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Optical & Mobile Communication

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CHAPTER 1

OVER VIEW OF FIBRE OPTIC COMMUNICATION

OBJECTIVES

1.1 State the advantages of Light wave communication system over EM wave systems.
1.2 Explain the structure of optical fibre
1.3 Classify optical fibres based on refractive index profile
1.4 List the types of fibres based on core diameter
1.5 Define Single mode(SMF) and Multimode fibre (MMF)
1.6 Define Snell's law in optics and Explain light wave propagation in OFC
1.7 Define acceptance angle and Cone of acceptance.
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1.9 Explain intrinsic and extrinsic losses
1.10 Classify different types of dispersions occur in optical fibres.
1.11 Explain the need for WDM in fibre optic communication
1.12 Draw and explain the block diagram of WDM system
1.13 Draw and explain the block diagram of DWDM

1.1. State the advantages of Light wave communication system over EM wave systems.

1. Low loss transmission
2. There is need of compact and least weight transmitters and receivers
3. The band width is more
4. Low cost transmission
5. Immunity to Electromagnetic interference
6. Security is high

1.2. Explain the structure of optical fibre

- Fiber optic cable is a combination of plastic and glass or glass or plastic which is capable of transmitting the images, voice, video and data in the form of **light**.
- An optical fiber consists of core, cladding and protecting cover (buffer). Core and cladding materials are made of glass or plastic and the protecting cover is made of steel or fiber glass or plastic.

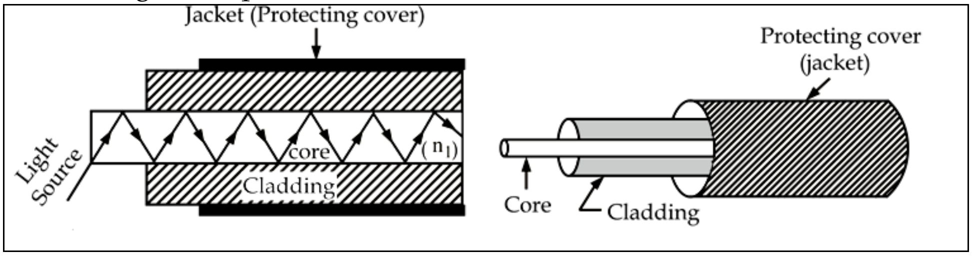


Fig. 1.2: Structure of Fiber optic cable

There are three essential types of optical fibers commonly used to all these varieties are constructed of either glass, plastic or a combination of glass and plastic.

1. Plastic core and plastic cladding
2. Glass core with plastic cladding
3. Glass core and glass cladding

- **Plastic fibers** : are more flexible and more rugged than **glass**, therefore plastic cables are easier to install, can better withstand stress, are less expensive and weight approximately 60% less than glass. Plastic fibers have higher attenuation characteristics do not propagate light as efficiently as glass. Therefore plastic fiber are used within a single building
- **Fibers with glass cores:** have less attenuation than plastic fibers. Glass core with plastic cladding is slightly better than glass core and glass cladding.
- **Glass core with plastic cladding fibers :** are also less effected by radiation and therefore more immunity to external interferences.

- The refractive index of core (n_1) is always greater than refractive index of cladding (n_2) i.e. $n_1 > n_2$.

Additional Information

Classification Of Optical Fibers

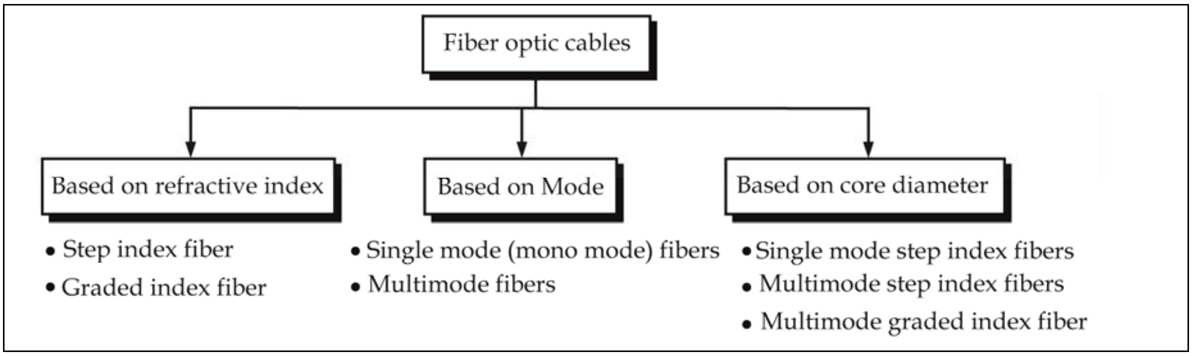
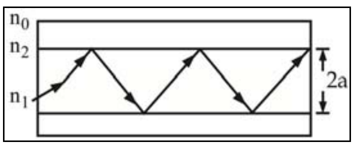
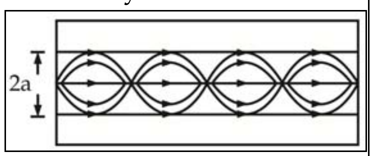


Fig. 1.2: Classification of fiber optical cables

1.3. Classify optical fibres based on refractive index profile

1. Step index fiber
2. Graded index fiber

- **Step Index Fiber:** The refractive index of core is uniform (constant), but the refractive index changes or step at the core and cladding interface. This is called **"Step index fiber"**.
- **Graded Index Fiber:** The refractive index of core is not constant but the refractive index of cladding is constant this is called **"graded index fiber"**.

S.No	Parameter	Step index fiber	Graded index fiber
1.	Data rate	Slow	Higher
2.	Coupling efficiency	Coupling efficiency with fiber is higher	Lower coupling efficiency
3.	Ray path	By the total internal reflection 	Light ray travels in oscillatory fashion 

4.	Index variation	$\Delta = \frac{n_1 - n_2}{n_1}$	$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2}$
5.	Numerical aperture	NA remains same	Changes continuously with distance from fiber axis.
6.	Material used	Normally plastic or glass is preferred	Only glass is preferred
7.	Bandwidth efficiency	10-20 MHz/Km	1 GHz/Km
8.	Pulse spreading	Pulse spreading by fiber length is more	Pulse spreading is less
9.	Attenuation of light	Less typically 0.34 dB/Km at 1.3μm	More 0.6 to 1 dB/Km at 1.3 μm
10.	Typical light source	LED	LED or Lasers
11.	Applications	Subscriber local network communication	Local and wide area networks.

1.4. List the types of fibres based on core diameter

Fibers are classified based on the core diameter is:

1. Single mode Step index fiber
2. Multi-mode Step index fiber
3. Multi-mode graded index fiber

1. Single mode Step index fibers:

- The refractive index of cladding (n_1) is slightly less than that of the core (n_2).
- A single mode step index fiber has a central core that is significantly smaller in diameter than only of the multimode fibers.
- The core diameter is 18μm-25 μm and cladding diameter is 125 μm.

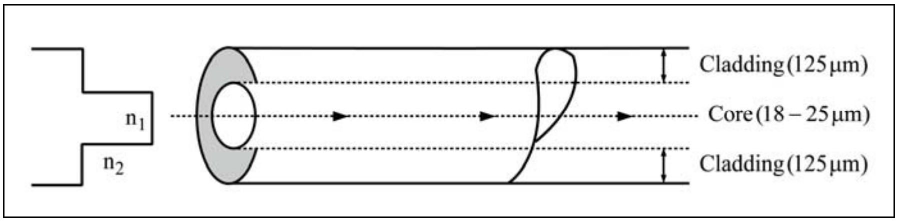


Fig. 1.4. (a): Single mode Step index fiber

Advantages:

- Maximum amount of information can be transmitted
- It is used for long distances
- No dispersions & small in size

Disadvantages:

- It is small in size, so it is difficult to make
- Very expensive
- Handling, splicing and making interconnections are also more difficult
- For proper operation, highly intensity light source must be used for long-distances

2. Multi-mode Step index fiber:

- These are similar to single mode step index fiber but the core diameter is much larger than single mode step index fiber.
- The core diameter is 50µm-200µm and cladding diameter is 125 µm - 400 µm.

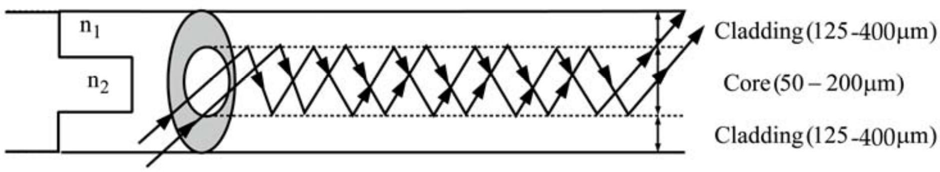


Fig. 1.4. (b): Multi-mode Step index fiber

Advantages:

- Easy to made
- Less Expensive
- Large core size
- Easy to coupled
- It can be used with both LED's & LASERS as sources.
- Coupling losses are less than single mode step index..

Disadvantages:

- It is suffered from modal dispersion
- It is used for lower data rates
- It is used for short distances

3. Multi-mode graded index fiber:

- In multimode graded index fiber , core has a non-uniform refractive index i.e, it is maximum at the center and decreases gradually towards the outer edge.
- The core diameter is 50µm-100µm and cladding diameter is 125 µm - 140µm.

- By using multimode graded index fiber, the modal dispersion is eliminated.

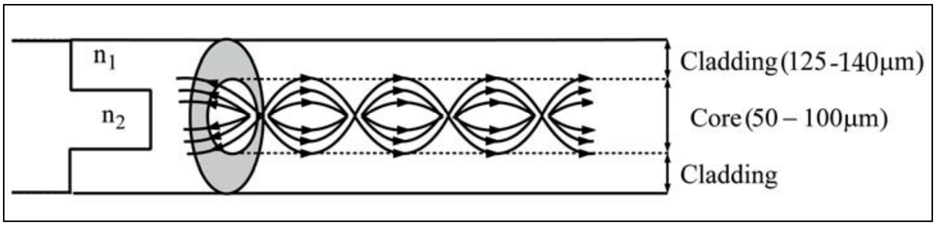


Fig. 1.4. (c): Multi-mode graded index fiber

Advantages:

- Less modal dispersion.
- Easy to splice and interconnect.
- It is cheaper.
- Less intense light sources may be used.
- It is good compromise between multimode & single mode.

Disadvantages:

- The model dispersion is not entirely eliminated.

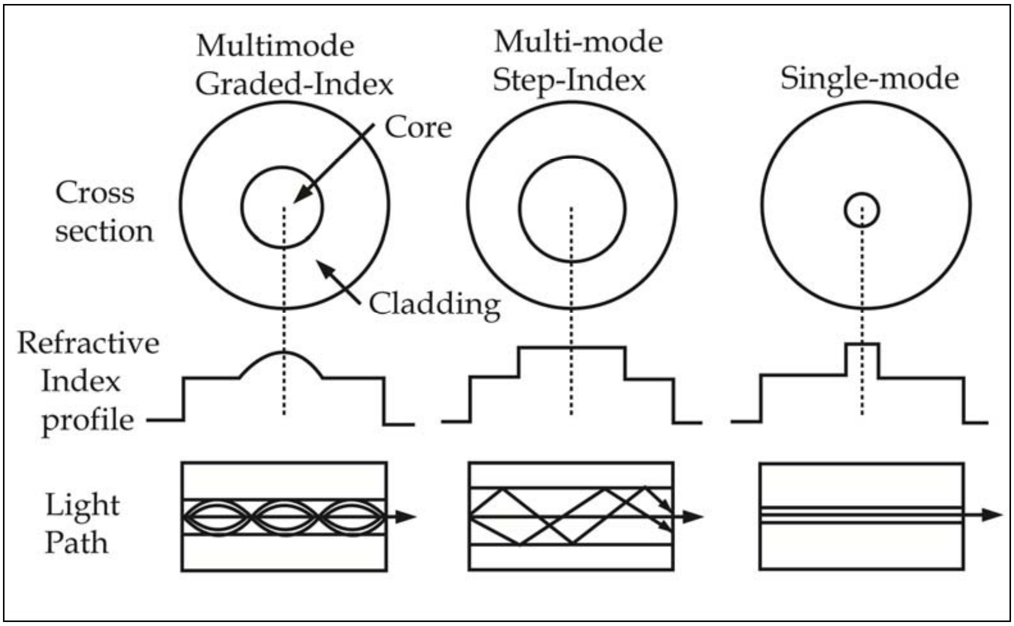


Fig 1.4. (d)

Additional Information

Refractive Index

- The amount of refraction or bending that occurs that interface of two materials of different densities is usually expressed as refractive index of two materials. Refractive index is also known as index of refraction and is denoted by n.
- Based on material density, the refractive index is expressed as the ratio of the velocity of light in free space to the velocity of light of the dielectric material (substance).

$$\text{Refractive index } n = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \frac{c}{v}$$

- The refractive index for vacuum and air is 1.0 for water it is 1.3 and for glass refractive index is 1.5.
- **Snell's law** states how light ray reacts when it meets the interface of two media having different indexes of refraction
- Let the two medias have refractive indexes n_1 and n_2 where $n_1 > n_2$.

  The refractive index is defined as the ratio of "velocity of light ray in free space to the velocity of light in a given material".

$$\text{Refractive index}(n) = \frac{\text{Velocity of light in free space}(c)}{\text{velocity of light in a given material}(v)}$$

Where n=Refractive index
C= velocity of light in free space
V= velocity of light in a given material

S.No	Medium	Refractive Index
1.	Air	1.0003
2.	Water	1.33
3.	Ethyl	1.36
4.	Alcohol	1.46
5.	Quartz	3.4
6.	Diamond	3.6

1.5. Define Single mode(SMF) and Multimode fibre (MMF)

- **Mode :** The path of light rays transmitted through the fiber optic cable is called "mode"
- There are two types of fibers based on modes. They are
  1. Single Mode Fibers (SMF) (or) Mono mode Fibers
  2. Multimode fibers (MMF)

1. **Single Mode Fibers (SMFs):** If there is only one path for light to travel in fiber optic cable is called "single mode fiber".

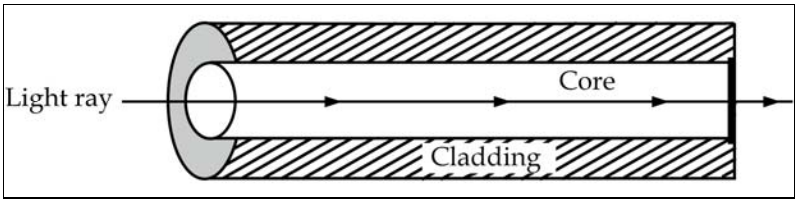


Fig. 1.5. (a): Single Mode Fiber (SMF)

2. **Multimode Fibers (MMFs):** If there is more than one path for light to travel in fiber optic cable is called "multimode fibers".

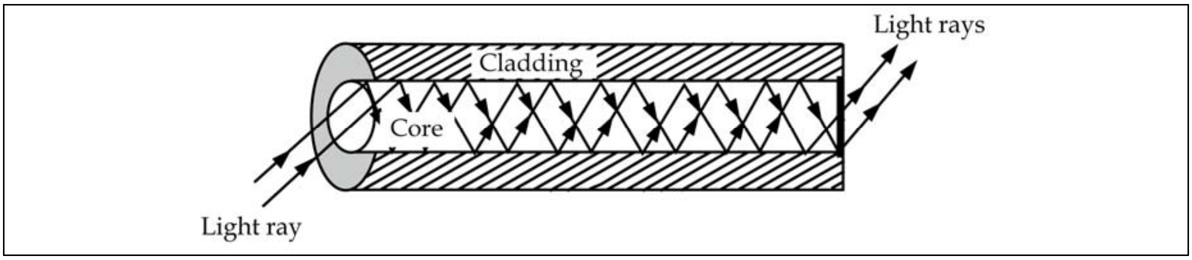


Fig 1.5. (b):Multimode fibers(MMF)

1.5.1. Advantages of SMFs over MMFs

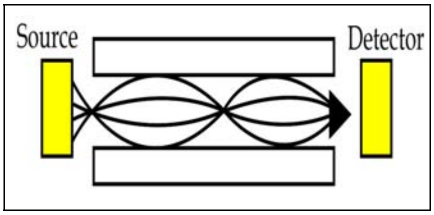
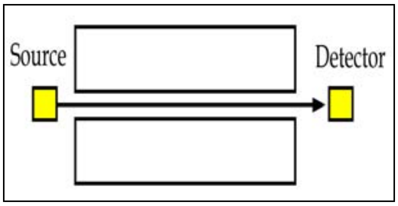
Advantages of SMFs over MMFs are:

- No dispersions
- Small size and light weight
- Higher band width (1000 MHz)
- Maximum amount of information can be transmitted (i.e high data rates)
- It is used for long distances

Disadvantages:

- Core size very small, it is difficult to make
- It is small in size, so it is difficult to make
- Very expensive
- Handling, splicing and making interconnections are also more difficult
- highly intensity light source(LASER) must be used for long-distances

1.5.2. Comparison between multimode and single mode fibers

Multimode Fiber	**Single-mode Fiber**
 1. Low cost sources • 850 nm and 1310 nm LEDs • 850 nm lasers at 1 & 10 Gb/s 2. Low precision packaging 3. Low cost connectors 4. Lower installation cost 5. High fiber cost 6. Lower system cost 7. Higher loss, lower bandwidth 8. Distance up to 2 Km 9. Best for: • LAN, Data Center, Central Office	 1. High cost sources • 1310+nm lasers 1 and 10 Gb/s • 1 Gb/s + w/DWDM 2. High precision packaging 3. Higher cost connectors 4. Higher installation cost 5. Lower fiber cost 6. Higher system cost 7. Lower loss, higher bandwidth 8. Distance 48 to 60 Km 9. Best for: • WAN, MAN, Campus

1.6. Define Snell's law in optics and Explain light wave propagation in OFC

1.6.1 Snell's Law In Optics

- In the field of optics in the light ray is travel from higher refractive index medium into lower refractive index medium then the light ray bends away from the normal. This is known as **Refraction**.
- θ_1 and θ_2 be the angles of incidence and angle of refraction respectively. Then according to Snell's law, a relationship exists between the refractive index of both materials given by,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} \textbf{ (or) } \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$$

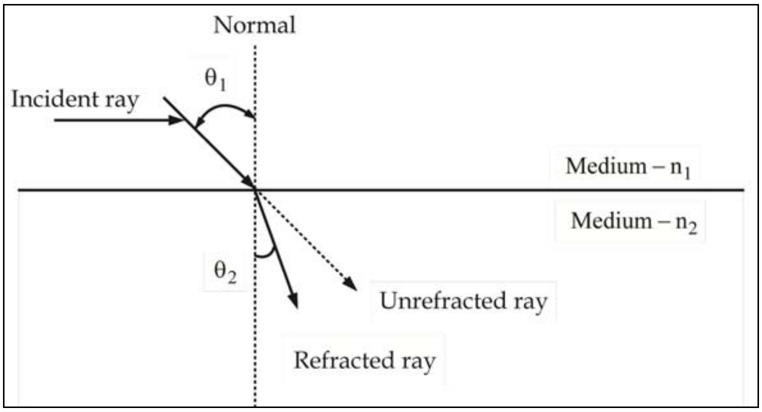


Fig. 1.6. Refractive model for Snell's law

1.6.2. Critical angle

- When the angle of incidence (ϕ_1) is progressively increased, there will be progressive increase of refractive angle (ϕ_2). At some condition (ϕ_1) the refractive angle (ϕ_2) become 90^0 to the normal. When this happens their refracted light ray travels along the interface. The angle of incidence (ϕ_1) at the point at which the refractive angle (ϕ_2) become 90^0 is called the critical angle. It is denoted by ϕ_c.

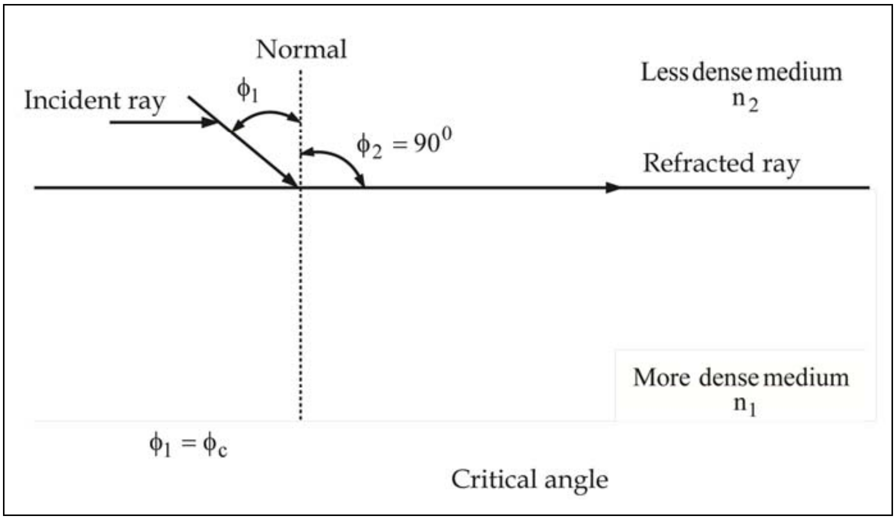


Fig. 1.6. 11 Critical angle

- The critical angle is defined as the minimum angle of incidence (ϕ_1) at which the ray strikes the interface of two media and causes an angle of refraction (ϕ_2) equal to 90^0.

  Fig. 1.6. shows critical angle refraction.

  Hence at critical angle $\phi_1 = \phi_c$ and $\phi_2 = 90^0$

Using snell's law : $n_1 \sin\phi_1 = n_2 \sin\phi_2$

$$\sin\phi_c = \frac{n_2}{n_1}\sin 90^0$$

$\because$ $\sin 90^0 = 1$

Therefore, $\sin\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

Critical angle $\boxed{\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$

1.6.3. Total internal reflection used in optical fibers

- When the angle of incidence of light ray is greater than the critical angle, (i.e $\theta_1 > \theta_c$), then the light ray totally reflects back in same medium. This phenomenon is known as "Total Internal Reflection".
- Fiber optic communication works on the principle of total internal reflection.
- In the field of optics in the light ray is travel from higher refractive index medium into lower refractive index medium then the light ray bends away from the normal. This is known as Refraction.
- According to Snell's law. The amount of refraction at the interface between two mediums is given by

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where n_1 = refractive index of core

n_2 = refractive index of core

θ_1 = incident angle

θ_2 = refractive angle

$$\sin\theta_1 = \frac{n_2}{n_1}\sin\theta_2$$

At $\theta_2 = 90^0$

$$\sin\theta_1 = \left(\frac{n_2}{n_1}\right)$$

if $\theta_1 = \theta_c$ (critical angle)

$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

- If the angle of incident (θ_1) of the light ray is equal to critical angle (θ_c) then the refracted light ray travels along the interface of the medium .

- When the angle of incidence of light ray is greater than the critical angle, (i.e $\theta_1 > \theta_c$) , then the light ray totally reflects back in same medium. This phenomenon is known as **"Total Internal Reflection".**

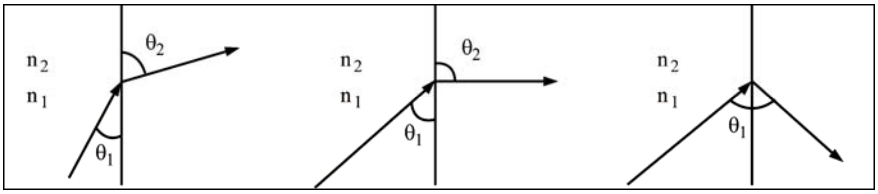


Fig. 1.6. Total internal reflection phenomenon

- In order to have total internal reflection in the following conditions are satisfied.

1. $\theta_1 > \theta_c$

$n_1 > n_2$

1.7. Define acceptance angle and Cone of acceptance.

1.7.1. Acceptance angle

- The maximum angle in which the light ray may incident on fiber to propagate down the fiber is called acceptance angle.
- Applying Snell's law to the external incidence angle

$$n_0 \sin\theta_0 = n_1 \sin\theta_1$$

- The maximum value of external incidence angle for which light will propagate in the fiber.

$$\theta_{0(max)} = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]$$

- When the light rays enters the fibers from an air medium $n_0 = 1$. Then above equation reduces to,

$$\theta_{0(max)} = \sin^{-1}\left[\sqrt{n_1^2 - n_2^2}\right]$$

- The angle θ_0 is called as acceptance angle and $\theta_{0(max)}$ defines the maximum angle in which the light ray may incident on fiber to propagate down the fiber.

1.7.2. Cone of Acceptance

- The maximum angle in which the external light rays accepted into core and is able to travel in the fiber is called cone of acceptance

(OR)

- The cone of acceptance is the within with the light is accepted into the core and is able to travel along the fiber.

