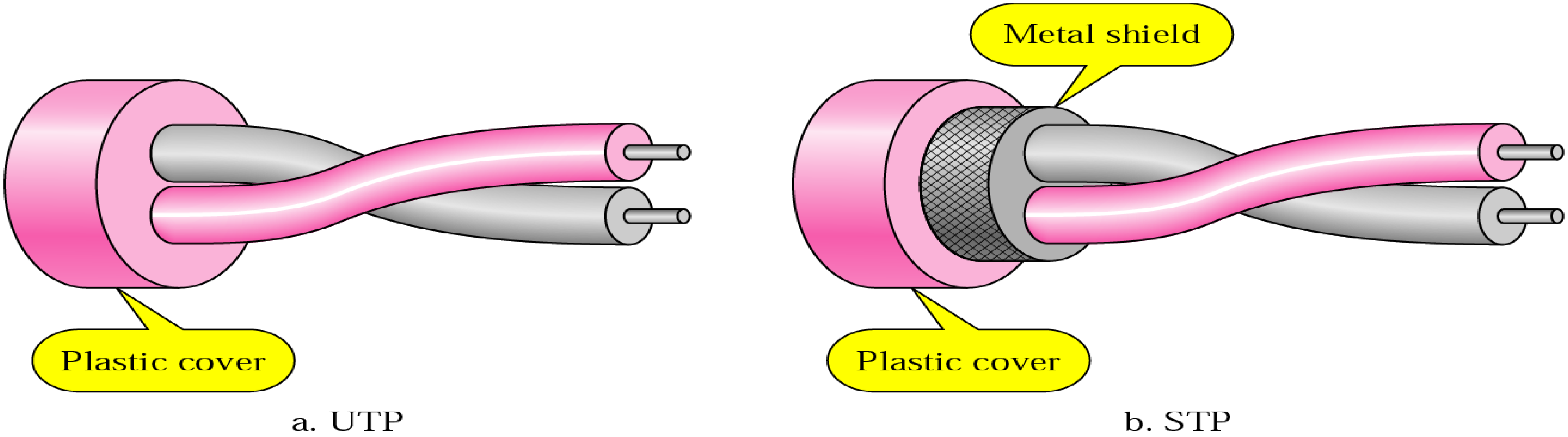
Transmission Media

Types of Twisted Pair

- ***UTP***
- ***STP***



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Transmission Media

1. Unshielded Twisted Pair (UTP) Cable

The Electronic Industries Association (EIA) has developed standards to grade UTP.

Category 1: The basic twisted-pair cabling used *in telephone systems*. This level of quality is *fine for voice but inadequate for data transmission*.

Category 2: This category is *suitable for voice and data transmission of up to 2Mbps*.

Category 3:This category is suitable for data transmission of *up to 10 Mbps*. It is now the standard cable for most telephone systems.

Category 4: This category is suitable for data transmission of *up to 20 Mbps*.

Category 5: This category is suitable for data transmission of *up to 100 Mbps*.

Twisted pair cable

Advantages

- Inexpensive and readily available
- Flexible and light weight
- Easy to work with and install

Disadvantages

- Susceptibility to interference and noise
- Attenuation problem
    - For analog, repeaters needed every 5-6km
    - For digital, repeaters needed every 2-3km
- Relatively low bandwidth (MHz)

Twisted pair cable

Applications

- Telephone lines to carry voice & data
- LAN s

Transmission Media

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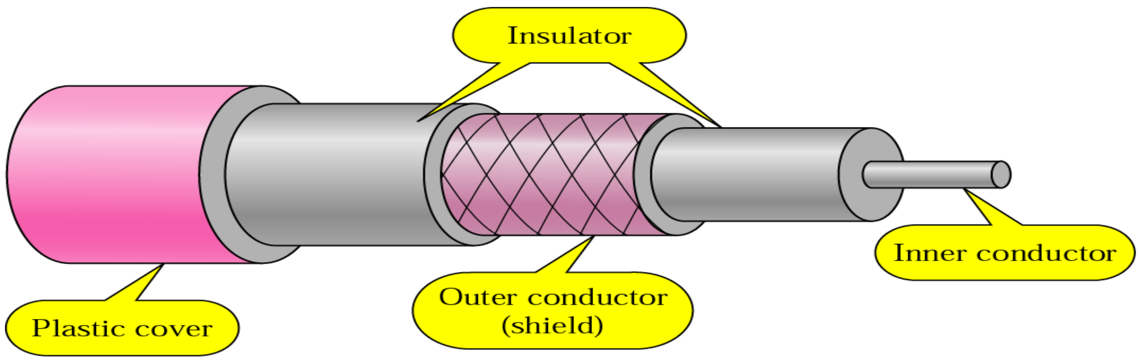
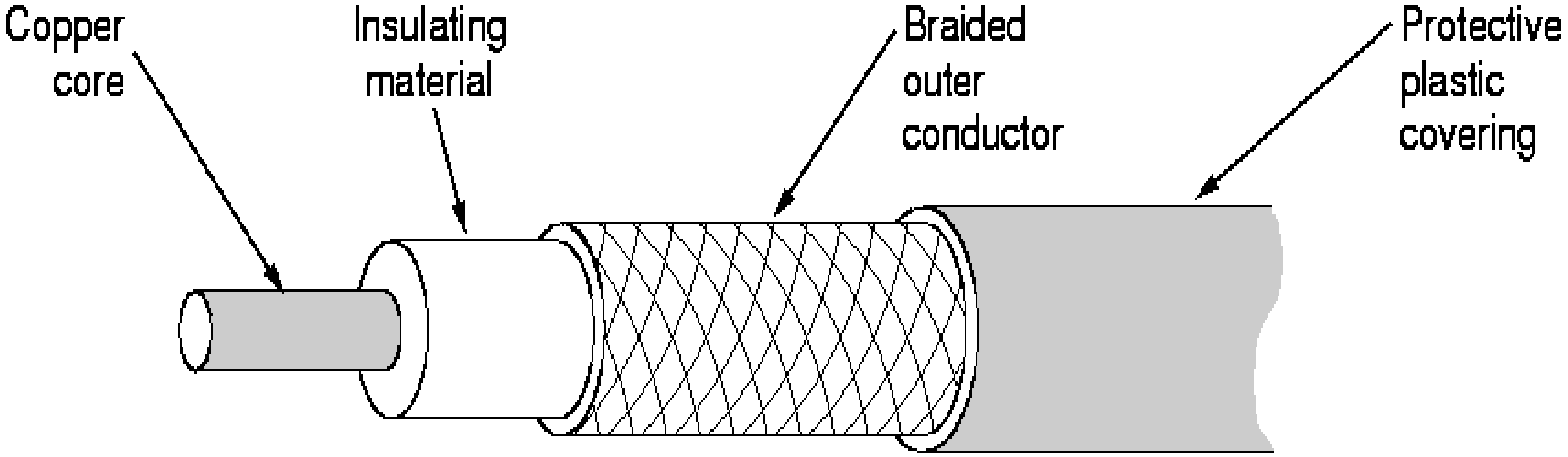
Copper Media: Coaxial Cable

- **Coaxial cable is a copper-cored cable surrounded by a heavy shielding and is used to connect *computers in a network*.**
- ***Outer conductor shields* the inner conductor from *picking up stray signal* from the air.**
- ***High bandwidth but lossy channel*.**
- ***Repeater* is used to regenerate the weakened signals.**



COAXIAL CABLE



COAXIAL CABLE

Characteristics of Coaxial cable

- Excellent noise immunity due to shield
- Larger BW & low losses
- Widely used in LAN network
- Costlier than twisted cable cheaper than fiber optic cable
- Easy to install
- Attenuation is less
- inexpensive

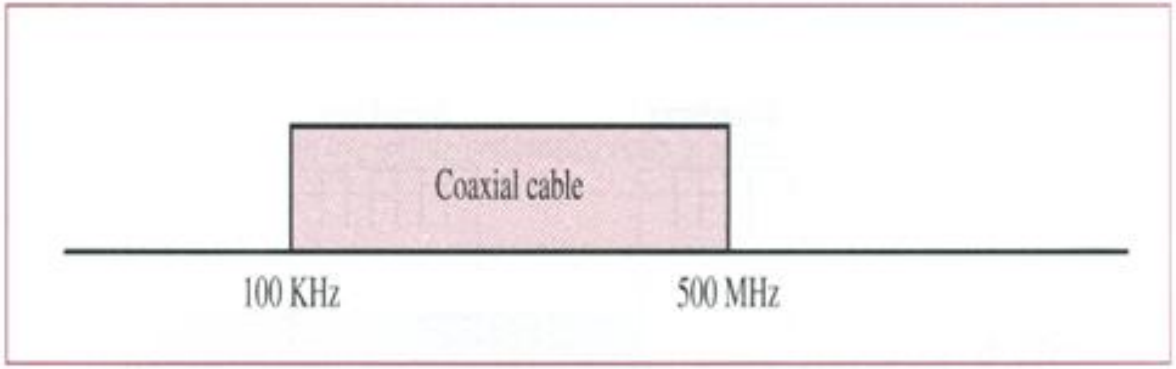
Transmission Media

Copper Media: Coaxial Cable

- Coaxial cable carries signals of higher frequency ranges than twisted-pair cable.
- Coaxial Cable standards:

Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

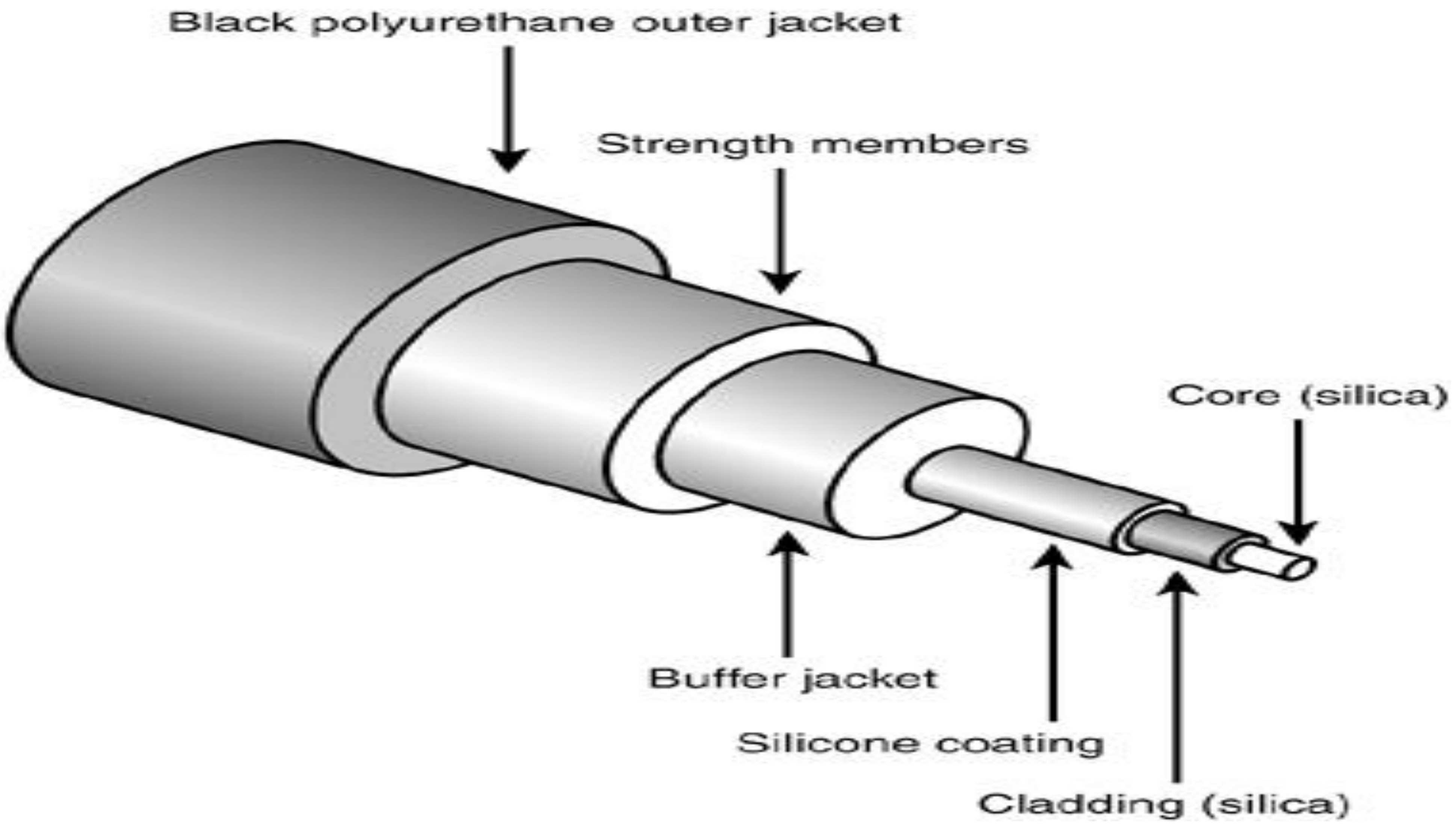
Frequency range of coaxial cable



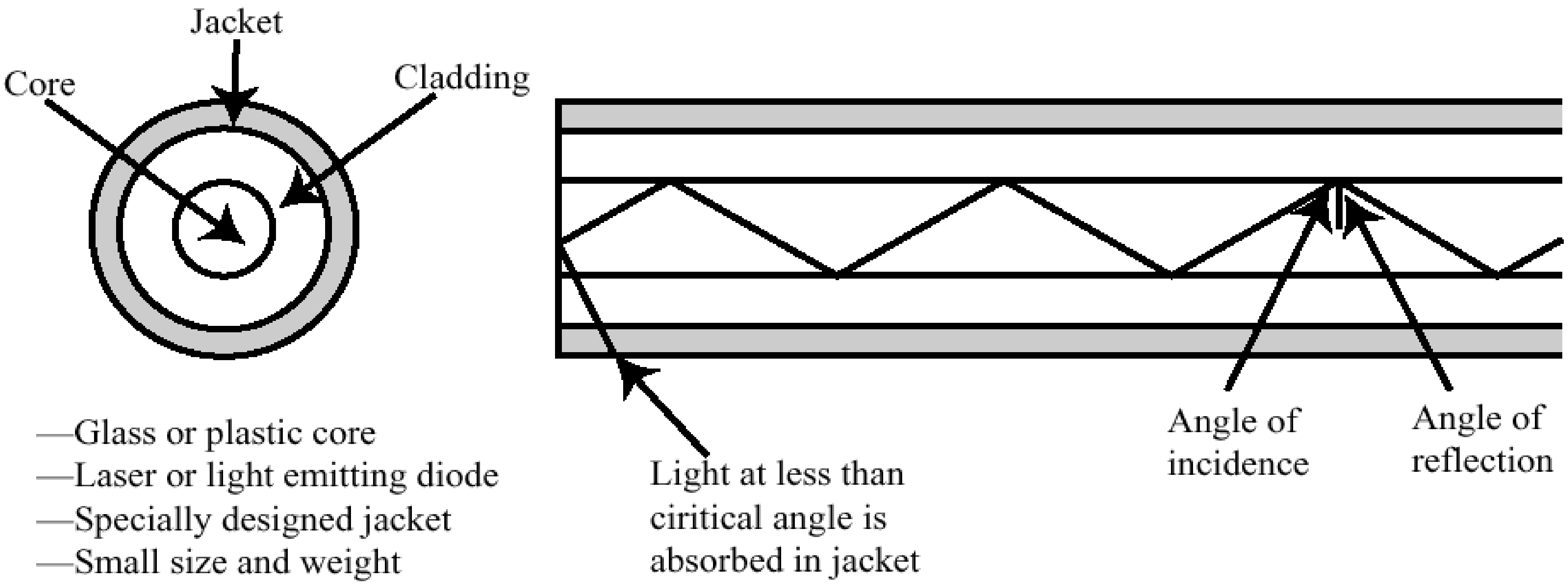
Transmission Media

Optical Fiber

- Metal cables transmit signals in the form of electric current.
- Optical fiber is made of glass or plastic and *transmits signals in the form of light*.
- Light, a form of electromagnetic energy, travels at 300,000 Kilometers/second (186,000 miles/second), in a vacuum.
- The *speed of the light depends on the density of the medium through which it is traveling* (the higher density, the slower the speed).