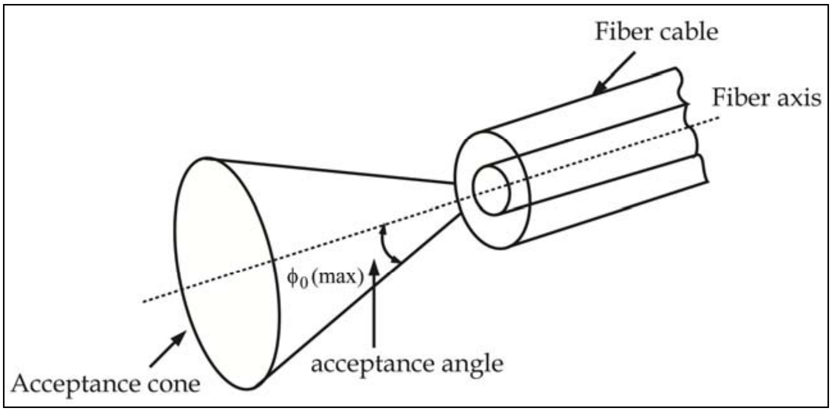


Fig. 1.7. Acceptance cone of a fiber cable

1.8. Define numerical aperture (NA)

The light gathering or light collecting capability of an optical fiber is called Numerical Aperture (NA). It is also called as figure of merit.

$$\boxed{NA = \sqrt{n_1^2 - n_2^2}}$$

Where n_1 = refractive index of fiber core.

n_2 = refractive index of the cladding

$$\boxed{NA = \sqrt{{n_{core}}^2 - {n_{cladding}}^2}}$$

1.8.1. Expression for NA in terms of core and cladding refractive indices:

- Applying Snell's law to the external incidence angle

$$n_0 \sin\theta_0 = n_1 \sin\theta_1 \qquad \ldots(1)$$

But $\theta_1 = (90 - \theta_c)$

$$\sin\theta_1 = \sin(90^0 - \theta_c) = \cos\theta_c$$

- Substituting $\sin\theta_1$ in equation (1)

$$n_0 \sin\theta_0 = n_1 \cos\theta$$

$$\sin\theta_0 = \frac{n_1}{n_0}\cos\theta_c$$

- Applying Pythagorean Theorem to ΔPQR

$$\cos\theta_c = \frac{\sqrt{{n_1}^2 - {n_2}^2}}{n_1}$$

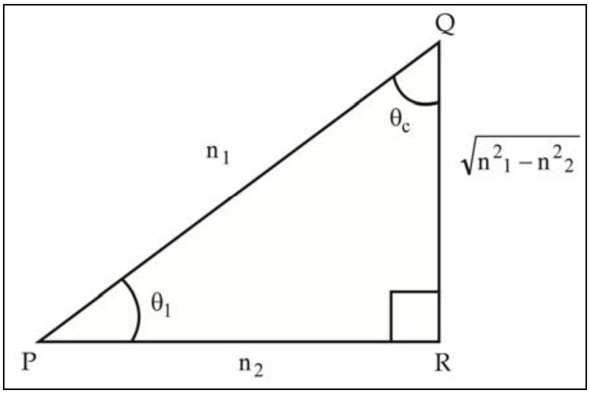


Fig 1.8

$$\sin\theta_0 = \frac{n_1}{n_0}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_1}\right]$$

$$\sin\theta_0 = \left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]$$

$$\theta_0 = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]$$

- The maximum value of external incidence angle for which light will propagate in the fiber.

$$\theta_{0(\max)} = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]$$

- When the light rays enters the fibers from an air medium $n_0 = 1$. Then above equation reduces to,

$$\theta_{0(\max)} = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)$$

- The angle θ_{01} is called as acceptance angle and $\theta_{0(\max)}$ defines the maximum angle in which the light ray may incident on fiber to propagate down the fiber.
- The cone of acceptance angle is defines the numerical aperture

$$\sin\theta_{0\max} = NA$$

$$\sin\theta_{0\max} = \sqrt{n_1^2 - n_2^2}$$

$$NA = \sqrt{n_1^2 - n_2^2}$$

NOTE:

Hence acceptance angle $= \sinh^{-1} NA$. By the formula of NA note that the numerical aperture is effectively dependent only on refractive indices of core and cladding material. NA is not function of fiber dimension.

- The index difference (Δ) and the numerical aperture (NA) are related to the core and cladding indicates:

$$\Delta = \frac{(n_1 - n_2)}{n_1}$$

$$\boxed{\Delta = \frac{NA^2}{2n^2_1}}$$

Also $$NA = \sqrt{n_1^2 - n_2^2}$$

` $$NA = (n_1^2 - n_2^2)^{1/2}$$

$$\boxed{NA = n_1 (2\Delta)^{1/2}}$$

Example: Calculate the numerical aperture and acceptance angle for a fiber cable of which $n_{core} = 1.5$ and $n_{cladding} = 1.48$. The launching takes place from air

Solution:

$$\boxed{NA = \sqrt{n_{core}^2 - n_{cladding}^2}}$$

$$NA = \sqrt{1.5^2 - 1.48^2}$$

$$NA = 0.244$$

$$\boxed{\text{Acceptance angle} = \sin^{-1}\sqrt{n_{core}^2 - n_{cladding}^2} = \sin^{-1} NA}$$

Additional Information

The various losses in the optical fiber cables are

1. Absorption losses
2. Material or Rayleigh scattering losses
3. Dispersion (distortion)
4. Radiation losses
5. Coupling losses

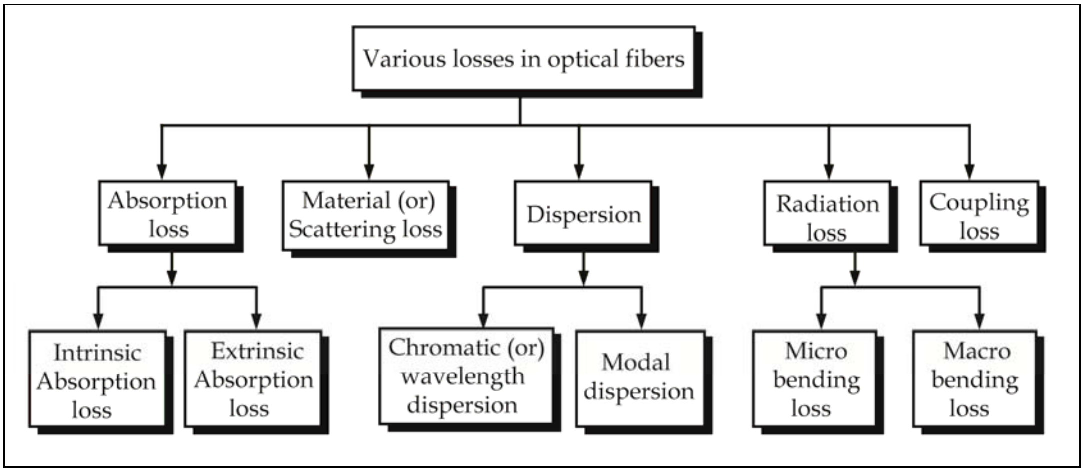


Fig 1.8. Various losses in optical fibers

1. **Absorption Loss:** Absorption loss in a optical fibers are similar to the power dissipation in copper cables. It is caused by the fiber itself or by impurities in the fiber. The Impurities in the fibers absorbs the light and convert it to heat.

   The ultra pure glass used to manufacture optical fibers are approximately 99.9999% pure the remaining 1% is absorption loss.

   Two types of absorption exist:

   a. **Intrinsic Absorption:** Intrinsic absorption loss is caused by the interaction of photons with the glass itself.

   b. **Extrinsic Absorption:** It is caused by impurities within the glass.

   Extrinsic absorption is caused by impurities introduced into the fiber material. Metal impurities, such as iron, nickel, and chromium, are introduced into the fiber during fabrication. There are three factors that contribute to the absorption losses in optical fibers

   1. Ultraviolet absorption
   2. Infrared absorption
   3. Ion resonance absorption

2. **Material (or) Rayleigh Scattering Loss:** Scattering loss is associated with the fiber material and structural imperfections (i.e., microscopic irregularities during the manufacture process). The light rays are diffracted when they are travel in the fiber strike the one of the impurities. Diffraction causes the light to disperse or spread out in many directions. Some of the diffracted light continuous down the fiber and some of it escapes through the cladding. The light that escapes into the cladding is represented as a loss, that loss is called scattering loss. Rayleigh scattering in the glass is the same phenomenon that scatters light from the sun in the atmosphere.

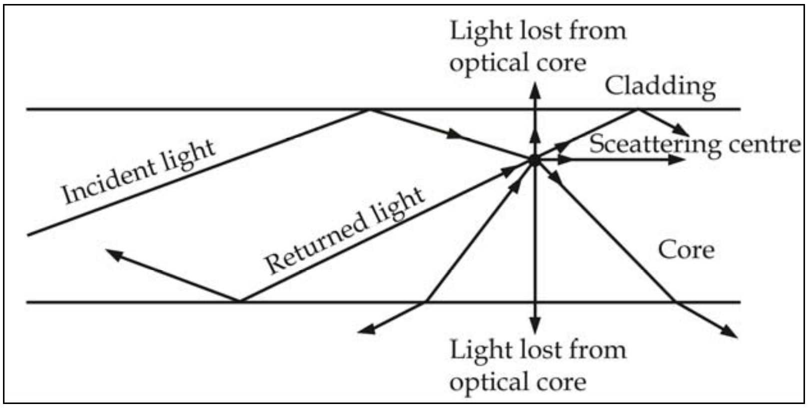


Fig 1.8. (a): Representation of scattering loss

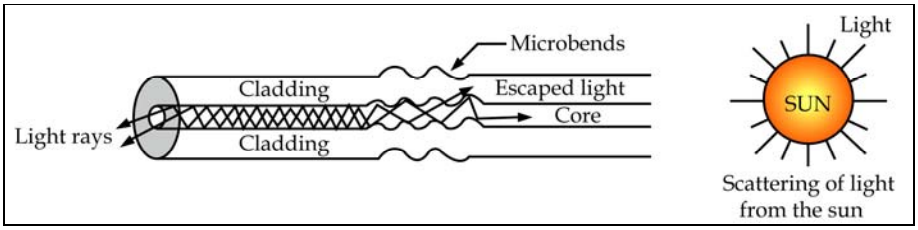


Fig 1.8. (b)

1. **Dispersion:** spreads the light pulse or change the shape of the light pulse as it travels along the fiber is called as dispersion.

➢ The input light pulse is applied to fiber optic cable, which is travel in the fiber optic cable and the shape of light pulse is changed when it is coming out from the fiber optic cable is known as Dispersion.

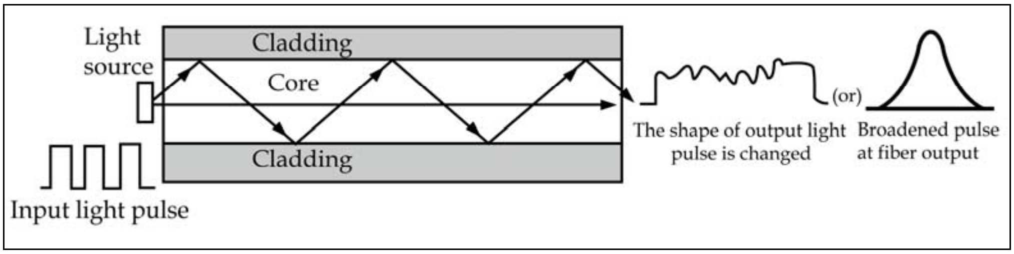


Fig 1.8. (c): Concept of dispersion

➢ In an optical fiber we find two types of dispersions: They are

a. Chromatic (or) Wavelength Dispersion
b. Modal Dispersion

- **Chromatic (or)Wavelength Dispersion**: This type of dispersion is caused by Each wavelength within the composite light signal travels at different velocity when are propagating through the fiber optic cable

- **Modal Dispersion:** It is caused by difference in propagation line of light rays that takes at different paths in a fiber.

2. **Radiation Loss:** Radiation losses are caused by bends in the fibers. There are two types of Radiation losses. They are
   a. Micro-bending losses
   b. Macro-bending losses

a) Micro-bending Loss : During the manufacture process of the fiber, microscopic irregularities are formed, when light propagate through this fiber, the light rays are spread in many directions causes the loss of the light.

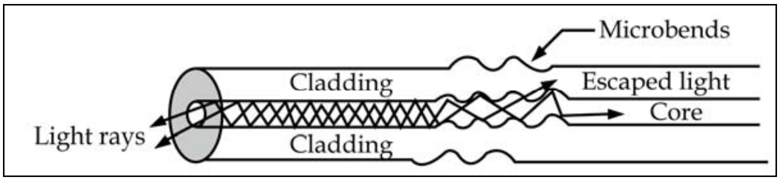


Fig 1.8. (d): Micro-bending loss

b) Macro-bending Loss : This loss is due to the bending of the fiber cable at corners. This loss is caused by light escaping into the cladding.

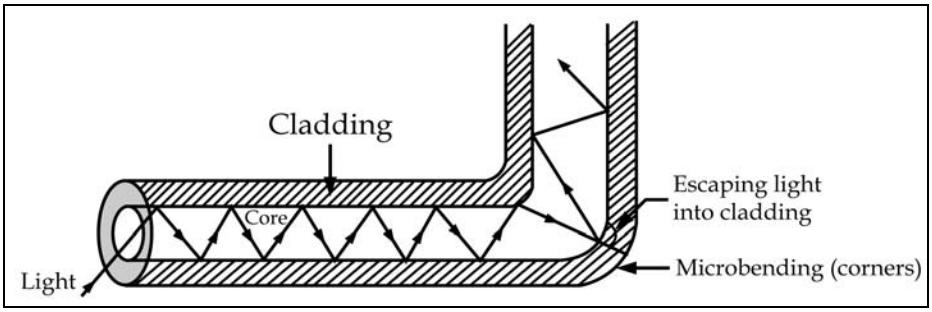


Fig 1.8. (e): Macro-bending loss

3. **Coupling Loss:** Coupling losses can occur in fibers due to optical junction such as light source to fiber connection, fiber to fiber connection and fiber to photo detector connections. These losses are caused by
   1. Lateral misalignment
   2. Gap misalignment
   3. Angular misalignment
   4. Imperfect surface finishes

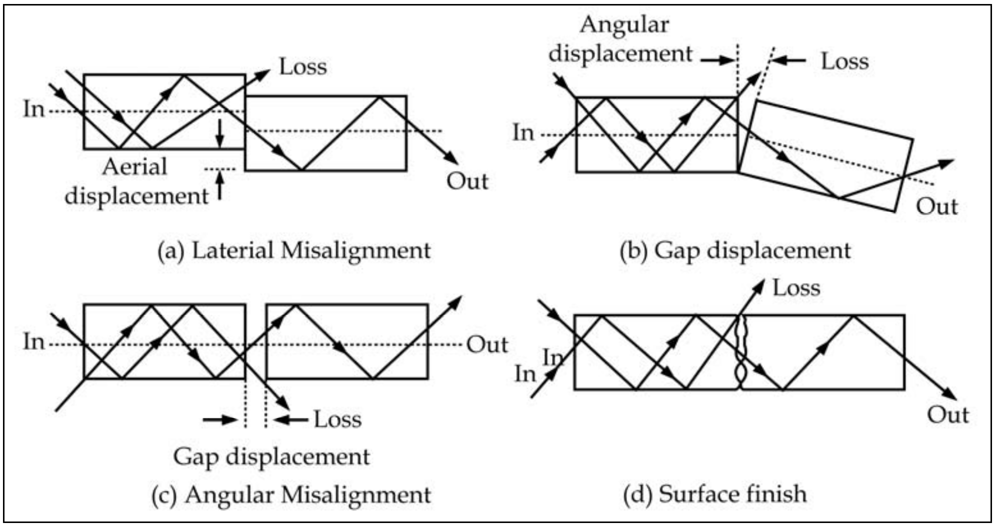


Fig. 1.8. (f): Different types of coupling loss

1.9. Explain intrinsic and extrinsic losses

Transmission of light via total internal reflection and it has no optical power loss takes place at the core-cladding interface. However, light is lost as it travels through the material of the optical core. This loss of transmitted power, commonly called attenuation or in section loss, occurs for the following reasons.

- Intrinsic fiber core loss
- Material absorption
- Material scatting
- Extrinsic fiber loss
- Microbending
- Macrobending

The term intrinsic and extrinsic relate to the manner in which the loss mechanisms operate. Intrinsic loss mechanisms are those occurring within the core material itself whereas extrinsic attenuation occurs due to non-ideal modifications of the core-cladding interface.

1.9.1. Intrinsic Loss In Optical Fiber

There are two methods by which transmitted power is attenuated within the core material of an optical fibers

1. Absorption
2. Scattering

1. **Absorption Loss:** Absorption loss in a optical fibers are similar to the power dissipation in copper cables. It is caused by the fiber itself or by impurities in the fiber. The Impurities in the fibers absorbs the light and convert it to heat.

   The ultra pure glass used to manufacture optical fibers are approximately 99.9999% pure the remaining 1% is absorption loss. Two types of absorption exist:

   (a) Intrinsic Absorption: Intrinsic absorption loss is caused by the interaction of photons with the glass itself.

   (b) Extrinsic Absorption: It is caused by impurities within the glass. Extrinsic absorption is caused by impurities introduced into the fiber material. Metal impurities, such as iron, nickel, and chromium, are introduced into the fiber during fabrication.

2. **Scattering Loss or Material:** Scattering loss is associated with the fiber material and structural imperfections i.e., microscopic irregularities during the manufacture process. The light rays are diffracted when they are travel in the fiber strike the one of the impurities causes the light to disperse or spread out in many directions. Some of the diffracted light continuous down the fiber core and some of it escapes through the cladding. The light that escapes into the cladding is represented as a loss, that loss is called scattering loss.

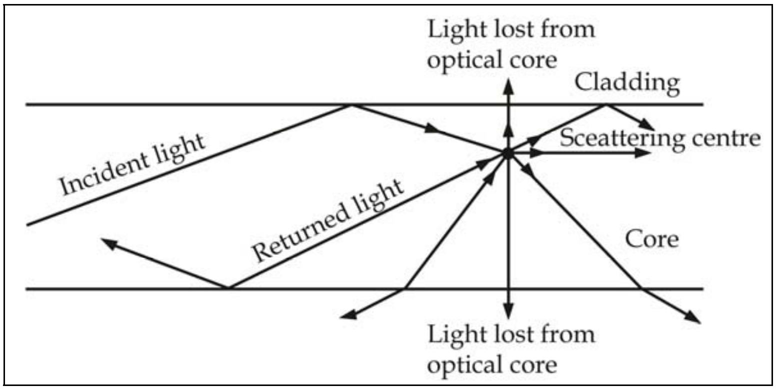


Fig 1.9. Scattering loss

1.9.2. Extrinsic Loss In Optical Fiber

Extrinsic loss (extrinsic attenuation) in optical fibers can be caused by two external mechanisms: macro-bending or micro-bending. Both cause a reduction of optical power. Light energy gets radiated at the bends on their path through the fiber and eventually is lost. This is the mechanism known as fiber bend losses.

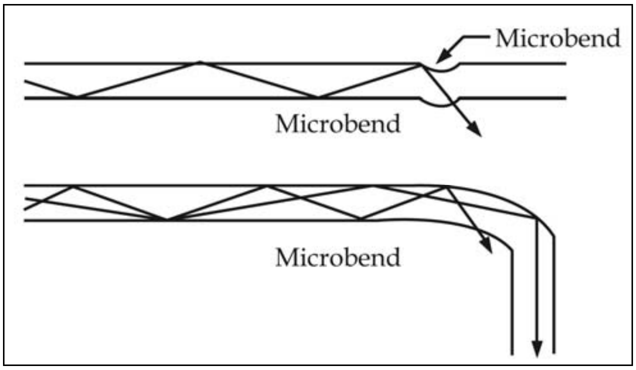


Fig 1.9. (a): Extrinsic loss in optical fiber

because of macro-bending or micro-bending

There are two types bending causing bending loss namely:

1. Micro bending loss
2. Macro bending loss

1. **Micro-bending Loss:** Micro-bending is caused by imperfections in the cylindrical geometry of fiber during the manufacturing process. During the manufacture process of the fiber, microscopic irregularities are formed, when light propagate through this fiber, the light rays are spread in many directions causes the loss of the light.

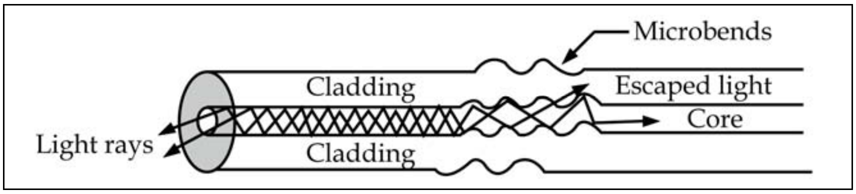


Fig 1.9. (b): Micro-bending loss

2. **Macro-bending Loss:** This loss is due to the bending of the fiber cable at corners. This loss is caused by light escaping into the cladding. To prevent macro-bends, all optical fiber has a minimum bend radius specification that should not be exceeded.

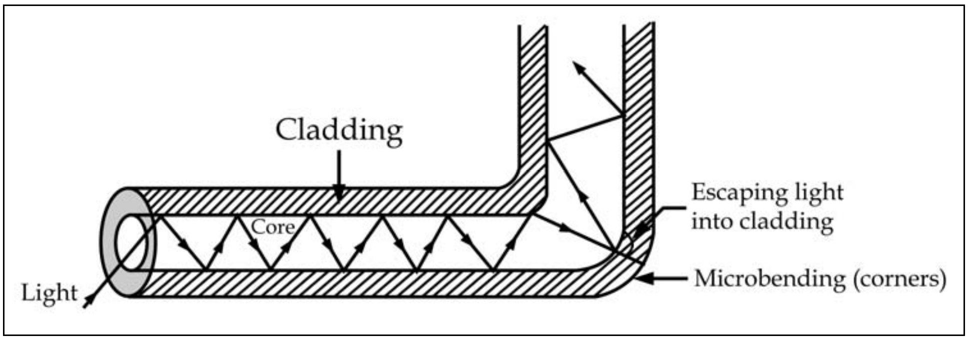


Fig 1.9. (c): Macro-bending loss

1.10. Classify different types of dispersions occur in optical fibres.

The input light pulse is applied to fiber optic cable, which is travel in the fiber optic cable and the shape of light pulse is changed or spreads when it is coming out from the fiber optic cable is known as Dispersion.

- The change in the shape of light pulses as they travel in the fiber optic cable is called "dispersion"..

(OR)

- The light pulses are spread as they travel in the fiber optic cable is called "dispersion".

(OR)

- Spreads the light pulse or change the shape of the light pulse as it travels along the fiber is called as dispersion

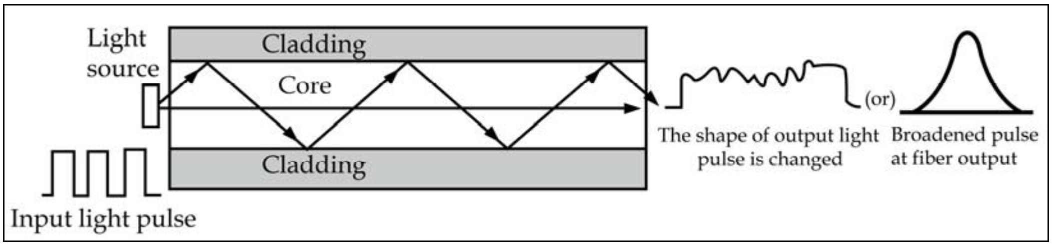


Fig 1.10. Concept of dispersion

- Dispersion limits the maximum possible bandwidth, which translate into lower data rates within a fiber. Pulse broadening is a very common problem created by dispersion in digital transmission. To avoid it, the digital bit rate must be less than the reciprocal of the broadened pulse duration.

Classification of different types of dispersions occur in optical fibres:

1. Intra-modal dispersion (or) Chromatic dispersion (or) Wavelength dispersion
    - Material dispersion
    - Waveguide dispersion
2. Inter-Modal dispersion (or) Modal dispersion
    - Polarization mode dispersion

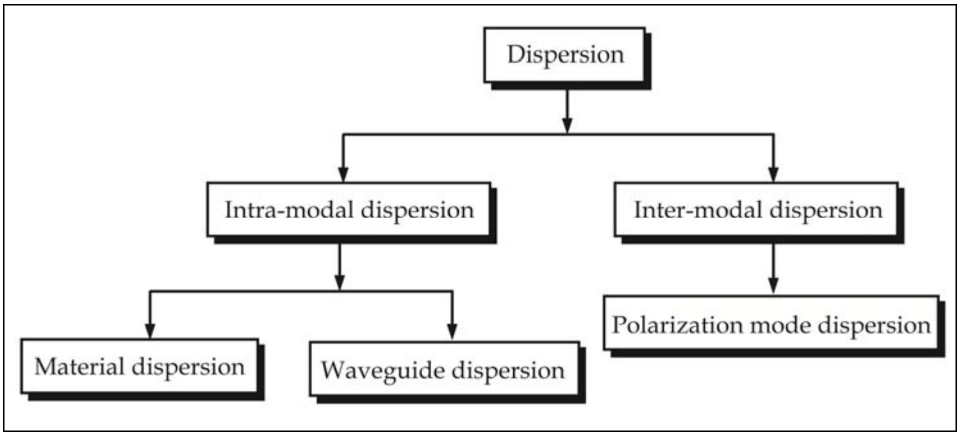


Fig:1.10. Types of dispersions

1.11. Explain the need for WDM in fibre optic communication

- The use of **W**avelength **D**ivision **M**ultiplexing (WDM) offers to vastly increase the transmission capacity of optical transmission media. WDM is the technology is use multiple sources operates at slightly different wavelengths to transmit several independent information signals simultaneously by using single fiber.
- In WDM, several highly concentrated light waves at different wavelengths are produced by several light sources (LASER) are transmitted simultaneously by using single fiber without interfering each other. At the receiving end, the transmitted different wavelengths are separated. Each wavelength carrying vast amounts of information.

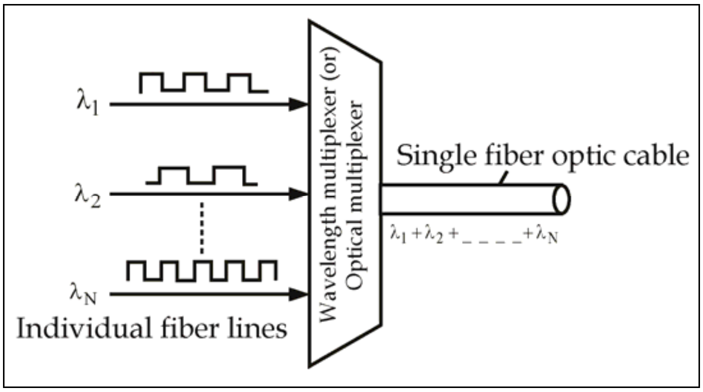


Fig. 1.11. (a): Basic concept of WDM

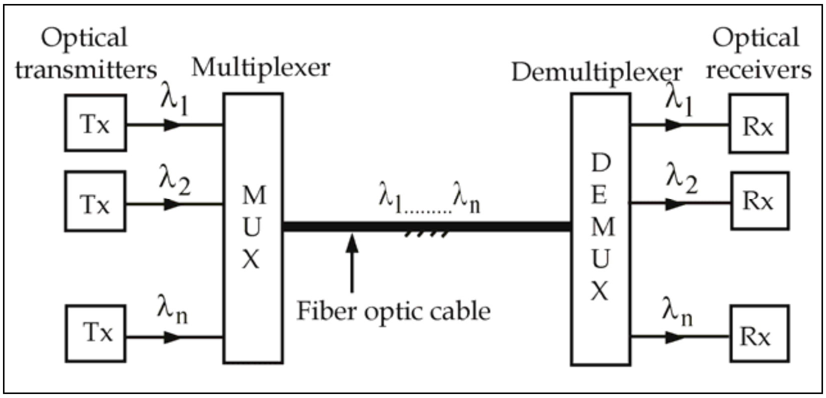


Fig. 1.11. (b): Wavelength division multiplexing (WDM)

WDM is necessary to

1. Upgrade the capacity of existing fiber networks without adding fibers.
2. Transparency-Each optical channel can carry any transmission format (analog or digital)
3. For additional demand, one can buy and install equipment easily.

1.11.1. TYPES OF WDM SYSTEMS

There are two types of WDM systems. They are

1. Narrowband WDM (NWDM)
2. Wideband WDM (WWDM)

- Narrowband WDM (NWDW) is a technology that doubles the fiber span's capacity. NWDM implements two wavelengths, typically 1533 and 1577 nm wavelengths.
- Wideband WDM (WWDM) is technology that increases a fiber span by twofold. WWDM is implemented by combining a 1310 nm wavelength with another into the low-loss window of a fiber opric cable between 1528 nm and 1560 nm in wavelength.

Note: WDM versus FDM

1. FDM and WDM are working on the same principles but they are not same. The most obvious difference is that optical frequencies (in THz) are used in WDM when higher than radio frequencies (In MHz and GHz) used in FDM

- FDM channels are propagated at the same time and over the same transmission medium and take some transmission path, but they occupy different bandwidths.

  In WDM, each channel propagate down the same transmission medium at the same time. But each channel occupies a different bandwidth (Wave length), and each wavelength takes a different transmission path.

1.12. Draw and explain the block diagram of WDM system

- The process of combining and transmitted several different wavelengths of light signals through a same fiber optic cable simultaneously is known as **Wavelength division multiplexing (WDM).**
- In WDM, high bandwidth is utilized to greater extent to transmit multiple optical signals through single optical fiber. WDM offers high transmitted capacity in fiber optic communication.
- In WDM, several highly concentrated light waves at different wavelengths are emitted by several lights by using single fiber optic cable without interfering each other.

At the Transmitter:

- Several input signals are converted into light waves at different wavelengths by using optical transmitters. These light waves at different wave lengths are combined using wavelength multiplexer, and transmitted through a single fiber optic cable without interfering each other.
- For long distance communications, the power losses are minimized and increasing signal strengths by using various amplifiers (post amplifier, in-line amplifier, pre amplifiers) in fiber optic cable as shown in the Fig. 1.12.

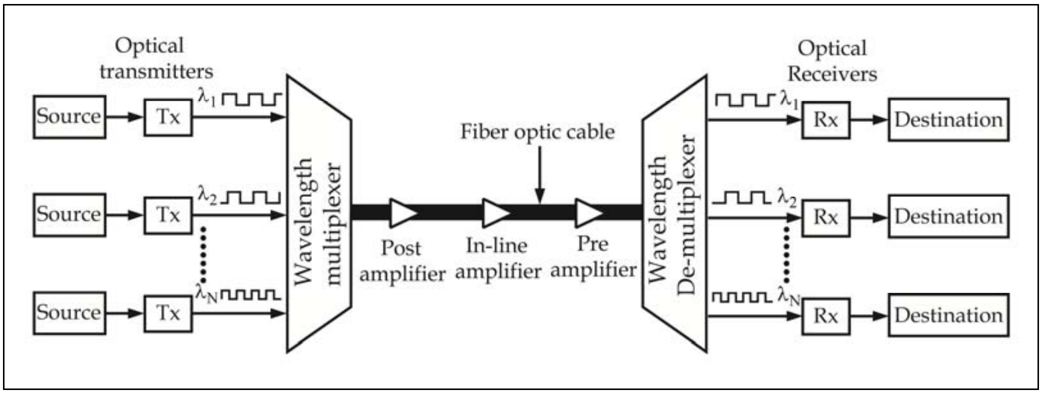


Fig. 1.12. Block diagram of WDM

At the Receiver:

- The wavelength de-multiplexers are used to separate light waves with different wavelengths, and these light waves at different wavelengths are converted into electrical signals using optical receivers and to recover the original message signals.

Advantages:

- Higher Bandwidths and higher transmissions capacity.
- Full duplex transmission is possible with single fiber.

- Optical communications networks use optical components that are simpler, more reliable and often less cost

1.13. Draw and explain the block diagram of DWDM

- DWDM stands for **D**ense **W**avelength **D**ivision **M**ultiplexing. Each wavelength in DWDM can carry 10 Gbps and all wavelengths can be amplified by a single optical amplifier (EDFA). For distance communication, the power losses are minimized and increasing signal strength by using various amplifiers as shown in Fig. 5.7.
- The use of DWDM has reduced the need to develop extremely high speed transmitters, receivers and switches. Each optical carrier (OC) –192 has a transmission rate of 10Gbps.
- DWDM is an optical technology used to increase bandwidth over exiting fiber optic backbones. Using DWDM, up to 80 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a single light stream, and then transmitted on a single fibre optic cable. Each channel carries a time division multiplexed (TDM) signal. In a system with each channel carrying data , billions of bits per second, can be delivered by the fibre optic cable.
- Since each channel is de- multiplexed at the transmission back into the original source, different data formats can be transmitted together, at different rates.
- DWDM technology is a suitable solution for high- speed data transmission, without the addition of more fibre cables.

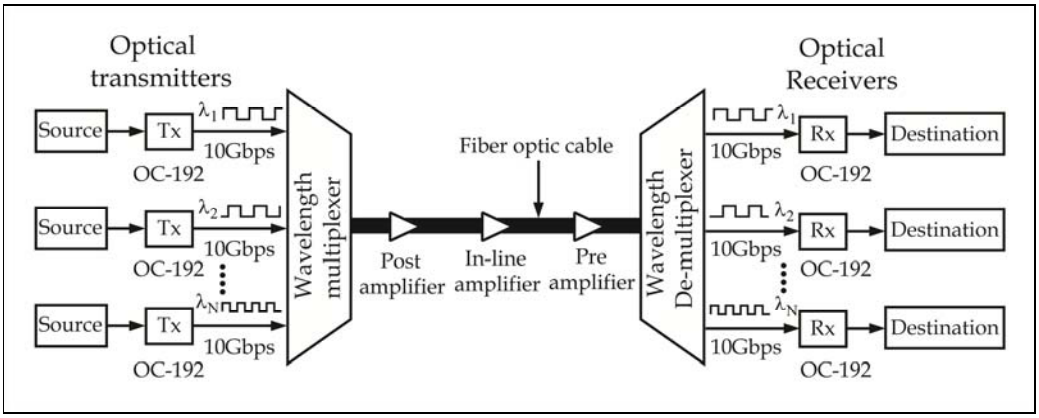


Fig. 1.13. Block diagram of DWDM

At the transmitter:

- Several input signals (each signal carries 10Gbps) are converted into light waves at different wavelengths by using optical transmitters. These light waves at different wavelengths are combined using wavelength multiplexer, and transmitted through a single fiber optic cable without interfering each other.

- For long distance communication, the power losses are minimized and increasing signal strength by using various EDFA amplifiers (post amplifier, in-line amplifiers and pre-amplifiers) in fiber optic cables Fig. 1.13.

At the receiver:

- The wavelength de-multiplexer are used to separate light waves with different wavelengths, and these light waves at different wavelengths are converted into electrical signals using optical receivers and to recover the original message signals with each signal of 10Gbps.

Optical Carrier	**OC-1**	**OC-3**	**OC-9**	**OC-12**	**OC-18**	**OC-24**	**OC-36**	**OC-48**	**OC-192**	**OC-256**
Transmission rate(Mbps)	51.84	155	467	622	933	1244	1866	2488	10000 (or) 10 Gbps	13271

CHAPTER 2

FIBRE OPTIC COMPONENTS AND DEVICES

OBJECTIVES

2.1. List various fibre optic components

2.2. State the function of splice in optical fibres

2.3. State the need for optical coupler/splitter

2.4. List two types of sources used in OFC

2.5. Define salient features of an optical source

2.6. List two types of detectors used in OFC

2.7. Define salient feature of an optical detector

2.8. State the principle of LASER.

2.9. Explain the construction and working of LASER source.

2.10. Draw the block diagram of fibre optic communication system and explain each block.

2.0. Introduction

A fiber optic data link sends input data through fiber optic components and provides this data as output information. It has the following three **basic functions**.

- To convert an electrical input signal to an optical signal
- To send the optical signal over an optical fiber.
- To convert the optical signal back to an electrical signal.

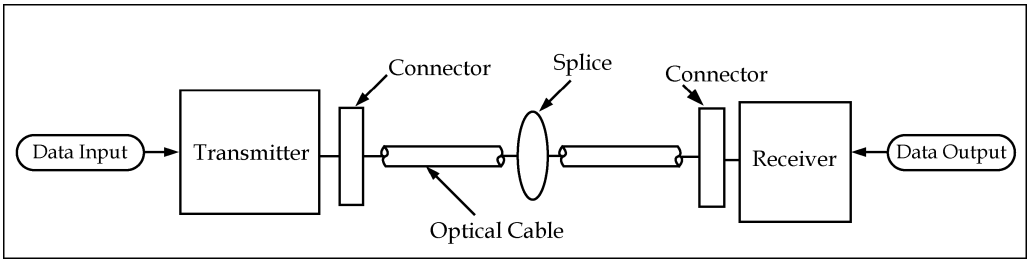


Fig (a) : Parts of a fiber optic data link

A significant factor in the installation of any optical fiber communication system is the interconnection of various components. The particular technique selected for interconnection depends whether a permanent bond or an easily demountable connector is required. A permanent bond is generally referred to as splice, whereas a demountable joint is known as connector. As single-mode fibers require the greatest precision, more emphasis has been placed on the interconnection of these fibers. Factors causing losses in both connectors and splices can be divided into two types, i.e., intrinsic and extrinsic losses.

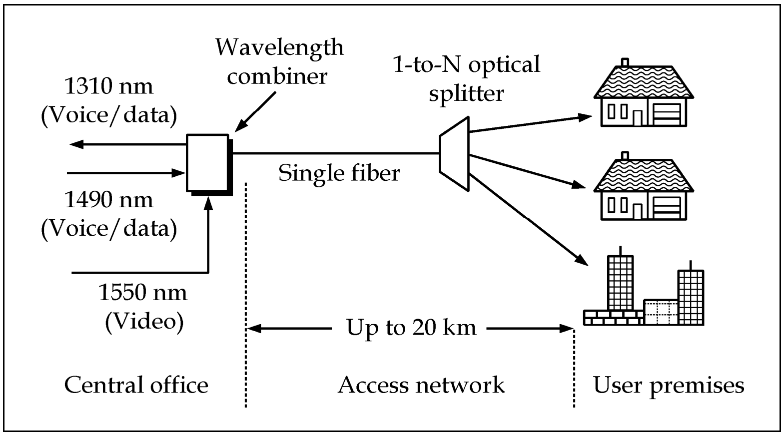


Fig. (b): Architecture of a typical optical network

Reflection loss also affects the optical power. The intrinsic losses arise due to intrinsic factors like mismatches in fiber core diameters, index profiles, ellipticity of the core, etc. The extrinsic losses arise due to factor external to the fibers such as mechanical misalignment, end face quality and reflections at the fiber-air interfaces.

2.1. List various fibre optic components

Optical components include

1. Optical sources (Lasers and LEDs,)
2. Photo detectors (PIN diode and APD)
3. Couplers
4. Splitters
5. Connectors
6. Optical switches
7. Isolators
8. Circulators
9. Optical attenuators
10. Amplifiers
11. Filters
12. Multiplexers and Demultiplexers

2.2. State the function of splice in optical fibres

- A permanent joint formed between two individual optical fibers is called **"fiber splicing".**

(OR)

- A **Fiber Optic Splice** is a permanent fiber joint whose purpose is to establish an optical connection between two individual optical fibers.
- Fiber splicing is a permanent and semipermanent joint between two two fibers. These are used to establish long fiber optic links where smaller fiber lenths need to be joined and used in situations where the frequent connections and disconnections are needed.
- There are two techniques used for fiber splicing.They are
    1. Fusion splicing (or welding splicing)
    2. Mechanical splicing
- **Fusion Splicing:** A Fusion Splice is a fiber joint which is done by Heat Fuses or by melting the ends of two optical fibers together. It is accomplished by applying localized heating(e.g by a flame or an electric arc) at the interface between two prealigned optical fiber ends causing them to soften and fuse.

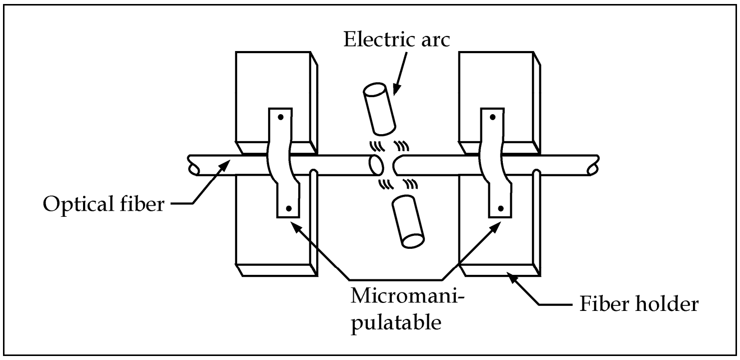


Fig 2.2. (a):Fusion Splicing

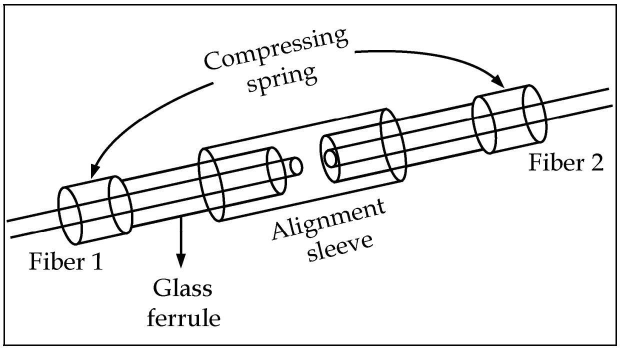


Fig 2.2. (b): Mechanical splice

- **Mechanical Splicing:** A mechanical splice has Mechanical Fixtures and materials that are used to fiber alignment and connection.In this splicing, the fibers are held in alignement by mechanically.

  This splice is mostly used for multimode fibers.

  Each fiber is placed in one ferrule which is a capillary glass tube under compression using spring. There is a sleeve with three glass rod to get prefect alignment. The fibres in the insertede into the sleeve(fig 2.2). This splice loss is about 0.2 dB

  Mechanical splicing may be achived by various methods including

  1. Tube splices(the use of tubes around the fiber ends)
  2. V-grooves splicing

2.3. State the need for optical coupler/splitter

- An optical fiber coupler is a device that distributes the light from a main fiber into one or more branch fibers OR combine light signals from the two or more fibers into single fiber.
- The optical couplers are used to split the power into different directions or to combine the optical power from the different sources. Fiber couplers are 2-port,4-

port or multiport. Requirements are increasing for the use of these devices to divide or combine optical signals for application within optical fiber information distribution systems including data buses, LANs, computer networks and telecommunication access networks.

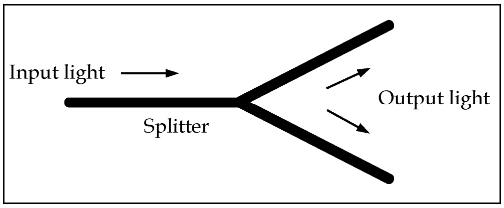


Fig 2.3. (a): Optical splitter

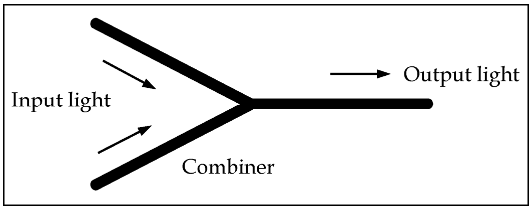


Fig 2.3. (b): Optical combiner

- An **optical splitter** is a passive device that splits the optical power carried by a single input fiber into two output fibers. Fig illustrates the transfer of optical power in an optical splitter. The input optical power is normally split evenly between the two output fibers. This type of optical splitter is known as a **X-Coupler.**

  An **optical combiner** is a passive device that combines the optical power carried by two input fibers into a single output fiber. Fig: illustrates the transfer of optical power in an optical combiners.

  An X-coupler combines the functions of the optical splitter and combiner. The x-coupler combines and divides the optical power from the two input fibers between the two output fibers. Another name for the X-coupler is the 2×2 coupler.

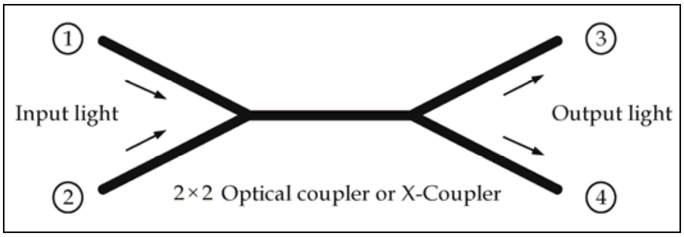


Fig 2.3. c): 2X2 optical coupler

2.4. List two types of sources used in OFC

- Optical transmitter converts electrical input signal into corresponding optical signal. The optical signal is then launched into the fiber. Optical source is the major component in an optical transmitter.

- There are two types of optical (light) sources are used in fiber optic communication to generate light signals.
    1. **LED** (Light Emitting Diode).
    2. **LASER** (Light Amplification by Stimulated Emission of Radiation)
- LED and LASER diodes are constructed from semiconductor materials. In both devices the junction is forward biased, the electrons and holes are injected into the 'p' and 'n' regions respectively. These injected carriers can recombine to emitted photon energy. This pn junction is known active or recombination region.
- A major difference between LED and LASER diodes is that the optical output from an LED is incoherent (disorderly) where as that from a LASER diode is coherent (orderly).
- LED's and LASER'S are constructed from Group - III atoms, such as Gallium (Ga) and **Al**uminum (Al), and a Group IV atoms such as Arsenide (As) for longer wave lengths **Ga**llium (Ga) is combined with Group-V atom phosphate (P), which forms a **ga**llium-**in**dium-**Ars**enide-**p**hosphate (GaIn AsP) junction.

2.5. Define salient features of an optical source

S.No	Parameter	LED	LD(Laser Diode)
1.	Principle of operation	Spontaneous emission	Stimulated emission
2.	Output beam	Non- coherent	Coherent
3.	Spectral width	Boar spectrum (20 nm-100nm)	Much narrow (1-5nm)
4.	Data rate	Low	Very high
5.	Transmission distance	Smaller	Greater
6.	Temperature sensitivity	Less sensitive	More temperature sensitive
7.	Coupling efficiently	Very low	High
8.	Compatible fibres	Multimode sleep Index Multimode GRIN	Single mode SI Multimode GRIN
9.	Circuit completely	Simple	Complex
10.	Life time	10^2 hours	10^4 hours
11.	Cost	Low	High

12.	Output power	Linearly proportional to drive current	Proportional to current above threshold
13.	Current required	Drive current 50 to 100 mA peak	Threshold current 5 to 40mA
14.	Wavelengths available	0.66 to $1.65\mu m$	0.78 to $1.65\mu m$
15.	Applications	Moderate distance low data rate	Long distance high data rates

2.6. List two types of detectors used in OFC

Light detectors are used to convert the light signal into electrical signals at the receiving end. Light signals are received by the receiver and they are converted into electrical signals using light detectors .

The most common types of detectors for fiber optic communication are

- PIN (**P**-type, **I**ntrinsic, **N**-type) diode
- APD (**A**valanche **P**hoto **D**iode)

2.7. Define salient feature of an optical detector

a) Responsivity : This is the sensitivity of a photo detector. Responsivity is defined as the ratio of detector output photocurrent to the detector input optical power. It is dependent wavelength of the incoming light. So, this is also known as the 'Spectral Responsivity'.

$$\text{Responsivity} = \frac{\text{Output photo current}}{\text{incident optical power}}$$

b) Quantum efficiency: It is defined as the ratio of number of newly generated charge carries to the number of incident photons. This is called the external quantum efficiency.

$$\eta_{ext} = \frac{\text{No.of newly generated charge carriers}}{\text{No.of incident photons}}$$

The internal quantum efficiency is defined as the ratio of number of pairs generated to the number of photons absorbed.

i.e.,

$$\eta_i = \frac{\text{No.of pairs generated}}{\text{No.of photons absorbed}}$$

The internal quantum efficiency is high.

c) **Dark Current** (I_D): Even though when light is not falling on the photodetector, some current passes through the circuit. This current under the darkness condition is called 'dark current'. A good photodetector should have low dark current.

d) **Noise equivalent power(NEP):** Due to the incident light intensity, charge carriers are generated. These charge carriers have random motions. As a result, the concentration of charge carriers gets fluctuated causing fluctuation in the conductivity of the photo detector. This rise to noise in photo detectors.

The noise equivalent power (NEP) is defined as the incident optical power required to produce a signal- to- noise ratio (SNR) of unity in a 1 Hz bandwidth. It is also defined by the ratio of noise current to the peak radiant sensitivity.

$$\therefore \quad \boxed{NEP = \frac{\text{Noise current}}{\text{peak radiant sensitivity}}.}$$

e) **Detectivity (D):** Detectivity is defined as the reciprocal of the noise equivalent power.

$$\therefore \quad \boxed{D = \frac{1}{NEP}}$$

$$\boxed{D = \frac{\text{Peak radiant sensitivity}}{\text{Noise current}}}$$

f) **Spectral response:** It is the ability of a photoconductor to give response to the incident light of different wavelengths. Hence the spectral response of the detector should match the spectral curve of the optical source.

2.8. State the principle of LASER.

LASER(Light Amplification by the Stimulated Emission of Radiation) works on the principle of **population inversion** that is needed for stimulated emission to occur.

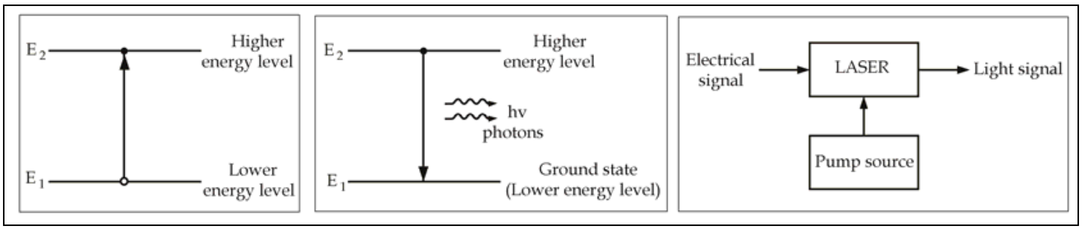


Fig. 2.8. (a) Population Inversion , Stimulated Emission, working principle of LASER

1. An electron within an atom (or a molecule or an ion) starts in a low energy stable state often called the "ground" state.
2. When LASER absorbs the supplied energy from an external source called pump source (flash lamp, electrical current to cause electron collisions etc). The pump source supplies energy to electrons in an active medium (GaAs), at that time the electrons are excited from ground state to higher energy state to

produce population inversion (The electrons in higher energy level is greater than ground state).

3. A photon arrives with an energy close to the same amount of energy as the electron needs to give up to reach a stable state. (This is just another way of saying that the wavelength of the arriving photon is very close to the wavelength at which the excited electron will emit its own photon.)
4. These excited electrons in higher energy level will fall to ground state. At this time the photons are emitted. These emitted photons stimulates many electrons to emit photons. This photon energy is light energy. This conduction is known as **stimulated emission.**

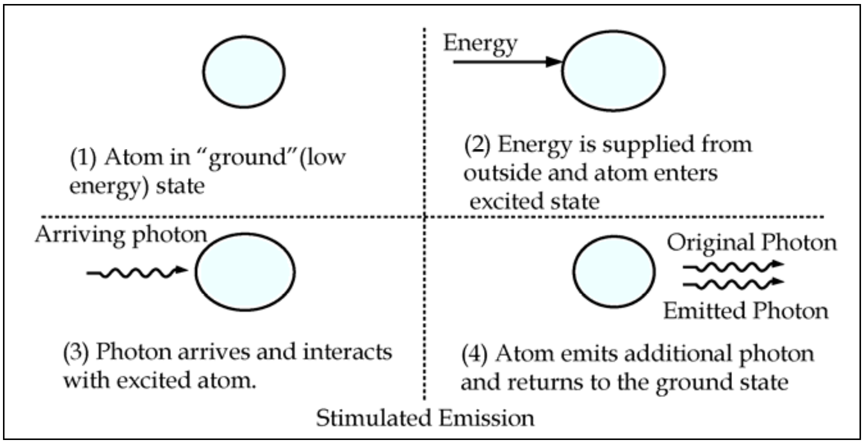


Fig. 2.8. (b)

2.9. Explain the construction and working of LASER source.

Construction:

- LASER is an acronym for "Light Amplification by the Stimulated Emission of Radiation". Ideal laser light is single-wavelength only.
- LASERs can produce relatively high power. Indeed some types of LASER can produce kilowatts of power. In communication applications, semiconductor lasers of power up to about 20 milliwatts are available. This is many times greater power than LEDs can generate. Other semiconductor LASERs (such as those used in "pumps" for optical amplifiers) have outputs of up to 250 milliwatts.
- Because LASER light is produced in parallel beams, a high percentage (50% to 80%) can be transferred into the fiber.
- The mostly used light source in fiber optic system is LASER Diode. It is a PN junction semiconductor (GaAs) device that emits light when it is connected in forward biased.