Black polyurethane outer jacket
Strength members
Core (silica)
Buffer jacket
Silicone coating
Cladding (silica)

OPTICAL FIBER CABLE



(c) Optical Fiber

OPTICAL FIBER CABLE

CHARACTERISTICS:

- Extremely high bandwidth since light has higher frequency than electricity
- Lower attenuation :Can carry signal to longer distances without amplifiers & repeaters in between
- Not affected by EMI
- Costlier
- Difficult installation

OPTICAL FIBER CABLE

ADVANTAGES:

- small size & light weight: diameter smaller than human hair
- Easy availability :silica glass easily available
- No electrical or electromagnetic interference: light rays do not get affected
- Larger bandwidth: as frequency of light is larger
- No cross talk
- 100 times faster signal can be sent
- Flexible installation
- Not affected by drastic environmental changes

OPTICAL FIBER CABLE

DISADVANTAGES:

- Sophisticated plants are needed to manufacture fiber optic cable
- High Initial cost
- Joining optical fibers is tedious job

OPTICAL FIBER CABLE

APPLICATIONS:

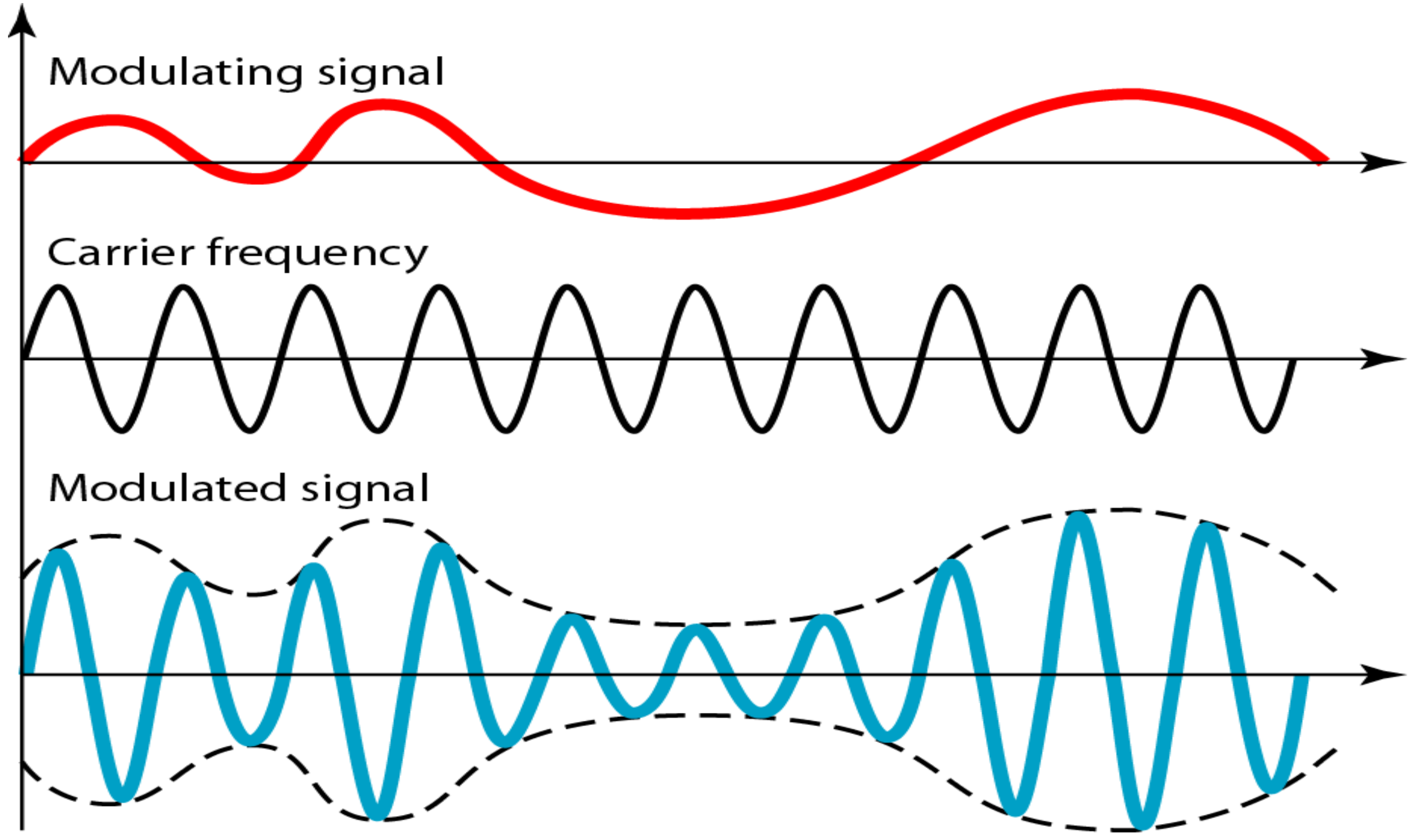
- Backbone for many networks
- Telephone systems
- LANs

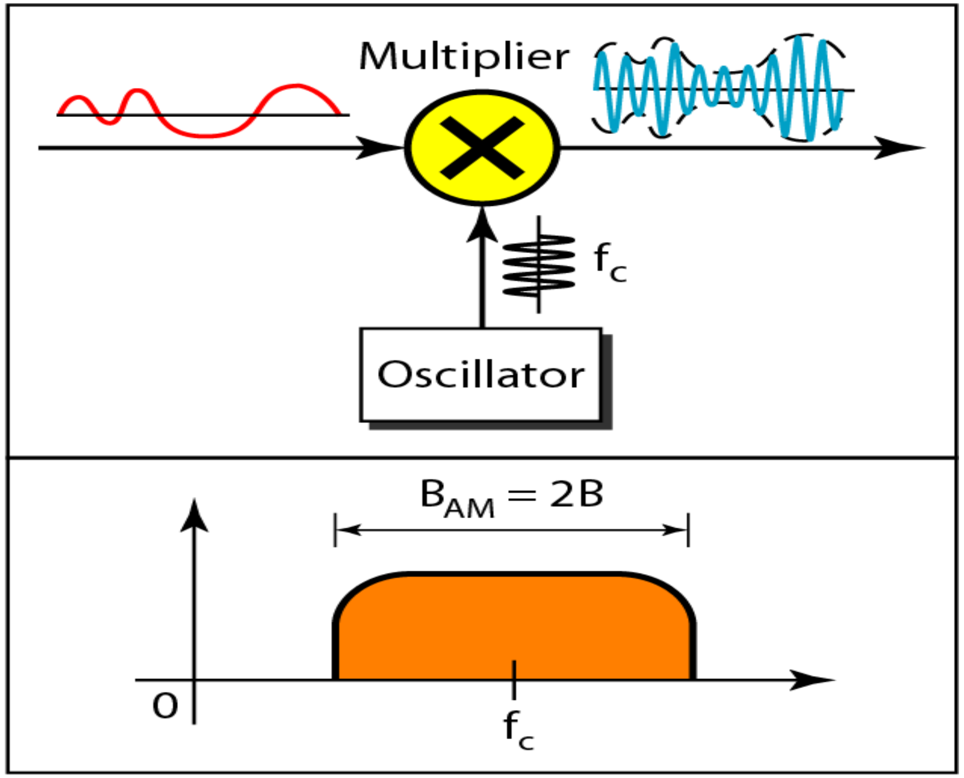
INTRODUCTION

- Amplitude Modulation is the simplest and earliest form of transmitters
- AM applications include broadcasting in medium- and high-frequency applications, CB radio, and aircraft communications
- *Amplitude modulation is defined as " change in amplitude of carrier signal with respect to the amplitude of modulating Signal or Information signal (Baseband Signal) without changing the frequency and phase of carrier signal".*
- The frequency of carrier signal (fc) is greater than the frequency of modulating signal (fm).

  (fc >> fm).

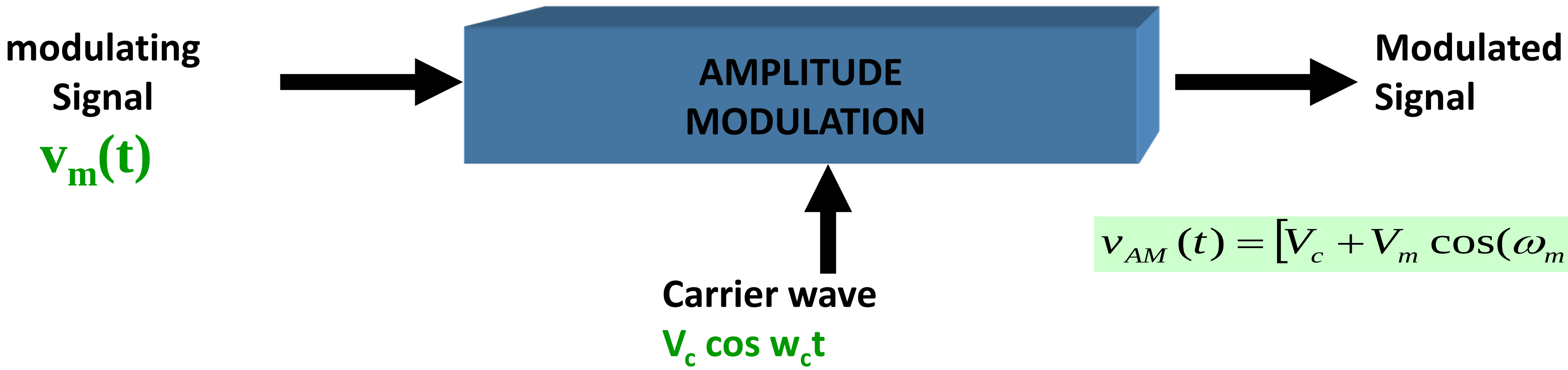
Amplitude Modulation





Amplitude Modulation

- In amplitude modulation, the amplitude of the carrier **varies proportional to the instantaneous magnitude** of modulating signal
- Assuming
  - Modulating signal : $\mathbf{v_m(t) = V_m \cos w_m t}$
  - carrier signal : $\mathbf{v_c(t) = V_c \cos w_c t}$