- The construction of LASER diode is similar to that of LED. The ends of the junctions have mirrored surfaces, with one mirror is **total reflecting** and other one is **partially reflecting mirror**, so that the light can escape in one direction only.

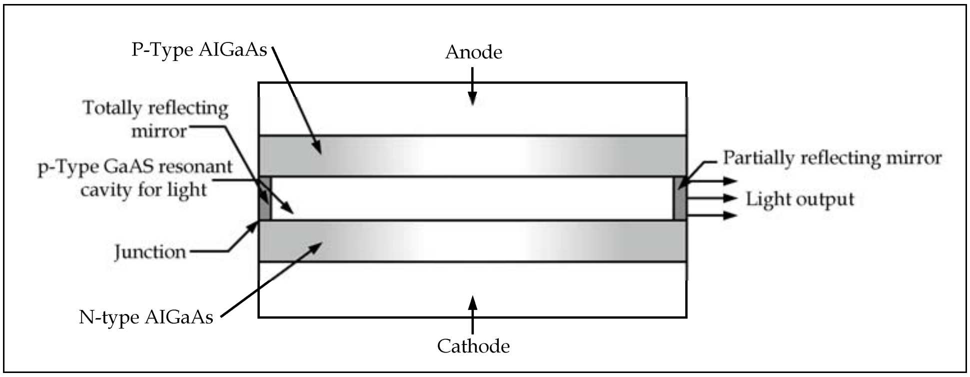


Fig. 2.9. (a): Stimulated cross section of LASER Diode

Working:

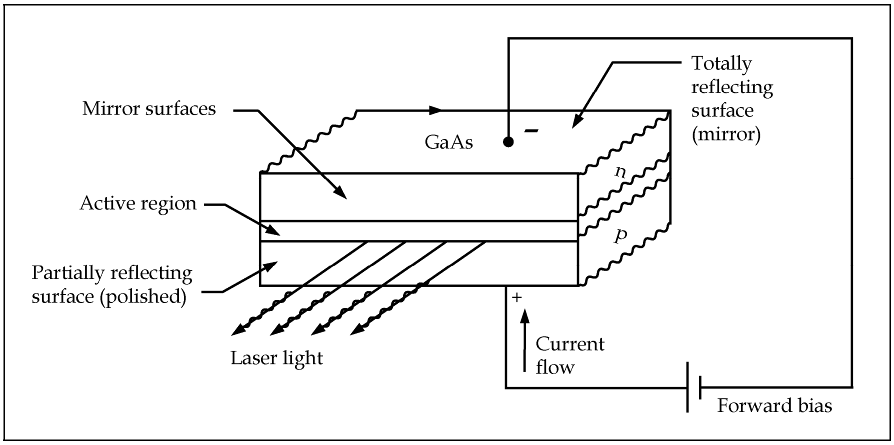


Fig. 2.9. (b): Schematic diagram of a semiconductor Laser diode

- A semiconductor laser is a specially fabricated pn junction device (both the p and n regions are highly doped) which emits coherent light when it is forward biased. In a normal p-n junction current flows across the p-n junction. This action can occur because the holes from the p-type region and the electrons from the n-type region combine. LASER diode operation occurs at the junction of the highly doped p and n type regions.
- LASER diode operates with high current densities of 11 kA/cm2. The high current density causes many electron - hole pairs to be generated.
- If the diode is set to be in forward bias using an external source, the electrons cross the junction and combine with the hole as in normal diodes. During this process, photons were released when the charge carriers move into the active region. These newly released photons collide with other atoms which causes further production of photons. If we

increase the forward bias current more photons are produced due to the collision of each other.

- Some of the photons reflected back from the depletion region, during the reflection again collide with other atoms and produce the photons. These reflections and generation of new photons results the intense laser beam and this beam pass through the partially reflected area of the p-n junction.
- If the forward bias voltage increases, the electron-hole recombination increases, this recombination generates more photons that stimulated the other pairs and emits more light energy.
- Almost every electron-hole pair injected into the active region generates a useful photon energy and stimulated emission occurs in a laser. All these photons emits light energy and that is coming from the junction of LASER.
- Now the semiconductor lasers are also made to emit light almost in the spectrum from UV to IR using different semiconductor materials. They are of very small size (0.1 mm long), efficient, portable and operate at low power.

Advantages:

- The output power is greater than LED.
- Coupling losses are reduced.
- Easier to couple light into optical fiber.
- LASER generates monochromatic light which reduces chromatic or wavelength dispersion.
- These are ability to turn off and ON at a faster rate.
- The digital data rates of high speed LASER diodes are capable of Giga bit/sec.

Disadvantages:

- LASER diodes are difficult to operate than LED's.
- LASER are more expensive than LED's.
- Shorter lifetime than LED's.
- More temperature dependant than LED's.

2.10. Draw the block diagram of fibre optic communication system and explain each block.

The block diagram of fiber optic communication system consists of mainly

1. Optical transmitter
2. Fiber optic cable (information channel)
3. Optical receiver

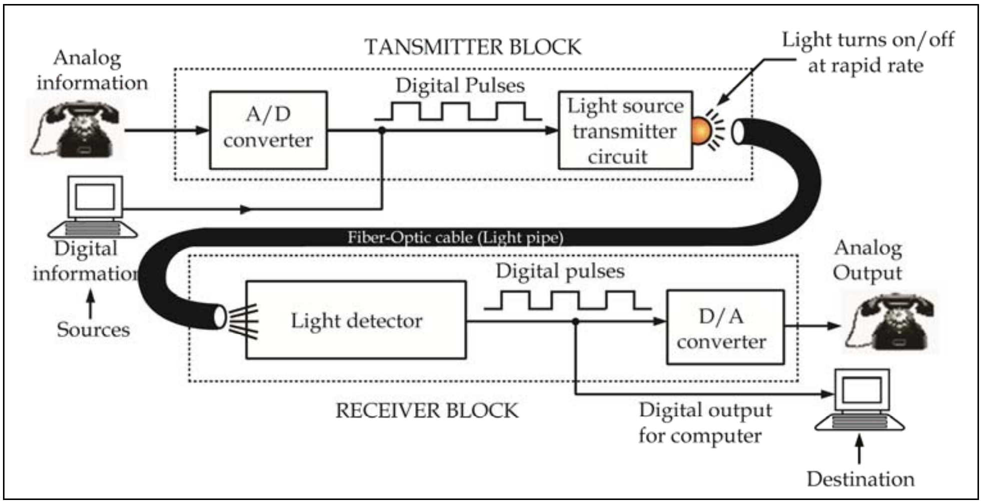


Fig. 2.10. (a)Block diagram of basic fiber-optic communication system

1. Optical transmitter:

Its main function is to transmit the information signals like video, voice or computer data in form of light signals. The information at input is converted into digital signals by using A-to-D converter. It consists of A-to-D converter and light source.

- **A-to-D converter:** The information signals like voice and video signals are analog in natures that are converted into digital signal by using A-to-D converter. These digital signals (electrical in nature) are fed to light source. If the input signals are coming from the computer i.e., digital signals they are directly connected to light source.
- **Light source:** The output of A-to-D converter is an electrical signal is given to light source, this light source convert's electrical signal to light signal. The light source turns on/off, depends on digital pulse thus its flashing is proportional to digital input. The most commonly used light sources are **LED** and **LASER**.

2. Fiber optic cable (information channel):

Information channel is the path between transmitter and receiver. In fiber optic communication the channel is fiber optic cable which is made of glass or plastic. When the light pulses are coming from optical transmitter fed to one end of the optical cable, they are passed onto the other end of the optic cable. For long distance communication repeaters are used to overcome the power loss of the signal.

3. Optical receiver:

At the receiving end, light signals are converted into electrical signal. The optical receiver consists of **light detector** & **D-to-A converter**.

- **Light detector:** The light signal from the fiber optic cable at the receiving end is given to light detector, the light detector converts light s/g into electrical signal. The most commonly used light sources are **PIN diode** or **APD**.
- **D-to-A converter:** The output of light detector is given to D-to-A converter which converts digital into analog signal. if the digital s/g for computer can be directly taken from the output of the light detector.

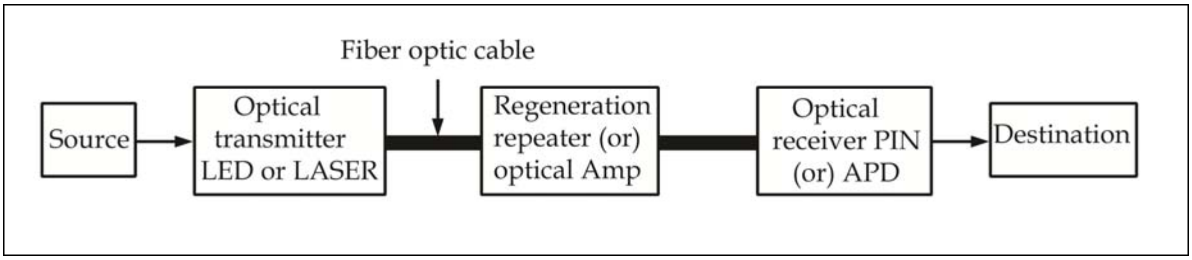


Fig. 2.10.(b):Block diagram of basic fiber-optic communication system with repeater

(OR)

Block Diagram Of Basic Fiber Optic Communication System

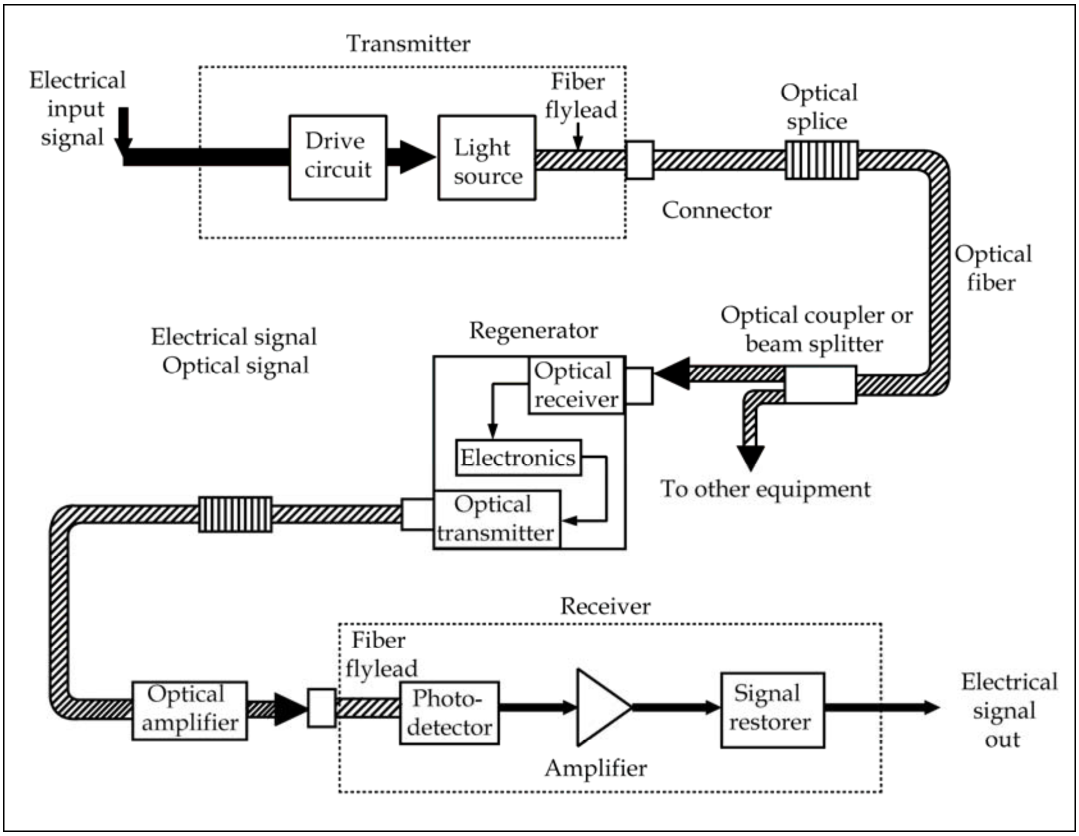


Fig. 2.10.(c)Block diagram of a optical communication system

- **Transmitter:** The transmitter consists of a light source and associated Electronic circuitry. The source can be a light-emitting diode or a laser diode. The electronics are used for setting the source operating point, controlling the light output Stability, and varying the optical output in proportion to an electrically formatted Information input signal
- **Optical fiber:** The optical fiber is placed inside a cable that offers mechanical and environment protection. A variety of fiber types exist, and there are many different cable configurations depending on whether the cable is to be installed inside a building , in underground pipes, outside on poles, or underwater.
- **Receiver:** Inside the receiver is a photodiode that detects the weakened and distorted optical signal emerging from the end of an optical fiber and converts it to an electric signal. The receiver also contains amplification devices and circuitry to restore signal fidelity.
- **Passive devices:** passive devices are optical components that required no electronic control for the operation. Among these are optical connectors for connecting cables, splices for attaching one bare fiber to another, optical isolators that prevent unwanted light from flowing in a backward direction, optical filters that select only a narrow spectrum of desired light, and couplers used to tap off a certain percentage of light, usually for performance monitoring purpose.
- **Optical amplifiers:** After an optical signal has traveled a certain distance along a fiber, it becomes weakened due to power loss along the fiber. At that point the optical signal needs to get a power boost. Traditionally the optical signal was converted to an electric signal, amplified electrically, and then converted back to an optical signal. The invention of an amplifier that boosts the power level completely in the optical domain.

CHAPTER 3

TELEPHONY AND MOBILE COMMUNICATION

OBJECTIVES

3.1. Introduction to Telephone Systems
3.2. Advantages of Electronic Telephony over Manual Telephony
3.3. Block diagram of Electronic Telephone exchange.
3.4. In-band and out-band telephone signals.
3.5. Pulsed and DTMF dialling
3.6. List the limitations of conventional mobile phone system.
3.7. Evolution of cellular mobile communication system.
3.8. Define the terms mobile station and base station
3.9. State the functions of Mobile switching centre (MSC)
3.10. Define voice and control channels in mobile communication

3.1. Introduction to Telephone Systems

The basic purpose of public telephone system is to facilitate two way voice communication between any pair of subscribers connected to the network. Present day networks offer much more. That is they provide services like connectivity with other systems, telegraph, internet, fax, computer data communication, conference calls, morning wake up services and so on. The interconnectivity among subscribers and various other customers who use the services is achieved through a network.

Today's telecommunication network is a complex interconnection of a variety of heterogeneous switching systems. Electromechanical and electronic systems, direct and common control systems and hard wired and stored program control systems coexist. Presently two important classes of telecommunication networks viz. Public Switched Telephone Network (PSTN) and Public Data Network (PDN) are in wide use. The newly emerging Integrated Services Digital Network (ISDN) is expected to be in place in the next 20 years or so as a result of the process of total digitalization of telecommunication networks currently under way.

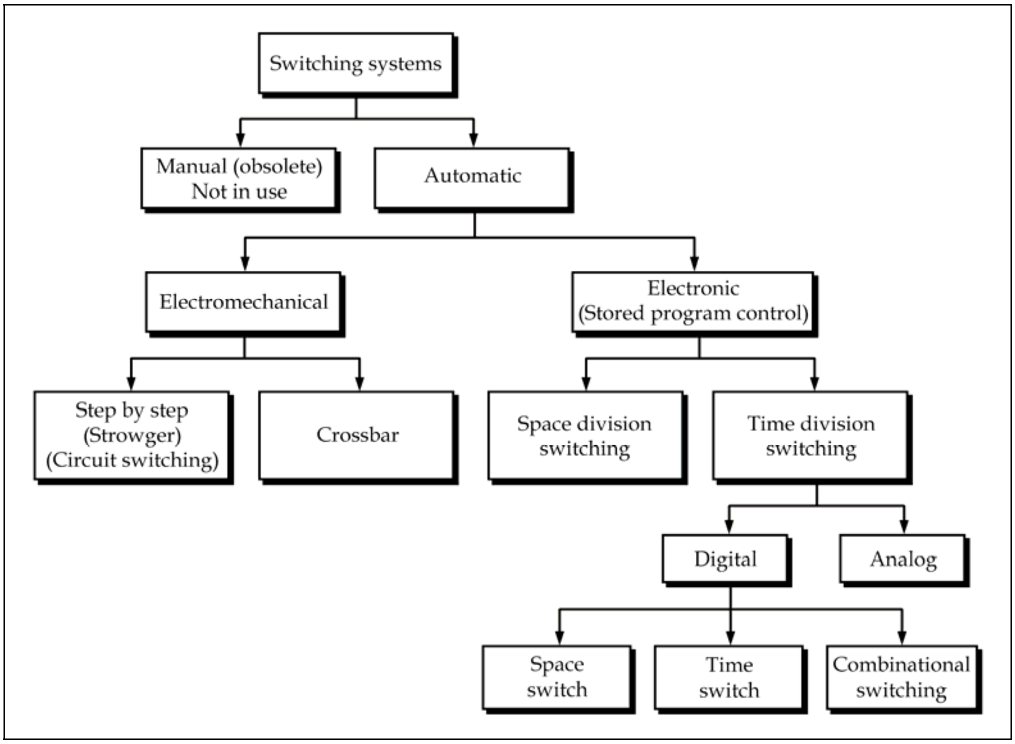


Fig. 3.1. Classification of Switching Systems

1. Manual switching systems

- Early switching systems were manual operator oriented. Limitations of operator manned switching systems were quickly recognized and automatic exchanges came into existence.

2. Automatic switching systems

- Automatic switching systems can be classified as electromechanical and electronic.

3. Electromechanical switching systems

- Electromechanical switching systems include step-by-step and crossbar systems. The step-by-step system is better known as strowger switching systems. The control functions in a strowger system are performed by circuits associated with the switching elements in the system.
- Crossbar systems have hard-wired control subsystems which use relays and latches.

4. Electronic switching systems

- In electronic switching systems, the control functions are performed by a computer or processor. Hence these systems are called Stored Program Control (SPC) systems. New facilities can be added to a SPC system by changing the control program. The switching scheme used by electronic switching systems may be either space division switching or time division switching.

5. Space division switching

- In space division switching a dedicated path is established between the calling and the called subscribers for the entire duration of the call. Space division switching is also the technique used in strowger and crossbar systems.
- An electronic exchange may use a crossbar switching matrix for space division switching. In other words a crossbar switching system with SPC qualified as an electronic exchange.

6. Time division switching

- In time division switching, sampled values of speech signals are transferred at fixed intervals. Time division switching may be analog or digital.
- In analog switching the sampled voltage levels are transmitted as they are, where as in digital switching they are binary coded and transmitted. If the coded values are transferred during the same time interval from input to output the technique is called space switching.
- If the values are stored and transferred to the output at a later time interval, the technique is called time switching.

- A time division digital switch may also be designed by using a combination of space and time switching techniques.

3.2. Advantages of Electronic Telephony over Manual Telephony

The electronic telephone systems offer number of advantages over manual telephony.

1. Speed dialing as DTMF tones are used
2. The complete units is embedded in an IC
3. The receiver equipment is compact and light in weight
4. Numeric key pad allows easy dialing
5. Built in processor permits many call processing functions like call forward, call blocking call waiting etc.
6. Electronic ring tones are generated.
7. Less timing
8. Fast switching
9. Billing equipment facility
10. High accuracy
11. Having ANI (Automatic Number Identification)
12. Low power consumption
13. Flexibility is more

3.4. In-band and out-band telephone signals.

3.4.1. In-Band Signaling

- Every communications system transmits data and control signals.
- When the data and control signals are transmitted within the same channel or frequency, the signaling is said to be “in-band”.
- In-band voice frequency signaling uses the same frequency band as the voice i.e., 300 – 3400 Hz.
- The control signals like DTMF signals, dial tones etc., are transmitted between subscriber and exchange are in the same voice frequency band. They are transmitted over the twisted pair.
- In-band signaling is most widely applied signaling system presently in the long distance telephone networks because of its flexibility of operation.
- An important advantage of in-band signaling is that the control signals can be sent to every part where a speech signal can reach.

- It is also independent of transmission systems as the signals would be carried along the route like the speech signals. Even A-to-D and D-to-A conversion do not affect them.
- In-band VF signaling must be protected against false operation by the speech of the subscriber.

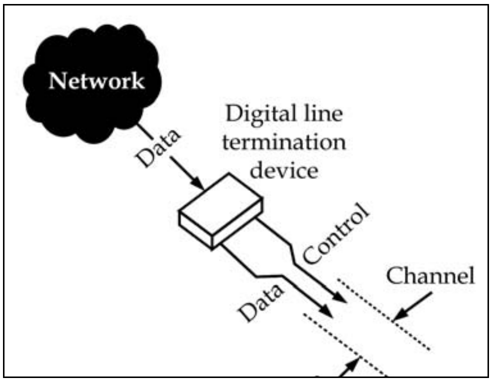


Fig. 3.4.1. In-Band Signaling

3.4.2. Out-Band Signaling

- Out-band signaling uses frequencies above the voice band but below the upper limit of 4 kHz of voice channel i.e., above 3.4 kHz and below 4 kHz.
- The status of telephone instrument off hook (low DC current), on hook (high DC current) are transmitted in terms of DC currents or voltages to the exchange. Because some of the signals like DC signals and other control signals which do not fall in the voice band, they are called out-band signals.

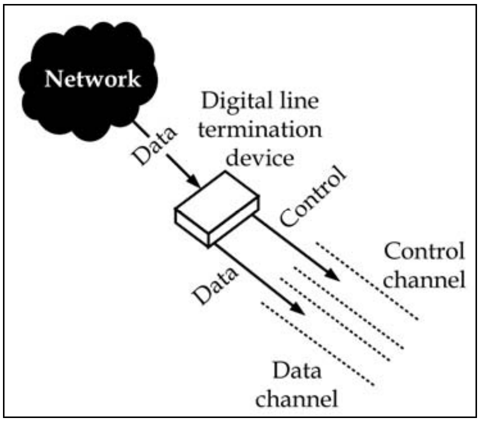


Fig. 3.4.2.Out-Of-Band Signaling

- When control signals reside in a channel separate from the data, they are "out-of-band" signals.
- Out-band signaling uses separate channels for data and control signals.

- For example, in ISDN service, the D channel is a dedicated channel for control signals, and the B channels carry the data. The traditional SS7 telephone system uses an entirely separate common channel signaling network for control signals. This eliminates toll fraud.
- The major advantages of out-of-band signaling is that continuous supervision is provided, whether tone on or tone off, during the entire telephone conversation.

3.4.3. Comparison between In-Band and Out-of-Band Signaling Systems

S.No.	In-Band Signaling	Out-of-Band Signaling
1.	In-band signaling uses the same channel for data and control signals.	Out-of-band signaling uses the separate channels for data and control signals.
2.	In-band signaling uses the frequency range from 300Hz to 3.4kHz.	Out-of-band signaling uses the frequency range from 3.4 kHz to 4 kHz.
3.	It uses the frequency range within the voice frequency range that's why it is called in-band.	It uses the frequency range above the voice frequency range that's why it is called out-of-band.
4.	Signals like dial tones, busy tones, ring-back tones, call progress tones are sent.	DTMF signals, off hook, on hook conditions, DC signals are sent.
5.	Wide bandwidth (2600 Hz)	Narrow bandwidth (600 Hz)
6.	Same telephone channel can be used.	Same telephone channel can be used.
7.	Limited information transfer capacity.	Limited information transfer capacity.
8.	Chance of false operation by speech.	Less chances of false operation by speech.

3.5. Pulsed and DTMF dialing

- The term dialing is used to describe the process of entering a telephone number to be called.
- In older telephone, a rotary dial was used.
- In more modern telephones, pushbuttons that generate electronic tones are used for "dialing".
- Dialing can be accomplished in two ways namely:
    1. Pulse dialing
    2. DTMF dialing (Tone dialing)

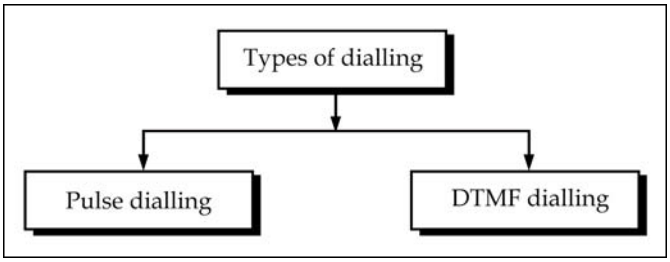


Fig.3.5. Types of Dialing

3.5.1. Explain Pulse Dialing and DTMF

1. Pulse Dialing

- The pulse dialing is old telephone rotary dial type.
- In pulse dialing, when a digit is dialed, a series of pulses is sent out.
- When the user dials 1, 1 pulse is transmitted to the exchange, when 2 is dialed, 2 pulses are sent, and so on; when 0 is dialed, 10 pulses are sent.
- The exchange uses a pulse counter to recognize the digits. Since pulses are likely to be distorted over the medium due to attenuation, pulse recognition accuracy is not very high.
- Many old switches and telephones support only pulse dialing, though slowly pulse dialing is becoming outdated.

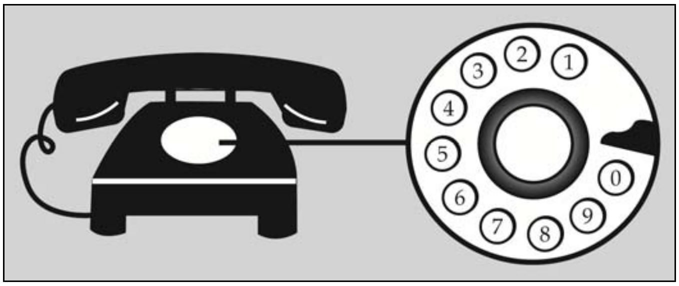


Fig. 3.5.1. Rotary Dialing (Pulse Dialing)

2. DTMF Dialing

- DTMF stands for Dual Tone Multi Frequency. DTMF dialing is also known as tone dialing or speed dialing.
- A typical DTMF keypad of a telephone is shown in fig. 3.5.1.
- The horizontal rows produce 4 lower band of frequencies i.e. 697 Hz, 770 Hz, 852 Hz, and 941 Hz. The vertical columns produce 3 upper band of frequencies i.e. 1209 Hz, 1336 Hz and 1477 Hz.
- When a button is pressed a tone is generated which is a combination of two frequencies, one from lower band and one from upper band. These two tones are linearly mixed producing a unique sound and can be detected by central office.

- When 1 is dialed, a combination of 697 Hz and 1209 Hz is sent from the terminal to the exchange. A DTMF recognition chip is used at the exchange to decode the digits.
- DTMF recognition is highly accurate and is becoming predominant. Most present-day telephones support DTMF.

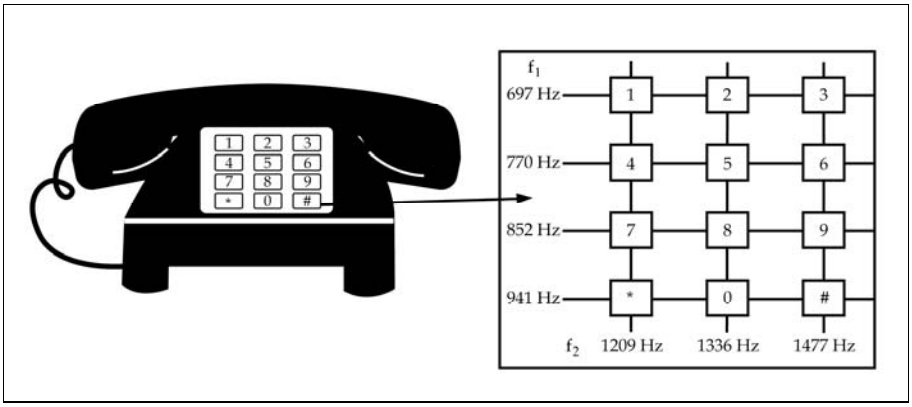


Fig. 3.5.1. DTMF Dialing

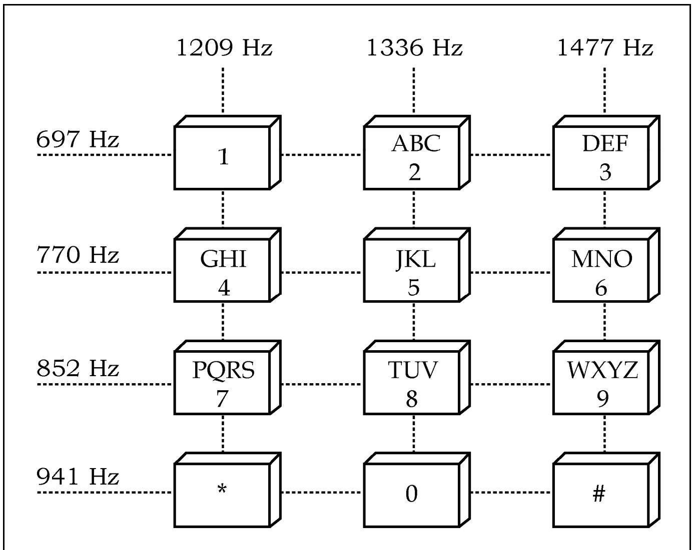


Fig. Dual – Tone Multi-Frequency (DTMF) (Touch Tone Dialing)

3.5.2. Comparison of Pulse and DTMF Dialing

S.No.	Pulse Dialing	DTMF Dialing
1.	Number of pulses are generated according to the digit pressed.	Combination of 2 different frequencies are generated according to the digit pressed.
2.	Due to make and break contact sparking occurs within the	No possibility of sparking.

	instrument.	
3.	Dialing speed is slow.	Dialing is fast.
4.	More noisy.	Less noisy.
5.	Minimum inter digit gap required is 200 ms.	Minimum inter digit gap required is 40 ms.
6.	Only 0 to 9 digit can be used.	Additional # and * buttons are provided for programming remote voice guiding purpose.

3.6. List the limitations of conventional mobile phone system.

The limitations of conventional mobile systems are

1. Service capacity is low
2. Poor service performance
3. Limited user capability (or) low calling capacity
4. Inefficient frequency spectrum utilization
5. Poor data communication
6. Low security
7. Information privacy is low

3.7. Evolution of cellular mobile communication system.

Wireless communication is basically transmitting and receiving voice and data using electromagnetic waves in open space. The origin of wireless communications can be traced back to the year 1857, when the behavior of electromagnetic waves was explained mathematically using four equations by James Clerk Maxwell.

The evolution of cellular communication systems is commonly known by the **1G, 2G, 3G** and **4G** designations.

1. First Generation (1G):.

The 1G mobile phone system was introduced in 1980 in the United States.

Analogue circuit-switched technology is used for this system, with frequency division multiple access(FDMA), as an air channel multiple access technique, and worked mainly in the 800-900 MHz frequency bands. The 1G mobile phone had only voice facility.

The most successful examples of 1G standards were Nordic Mobile Telephone (NMT), Total Access Communications System (TACS), and Advanced Mobile Phone Service (AMPS). For example, a total of 50 MHz in the band 824-849 MHz and 869-894 MHz is allocated for AMPS. This spectrum is divided into 832 frequency channels (416 downlinks and 416 uplinks).

The following are the limitations of 1G:

1. Supports only analog voice signals.
2. Low traffic capacity.
3. Unreliable handover.
4. Long-call setup time and frequent call drops.
5. Inefficient use of bandwidth and poor battery life.
6. Poor voice quality and large phone size.
7. Allows users to make voice calls in 1 country only.
8. Interference from other users.
9. International roaming is not possible.

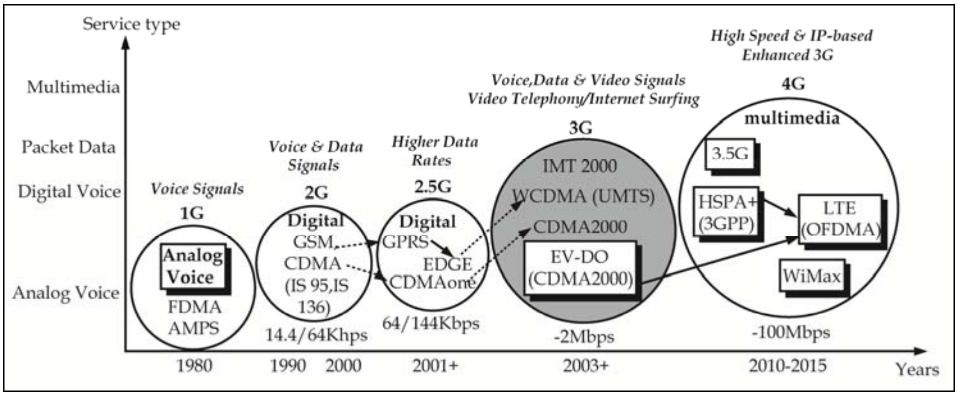


Fig. 3.7. Evolution of cellular mobile communication

2. Second Generation (2G):

The need for more user capacity per cell led to the development of 2G technologies. 2G systems are digital cellular systems and were introduced in the late 1980s and were in use till the late 1990s. 2G technology supports data, speech, FAX, SMS and WAP services. The frequency bands used by GSM are 890–960 MHZ and 1710–1880 MHz. In the 890–960 MHz frequency band, the band at 890--915 MHz is dedicated to uplink communications from the mobile station (MS) to the BS, and the band at 935–960 MHz is used for the downlink communications from the BS to the MS. 2G digital technology is divided into two standards: time division multiple access (TDMA) and code-division multiple access (CDMA).

- Global system for mobile (GSM) was the first commercially operated digital cellular system and uses TDMA/frequency – division duplexing (FDD).
- IS-95 is commonly referred to as CDMA one standard and is used in North America and some parts of Asia.

The following are limitations of 2G:

1. Provides low data rates ranging from 9.6 kbps to 28.8 kbps.

2. Circuit-switched network, where the end systems are dedicated for the entire call session. This causes reduction in usage of bandwidth and resources.
3. Speed of the data is low.

3. Generation (2.5G):

The need for increased throughout data rates in data transfer (such as web browsing and e-mail) led to the evolution of 2.5G which is between 2G and 3G. The mobile technology using GRPS standard has been termed as 2.5G.

The 2.5G was started in 1998 with added GPRS and enhanced data rates for GSM evolution (EDGE). In addition to the hyper text transfer protocol (HTTP), it supports the wireless access protocol (WAP) through which web pages can be viewed on the small screen of a mobile phone or a handheld device, which led to mobile commerce (m-commerce).

4. Third Generation (3G):

The need for high-speed internet access, live video communications, and simultaneous data and voice transmission led to the development of 3G cellular networks. The 3G technology has added multimedia facilities to 2.5G phones. 3G operates in the frequency band of 1710–2170 MHz. It provides high transmission rates from 348 kbps in a moving vehicle to 2 Mbps for stationary or mobile users.

The aim of 3G systems is to provide communication services from person-to-person at any place (global roaming) and at any time through any medium with guaranteed quality of service.

Examples of 3G system are universal mobile telecommunication systems (UMTS) and international mobile telecommunications at 2,000 MHz (IMT–2000).

UMTS are designed to provide different types of data rates, based on the following circumstances: up to 144 kbps for moving vehicles, 384 kbps for pedestrians, and 2 Mbps for indoor or stationary users. UMTS will integrate all the services offered by different mobile communication systems such as mobile phone, cordless telephone, and satellite radio in one service. Japan was the first country to introduce 3G system IMT-2000 network nationally, and in Japan the transition to 3G was completed in the year 2006.

The following are the drawbacks of 3G system:

- High bandwidth requirement.
- High spectrum licensing fees.
- 3G phones are expensive.
- Lack of 2G mobile user buy in for 3G wireless service.
- Lack of network coverage because it is still a new service.
- High prices of 3G mobile services in some countries.
- High input fees for the 3G service licenses.

5. Fourth Generation (4G):

Even though the 3G networks have been deployed since 2001, the true broadband access will be achieved with t he 4G mobile phones. The 4G mobile communications will have transmission rates up to 20 Mbps higher than that of 3G.

4G technology is expected to provide very smooth global roaming universally with lower cost. Theoretically, 4G is set to deliver 100 Mbps to a roaming mobile device globally, and up to 1 Gbps to a stationary device. 4G will bring almost the perfect real world wireless internet working called "WWWW: **WorldWide Wireless Web**".

With the expected features in mind, 4G allows for video conferencing, streaming picture perfect video (e.g. tele-medicine and tele-geo processing application) and much more. Since the 4G is a research item for the next – generation wide-area cellular radio, the technology is expected to be available around 2012–2015.

3.8. Define the terms mobile station and base station

1. Mobile Station (MS):

A **Mobile Station** is a device used by a mobile user to access the mobile network. The mobile station (MS) consists of two units mobile handset with battery and **S**ubscribes **I**dentity **M**odule (SIM).

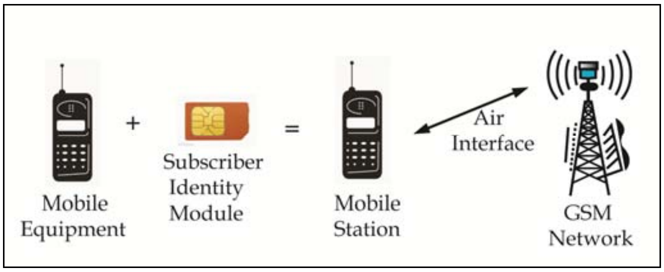


Fig. 3.8. (a) Mobile station

Mobile Stations are usually a mobile phone. Each mobile phone contains a transceiver (transmitter and receiver), an antenna, and control circuitry. Antenna converts the transmitted RF signal into an EM wave and the received EM waves into an RF signal. The same antenna is used for both transmission and reception, so there is a duplexer switch to multiplex the same antenna.

2. Base Station (BS):

1. A fixed station in a mobile radio system used for radio communication with mobile stations. Base stations are located at the centre or on the edge of a coverage region and consists of radio channels and transmitter and receiver antennas mounted on a tower.
2. A base station is a radio transceiver (transmitter/receiver), including an antenna, that receives and transmits the signals in the cellular network to customer phones (mobile station) and cellular devices. The base station

maintains the communication between the network and the mobile users through a radio link.

3. Base station is also called as **Base Transceiver Station** (BTS) because it consists of transceiver (transmitter/receiver) with antenna used to communicate directly with mobile stations (MS).

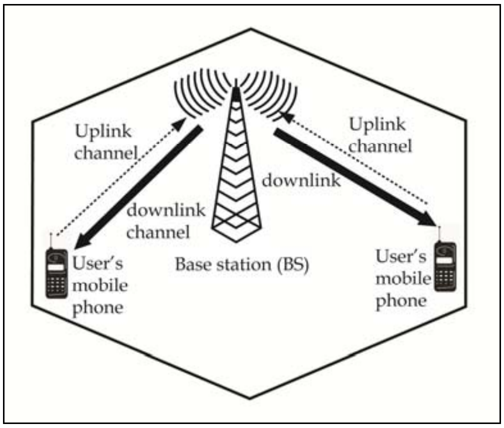


Fig. 3.8.(b) Base station

4. Each BTS covers a defined area, known as a cell. A BTS is under control of a BSC(Base Station Controller), which is in turn under control of a MSC (Mobile Switching Center). A base station is a fixed point of communication for customer cellular phones on a cellular network.
5. Base Station (BS) provides functionalities between mobile unit and Mobile Switching Center (MSC). The base station is located in each cell and it links the subscriber mobile unit with the MSC.

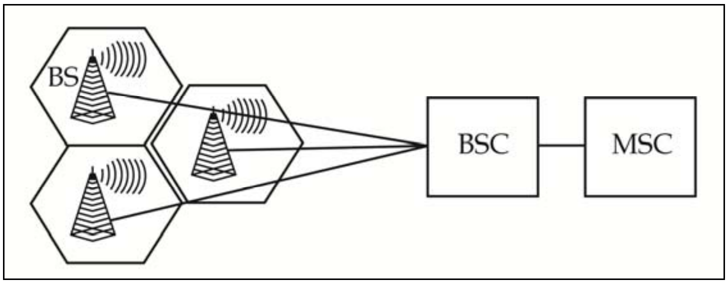


Fig. 3.8. (c) Interconnection of Base Station (BS) with BSC and MSC

3.9. State the functions of Mobile switching centre (MSC)

1. **Mobile Switching Centre (MSC)** is heart of the entire network connecting the fixed line networks (ISDN, PSTN etc.) to the mobiles. It manages all call – related functions and billing information.
2. The **Mobile Switching Centre (MSC)** is a telephone exchange that makes the connection between mobile users within the network, from mobile users to the

public switched telephone network (PSTN) and from mobile users to other mobile networks.

3. Switching center which coordinates the routing of calls in a large service area. In a cellular radio system, the MSC connects the cellular base stations and the mobiles to the PSTN. An MSC is also called a mobile telephone switching office (MTSO).

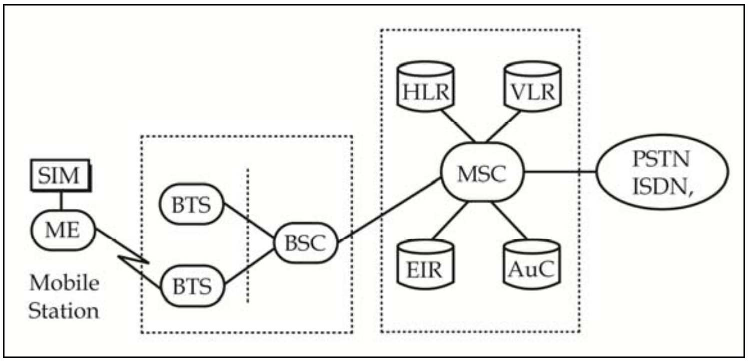


Fig. 3.9.

MSC performs the following functions:

- Coordinates the routing of calls in large service area.
- Call setup.
- Supervision and release.
- Call routing.
- Billing information.
- Echo cancellation.
- Manage connection to BSS, other MSC and PSTN.
- Management of Radio resources during a call.
- It is connected to HLR and VLR for subscriber identification and for routing incoming calls.
- It is also connected to AUC for authentication.
- It communicates with BSs, routing calls and controlling them as required.
- It contains databases detailing the last known locations of the mobiles.
- It also contains facilities for authentication centre allowing mobiles onto the network.
- It contains facilities to generate billing information for individual accounts.
- Mobility management registration location updating inter – BSS and inter – MSC all the handoffs.

For this purpose, the MSC makes use of the three major components of the network subsystem (NSS) that is HLR, VLR, and AUC.

Note:

Home Location Register (HLR): All the subscriber data is stored in HLR. It has a permanent database of all the registered subscriber. When a user switches ON the phone, the phone registers with the network and from there it is possible to determine which BTS it communicates with so that the incoming calls can be routed appropriately.

Visitor Location Register (VLR): An active subscriber is registered in VLR. It has temporary database of all the active subscribers used for their call routing. The MSC asks VLR before routing incoming calls.

Authentication Centre (AUC): The AUC is a protected data – base that contains the secret keys also contained in the users SIM card. It is used for authentication. Authentication is a process to verify the subscriber SIM. Secret data and verification algorithms are stored in the AUC.

Additional Information

Various Channels In Mobile Communication

The base stations are capable of handling many full duplex cellular communications. The mobile switching center can handle atleast 5000 telephonic conversation at a time and 1,00,000 cellular users/subscribers in a network. The cellular communication is made possible between mobile units and the base stations with the help of Common Air Interface (CAI) which specifies four channels.

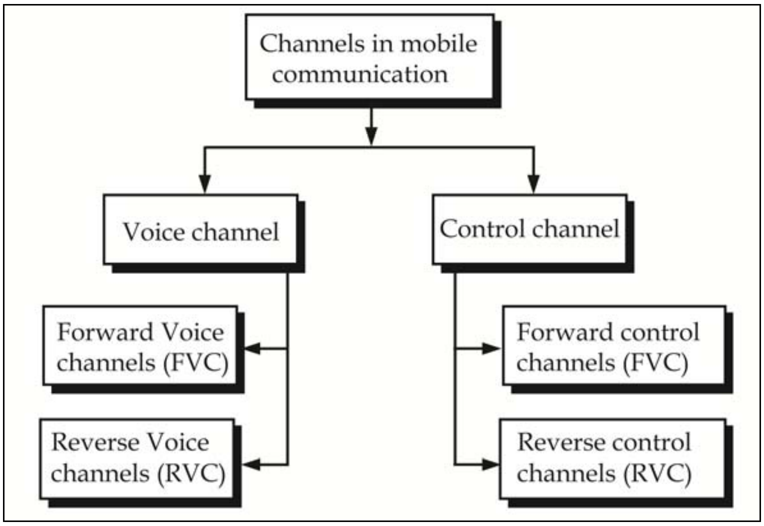


Fig. 3.9. Various channels in mobile communication

3.10. Define voice and control channels in mobile communication

In cellular communication, when a call is initiated the control channel is activated. After the call has been established the control channel becomes free and voice channel is activated and this voice channel carry the information. In cellular communication 95% of signals are used for voice signals and 5% of signals are used for control channels.

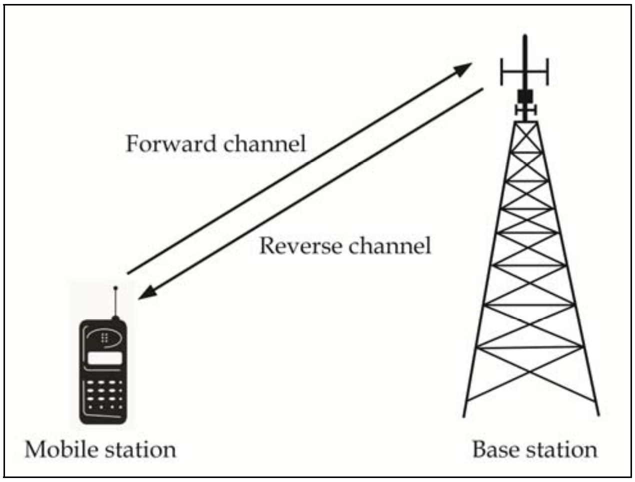


Fig. 3.10. Forward and reverse channels in mobile communication

In each cell, there are two types of channels that active during a each mobile call.

- Voice channel
- Control channel

1. **Voice Channel:** It is defined as the channel which carry actual voice signal of information signal. There are two types of voice channels. They are:

- **Forward Voice Channel (FVC):** This channel is used for transmission of information from the Base Station (BS) to the Mobile Station (MS).
- **Reverse Voice Channel (RVC):** This channel is used for transmission of information from the Mobile Station (MS) to the Base Station (BS).

2. **Control Channel:** The radio channel that is used for call setup, call request, call maintains, call termination and control purpose is called control channel. There are two types of control channels. They are:

- **Forward Control Channel (FCC):** This channel is used for call control from the Base Station (BS) to the Mobile Station (MS).
- **Reverse Control Channel (RCC):** This channel is used for call control from the Mobile Station (MS) to the Base Station (BS).

CHAPTER 4

CELLULAR SYSTEM DESIGNFUNDAMENTALS AND MULTIPLEXING TECHNIQUES

OBJECTIVES

4.1. Draw the block diagram of a basic cellular system.

4.2. Explain the process of call progress in a cellular telephone system

4.3. State the need for hexagonal cell site.

4.4. Explain the concept of Frequency reuse.

4.5. Define the term Cell and cluster

4.6. Explain the capacity of a cellular system

4.7. Define Hand-off in mobile communication

4.8. List the drawbacks of analog cellular system.

4.9. State the need for multiple access techniques

4.10. List the three types of multiple access techniques.

4.11. Explain TDMA and its frame structure

4.12. Explain FDMA and its features

4.13. Explain the concept of spread spectrum technique

4.14. Explain CDMA and its features

4.15. Compare FDMA, TDMA and CDMA

4.1. Draw the block diagram of a basic cellular system.

Cellular telephone systems must accommodate a large number of users over a large geographic area with limited frequency spectrum, i.e., with limited number of channels.

A cellular network is a radio network which allows a number of handheld mobile stations (More commonly known as mobile phone or cell phone) to communicate with each other through voice and text message and access to the internet through mobile phone.

Cellular networks offer a number of advantages:

1. Increased capacity.
2. Reduced power usage.
3. Larger coverage area.
4. Reduced interference from other signals.

- The cellular phone concept was developed and introduced by BELL laboratories in early 1970's. The most successful implementation of cellular concept was AMPS since 1983 in USA.
- A cellular system is generally characterized as a high capacity mobile system in which available frequency spectrum is partitioned into channels which all assigned groups to geographical cells covering a cellular geographical service area.

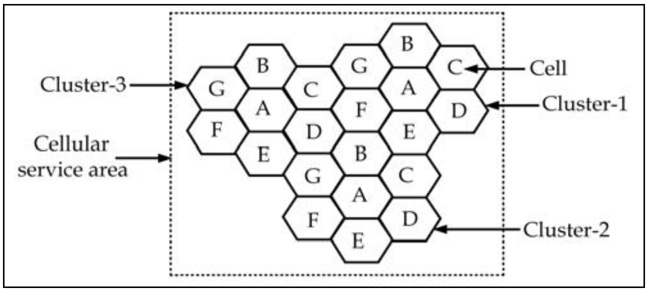


Fig. 4.1.(a) Cellular system divided into cells

- The principal of cellular system is, each cellular service area is divided into small regions called cells. The group of cells is called clusters. Each cell contains the transmitter and receiver with antenna is Base Station (BS) or Base Transceiver Station (BTS). The each user information is transmitted and received through base station.

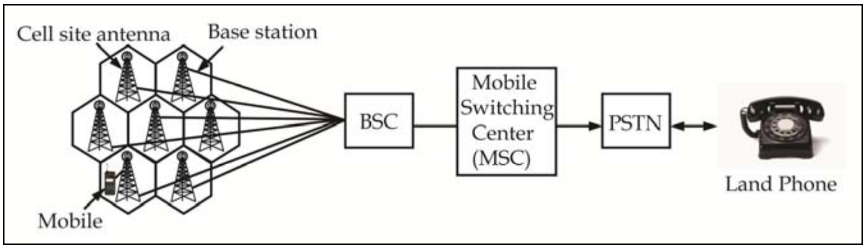


Fig. 4.1.(b) Basic cellular system

(OR)

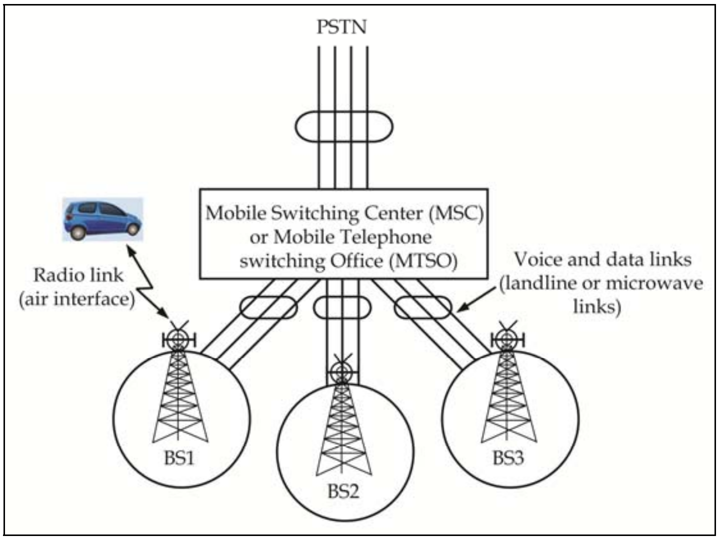


Fig. 4.1.(c) Basic cellular system

- Each base station is controlled by Base Station Controller (BSC). The number of BTS are connected to a Base Station Controller (BSC), the BSC manages the handoff, the mobile moves from one BTS to another BTS during the call in progress. The BSC are connected to the Mobile Switch Centre (MSC), also referred as Mobile Telephone Switching Office (MTSO). Mobile Switching Centre (MSC). The Mobile Switching Centre (MSC) also coordinates the communication between base stations and PSTN.