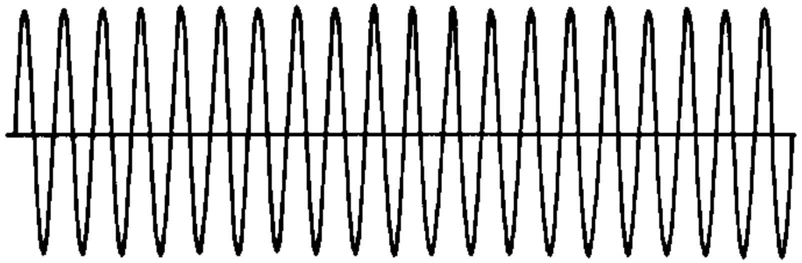


$$v_{AM}(t) = [V_c + V_m \cos(\omega_m t)]\cos(\omega_c t)$$

Amplitude Modulation

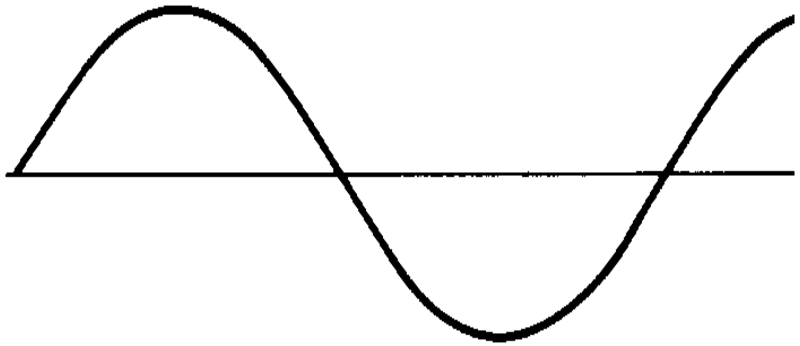
Carrier signal

$$v_c(t) = V_c \cos(\omega_c t)$$



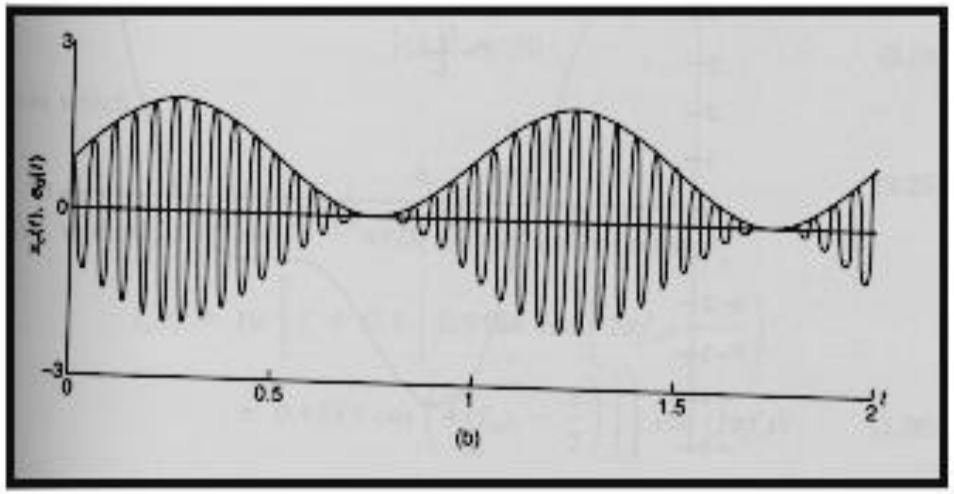
Modulating signal

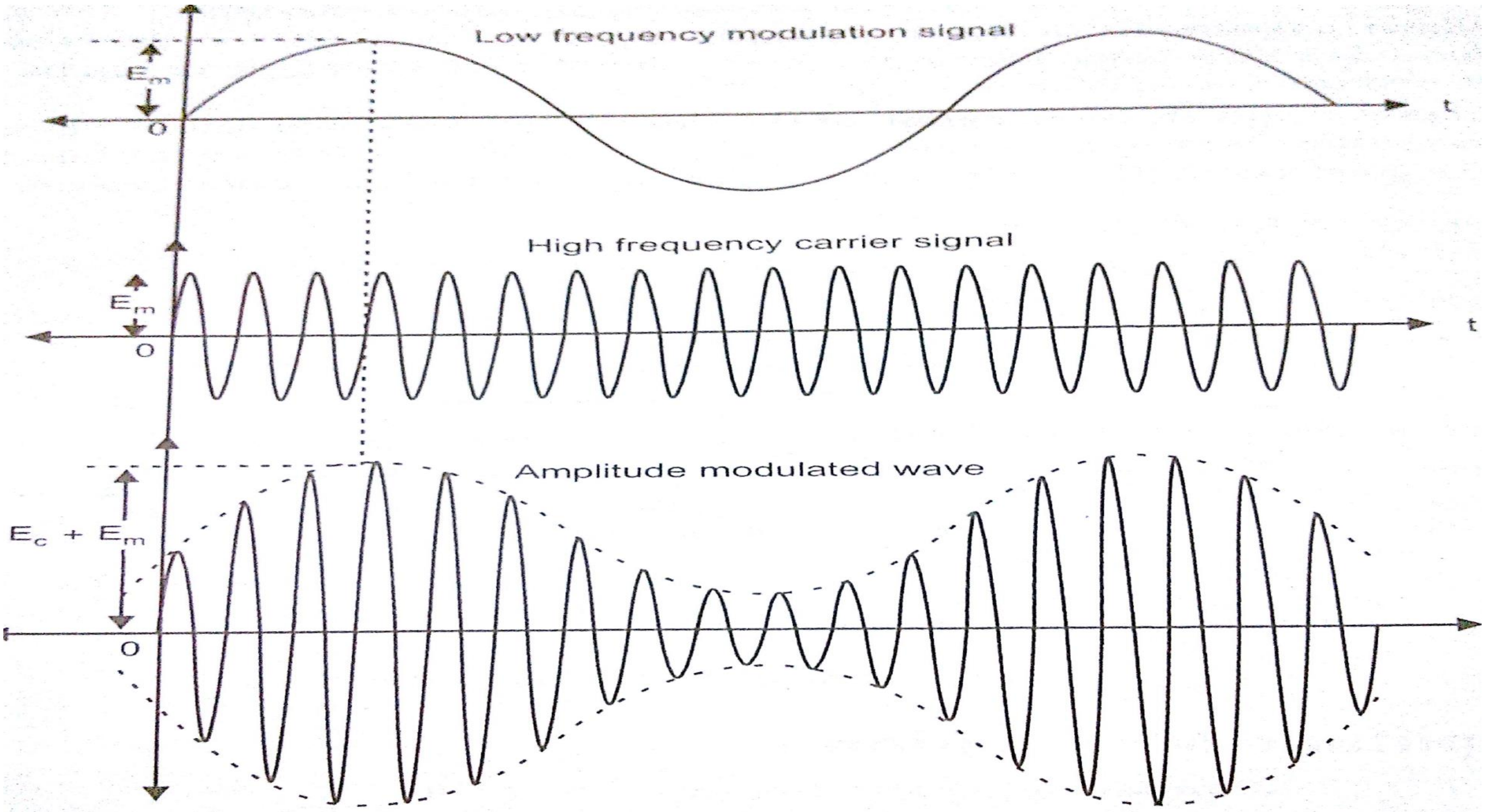
$$v_m(t) = V_m \cos \omega_m t$$



$$\omega_c = 2\pi f_c$$

v_{am}





Amplitude modulated wave

- Modulation Index or Modulation Factor or Modulation Coefficient or Degree of modulation

Definition

- The ratio of amplitudes of the modulating signal and carrier signal , expressed by the equation:

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

Modulation index are key parameters for any AM transmission as it is necessary to keep the index within limits to reduce distortion and interference.

DERIVATION OF AM EQUATION

- **AM begins with carrier v_c , → a sine wave with frequency f_c & amplitude V_c:**
- **Modulating signal:**

$$v_m = V_m \sin 2\pi f_m t$$

- **Carrier Signal:**

$$v_c = V_c \sin 2\pi f_c t$$

- **Then Envelope is:**

$$V_{env} = V_c + v_m$$

$$V_{env} = V_c + V_m \sin 2\pi f_m t \qquad [m = V_m / V_c]$$

$$V_{env} = V_c + mV_c \sin 2\pi f_m t$$

$$V_{env} = V_c (1 + m \sin 2\pi f_m t)$$

DERIVATION OF AM EQUATION

- **The voltage resulting AM wave envelope at any instant is:**

$$
\begin{aligned}
v &= V_{env} \sin 2\pi f_c t \\
&= V_c(1 + m \sin 2\pi f_m t) \bullet \sin 2\pi f_c t \\
&= V_c \sin 2\pi f_c t + mV_c \sin 2\pi f_m t \sin 2\pi f_c t
\end{aligned}
$$

Using Trigonometric Formula

$$(\sin a)(\sin b) = 1/2\left[\cos(a-b) - \cos(a+b)\right]$$

$$v_{AM} = \underbrace{V_c \sin 2\pi f_c t}_{\text{Carrier}} + \underbrace{\frac{mV_c}{2}\cos 2\pi(f_c - f_m)t}_{\text{LSB}} - \underbrace{\frac{mV_c}{2}\cos 2\pi(f_c + f_m)t}_{\text{USB}}$$

DERIVATION OF AM EQUATION

- **AM begins with carrier v_c , → a cosine wave with frequency f_c & amplitude V_c:**

$$v_c = V_c \cos 2\pi f_c t$$

- **Modulating signal:**

$$v_m = V_m \, \mathrm{Cos}\, 2\pi f_m t$$

- **Then Envelope is:**

$$V_{env} = V_c + v_m$$
$$V_{env} = V_c + V_m \cos 2\pi f_m t \qquad [m = V_m / V_c]$$
$$V_{env} = V_c + mV_c \cos 2\pi f_m t$$

DERIVATION OF AM EQUATION

- **Where *m (modulation index)* is defined as *V_m/V_c*, hence:**

$$\boxed{V_{env} = V_c(1 + m\cos 2\pi f_m t)}$$

- **The voltage resulting AM wave envelope at any instant is:**

$$\boxed{\begin{aligned} v &= V_{env} \cos 2\pi f_c t \\ &= V_c(1 + m\cos 2\pi f_m t) \bullet \cos 2\pi f_c t \\ &= V_c \cos 2\pi f_c t + mV_c \cos 2\pi f_m t \cos 2\pi f_c t \end{aligned}}$$

Using Trigonometric Formula

$$(\cos a)(\cos b) = 1/2\left[\cos(a-b) + \cos(a+b)\right]$$

$$\begin{aligned} v &= V_c Cos 2\pi f_c t \\ &+ \frac{m}{2} V_c \cos 2\pi (f_c - f_m)t \\ &+ \frac{m}{2} V_c \cos 2\pi (f_c + f_m)t \end{aligned}$$

$$v_{AM} = V_c \cos 2\pi f_c t + \frac{mV_c}{2} \cos 2\pi (f_c - f_m)t + \frac{mV_c}{2} \cos 2\pi (f_c + f_m)t$$

Carrier LSB USB

- This yield, the upper and lower sidebands – frequency & amplitude.

Frequency Spectrum of AM

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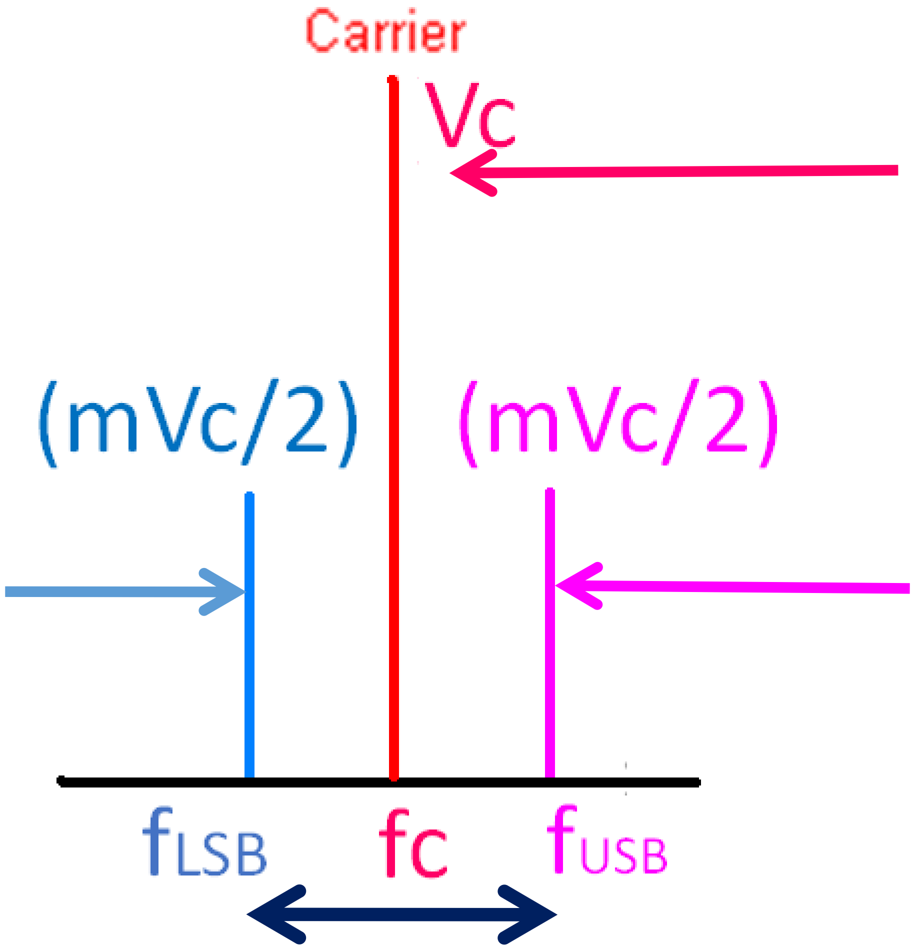


$f = f_c$

Ampl=(Vc)

$f_{LSB} = f_c - f_m$

Ampl=(mVc/2)

$f_{USB} = f_c + f_m$

Ampl=(mVc/2)

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

$= (f_c + f_m) - (f_c - f_m)$

$= 2\, f_m$

5. MODULATION INDEX AND SIGNAL POWER

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

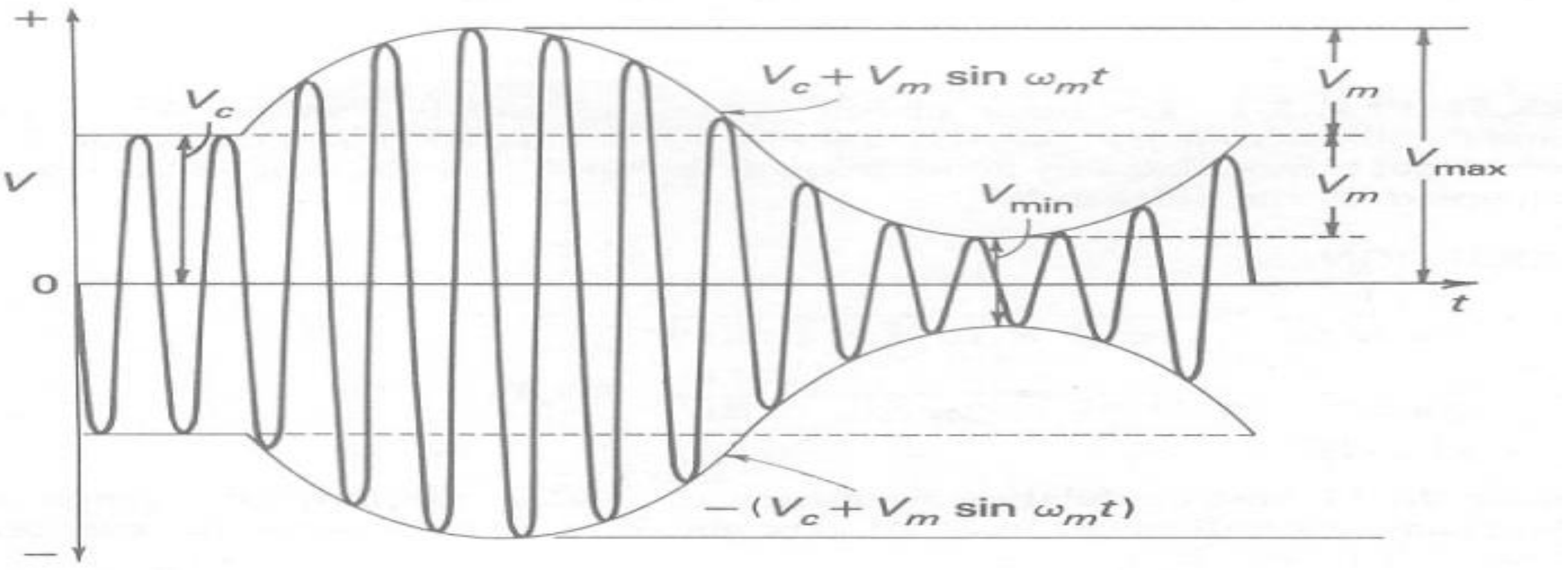
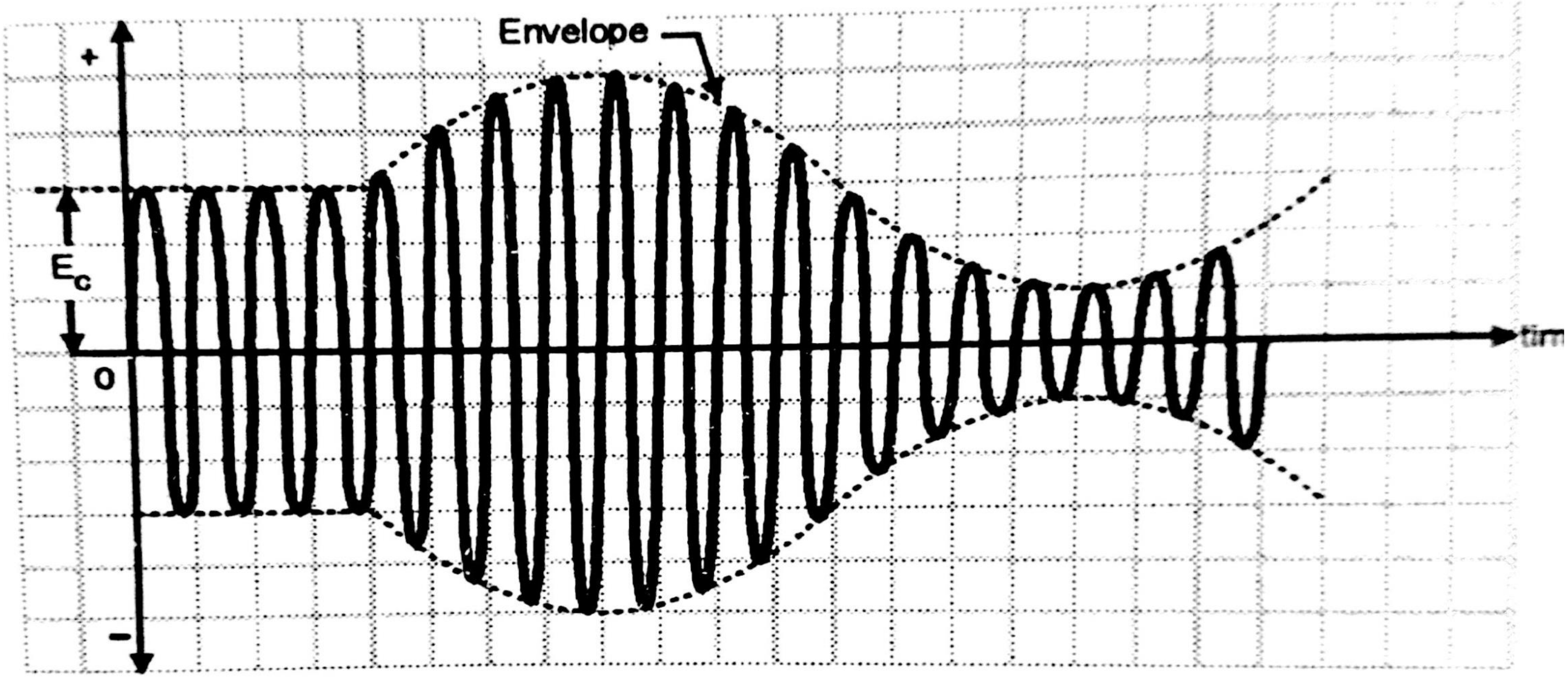


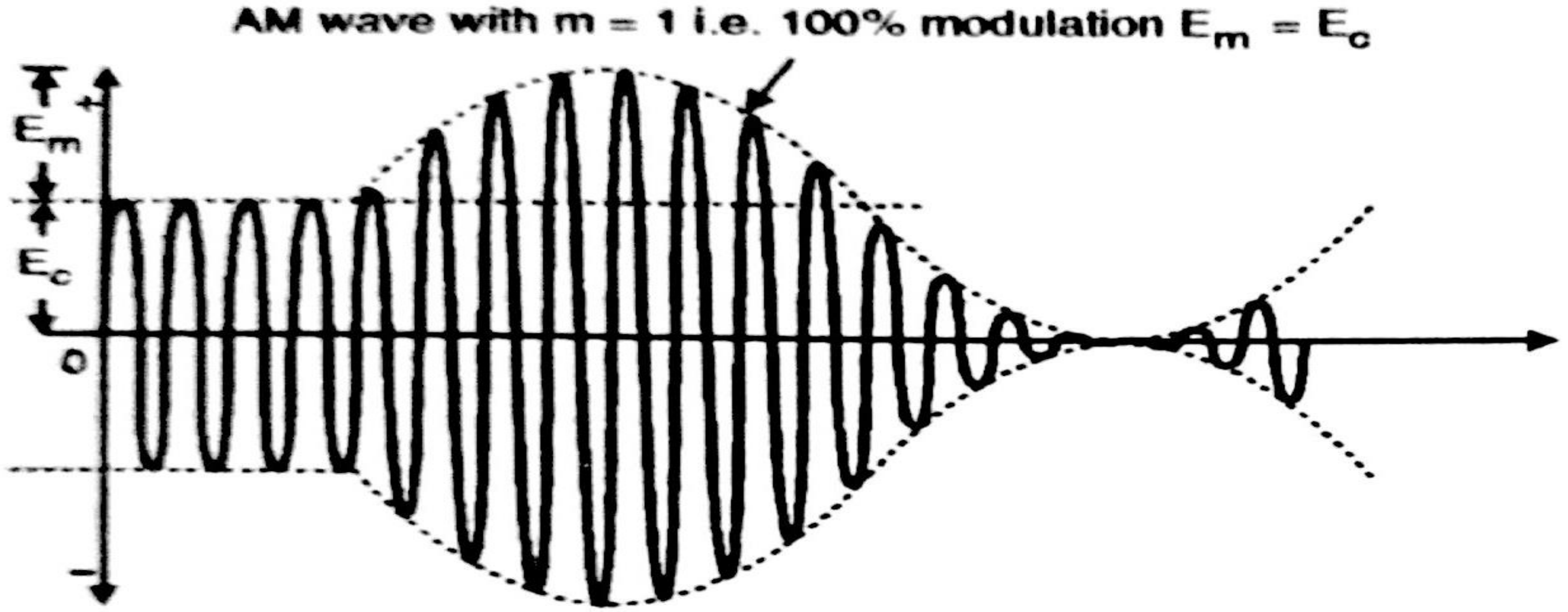
FIGURE 3-3 Amplitude-modulated wave.

Modulation index less than 1 or 100

(Under Modulation)

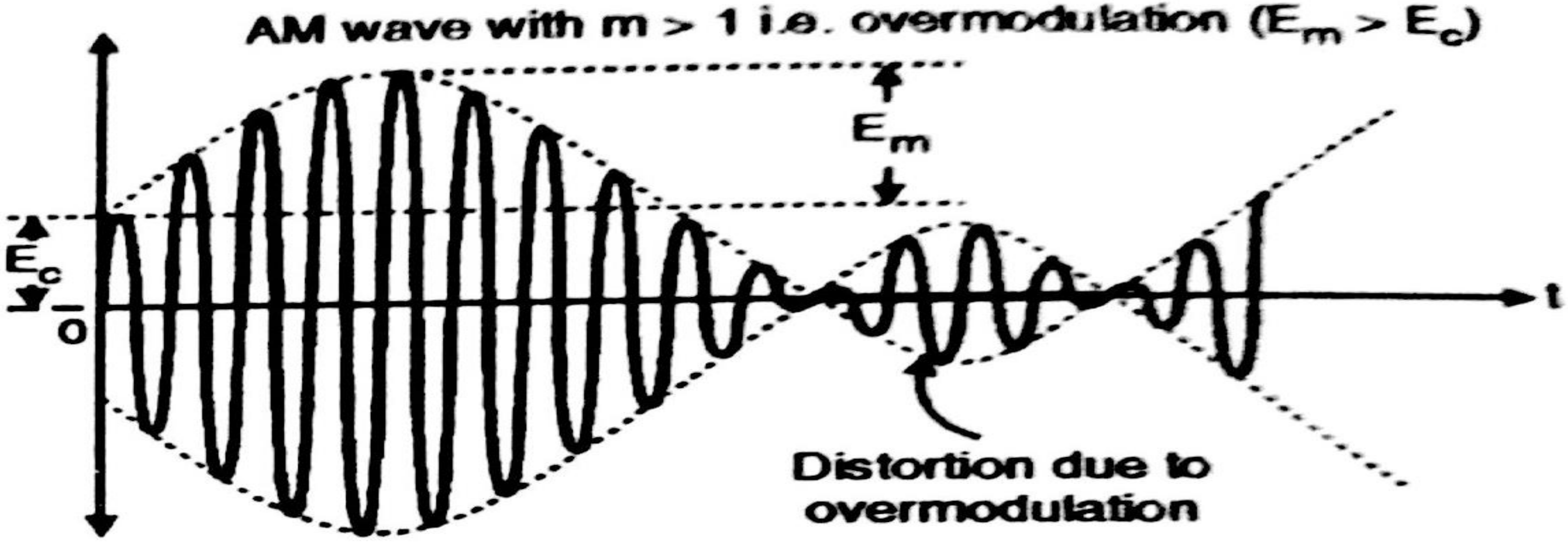


Modulation index Equal to 1 or 100
(Exact or Perfect Modulation)



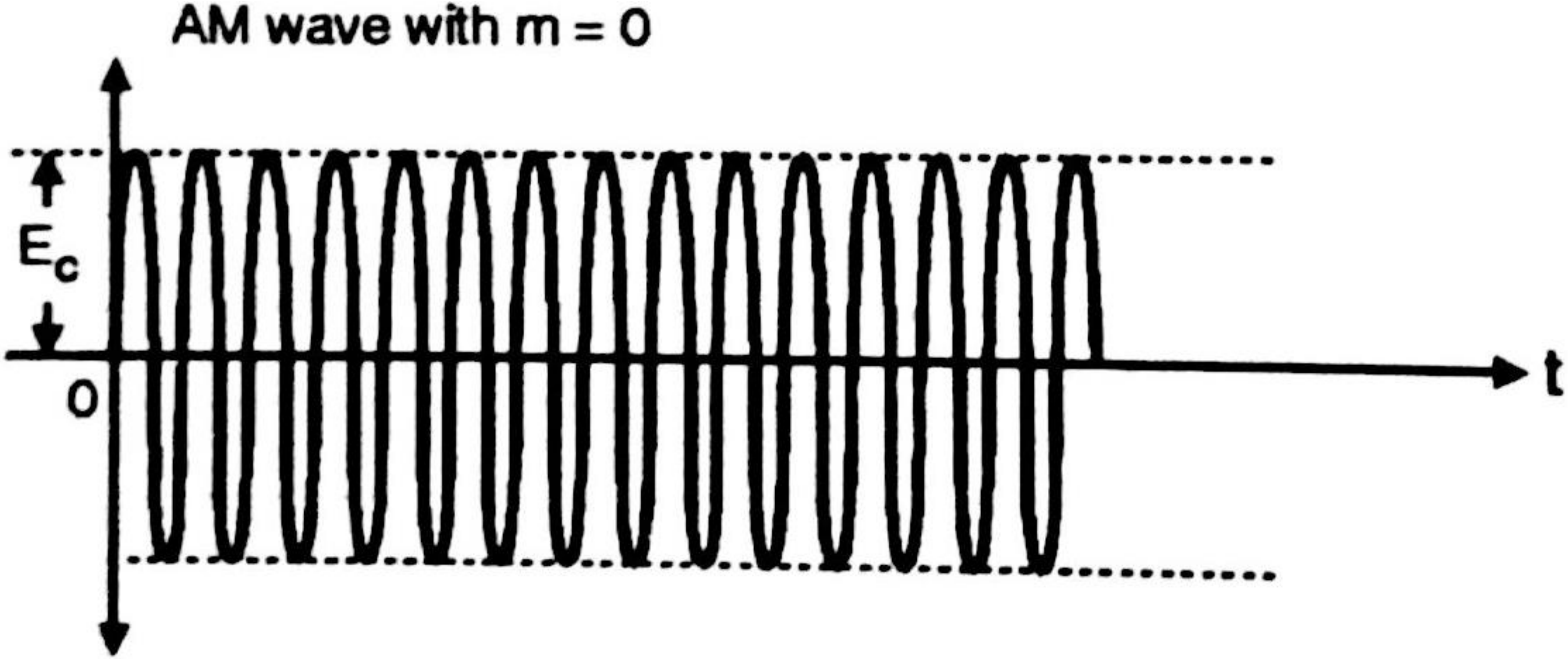
(b) AM wave with 100% modulation

Modulation index > 1 or 100
(Over modulation)



(c) AM with over modulation

Modulation Index equal to 0



Advantages/disadvantages

Advantages of Amplitude Modulation, AM

- It is **simple** to implement
- it can be demodulated using a circuit consisting of **very few components**
- AM receivers are **very cheap** as no specialized components are needed.
- AM waves can travel a longer distance
- Low bandwidth
- AM transmitters are **less complex**

Disadvantages of amplitude modulation

- Power wastage takes place
- AM needs larger Bandwidth
- AM wave gets affected due to noise

Common Application of AM

- ✓ AM radio Broadcasting
- ✓ TV Picture or Picture Transmission in a TV System
- ✓ Two way radio
- ✓ Digital data transmission
- ✓ Computer Modems

Numerical on AM

A carrier of 10 V peak and frequency 100 KHz is amplitude modulated by a sine wave of 4 V peak and frequency 1000 Hz. Determine the modulation index for the modulated wave and draw the frequency spectrum for AM wave.