4.2. Explain the process of call progress in a cellular telephone system

There are three different call setup requirements in mobile communication

1. Mobile to mobile
2. Mobile to fixed
3. Fixed to mobile

Call is made from mobile phone to mobile phone:

- Each mobile has a **mobile identification number** (MIN). When a mobile user wants to make a call, he sends a call request to the reverse control channel. The mobile phone also sends its Mobile Identification number (MIN), **Electronic serial number** (ESN) and the dialed telephone number. The base station receives this data and sends it to the Mobile Switching Centre (MSC).
- The MSC then sends this MIN to all the base stations. The base station transmits this MIN and all the mobiles within the coverage area of that base station receive the MIN and match it with their own. If the MIN matches with a particular MS, that mobile sends an acknowledgment to the BS.
- The BS then informs the MSC that the mobile is within its coverage area. The MSC then instructs the base station to access specific unused voice channel pair. The base station then sends a message to the mobile to move to the particular channels and it also sends a signal to the mobile for ringing. In order to maintain the quality of the call, the MSC adjusts the transmitted power of the mobile which is usually expressed in dB or dBm.

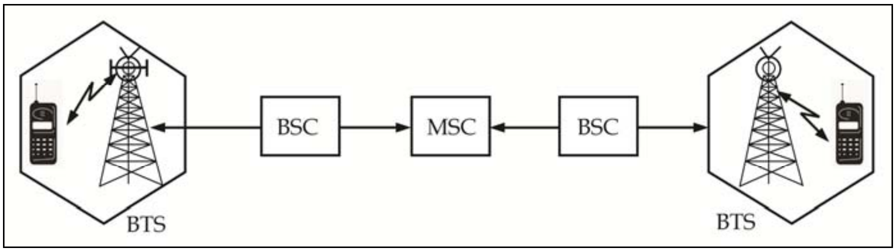


Fig. 4.2.(a) Call is made from mobile phone to mobile phone

- When a mobile moves from the coverage area of one base station to the coverage area of another base station i.e., from one cell to another cell, then the signal strength of the initial base station may not be sufficient to continue the call in progress. So the call has to be transferred to the other base station. This is called handoff.

Call is made from mobile phone to landline phone:

Each mobile has a mobile identification number (MIN). When a mobile user wants to make a call, he sends a call request to the reverse control channel. The mobile phone also sends its Mobile Identification Number (MIN), Electronic Serial Number (ESN) and the dialed telephone number. The base station receives this data and sends it to the Mobile Switching Center (MSC). The MSC validates the request by checking the MIN with the records on its data base. If it is valid, a connection to the called party is made through Public Switched Telephone network (PSTN). Then the MSC requests the base station to move the mobile phone to an unused voice channel so that the conversation can begin.

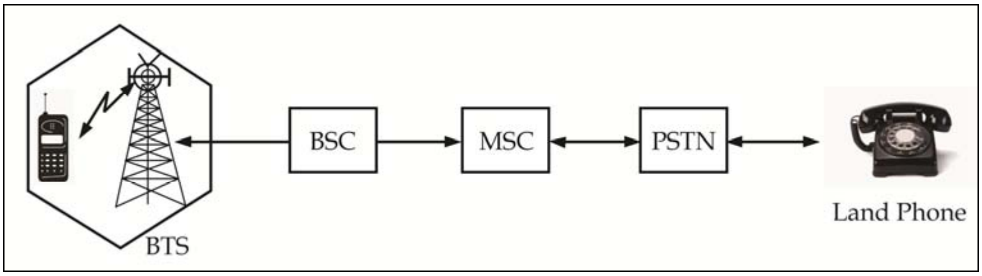


Fig. 4.2.(b) Call is made from mobile to land phone and vice versa

Call is made from landline phone to mobile phone

When a mobile phone user dials a number to make a call. First of all, a call initiation request is sent on the reverse control channel. Along with this request, the mobile phone also sends its Mobile Identification Number (MIN), Electronic Serial Number (ESN) and the dialed telephone number. The base station receives this data and sends it to the Mobile Switching Center (MSC). The MSC validates the request by checking the MIN with the records on its database. If it is valid, a connection to the called party is made through Public Switched Telephone Network (PSTN). Then the MSC requests the base station to move the mobile phone to an unused voice channel so that the conversation can begin.

Additional Information

State The Need For Cellular Concept In Mobile Communication

The cellular concept was developed in response to the limitations of conventional mobile radio services. The main limitations of the previous mobile communication systems are as follows:

1. High – power transmitters were used to cover very large area.
2. Inefficient use of allocated radio spectrum.
3. If a user leaves the coverage area, they had to reinitiate the call on a different frequency channel.

Need for Cellular Concept in Mobile Communication:

1. Cellular telephone system must accommodate a large number of users over large geographic area with limited frequency spectrum.
   The design objective of early mobile radio systems was to achieve a large coverage area by using a single, high powdered transmitter with an antenna mounted on a tall tower. While this approach achieved very good coverage.
2. To restructure the radio telephone system to achieve high capacity with limited radio spectrum while at the same time covering very large areas.

3. The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. It offered very high capacity in a limited spectrum allocation without any major technological changes.
4. Reuse of radio channel in different cells.
5. Reduced power usage.
6. Larger coverage area.
7. Reduced interference from other signals.

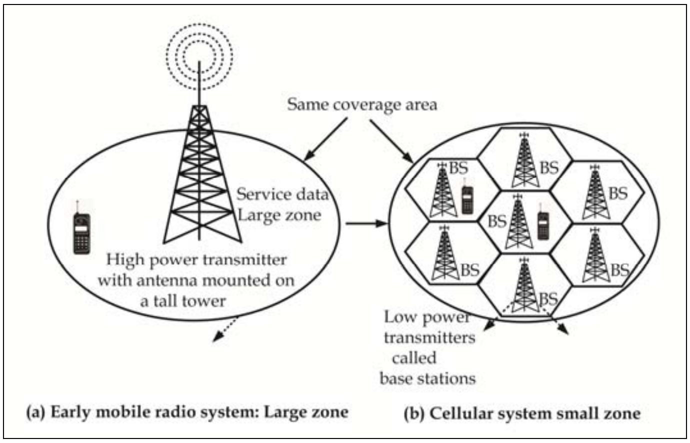


Fig. 4.2. Early mobile radio system and cellular system

4.3. State the need for hexagonal cell site.

1. Shell Shapes

In cellular mobile communication the geometric shape of the cells has to planned since it influences the coverage capacity of the cell site.

The main choices of the cell shapes are as follows.

1. Square
2. Hexagon
3. Circle
4. Triangle

A cell shape has to be selected such that it should be capable of serving even the weakest mobiles within the foot print margin. Comparing all the shapes the hexagon cell shape has the largest area for a given distance between the perimeter points and the center of a polygon. The hexagon shape can closely approximate the circular radiation pattern which is suitable for omni-directional antennas.

But in practical case the shape of the cell is not a perfect hexagon as shown in fig. The ideal are real cal shaped are differentiated. A statistical approach towards the coverage point of view expresses that hexagonal shaped cells suits well than other cell shapes. Thus the hexagon cell shape is widely accepted for mobile communication.

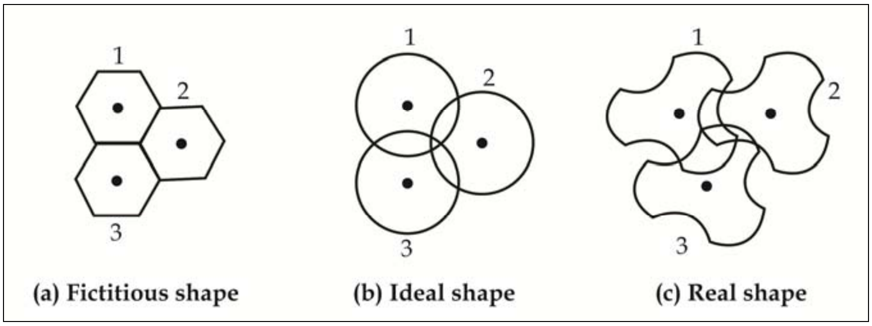


Fig. 2.3.1 Shape of the cells

Need For Hexagonal Cell Site

The geographic area of cellular service area is divided into small hexagonal region called cells. It is the basic unit of a cellular system. These cells collectively provide coverage over larger geographical areas.

Hexagonal cell shape is perfect over square or triangular cell shapes in cellular architecture because it cover an entire area without overlapping i.e. they can cover the entire geographical region without any gaps.

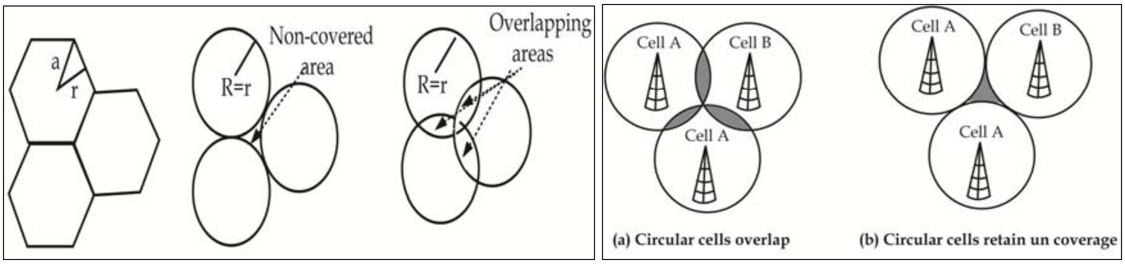


Fig. 4.3. selection of cell

The regular hexagon is favored by system designers for the following reasons:

1. It provides the best approximation to the circular omni-directional radio patterns achieved in practice.
2. It is more economical to use since a hexagonal layout requires fewer cells and hence fewer stations.
3. It combines ease of geometry with the practical realization of overlapping circles.
4. For a given distance between the centre of a polygon and its farthest perimeter points, the hexagon has the largest area, and it almost approximates a circular radiation pattern.
5. A hexagon layout requires fewer cells to cover a given area. Hence, it envisages fewer base stations and minimum capital investment.

6. Other geometrical shapes cannot effectively do this. For example, if circular shaped cells are there, then there will be overlapping of cells.
7. Also for a given area, among square, triangle and hexagon, radius of a hexagon will be the maximum which is needed for weaker mobiles.

4.4. Explain the concept of Frequency reuse.

1. Frequency reuse or frequency planning is a technique of reusing frequencies and channels within a communication system to improve capacity and spectral efficiency.
2. Frequency reuse is the process in which the same set of frequencies (channels) can be allocated to more than one cell. The frequency reuse cells are separated by sufficient distance for reducing co-channel interference. Fig. shows the concept of frequency reuse in a cellular telephone system. The fig. shows a cellular radio coverage area containing three clusters (group of cells). Each cluster has seven cells in it, and the cells with the same letter use the same set of channel frequencies which essentially increases the number of usable cellular channels available three fold. The letter A, B, C, D, E, F and G denote the seven sets of frequencies.

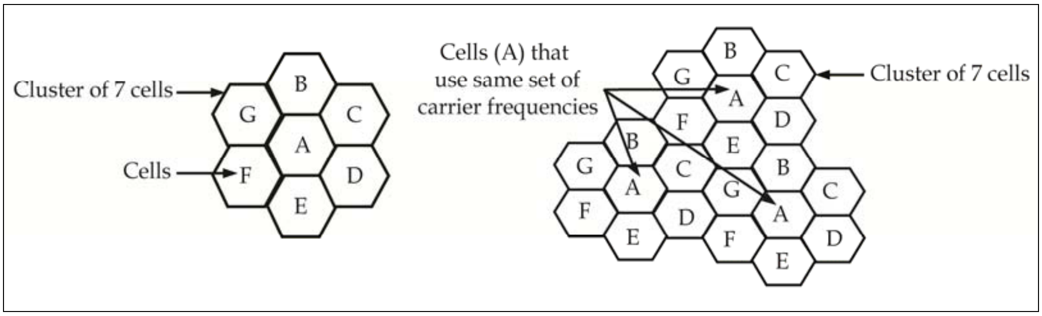


Fig. 4.4. Cellular frequency reuse concept

4.5. Define the term Cell and cluster

Cell: The geographic area covered by a base station is called a cell.

(or)

In cellular mobile communication, each cellular service area is divided into small regions called cells.

(or)

The smallest geographical area in cellular mobile communication is called cell.

Each cell contains the transmitter and receiver with antenna is Base Station (BS) or Base Transceiver Station (BTS). The each user information is transmitted and received through base station.

Cluster: The groups of cells in cellular communication are called clusters.

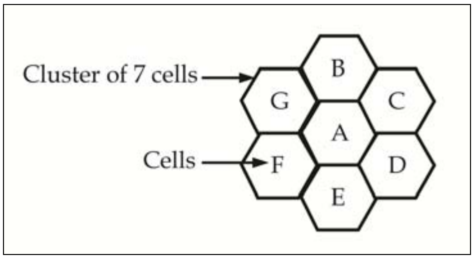


Fig. 4.5.Cell and cluster

4.6. Explain the capacity of a cellular system

Channel capacity for a radio system can be defined as the maximum number of channels or users that can be provided in a fixed frequency band. Radio capacity is a parameter which measures spectrum efficiency of a wireless system. This parameter is determined by the required carrier-to-interference ratio (C/I) and the channel bandwidth B_c.

In a cellular system, the interference at a base station receiver will come from the subscriber units in the surrounding cells. This is called reverse channel interference. For a particular subscriber unit, the desired base station will provide the desired forward channel while the surrounding co-channel base stations will provide the forward channel interference. Considering the forward channel interference problem, let D be the distance between two co-channel cells and R be the cell radius. Then the minimum ratio of D/R that is required to provide a tolerable level of co-channel interference is called the co-channel reuse ratio and is given by [Lee89a]

$$Q = \frac{D}{R} \qquad \text{.................. (1)}$$

The radio propagation characteristics determine the carrier-to-interference ratio (C/I) at a given location, and models presented in chapter 4 and appendix B are used to find sensible C/I values. As shown in fig., the M closest co-channel cells may be considered as first order interference, in which case C/I is given by

$$\frac{C}{I} = \frac{D_0^{-n_0}}{\sum_{k=1}^{M} D_k^{-n_k}}$$

Where n_0 is the path loss exponent in the desired cell, D_0 is the distance from the desired base station to the mobile, D_k is the distance of the k^{th} cell from the mobile, and n_k is the path loss exponent to the k^{th} interfering base station. If only the six closest interfering cells are considered, and all are approximately at the same distance D and have similar path loss exponents equal to that in the desired cell, then C/I is given by

$$\frac{C}{l} = \frac{D_0^{-n}}{6D^{-n}}$$

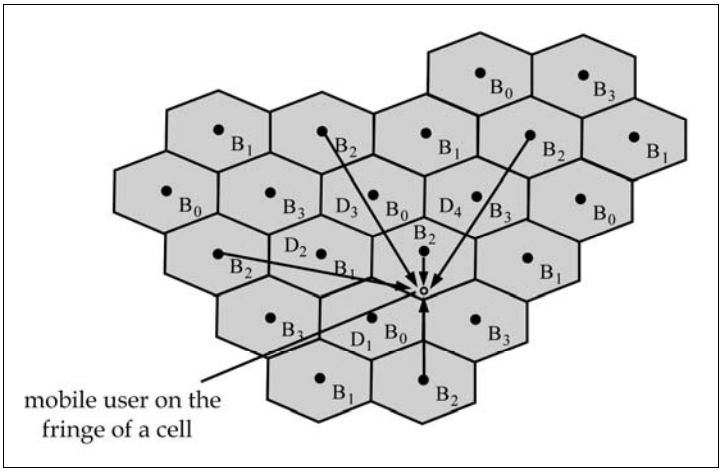


Fig. 4.6. Illustration of forward channel interference for a cluster size of N=4

Fig. 4.6. Illustration of forward channel interference for a cluster size of $N = 4$. Shown here are four co-channel base stations which interfere with the serving base station. The distance from the serving base station to the user is D_0, and interferes are a distance D_k from the user.

Now, if it is assumed that maximum interference occurs when the mobile is at the cell edge $D_0 = R$, and if the C/l for each user is required to be greater than some minimum $(C/l)_{min}$, which is the minimum carrier-to-interference ratio that still provides acceptable signal quality at the receiver, then the following equation must hold for acceptable performance:

$$\frac{1}{6}\left(\frac{R}{D}\right)^{-n} \geq \left(\frac{C}{l}\right)_{min}$$

Thus, from equation (1), the co-channel reuse factor is

$$Q = \left(6\left(\frac{C}{l}\right)_{min}\right)^{\frac{1}{n}} \qquad \text{.................. (2)}$$

The radio capacity of a cellular system is defined as

$$m = \frac{B_t}{B_c N} \quad \text{radio channels/cell} \qquad \text{.................. (3)}$$

Where m is the radio capacity metric, B_t is the total allocated spectrum for the system, B_c is the channel bandwidth, and N is the number of cells in a frequency reuse pattern., N is related to the co-channel reuse factor Q by

$$Q = \sqrt{3N} \quad \text{.................. (4)}$$

From equations (2), (3) and (4), the radio capacity is given as

$$m = \frac{B_t}{B_c \frac{Q^2}{3}}$$

$$= \frac{B_t}{B_c \left(\frac{6}{3^{\frac{n}{2}}} \left(\frac{C}{I} \right)_{min} \right)^{\frac{2}{n}}}$$

when $n = 4$, the radio capacity is given by

$$m = \frac{B_t}{B_c \sqrt{\frac{2}{3} \left(\frac{C}{I} \right)_{min}}} \quad \text{radio channels/cell}$$

4.7. Define Hand-off in mobile communication

Hand Off: When call is in progress, the mobile user (Mobile Station) is transfer from one Base Station to another Base Station without interrupting the call is called **hand off** (or) **handover**. There are two types of hand off's. They are

1. Hard Hand-off
2. Soft Hand-off

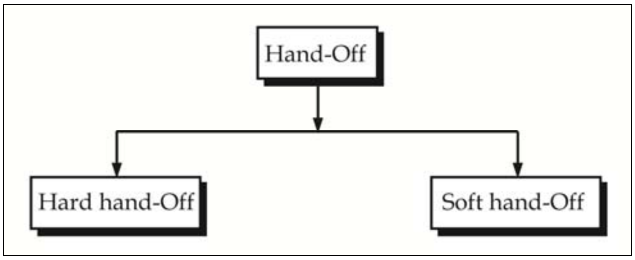


Fig. 4.7.(a) Types of hand offs

Hard Hand – Off:

- A connection that is momentarily broken during the cell to cell transfer is called **hard hand off**.

- Hard hand off is a **break-before-make process** i.e., the mobile unit breaks its connection with one base station before establishing voice communication with a new base station.
- Hard handoff is "break-before-make", meaning that the connection to the old BS is broken before a connection to the new BS is made. Hard handoff occurs when handoff is made between disjointed radio systems, different frequency assignments, or different air-interface characteristics or technologies.
- Usually, the hard handoff can be further divided into two different types: Intracellular and Intercellular handoffs.
- A handoff made within the currently serving cell (e.g. by changing the frequency) is called an intracellular handoff. A handoff made from one cell to another is referred to as an intercellular handoff.

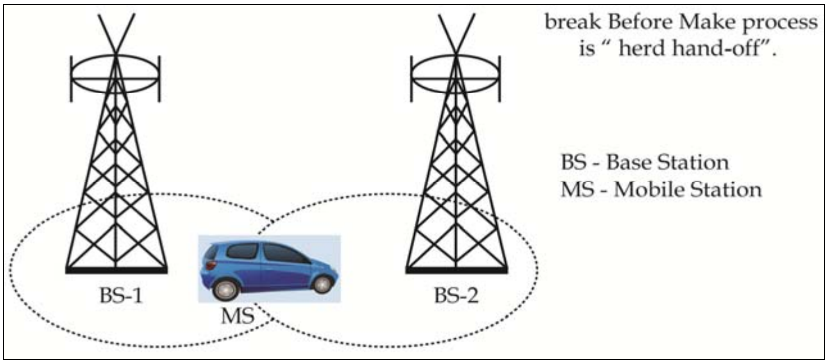


Fig. 4.7. (b) Hard hand-off

Soft Hand – Off:

- A flawless handoff (i.e., no perceivable interruption of service) is called a soft hand off.
- Soft hand is a **"make before break process"** meaning that the connection to the old Base Station is not broken until a connection to the new Base Station is made.
- i.e., a mobile station establishes contact with a new base station before giving up its current radio channel by transmitting coded speech signals to near two base stations simultaneously. Both base stations send their received signals to MSC, which estimates the quality of the two signals and determines when the transfer should occur. A complementary process occurs in the opposite direction. A soft handoff requires that the two base stations operate synchronously with one another.

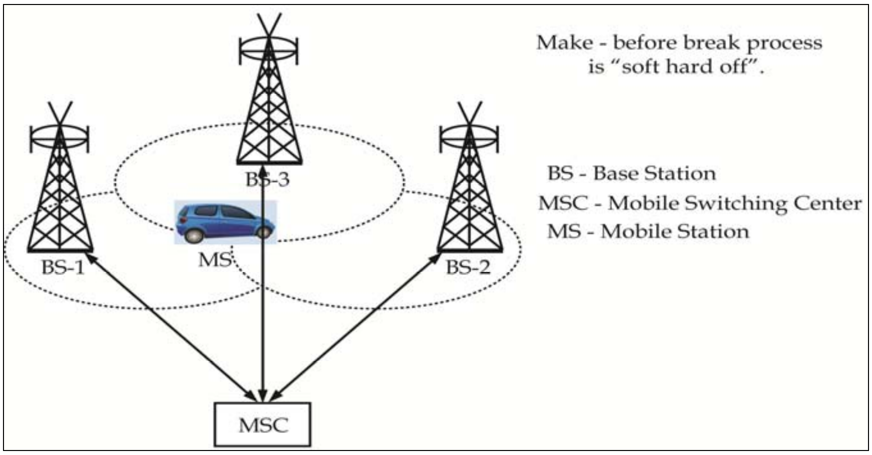


Fig. 4.7. (c) Soft hand-off

4.8. List the drawbacks of analog cellular system.

The drawbacks of analog cellular systems are:

1. Noise is more
2. Quality is less
3. Limited spectrum
4. Limited user capability (or) low calling capacity
5. Inefficient frequency spectrum utilization
6. Poor data communication
7. Security is less
8. Privacy is poor
9. Inadequate protection

Additional Information

In case of mobile communication, which is a form of wireless communication, the only restraint on communication is the bandwidth restraint which means we have a limited frequency range that we can use for communication. Hence, we must somehow, allow multiple users communicate in the same frequency range.

Multiple Access Techniques are ways to access a single channel by multiple users: They provide multiple access to the channel. A "Channel" refers to a system resource allocated to a given mobile user enabling the user to establish communication with the network (other users). Based on the type of channel, we can use a particular multiple access technique for communication.

Multiple access techniques are then deployed so that many users can share the available spectrum in an efficient manner. Multiple access systems specify how signals from different sources can be combined efficiently for transmission over a given radio frequency band and then separated at the destination without mutual interference.

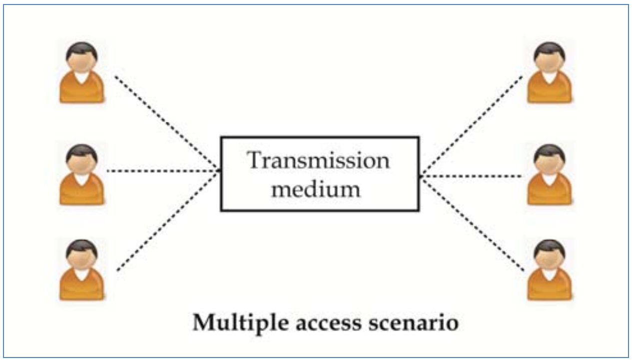


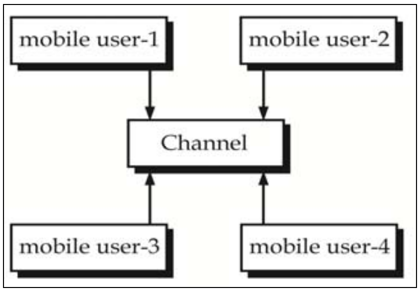
Fig. 4.8. Multiple access scenario

4.9. State the need for multiple access techniques

To allow many mobile users to share simultaneously a finite amount of radio spectrum, in a most efficient way, various technologies have been developed and the goal behind these methods is to handle as many calls as possible in a given bandwidth (i.e., call-handling capacity). This concept is called "multiple access".

Simply, when signals from several different sources (Mobile Station) are combined in a single channel and transmitted to Base Station is known as **Multiple Accessing**.

The choice of multiple access (MA) technology is to share the available scarce bandwidth efficiently among a large number of users which could significantly enhance or lower the service quality delivered to end users.



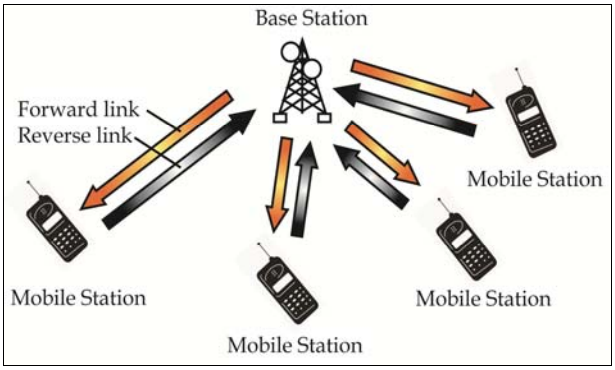


Fig.4.9. Concept of multiple access

For any wireless service, only a fixed limited finite amount of radio spectrum (or number of channels) is available to provide simultaneous communication links to many subscribers in a given service area. Multiple access techniques are used to achieve high subscriber capacity by sharing the available limited spectrum among many subscribers simultaneously, while maintaining the desired quality of communications.

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum. The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users. For high quality communications, this must be done without severe degradation in the performance of the system.

4.10. List the three types of multiple access techniques.

Cellular systems divide a geographic region into cells where a mobile unit in each cell communicates with a base station. The goal in the design of cellular systems is to be able to handle as many calls as possible (this is called capacity in cellular terminology) in a given bandwidth with some reliability. There are mainly three different ways to allow access to the channel.

The three basic multiple access methods currently in use in cellular systems are:

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA)
3. Code Division Multiple Access (CDMA)

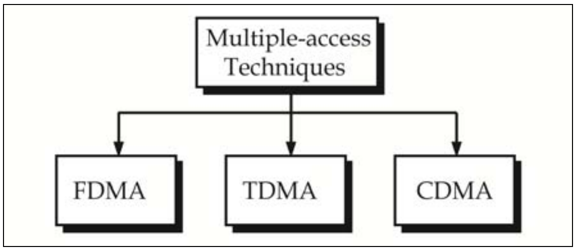


Fig.4.10.(a) Types of multiple access techniques

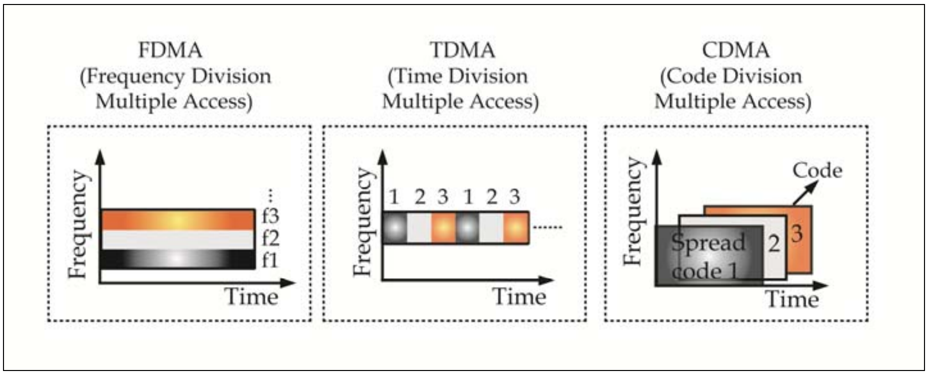


Fig. 4.10.(b)

4.11. Explain TDMA and its frame structure

Time – division multiple access (TDMA) technique refers to allowing a number of subscribers to access a specified channel bandwidth on a time – shared basis. TDMA systems divide the carrier channel bandwidth into time slots, and in each time slot only one subscriber is allowed to either transmit or receive. TDMA utilizes the digital technology with more efficient and complex strategies of sharing the available spectrum among a number of subscribers simultaneously. In TDMA systems, number of subscribers shares the same frequency band by taking their assigned turns in time for transmission or reception.

The major advantage of the TDMA is the flexibility of its digital format which can be buffered and multiplexed efficiently, and assignments of time – slots among multiple subscribers which are readily adaptable to provide different access rates. With TDMA, a base – station controller assigns time slots to subscribers for the requested service, and an assigned time slot is held by a subscriber until it releases it. The receiver synchronizes to the incoming TDMA signal frame, and extracts the time slot designated for that subscriber. Therefore, the most critical feature of TDMA operation is time synchronization.

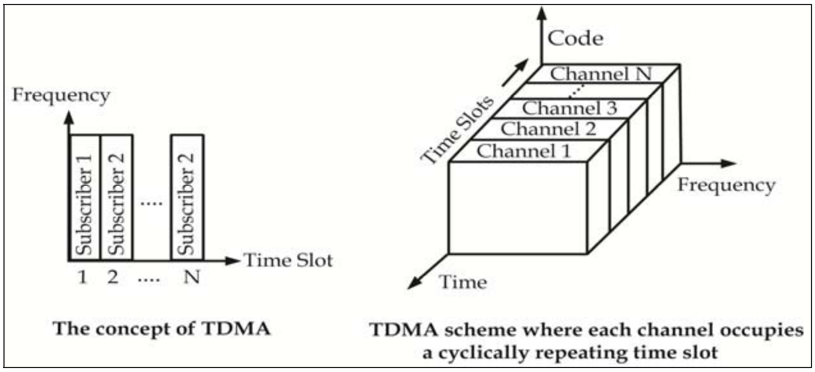


Fig. 4.11.(a) TDMA

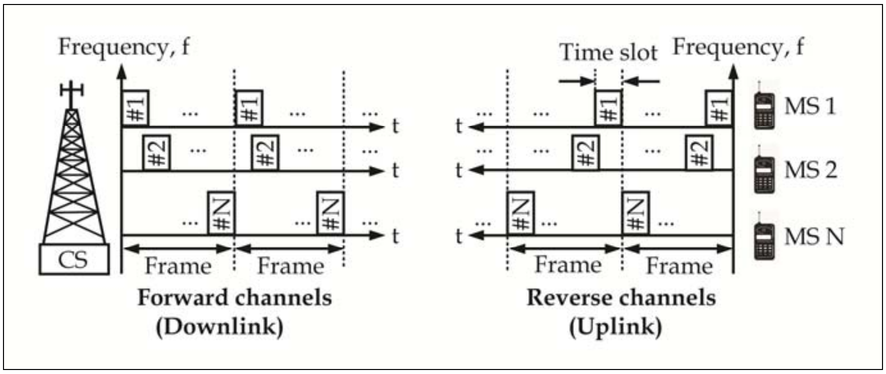


Fig. 4.11.(b) Basic structure of TDMA system

In TDMA, a carrier channel is divided into N number of time slots. These time slots are allocated for each subscriber to transmit and receive information. The number of distinct consecutive time slots is called a frame before these time slots are repeated. Each frame of the TDMA structure contains N number of time slots of equal duration. Information data is transferred and received in the form of TDMA frames. The transmission rate for a digital TDMA channel is typically N times higher than that required for a single channel.

The total number of TDMA time slots that can be provided in a TDMA system is determined by multiplying the number of time slots per carrier channel by the number of channels available and is given by

$$N = \lfloor m \times (B_t - 2B_g) \rfloor / B_c \quad (3.2)$$

Where N is the total number of TDMA time slots in a TDMA system

M is the number of time slots per carrier channel or the maximum number of TDMA subscribers supported on each carrier channel

B_t is the total allocatad spectrum bandwidth in Hz

B_c is the carrier channel bandwidth in Hz

B_g is the guard bandwidth in Hz

Two guard bands, one at the lower end and another at the higher end of the allocated frequency band, are required to ensure that subscribers operating at the edges of the allocated frequency band do not interfere with other wireless communication service operating in an adjacent frequency band.

4.11.1.Tdma Frame Structure

TDMA, frame consists of a number of slots. Each frame is made up of a preamble, an information message, and tail bits. In TDMA/TDD, half of the time slots in the frame information message would be used for the forward link channels and half would be used for reverse link channels. In TDMA/FDD systems, an identical or similar frame structure would be used solely for either forward or reverse transmission, but the carrier frequencies would be different for the forward and reverse links. In general, TDMA/FDD systems intentionally induce several time slots of delay between the forward and reverse time slots for a particular user, so that duplexers are not required in the subscriber unit.

In a TDMA frame, the preamble contains the address and synchronization information that both the base station and the subscribers use to identify each other. Guard times are utilized to allow synchronization of the receivers between different slots and frames. Different TDMA wireless frame structure. The frame is cyclically repeated over time.

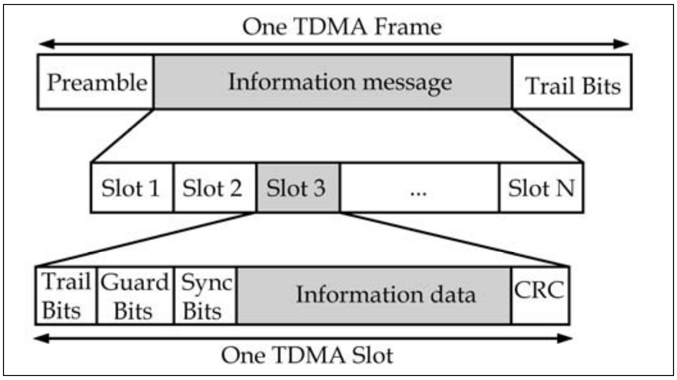


Fig. 4.11.1. One TDMA frame

4.11.2.Features of Tdma

Features of TDMA include the following:

1. TDMA shares a single carrier frequency with several users, where each user makes use of non overlapping time slots. The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth etc.
2. Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).
3. Because of discontinuous transmissions in TDMA, the handoff process is much simpler for a subscriber unit, since it is able to listen for other base stations during idle time slots. An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening on an idle slot in the TDMA frame.
4. TDMA uses different time slots for transmission and reception, thus duplexers are not required. Even if FDD is used, a switch rather than a duplexer inside the subscriber unit is all that is required to switch between transmitter and receiver using TDMA.
5. Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.
6. In TDMA, the guard time should be minimized. If the transmitted signals at the edges of a time slot are suppressed sharply in order to shorten the guard time, the transmitted spectrum will expand and cause interference to adjacent channels.
7. High synchronization overhead is required in TDMA systems because of burst transmissions. TDMA transmissions are slotted, and this requires the receivers to be synchronized for each data burst. In addition, guard slots are necessary to separate users, and this results in the TDMA systems having larger overheads as compared to FDMA.

4.12. Explain FDMA and its features

Frequency division multiple access (FDMA) assigns individual channels to individual users. It can be seen from figure that each user is allocated a unique frequency band or channel. These channels are assigned on demand to users who request service. During the period of the call, no other user can share the same channel. In FDD systems, the users are assigned a channel as a pair of frequencies; one frequency is used for the forward channel, while the other frequency is used for the reverse channel.

In FDMA the available bandwidth is divided into m number of smaller frequency bands called sub-bands. Each station transmits its information continuously on an assigned sub-band. To reduce co-channel interference guard band between two sub-bands is provided.

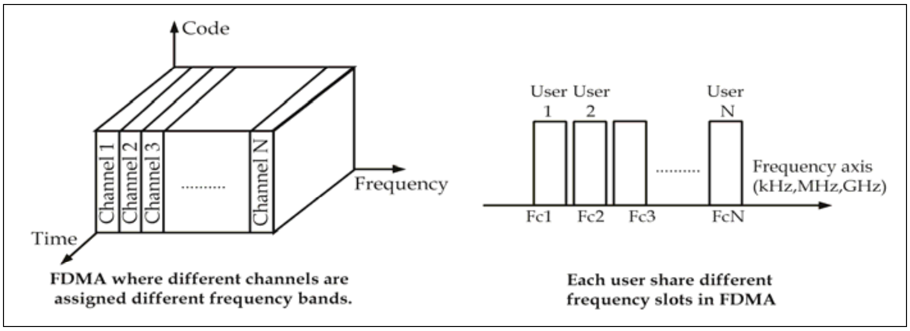


Fig. 4.12.

The number of channels that can be simultaneously supported in FDMA system is given

$$\text{Number of channels, } (N) = \frac{B_t - 2B_g}{B_c}$$

Where, B_t = Allocated frequency spectrum

B_g = Guard band allocated at the edge of frequency spectrum

B_c = Channel bandwidth

4.12.1. Features and Applications of Fdma

The features of FDMA are as follows:

1. The FDMA channel carriers only one phone circuit at a time.
2. If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.
3. After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously.

4. The bandwidth of FDMA channels are relatively narrow (30 kHz in AMPS) as each channel supports only one circuit per carrier. That is, FDMA is usually implemented in narrow band systems.
5. The symbol time of a narrowband signal is large as compared to the average delay spread. This implies that the amount of intersymbol interference is low and, thus, little or no equalization is required in FDMA narrowband systems.
6. The complexity of FDMA mobile systems is lower when compared to TDMA system, though this is changing as digital signal processing methods improve for TDMA.
7. Since FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes (such as synchronization and framing bits) as compared to TDMA.
8. FDMA systems have higher cell site system costs as compared to TDMA systems, because of the single channel per carrier design, and the need to use costly bandpass filters to eliminate spurious radiation at the base station.
9. The FDMA mobile unit uses duplexers since both the transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units and base stations.
10. FDMA requires tight RF filtering to minimize adjacent channel interference.

Applications of FDMA:

1. Walkie – talkies and mobile networks for closed user groups often use FDMA.
2. Another example of FDMA is AM or FM radio broadcasting, where each station has its own channel.
3. Early cellular telephony mostly used FDMA analogue transmission.

4.13. Explain the concept of spread spectrum technique

- Spread spectrum technology means it spreads the signal spectrum over a much wider B.W. i.e., the B.W. of spread spectrum is much larger than information rate. The speed spectrum systems are widely used for transmission of voice and data with more security and secrecy.
- Spread spectrum is a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information; the band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for de-spreading and subsequent data recovery.
- The term **"spread spectrum"** refers to the expansion of signal bandwidth, by several orders of magnitude in some cases, which occurs when a key is attached to the communication channel.

- The spread spectrum signals are characterized by their Pseudo random nature, which makes it very difficult to demodulate (by unauthorized systems).
- ***Advantages of Spread Spectrum are***
    - o To reduce the interference
    - o Low susceptibility to multipath fading
    - o Immunity of jamming
    - o Security of information and secrecy
    - o Low power spectral density
    - o Privacy due to unknown random codes
- Spread spectrum system ability to withstand strong interference. Sometimes to block the communication link for the protection of enemies. For the reason spread spectrum is extensively used in military communication.

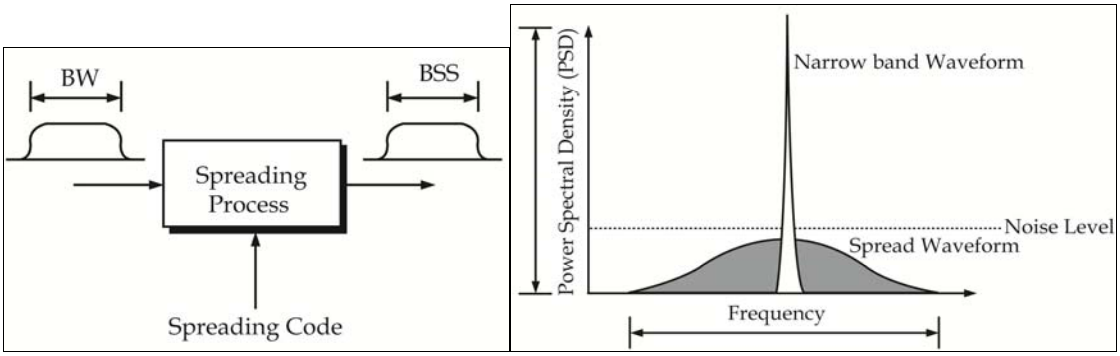


Fig. 4.13.(a) Concept of spread spectrum

B = Required B.W for each station (original B.W. is B)

BSS = After the spreading it is BSS (Spreaded B.W is BSS)

Block Diagram of Spread Spectrum Digital Communication System:

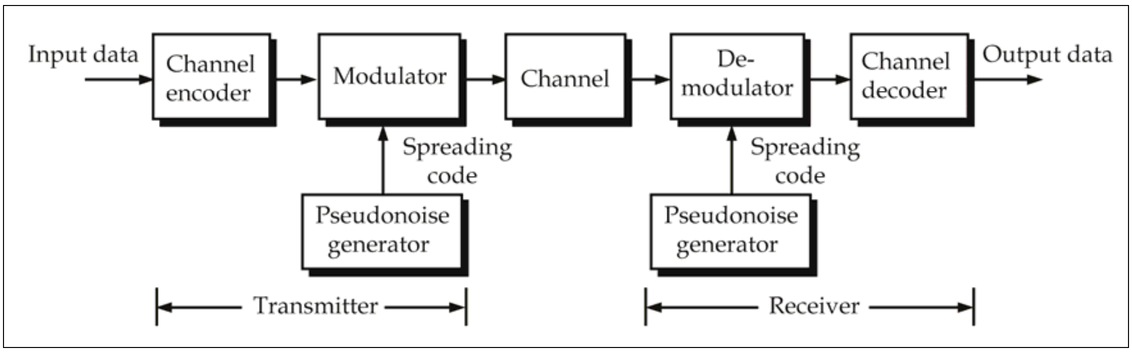


Fig. 3.7(b) Block diagram of spread spectrum communication system

- At the transmitter, the incoming data is encoded by encoder and a Pseudo noise generator generates Pseudo noise (PN) binary valued sequence. The encoder O/P and pseudo noise is given to modulator. The modulator transmits this noise added signal over the channel.
- At the receiving end the signals are demodulated and an identical pseudo noise (PN) generator removes the pseudo noise (PN) from the received signal. The demodulator o/p is fed to a channel decoder to recover the original data.

Types Of Spread Spectrum Systems

There are two types of spread spectrum systems. They are:

1. Frequency Hopping Spread Spectrum (FHSS)
2. Direct Sequence Spread Spectrum (DSSS)

4.14. Explain CDMA and its features

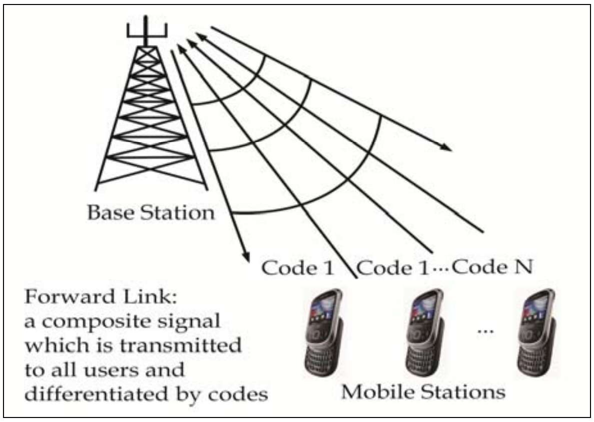


Fig. 4.14.(a) Concept of CDMA

1. With FDMA, earth stations are limited to a specific B.W within a cellular channel or system but have no restricted on what precise time.
2. With TDMA, an earth stations transmission are restricted to a precise time slot but have no restriction on what frequency or B.W. it may use within a specified satellite system (or) channel allocation.
3. **Definition:** With CDMA, there is no restrictions on "time" or 'B.W'. It allows each user to transmit over the entire frequency spectrum all the time.
4. In CDMA, each transmitter to be assigned a different Pseudo noise (PN) sequence. The PN sequence for the transmitter is given only to receiver. The receiver will then receive only the correct transmissions and all over other receivers will ignore these signals.

5. CDMA assigns to each user a unique code sequence that is used to code data before transmission. If a receiver knows the code sequence related to a user, it is able to decode the received data.
6. In CDMA technique, one unique code is assigned to each subscriber and distinct codes are used for different subscribers. This code is employed by a subscriber to mix with each information bit before it is transmitted. The same code is used to decode these encoded bits, and any mismatch in code interprets the received information as noise.
7. The CDMA technique utilizes a wider frequency band for each subscriber. In a CDMA system, different spread-spectrum codes are generated by the PN code generator and assigned to each subscriber, and multiple subscribers share the same frequency, as shown in fig. A basic structure of a CDMA system is shown in fig.

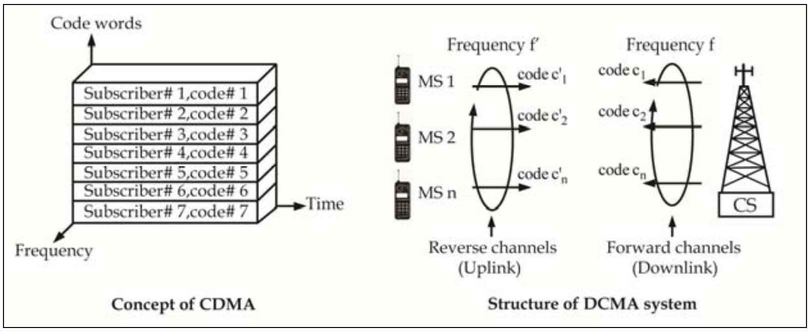


Fig. 4.14. (b) CDMA

Analogy: CDMA simply means communication with different codes. For example, in a large room with many people, two people talk in Chinese if nobody else understood Chinese. Another two people can talk in English if they are the only ones who understand English and so on. In other words, the common channel (the space of the room) can easily allow communication between several couples, but in different languages (codes).

Idea: Let us assume we have 4 users, 1, 2, 3, 4 connected to same channel.

The data from station 1 are d1
2 are d2
3 are d3
4 are d4

The code assigned to First mobile user is C1, second mobile user is C2, third mobile user is C3, fourth mobile user is C4.

Mobile user 1 multiplies its data by its code to get d1C1
Mobile user 2 multiplies its data by its code to get d2C2
Mobile user 3 multiplies its data by its code to get d3C3

Mobile user 4 multiplies its data by its code to get d4C4

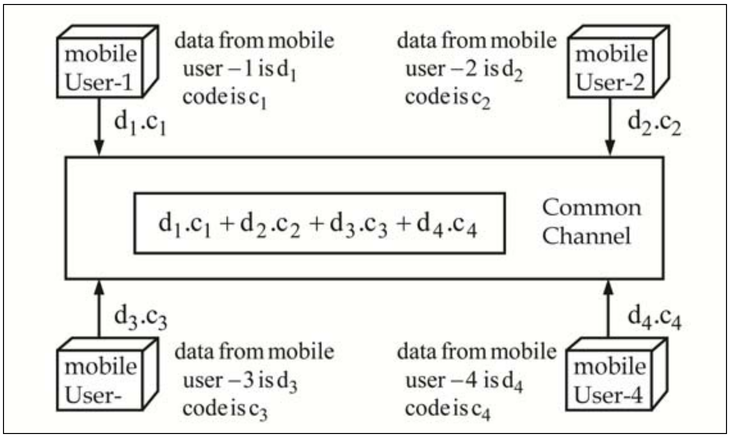


Fig. 4.14.(c) Concept of CDMA

The data that go on the channel are the sum of all these terms as shown in fig. Any mobile user that wants to receive data from one of the other three multipliers the data on the channel by C1 the code of sender.

Example: Suppose if we want to station 1 data, multiplies the data on the channel by C1 the code of station 1.

Data of mobile user 1 = $(d1.C1 + d2.C2 + d3.C3 + d4.C4).C1$

$$= d1.C1.C1 + d2.C2.C1 + d3.C3.C1 + d4.C4.C1$$

$$= d1.4 + 0 + 0 + 0$$

$$= 4\,d1$$

Note:

- In above 4d1, the '4' indicates the numbers of station are used.
- If we multiply each code by another, we get '0'.
- If we multiply each code by itself, we get '4', i.e. numbers of mobile users are used.

$$C1.C1 = 4,\ C1C2 = 0,\ C1C3 = 0,\ C1.C4 = 0$$

4.14.1. Advantages and Disadvantages of Cdma

Advantages of CDMA

1. Each station can use entire bandwidth at any time.
2. Noise rejection capability of CDMA is better.
3. High immunity for interference and jamming.
4. CDMA does not require any time synchronization among the stations.
5. High capacity than TDMA and FDMA.
6. CDMA consumes less power and is able to produce a reasonable call with lower signal levels, while GSM require more power and is not able to produce a reasonable call with low signals.

Disadvantages of CDMA

1. The system is little complicated.
2. The overall performance degrades with increase in number of users.
3. Low through put efficiency.

4.14.2. Applications of Cdma

1. CDMA is used for wireless systems with fixed base station and many mobile stations at varying distance from it.
2. CDMA is used in satellite systems so that many signals can use a transponder; making it more efficient.
3. CDMA is used in digital cellular telephone services because it permits more users to occupy a given band.
4. Wideband CDMA (W-CDMA) is used for digital cell phone systems to accommodate voice transmission along with high speed data, FAX and internet communication.
5. CDMA is ideally suited for military application because of immunity to noise.

4.14.3. Features of Cdma

1. High immunity to interference.
2. Multipath fading is reduced because the signal is spread over the spectrum.
3. High security.
4. Privacy.
5. Channel data rates are very high.
6. Soft handoff is provided.
7. Each user can use entire bandwidth.
8. Noise rejection capability of CDMA is better.
9. Does not require any synchronization.
10. Many users of the CDMA system share the same frequency.

4.15. Compare FDMA, TDMA and CDMA

S.No.	Parameter	FDMA	TDMA	CDMA
1.	Signal Separation	Separated in frequency slots	Separated in time slots	Separated in addressing schemes (codes)
2.	Complexity	Less	More	More
3.	Suitability	Analog signals	Digital signals	Digital signals
4.	Interference	Yes	No	No
5.	B.W.	Limited	More	More

6.	Security	Less	More	More
7.	Capacity	Low	Low compared to CDMA	High
8.	Restriction	Frequency	Time	No restriction
9.	Applications	Satellite and mobile communication	Satellite and mobile communication	Satellite and mobile communication
10.	Handover	Hard	Soft	Soft

CHAPTER 5

DIGITAL CELLULAR MOBILE SYSTEM

OBJECTIVES

5.1. List the features of digital cellular system.

5.2. Explain the Global system for mobile communication (GSM) with block diagram

5.3. List various interfaces in GSM architecture

5.4. List the service and security aspects of GSM.

5.5. List the advantages of GSM

5.6. List the draw backs of GSM system.

5.7. List the features of GPRS and EDGE

5.8. Compare the features of GSM, GPRS and EDGE systems

5.9. List the salient features of 3G system

5.10. List the advantages of 3G over earlier versions

5.11. List the basic concepts of 4G aspects

5.12. Explain IP Multimedia Subsystem (IMS)

5.13. Give the list of different IMS applications

5.0. Introduction

Digital cellular systems have many features such as improved communication quality due to the use of various digital signal processing technologies, new services (e.g. non-telephony services), improved ciphering, greater conformity with digital networks, and efficient utilization of the radio spectrum.

The development of digital cellular system was triggered by standardization efforts in Europe, which was home to many competing analogue systems. In Europe, analogue cellular systems were using different frequency bands and schemes which made interconnection impossible across national borders. In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) established the global system for mobile (GSM) and developments were carried out under the leadership of the European Telecommunications Standards Institute (ETSI). The GSM-based services were launched in 1992.

Digital transmission has a number of advantages over analogue transmission:

- It economizes bandwidth.
- It allows easy integration with personal communication system (PCS) devices.
- It maintains superior quality of voice transmission over long distances.
- It can use lower average transmitted power.