To find : 1. Modulation index 2. Frequency spectrum of AM wave

Step 1 : Calculate modulation index :

$$m = \frac{E_m}{E_c} = \frac{4}{10} = 0.4$$

Step 2 : Frequencies of sideband components :

1. Upper sideband, $f_{USB} = f_c + f_m = (100\text{ k} + 1\text{ k}) = 101\text{ kHz}$
2. Lower sideband, $f_{LSB} = f_c - f_m = (100\text{ k} - 1\text{ k}) = 99\text{ kHz}$

Step 3 : Amplitude of sidebands :

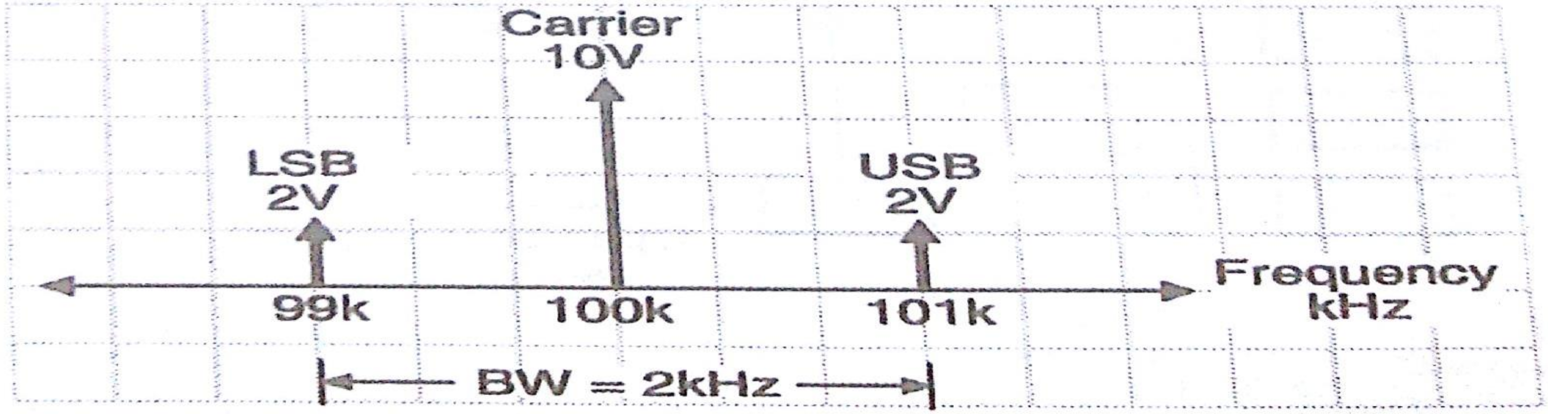
The amplitudes of upper as well as lower sideband is given by,

$$\text{Amplitude of each sideband} = \frac{m\,E_c}{2} = \frac{0.4 \times 10}{2} = 2\text{ Volts}$$

Step 4 : Bandwidth :

$$\text{Bandwidth} = 2\,f_m = 2 \times 1\text{ k} = 2\text{ kHz}$$

Step 5 : Spectrum of AM wave :



1: A modulating signal 10 sin $(2\pi \times 10^3\ t)$ is used to modulate a carrier signal 20 sin $(2\pi \times 10^4\ t)$. Find the modulation index, percentage modulation, frequencies of the sideband components and their amplitudes. What is the bandwidth of the modulated signal ? Also draw the spectrum of the AM wave.

Soln. :

- The modulating signal $e_m = 10 \sin (2\pi \times 10^3 t)$. So comparing this with the expression $e_m = E_m \sin (2 \pi f_m t)$ we get,

$$E_m = 10 \text{ volt}, f_m = 1 \times 10^3 \text{ Hz} = 1 \text{ kHz}$$

- The carrier signal $e_c = 20 \sin (2\pi \times 10^4 t)$.

Comparing this with the expression $e_c = E_c \sin (2 \pi f_c t)$ we get,

$$E_c = 20 \text{ volt}, f_c = 1 \times 10^4 \text{ Hz} = 10 \text{ kHz}$$

Step 1 : Modulation index and percentage modulation :

$$m = \frac{E_m}{E_c} = \frac{10}{20} = 0.5 \text{ and } \quad \% \text{ modulation} = 0.5 \times 100 = 50\%.$$

Step 2 : Frequencies of sideband components :

1. Upper sideband $f_{USB} = f_c + f_m = (10 + 1) = 11$ kHz
2. Lower sideband $f_{LSB} = f_c - f_m = (10 - 1) = 9$ kHz

Step 3 : Amplitudes of sidebands :

The amplitudes of upper as well as the lower sideband is given by,

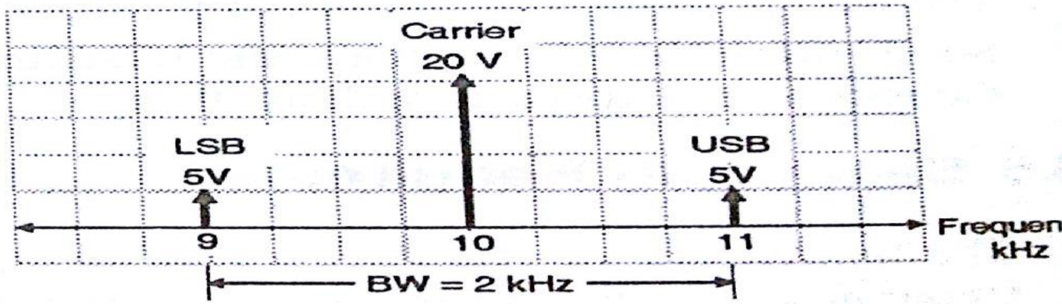
$$\text{Amplitude of each sideband} = \frac{m E_c}{2} = \frac{0.5 \times 20}{2} = 5 \text{ Volts}$$

Step 4 : Bandwidth :

$$\text{Bandwidth} = 2 f_m = 2 \times 1 = 2 \text{ kHz}$$

Step 5 : Spectrum :

The spectrum of AM wave is shown in Fig. P. 9.16.1.



(B-703)**Fig. P. 9.16.1 : Spectrum of the AM w**

- **Frequency Modulation (FM)**

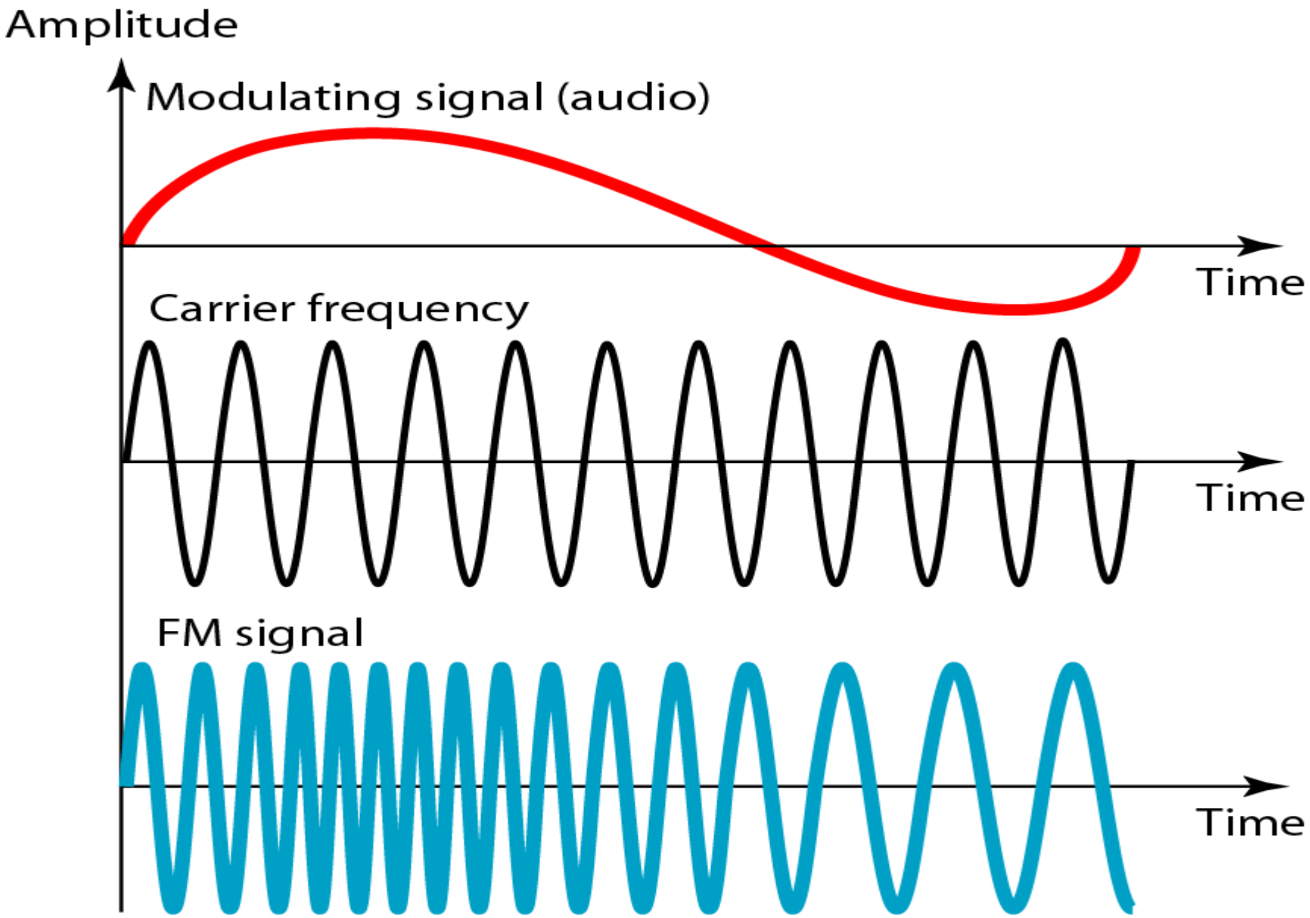
What is frequency modulation?

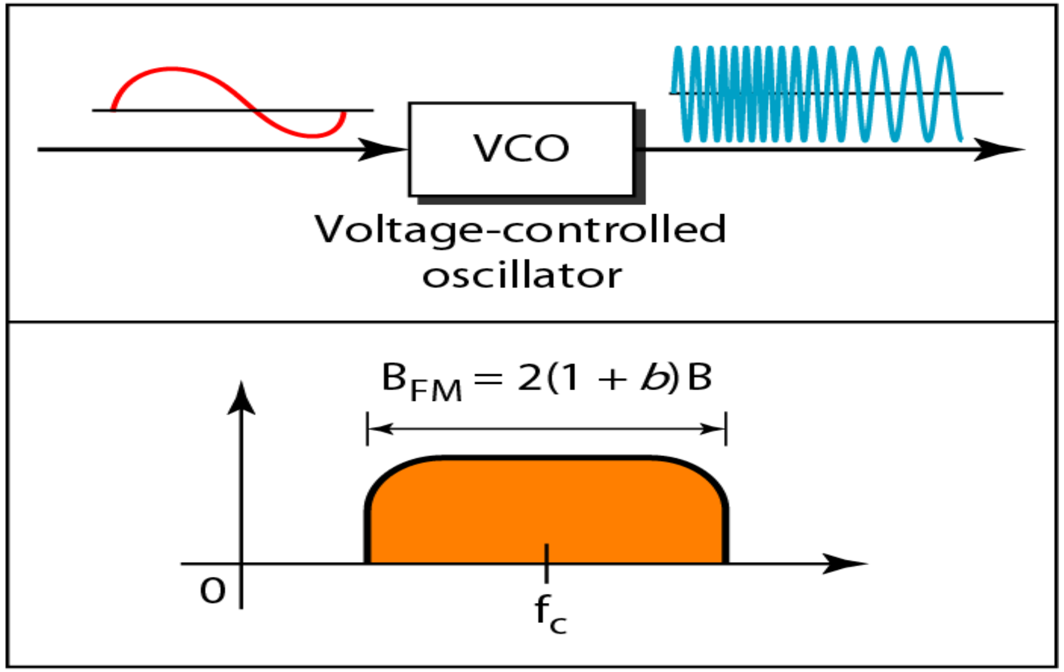
- When the frequency of **carrier wave** is changed in accordance with the message **signal**, The process is called frequency modulation.

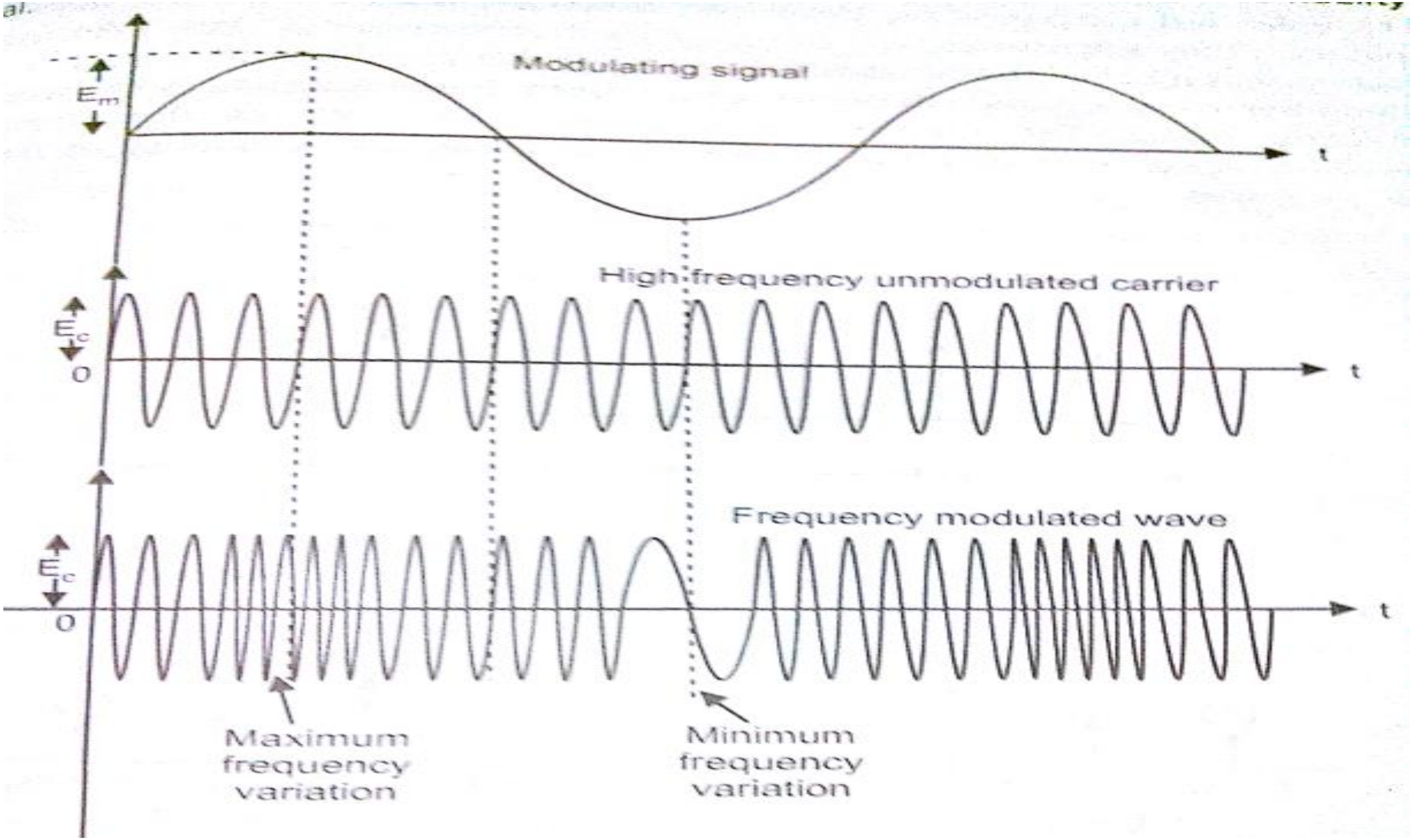
- In FM the carrier amplitude remain constant the carrier frequency varies

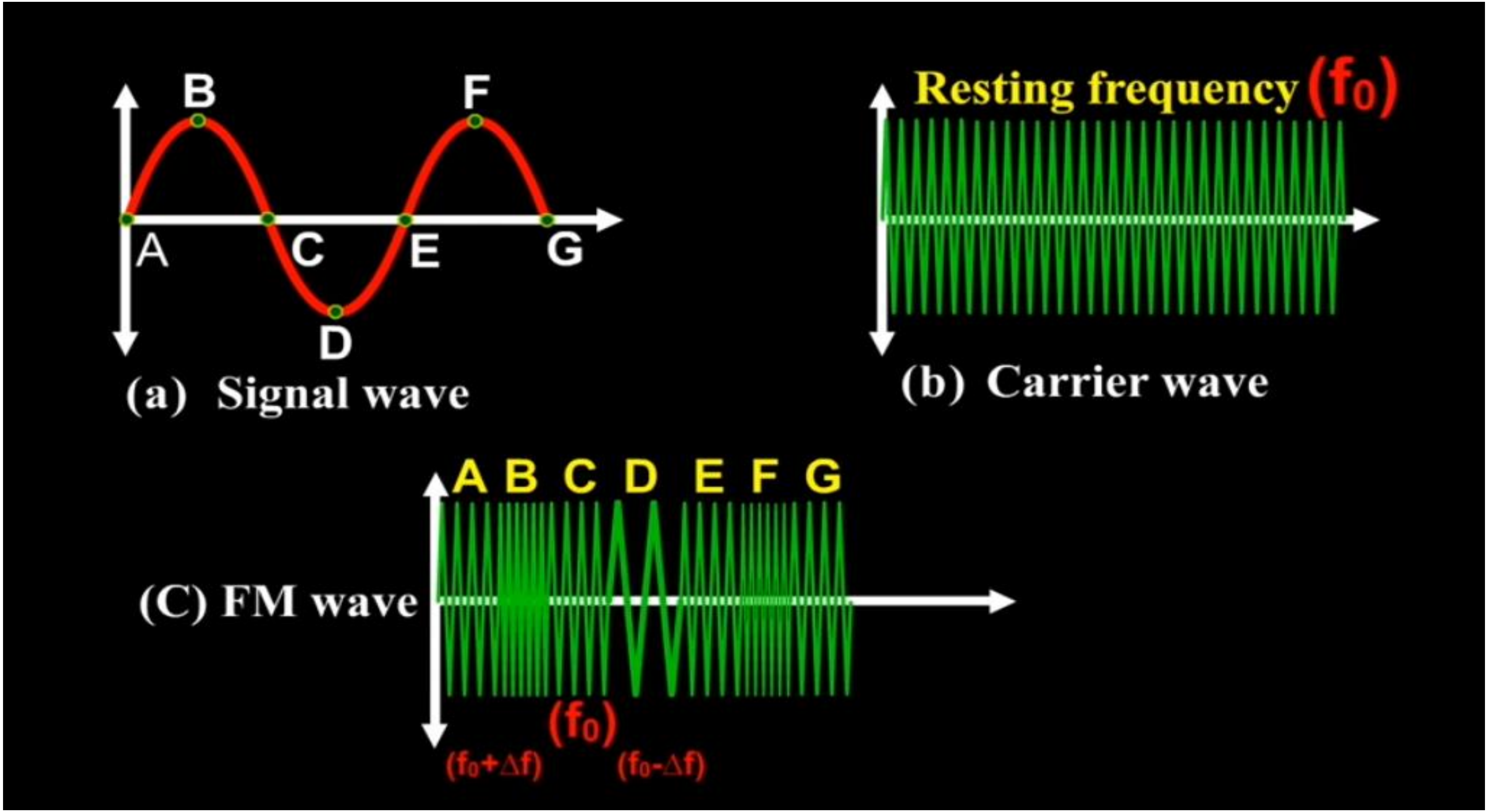
- It is a type of Angle modulation

Frequency Modulation






Modulating signal
E_m
t
High frequency unmodulated carrier
E_c
O
t
Frequency modulated wave
E_c
O
t
Maximum frequency variation
Minimum frequency variation


B
F
A
C
E
G
D
(a) Signal wave
Resting frequency (f0)
(b) Carrier wave
A B C D E F G
(C) FM wave
(f0)
(f0+Δf)
(f0-Δf)

Frequency Modulation. The carrier's instantaneous frequency deviation from its unmodulated value varies in proportion to the instantaneous amplitude of the modulating signal.

$$e_{FM} = E_c \sin(\omega_c t + m_f \sin \omega_m t)$$

Where

$(\omega_c t + m_f \sin \omega_m t) =$ ***Frequency of FM Wave varies according to the modulating signal***

Sin= FM wave is a sine

Ec =Peak amplitude of FM Wave is constant and equal to the peak amplitude of the carrier

Frequency deviation

- δ Represents the maximum departure of the instantaneous frequency of the FM wave from the carrier frequency
- Since $\delta = kf\ Em$, Kf is constant with units Hz/Volts.
- The Frequency deviation is proportional to the amplitude of modulating voltage (Em) & its independent of the modulating frequency fm.
- Max. Freq. of FM =fmax=Fc $+ \delta$
- Min. Freq. of FM =Fmin=Fc $- \delta$

Deviation Ratio

It is defined as the ratio of maximum frequency deviation to maximum modulating frequency.

The modulation index corresponding to the maximum deviation and maximum modulating frequency is called as the "Deviation ratio ".

According to the Federal Communication Commission(FCC) the maximum value of δ Is limited to 75 kHz and Fm max is limited to 15 kHz in FM broadcasting.

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

$$= \frac{\delta_{\text{max}}}{F_{m\,\text{Max}}}$$

FM modulation index

- FM modulation index is equal to the ratio of the frequency deviation to the modulating frequency.
- Thus the formula for the modulation index for FM is simply given by that shown below:

$$\mathbf{m} = \frac{\text{Frequency Deviation}}{\text{Modulating Frequency}}$$

And also,

$$m_f = \frac{\delta}{f_m}$$

Bandwidth Requirements for FM

- The higher the modulation index, the greater the required system bandwidth

$$BW = 2(n \times f_m)$$

where n is the highest number of significant sideband components and f_m is the highest modulation frequency.

Carson's Rule

$$BW = 2(\delta + f_m) = 2 f_m (1 + m_f)$$

- The number of sidebands depends upon both the amplitude and the frequency of the modulating signal.
- The number of sidebands pairs increases as the amplitude of the modulating signal increases.
- The number also increases as the frequency of the modulating signal decreases.
- Modulation index is related with effective sidebands.

MI	0.5	1	2	3	4
Number of sidebands	2	3	4	6	7

TABLE 4-3
Modulation Index versus the Number of Significant Sidebands

Modulation index, m_f	Significant sidebands, n
0.00	0
0.25	1
0.50	2
1.00	3
2.00	4
3.00	6
4.00	7
5.00	8
7.00	10
10.00	14
15.00	16

Advantages

1. Amplitude of the frequency modulated wave remains unaffected.

2. Large decrease in noise, hence increase in S/N ratio.

3. Noise may reduce by increasing deviation.

4. Frequency allocation allows for a guard band which reduces adjacent channel interference.

5. Operate In Very high frequency (VHF).

Disadvantages

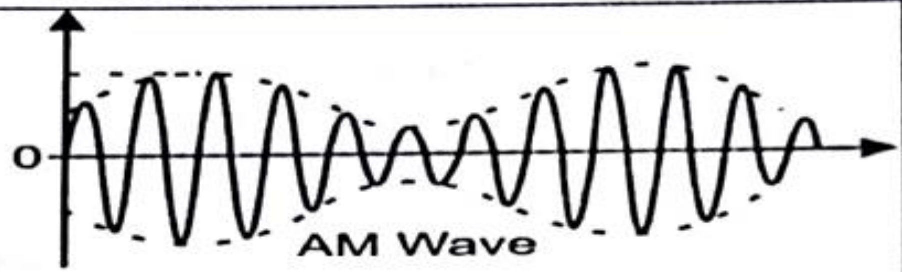
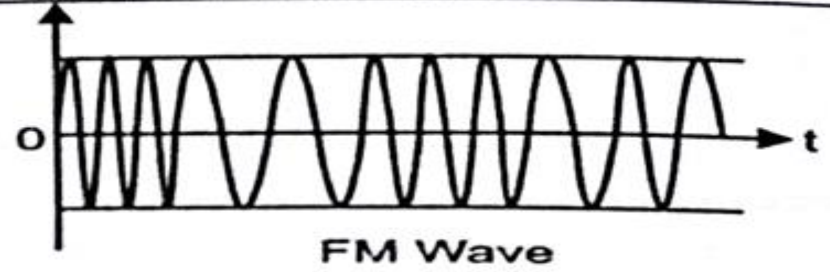
- FM has too much advantages besides it also has some disadvantages

1. FM wave can’t cover large area.
2. Transmitting & receiving equipments for FM are complex & costly.
3. A much wider channel, typically 200 kHz, is needed for FM.

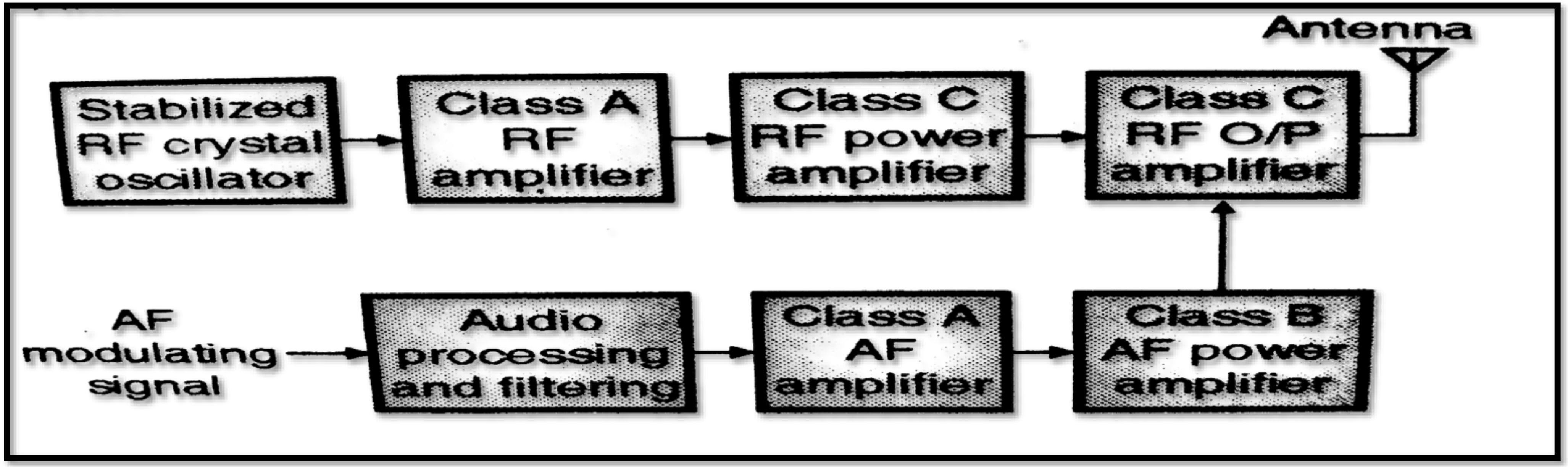
Common Application of FM

- ✓ FM radio Broadcasting
- ✓ TV Sound Broadcasting
- ✓ Two way mobile radio
- ✓ Digital data transmission
- ✓ Cellular Telephones
- ✓ Satellite TV.

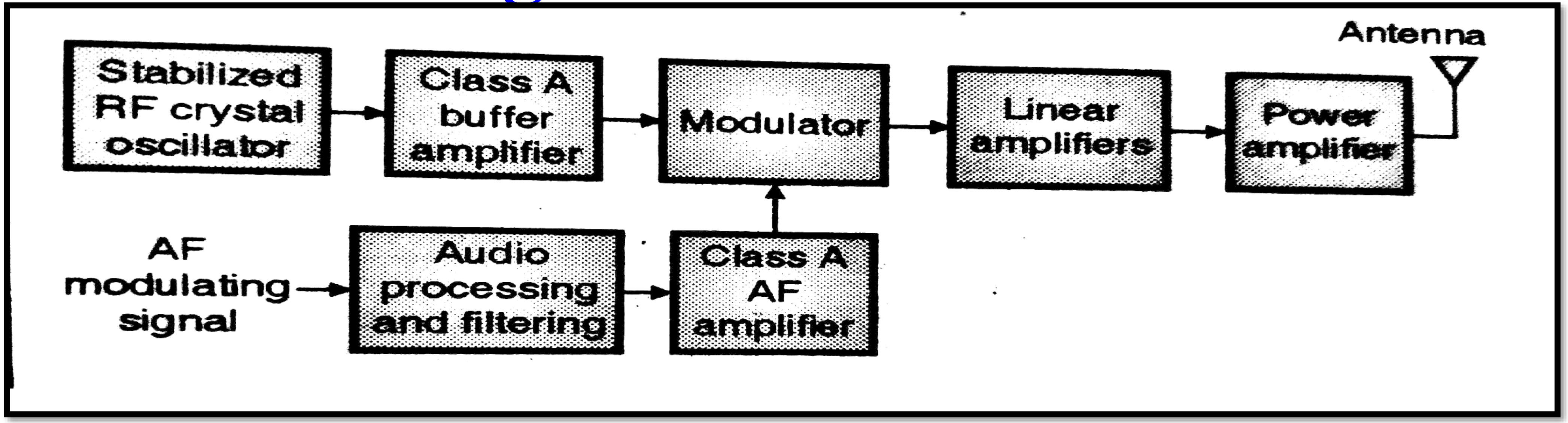
Parameter	AM	FM
Equation	$V = (V_c + V_m \sin \omega_m t) \times \sin \omega_c t$	$v = A \sin[\omega_c t + m_f \sin \omega_m t]$

Transmitted power	Depends on the modulation index. Carrier power is useless.	All the transmitted power remains constant and is useful. It is independent of m_f.
Modulated signal		
Area covered	Larger area is covered than FM because ground wave and sky wave propagation is used.	The radius of transmission is limited to line of sight because space wave propagation is used.
Complexity	AM equipments are less complex.	FM transmission and reception equipments are more complex.
Actual information	The information is contained in the amplitude variation of the carrier.	The information is contained in the frequency variation of the carrier.
Modulation Index	$m = \frac{E_c}{E_m}$	$m = \frac{\delta}{f_m}$
Number of sidebands	Only two.	Infinite and depends on m_f.
Bandwidth	$BW = 2f_m$ BW is much less than FM.	$BW = 2\ (\delta + f_{m\ (max)})$. BW is large. Hence, wide channel required.
Application	Radio and TV broadcasting.	Broadcasting FM, audio transmission in TV, Point to point communication.

Q. Draw & Explain Block Diagram of AM Transmitter

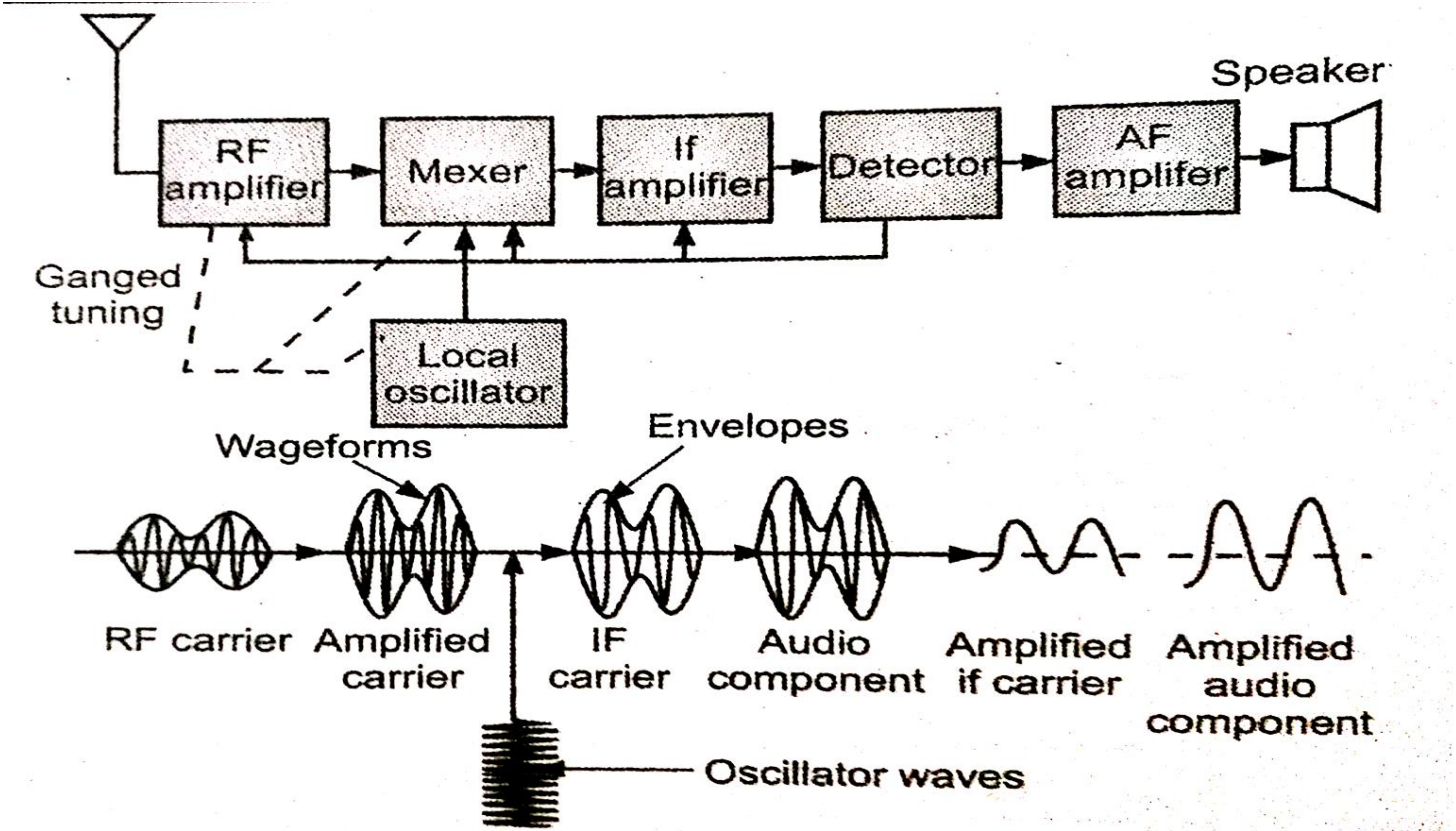


High Level AM Transmitter



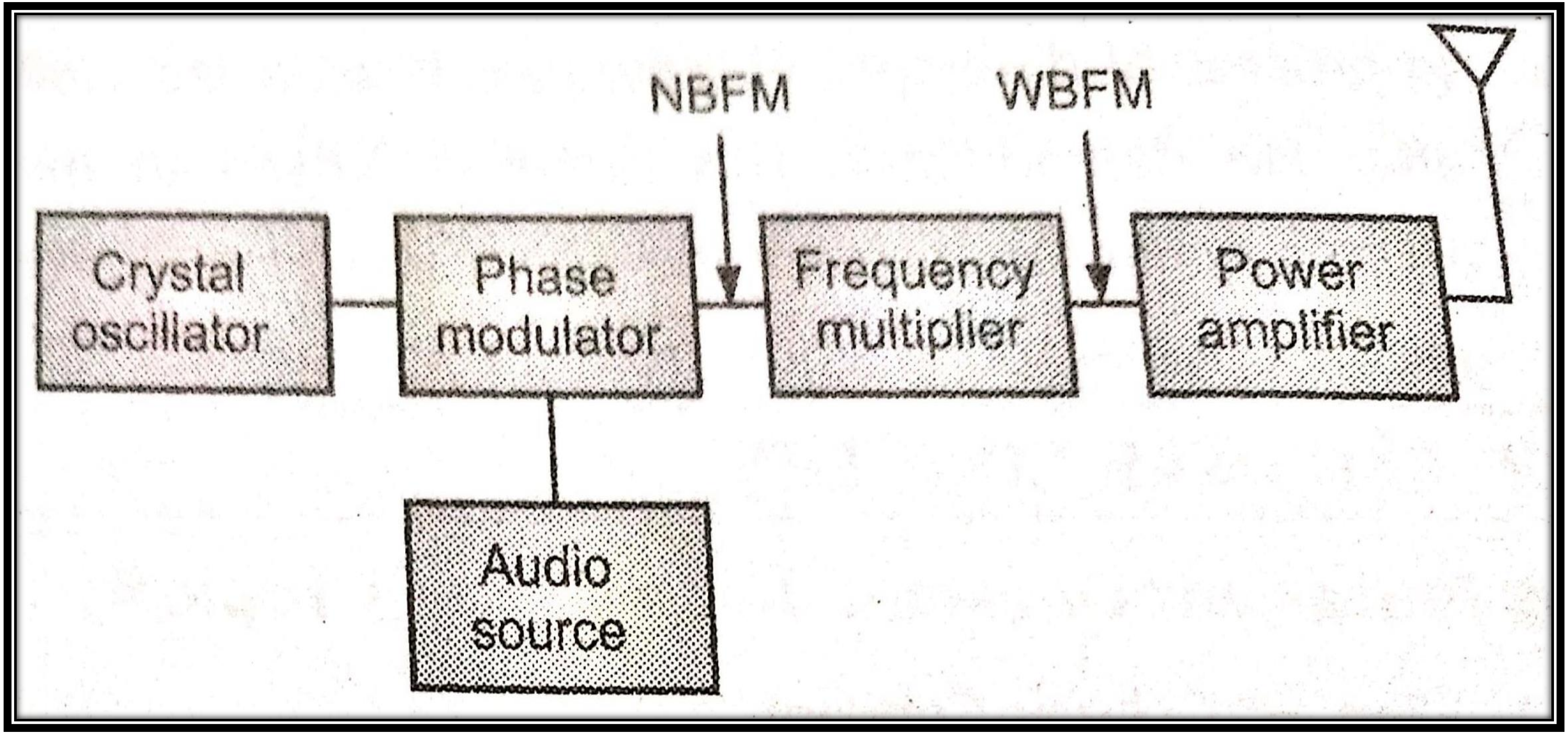
Low Level AM Transmitter

Q. Draw & Explain Block Diagram of AM Receiver


Speaker
RF amplifier
Mexer
If amplifier
Detector
AF amplifer
Ganged tuning
Local oscillator
Wageforms
Envelopes
RF carrier
Amplified carrier
IF carrier
Audio component
Amplified if carrier
Amplified audio component
Oscillator waves

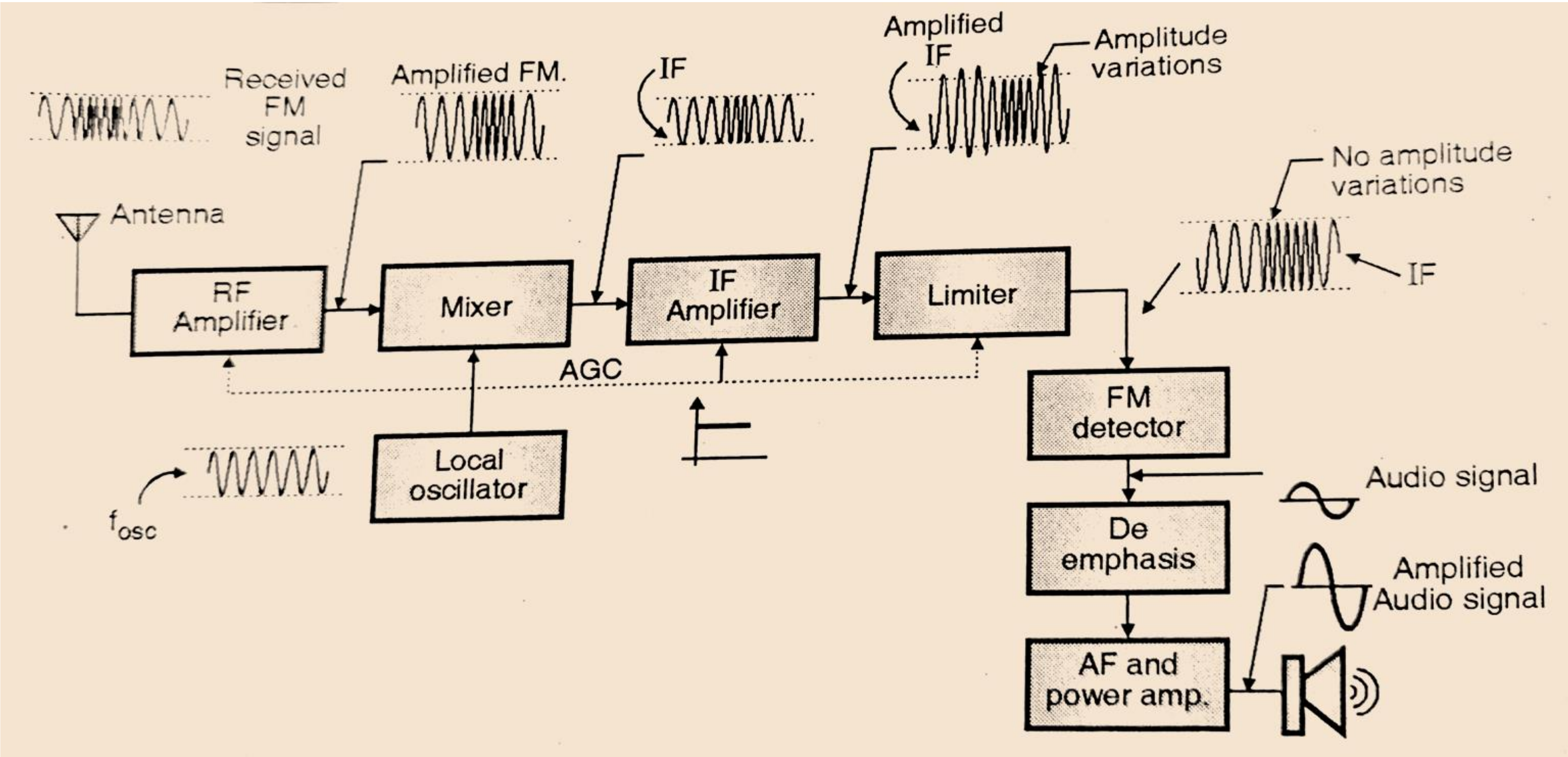
AM Receiver

Q. Draw & Explain Block Diagram of FM Transmitter



FM Transmitter

Q. Draw & Explain Block Diagram of FM Receiver


Received
FM
signal
Amplified FM.
IF
Amplified
IF
Amplitude
variations
No amplitude
variations
IF
Antenna
RF
Amplifier
Mixer
IF
Amplifier
Limiter
AGC
FM
detector
Local
oscillator
f_{osc}
Audio signal
De
emphasis
Amplified
Audio signal
AF and
power amp.

FM Receiver

Mobile Communication System

What is a Mobile?

- **A cellular phone is a portable telephone that does not use a wired connection. It connects to a wireless carrier network using radio waves.**

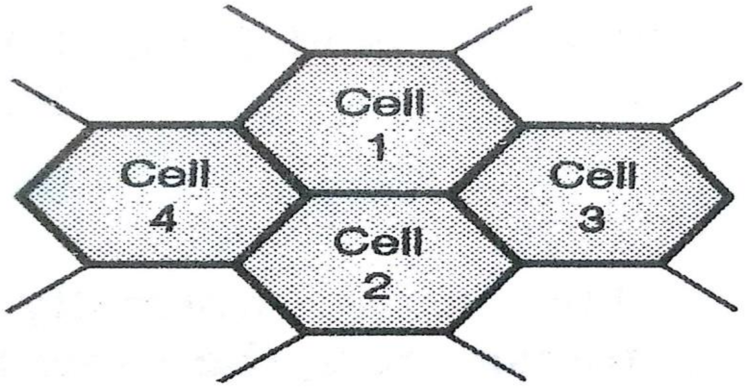
Mobile communication

CELL

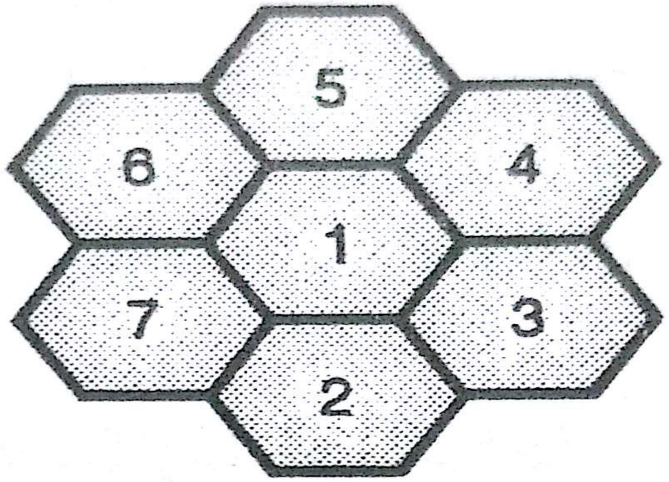
- Basic geographical unit of a cellular communication
- Base stations transmitting over small geographical area
- No fixed size/ may not be perfect hexagon

CLUSTER

- group of cells
- cluster of 7 cellS
- Base stations transmitting over small geographical area
- No fixed size/ may not be perfect hexagon
- 1G---- analog signal
- 2G----digital signal, SMS
- 3G----MMS,Internet
- 3.5G

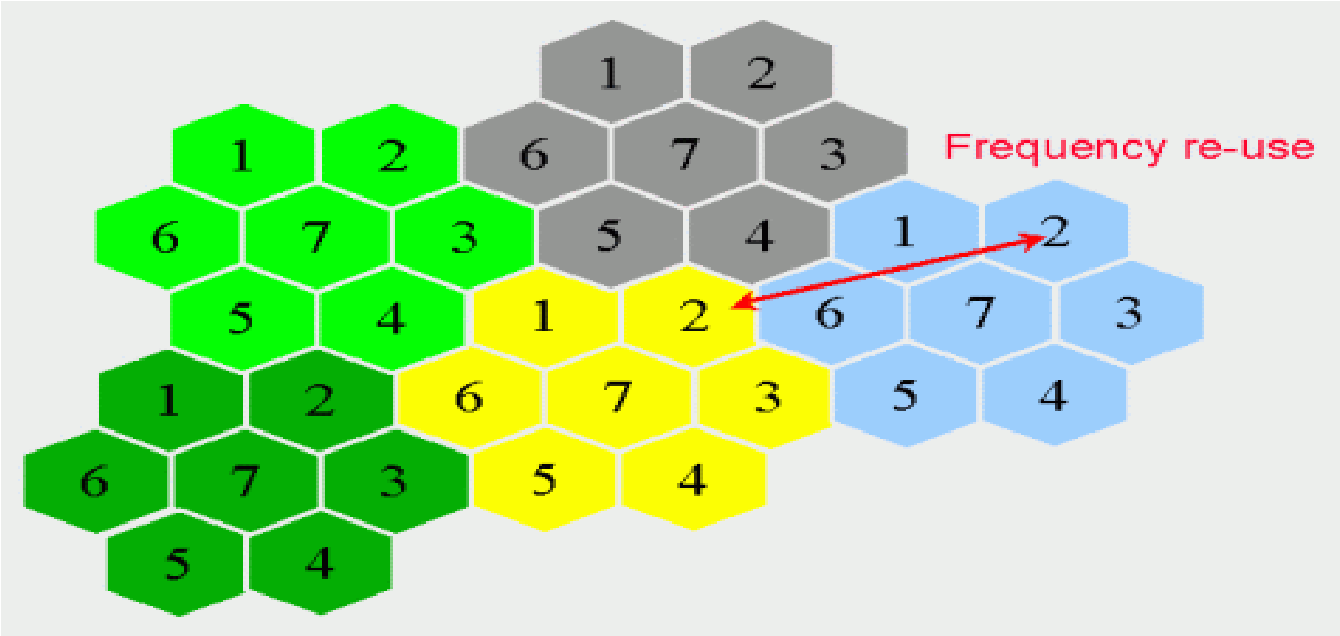


Cell

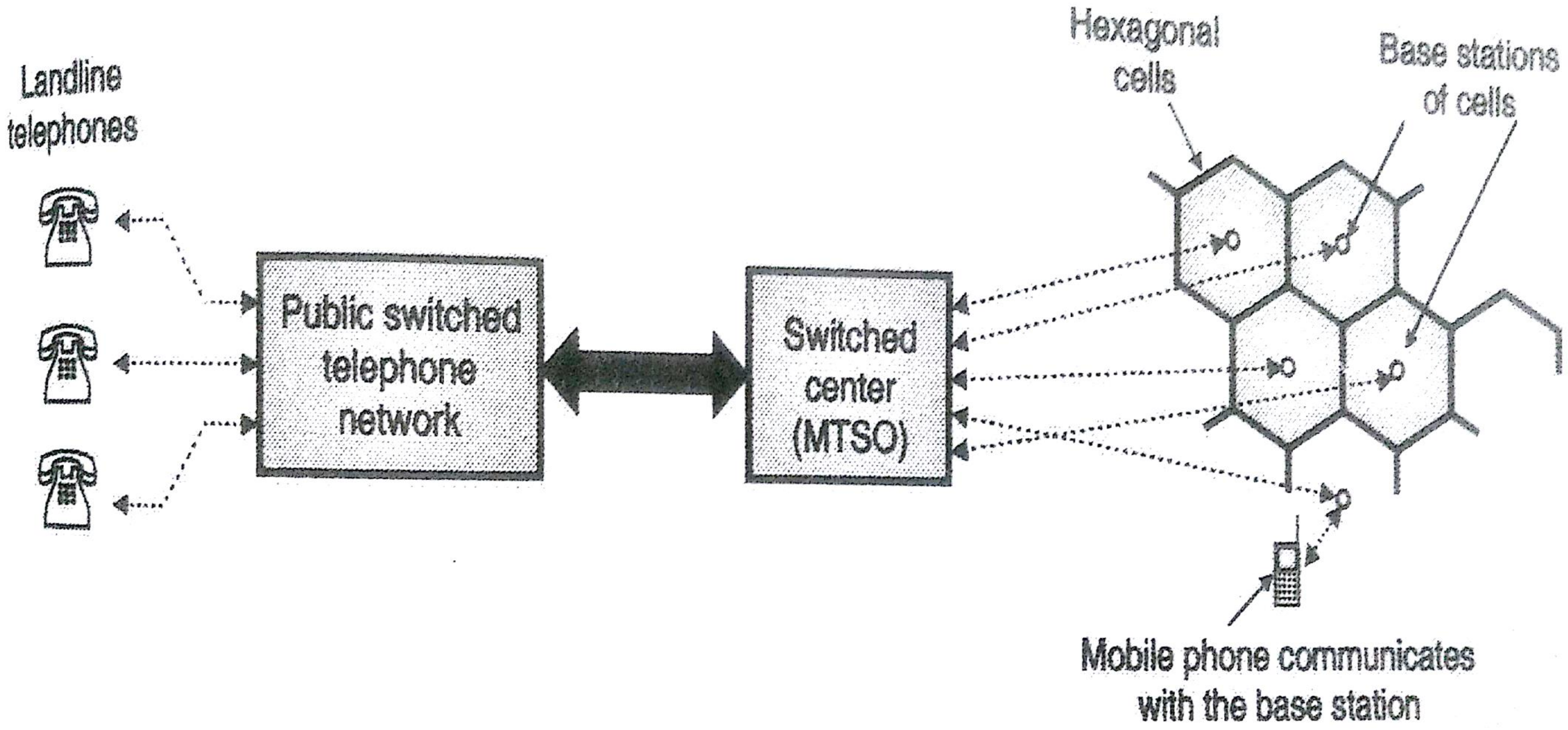


A seven Cell Cluster

Mobile communication



Basic structure of Mobile Phone System



Evolution of Cellular Networks

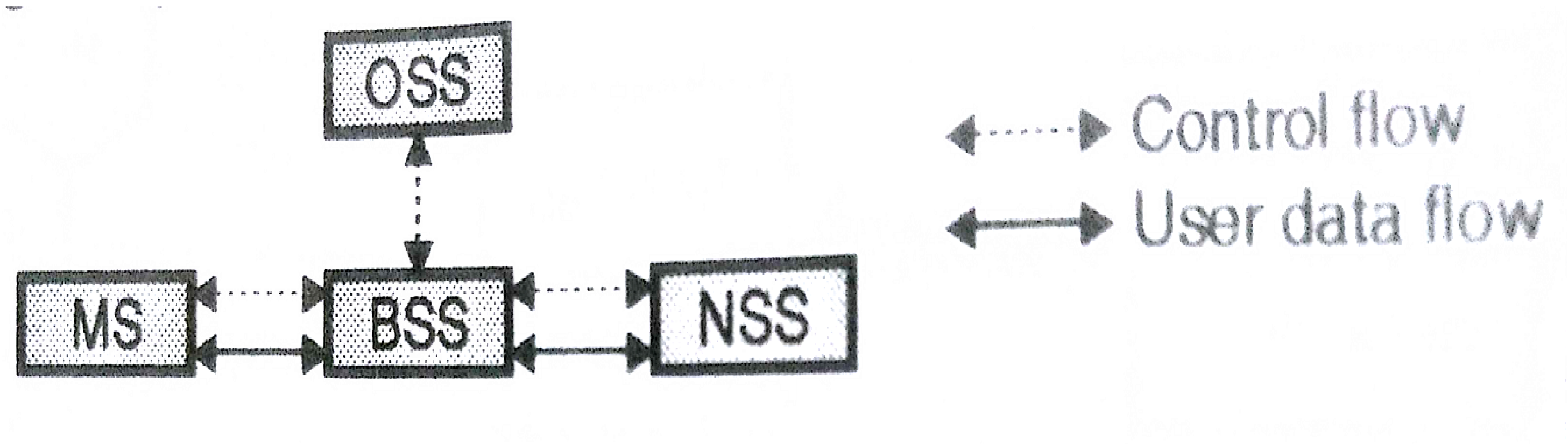
1G → 2G → 2.5G → 3G → 4G

Analog | Digital

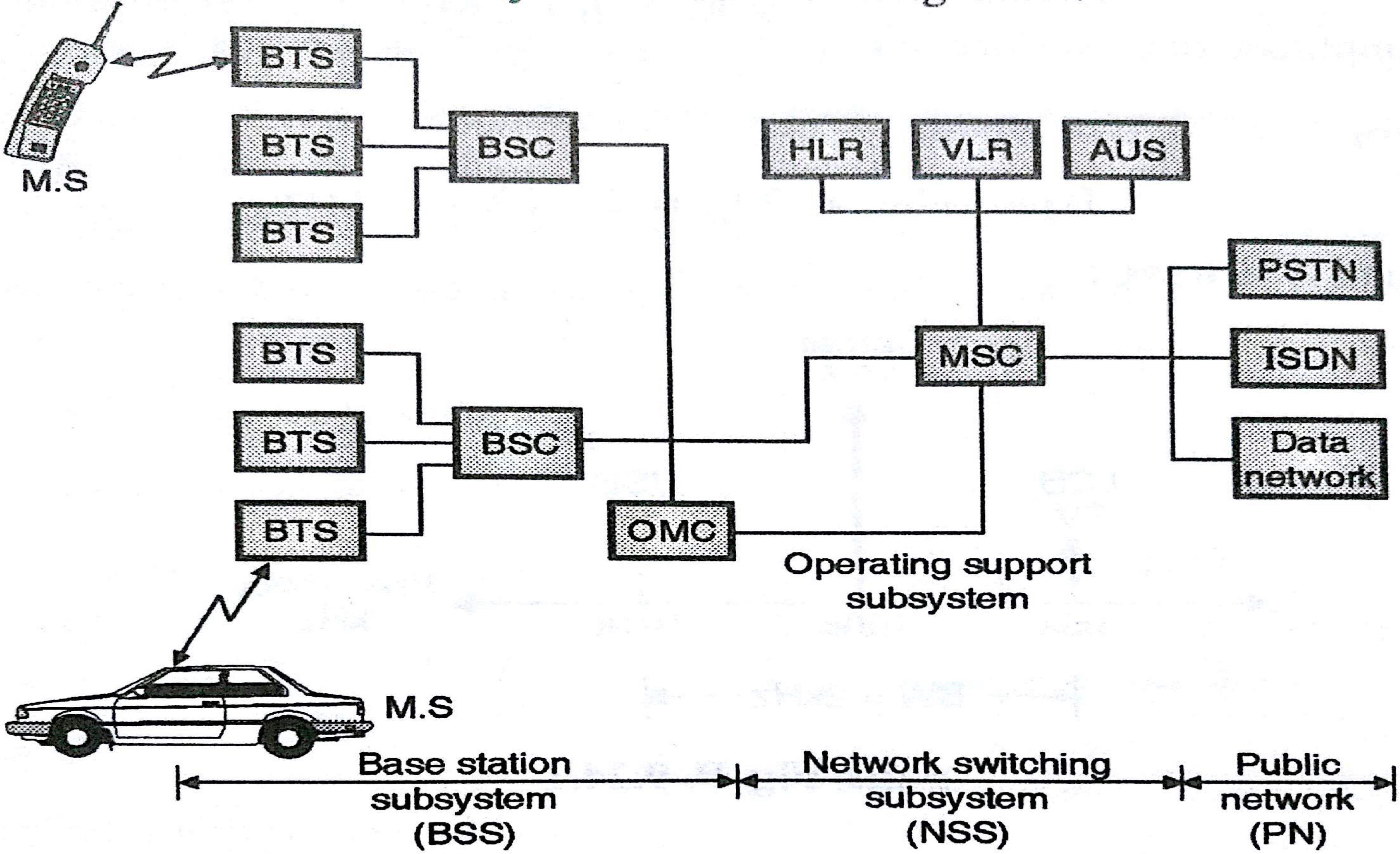
Circuit-switching | Packet-switching

Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2014/2015
Bandwidth	2kbps	14-64kbps	2mbps	200mbps	>1gbps
Technology	Analog cellular	Digital cellular	Broadbandwidth/ cdma/ip technology	Unified ip & seamless combo of LAN/WAN/WLAN/PAN	4G+WWWW
Service	Mobile telephony	Digital voice, short messaging	Integrated high quality audio, video & data	Dynamic information access, variable devices	Dynamic information access, variable devices with AI capabilities
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit/circuit for access network&air interface	Packet except for air interface	All packet	All packet
Core network	PSTN	PSTN	Packet network	Internet	Internet

GSM Architecture



MS- Mobile Station
OSS- Operating Subsystem
BSS- Base Station Subsystem
NSS- The Network and Switching Subsystem



GSM Detail Architecture

GSM System – Services

Services provided by GSM system:

- Teleservices
- Data Services
- Facsimile (FAX)
- Short Message Service (SMS) , Multimedia Message Service(MMS)

END OF BXE SYLLABUS

THANK YOU

BEST OF LUCK