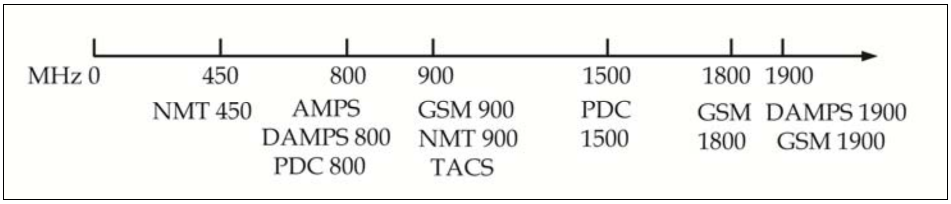


Fig. 5.0(a)

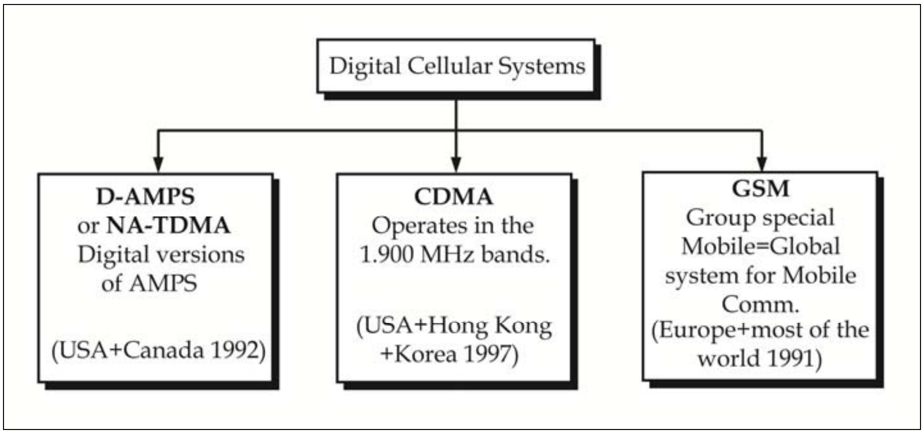


Fig. 5.0(b)

In GSM, time division multiple access (TDMA) technique is used for transmitting voice and data through air interface. TDMA is a digital technology and support data rates in the range between 64 kbps and 120 Mbps. As mentioned in the standard it supports roaming service, which makes it possible to use one GSM mobile phone number in another GSM network.

5.1. List the features of digital cellular system.

- The analog mobile systems suffered from interference problems and inability to accommodate the growing demand for mobile services.
- Digital cellular system uses the same radio technology as analog cellular system. Analog systems do not completely utilize the signal between the MU and cellular network. Analog signals can't be compressed as easily as a digital signal.

5.1.1. Features of Digital cellular system

1. Small cells
2. Frequency reuse
3. Small, battery-Powered handset
4. Performance of handovers
5. High level of security through encryption
6. Reduction of mobile unit size
7. Reduction of power requirements
8. Increased battery life

5.1.2. Advantages of Digital cellular Telephone system

The advantages of digital cellular telephone systems are:

1. Increase in capacity
2. Longer battery life
3. Less RF transmission power
4. Wider area coverage (Global coverage)
5. Higher level of security
6. Information privacy through data encryption
7. ISDN compatibility that offers wide range of services
8. Operates in micro cell environment

Additional Information

Global System For Mobile Communication (Gsm)

- GSM is a second generation (2G) cellular system that was developed to solve problems in the first cellular systems in Europe. GSM was first world digital cellular system. The most successful mobile digital communications system in today's world is GSM. GSM (Global System for Mobile Communication) is first digital mobile telephony system in the world that is widely used in Europe and other parts of the world.

- Mobile services based on GSM technology were first launched in Finland in 1991. Today, more than 690 mobile networks provide GSM services across 213 countries and GSM represents 82.4% of all global mobile connections.
- Before GSM there are many existing analogue mobile networks in Europe, which were based on similar standards, however they were all running on slightly different carrier frequencies. To avoid this problem in the second generation mobile phone system, the group special mobile (GSM) was created in 1982. Now the system developed by this group is known as global system for mobile communications (GSM). As 2001, 350 million GSM subscribers worldwide.
- The primary goal of GSM was to provide a mobile phone system that would allow it's users to use their mobile phone in any European country i.e. roaming. This system would have to provide voice services comparable with ISDN and other PSTN systems
- GSM, together with other technologies, is part of the evolution of wireless mobile telecommunications that includes High Speed Circuit – Switched Data (HSCSD), General Packet Radio System (GPRS), Enhanced Data GSM Environment (EDGE), and Universal Mobile Telecommunications Service (UMTS).
- GSM was initially developed in Europe using the 890 – 915 MHz band for the uplinks and the 935 – 960 MHz band for the downlinks. This version is commonly known as GSM 900, and later version GSM 1800 (1710 – 1785 MHz uplink, 1805 – 1880 MHz downlink) which commonly known as DCS (Digital Cellular System).
- GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band. GSM uses time division multiple access (TDMA) and FDMA.

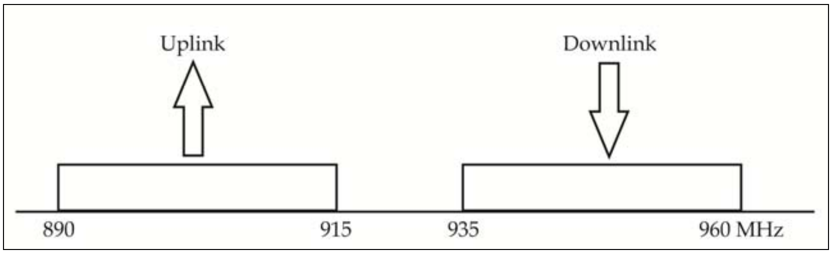


Fig. 5.1.

- GSM was first introduced into the European market in 1991. By the end of 1993, several non – European countries in South America, Asia and Australia has adopted GSM and the technically equivalent offshoot, DCS 1800, which supports Personal

Communication Services (PCS) in the 1.8 GHz to 2.0 GHz radio bands recently created by governments throughout the world.

5.1.3. Characteristics of Gsm

- **Communication:** Mobile, wireless communication, support for voice and data services.
- **Total Mobility:** International access, chip – card enables use of access points of different providers.
- **Worldwide Connectivity:** One number, the network handles localization.
- **High Capacity:** Better frequency efficiency, smaller cells, more customers per cell.
- **High Transmission Quality:** High audio quality and reliability for wireless, uninterrupted phone calls at higher speeds (e.g., from cars, trains).
- **Security Functions:** Access control, authentication via chip – card and PIN.

5.2. Explain the Global system for mobile communication (GSM) with block diagram

The GSM system architecture consists of three major interconnected subsystems that interact among one another.

1. Radio Sub System (or) Base Station Subsystem (BSS)
2. Network Switching Subsystem (NSS)
3. Operational Support Subsystem (OSS)

1. Radio Sub System (RSS):

The BSS is sometimes known as the Radio Sub System because it provides and manages radio – frequency transmission paths between Mobile Stations (MS) and Mobile Switching Center (MSC).

Radio Sub System (RSS) = MS + Base Station Subsystem (BSS)

= MS + (Base Transceiver Station (BTS) + Base Station Controller (BSC))

- **Mobile Station:** The mobile station consists of two units mobile handset with battery and Subscribers Identity Module (SIM). The mobile station is also subsystem but it is usually considered to be part of the Radio Sub System (RSS).
- **Base Transceiver Station (BTS):** It consists of antennas that transmit and receive to directly communicate with the mobiles. The BTS's are connected to BSC.
- **Base Station Controller (BSC):** Each BSC controls several BTS's. It manages channel allocation and handoff of calls from one BTS to another BTS. The BSC's are connected to MSC. It provides path from MS to MSC.

2. Network Switching Subsystem (NSS):

It provides main control and interfacing for the whole mobile network. It allows MSC's to communicate with other telephone networks such as Public Switched

Telephone Network (PSTN) and Integrated Service Digital Network (ISDN). The NSS consists of MSC, HLR, VLR and AUC.

3. Mobile Switching Centre (MSC):

- Mobile Switching Center (MSC) is heart of the entire network connecting the fixed line networks (ISDN, PSTN etc) to the mobiles. It manages all call – related functions and billing information.
- The Mobile Switching Center (MSC) is a telephone exchange that makes the connection between mobile users within the network, from mobile users to the public switched telephone network (PSTN) and from mobile users to other mobile networks.
- Switching center which coordinates the routing of calls in a large service area. In a cellular radio system, the MSC connects the cellular base stations and the mobiles to the PSTN. An MSC is also called a mobile telephone switching office (MTSO).

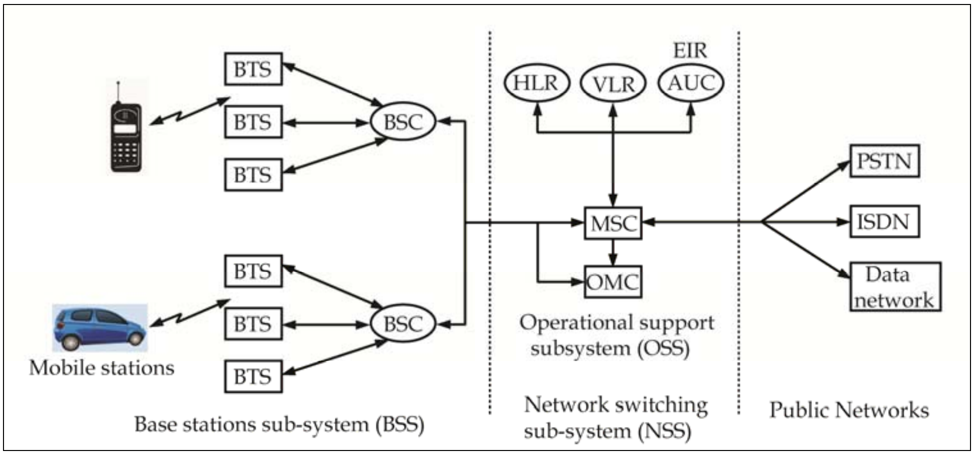


Fig. 5.2. GSM reference architecture

- MSC performs the following functions:
    - Coordinates the routing of calls in large service area.
    - Call setup.
    - Supervision and release.
    - Call routing.
    - Billing information.
    - Manage connection to BSS, other MSC and PSTN.
    - Management of radio resources during a call.
    - It is connected to HLR and VLR for subscriber identification and for routing incoming calls.
    - It is also connected to AUC for authentication.

- It communicates with the BSS, routing calls and controlling them as required.
- It contains databases detailing the last known locations of the mobiles.
- It also contains facilities for authentication centre allowing mobiles onto the network.
- It contains facilities to generate billing information for individual accounts.

- **Home Location Register (HLR):** All the subscriber data is stored in HLR. It has a permanent database of all the registered subscriber. When a user switches ON the phone, the phone registers with the network and from there it is possible to determine which BTS it communicates with so that the incoming calls can be routed appropriately.
- **Visitor Location Register (VLR):**An active subscriber is registered in VLR. It has temporary database of all the active subscribers used for their call routing. The MSC asks VLR before routing incoming calls.
- **Authentication Centre (AUC):** The AUC is a protected database that contains the secret keys also contained in the users SIM card. It is used for the authentication. Authentication is a process to verify the subscriber SIM. Secret data and verification algorithms are stored in the AUC. The AUC and HLR combine to authenticate the subscribers. Subscriber authentication can be done on every call, if required.
- AUC contains a Equipment Identity Register (EIR). All the subscribers mobile handset data is stored in EIR. Each mobile equipment has a International Mobile Equipment Identity (IMEI). This IMEI is installed in the equipment and is checked by the network during registration. EIR identifies stolen or fraudulent phones that identify the data that does not match information contained in either the HLR or VLR.

4. Operational Support Subsystem (OSS):

It supports one or several operation and maintenance centres (OMC), which is used to monitor and maintain the performance of each MS, BSC and MSC's within a GSM system

5.3. List various interfaces in GSM architecture

Various interfaces in GSM architecture are:

1. **'Air' Interface or 'Um' Interface** : Between Mobile Station (MS) and BTS.
2. **'A-bis' Interface** : Between BTS and BSC.
3. **'A' Interface** : Between BSC and MSC.
4. **SS7 Interface or 'O' Interface** : Between MSC and PSTN.

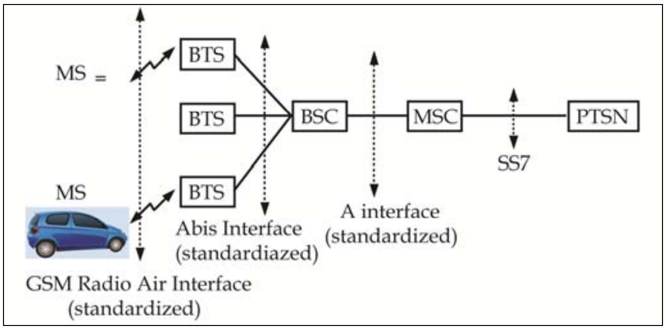


Fig. 5.3. Various interfaces in GSM

5.4. List the service and security aspects of GSM.

5.4.1. GSM Service Aspects

GSM stands for Global System for Mobile Communication. It is a second generation (2G) cellular system. GSM offers a wide range of services, including telephony, emergency calling, data up to 14.4 kbps, fax up to 9.6 kbps, SMS and others. In addition, it also offers a rich set of supplementary services.

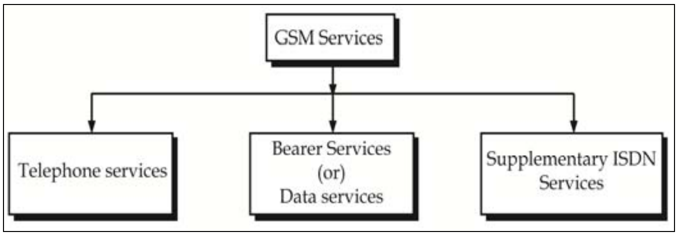


Fig. 5.4. GSM services

GSM Services: GSM services are classified into three categories.

- Telephone Services
- Bearer Services or Data Services
- Supplementary ISDN Services

Telephone Services:

- With GSM analog speech signals are digitally encoded and then transmitted through the network as a digital data stream.
- Voice calls, short text messages, emergency calling, fascimile, standard mobile.

Bearer Services or Data Services:

- Data services or Bearer services are used through a GSM phone to receive and send data is the essential building block leading to widespread mobile internet access and mobile data transfer.
- These are included computer – computer communication.
- It supports packets switching with data rates from 300 bps to 9.6 kbps.

- Short message service (SMS), a non voiceless service, offers customers to send short message not exceeding 160 characters. Today more than 30 billion short messages are transferred worldwide per month.
- The important of services offered by telephone is audio service, this involves mechanism for secure, high quality service and lossless transmission of data. To offer high – quality digital voice transmission, at least the typical bandwidth of analog phone systems should be of 3.1 KHz.
- Another important service is Emergency Number. This service is offered free of cost to the customers to assist in the case of emergency situations.

Supplementary ISDN Services:

In addition to tele and bearer services, GSM providers can offer supplementary services. Similar to ISDN networks, these services offer various enhancements for the standard telephony services.

- These are digital in nature.
- Call forwarding.
- Call maintaining up to user requirement.
- Call closing.
- Caller identification.
- SMS.
- Call waiting.
- Call-hold service.
- Conferencing.

5.4.2. Security Aspects of GSM

The main aim of GSM is for

- Protecting the network against unauthorized access (fraud).
- Protecting eavesdropping (hear secretly) for privacy of the mobile subscriber.
- In GSM the security procedures prevent unauthorized parties from tracing the identity and location of the subscribers as they roam within or outside the home network and also prevented eavesdropping on subscriber's communication.
- To protect the identity and location of the subscriber, the appropriate radio signaling (control) channels are ciphered (secret code) and used a temporary mobile subscriber identity (TMSI) instead of actual identity i.e., international mobile subscriber identity (IMSI) over radio path.
- In GSM systems, each mobile user is provided with a subscriber identity module (SIM). Each SIM contains the IMSI and secret authentication keys and algorithms [Individual subscriber authentication key (ki) (ciphering key (kc) and algorithm (A8), the authentication algorithm (A3) and the encryption algorithm (A5) are programmed into the SIM by the SIM operator].

- The encrypted algorithm (A3, A5 and A8) are present in GSM handset and also in GSM networks.
- The authentication center (AUC) is responsible for generating the sets of RAND (Random Number), SRES (Signed Response) and kc (ciphering key) which are stored in the HLR and VLR for providing authentication check and provide appropriate ciphering key (kc) to the BTS for encryption / decryption of radio path.
- The AUC performs the basic generation of the RAND, signed responses SRES, and cipher key kc for each IMSI, then forward this information to the HLR, then current VLR then requests the suitable values for the RAND, SRES and the kc from the HLR.
- For authentication the VLR sends the random value RAND to the SIM. Each side, the GSM network and the subscriber module, must perform the same operation with the RAND and the ki. The MS sends back the SRES generated by the SIM, the VLR can now compare both values. If the value produced by the SIM and the VLR match then the user is granted to access the GSM network, however if they do not match then the subscriber is refused access to the network.

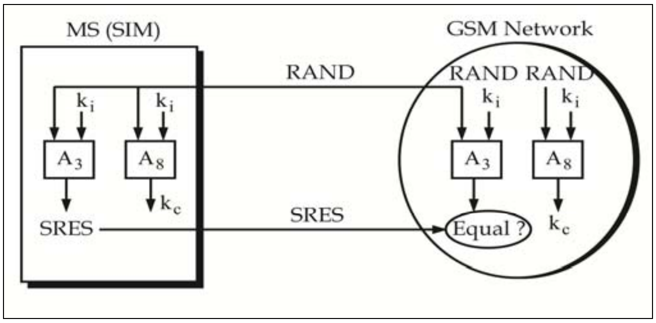


Fig. 5.4. Security checking in GSM

5.5. List the advantages of GSM

Advantages of GSM are:

1. GSM uses digital technology while AMPS uses analog technology.
2. Security against fraud and eavesdropping.
3. International roaming capability in over 213 countries.
4. Improved battery life.
5. Efficient network design for less expensive system expansion.
6. Efficient use of spectrum.
7. Voice is encoded in digital.
8. GSM carry both voice and data.
9. GSM offers advanced features such as short messaging, call forwarding, call waiting, caller ID etc.

10. GSM offers wide variety of handsets and accessories.

11. High stability mobile fax and data at up to 9600 baud.

12. The availability of subscriber identity modules allows users to switch networks and handsets.

5.6. List the draw backs of GSM system.

1. Each radio channel uses a frequency guard band, which is inefficient.
2. Complex frequency planning is required for avoiding a co-channel and an adjacent channel interference.
3. It uses a combination of FDMA and TDMA. A time slot has to be given as a time guard. So, every time a slot requires a guard band before and after so as not to emerge into the next adjacent time slot, making it inefficient. A time slot is occupied even when there is a pause in the speech.
4. In case of GSM, SIM cards, individual authentication keys of the users are stored in the authentication centres. Any person with the right and qualifications to access to authentication center can manipulate these to impersonate that mobile user.
5. Security algorithms used in GSM e.g., A3, A5 and A8 are all undisclosed algorithms. But researchers have proved that these algorithms cannot guarantee 100% security.
6. Pulse nature of TDMA transmission used in 2G interferes with some electronics, especially certain audio amplifiers. 3G uses W-CDMA now.
7. GSM has a fixed maximum cell site range of 35 km, which is imposed by technical limitations.
8. Many of the technology are patented and should be license from Qualcomm.
9. When customers using particular sites going up and the range of the sites goes down.

5.7. List the features of GPRS and EDGE

5.7.1. FEATURES OF GPRS

1. The most popular 2G (second generation) technology is GSM (Global System for Mobile Communication) which supports eight time slots for each 200 KHz radio channel. The maximum data of GSM is 9.6 Kbps, this data rate is very low, which is too slow for rapid email and internet browsing applications.
2. GPRS (General Packet Radio Service) is a 2.5G technology which has much higher data rates than GSM. GPRS is a enhanced technology of GSM. GSM technology uses a circuit switching but GPRS is a packet switched network. GPRS supports data rates upto 171.2 Kbps. It is used for voice and data applications. Email and internet browsing is very high compared to GSM. Implementation of GPRS requires the GSM operator to install new routers and internet gateways at base stations along with new softwares, that's why GPRS supports higher data rates than GSM.

FEATURES OF GPRS

1. **High Data Rate:** The maximum data of GSM is 9.6 Kbps. GRPS has much higher data rates than GSM. GPRS supports data rates upto 171.2 Kbps.
2. **Technology:**2.5 G
3. **Speed of Access:** High compared to GSM. GPRS allows information to be transmitted more quickly and efficiently.
4. **Modulation Technology:** GPRS uses GMSK (Gaussian Minimum Shift Keying).
5. **Channel B.W:** 200 KHz
6. **Switching Network:** GSM is circuit switching. GPRS is packet switching which means that multiple users share the same transmission channel.
7. **Provide New and Better Applications:** It is used for voice and data applications, length of SMS high compared to GSM. It provides Email and Internet Browsing and is very high compared to GSM. GPRS supports file transfer and home automation (control in-house appliance remotely).
8. **Spectrum Efficiency:** GPRS services are used to specially when a user is sending or receiving data. GPRS users can potentially share the same bandwidth and be served from a single cell, the area covered by a base station.

Note: GMSK is a form of modulation used in variety of digital radio communication systems. It has advantages of being able to carry digital modulation while still using the spectrum efficiently. One of the problems with other forms of phase shift keying is that the sidebands extend outwards from the main carrier and these can cause interference to other radio communications systems using nearby channels.

5.7.2. FEATURES OF EDGE

The 2.5G improvement to GSM is EDGE. Originally this acronym stood for Enhanced Data Rates for GSM Evolution, but now it translates into Enhanced Data rates for Global Evolution as the EDGE idea can also be used in systems other than GSM. The idea behind EDGE is a new modulation scheme called Eight-Phase Shift Keying (8PSK). It increases the data rates of standard GSM up to threefold.

EDGE was designed specifically as an upgrade to GPRS for integration into GSM network starting from the GSM community as a path of 3G. It uses the same basic GSM infrastructure with the difference being that it can use 8-PSK modulation in addition to the GMSK.

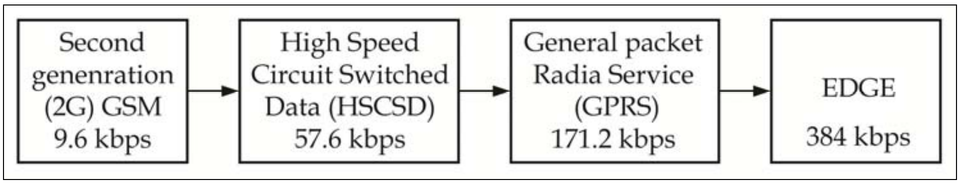


Fig.5.7. Upgrades in GSM

GMSK for a low data rate (8.8 – 17.6 Kbps) or 8-PSK for a high data rate (22.4 – 59.2 Kbps) for each time slot. According to the level of error correction needed for the application every mobile users can adopt whatever MSC is suitable without the error protection and eight time slots taken when it theoretically connects with $8 \times 59.2 = 547.2\,\text{Kbps}$. A minimum error control and network considerations limit the throughput at 384 Kbps. It requires new hardware (routers, gateways) and software updates at the base stations.

EDGE (Enhanced Data rates for GSM Evolution) is a more advanced upgrade to the GSM standard and requires the addition of new hardware and soft wares at existing base stations.

EDGE is sometimes referred to as EGPRS (Enhanced GPRS). The speech of EDGE is more than GPRS. For this, EDGE technology requires additional network architecture, namely GGSN and SGSN.

GGSN: GGSN stands for Gateway GPRS Support Node. It is connects to packet switched networks such as internet and other GPRS networks.

SGSN: SGSN stands for Serving GPRS Support Node. It provides packet switched link to mobile stations.

To achieve higher data rates in EDGE, the modulation format can be changed from GMSK (Gaussian Minimum Shift Keying) to 8-PSK (8-Phase Shift Keying), 8-PSK modulation provided a significant advantage in being able to transfer 3-bit per symbol there by increasing the maximum data rate.

FEATURES OF EDGE

1. **Higher Data Rate:** The maximum data of EDGE is 384 Kbps.
2. **Technology:**2.5G and sometimes called 2.75G.
3. **Speed of Access:** High compared to GPRS and allows information to be transmitted more quickly and efficiently than GPRS.
4. **Modulation Technique:** GSM and GPRS uses GMSK but which has low data rate. EDGE technology uses 8-PSK which has 3 times data rate compared to
5. **Channel B.W:** 200 KHz
6. **Switching Network:** EDGE is a Packet Switching which means that multiple users share the same transmission channel.
7. **Provides More Applications:** It is used for voice and data applications. Voice transfer in digital format. It supports SMS, Image Sharing, Email, Internet Browsing, especially Video Calling.
8. **High Speed Internet:** EDGE technology provides High Speed Internet on Mobile.

5.8. Compare the features of GSM, GPRS and EDGE systems

S.No.	Parameter	GSM	GPRS	EDGE
1.	Data rate	9.6 Kbps	171.2 Kbps	384 Kbps
2.	Speed	Low	Medium	High
3.	Technology	2G	2.5G	2.5G and Sometimes called 2.75G
4.	Modulation	GMSK	GMSK	8-PSK
5.	Channel B.W	200 KHz	200 KHz	200 KHz
6.	Switching Network	Circuit Switching	Packet Switching	Packet Switching

5.9. List the salient features of 3G system

1. 3G, short form of third generation, is the third generation of mobile telecommunications technology. This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications–2000(MT–2000) specifications by the International Telecommunication Union. 3G finds application in wireless voice telephony, mobile internet access, fixed wireless internet access, video calls and mobile TV.
2. 3G telecommunication networks support services that provide an information transfer rate of atleast 200 Kbits/s. Later 3G releases, often denoted 3.5G and 3.75G also provide mobile broadband access of several Mbits/s to smart phone and mobile modems in laptop computers. This ensures it can be applied to wireless voice telephony, mobile internet access, fixed wireless internet access, video calls and mobile TV technologies.
3. 3G technology refer to third generation which was introduced in year 2000s. Typically called smart phones and features increased its bandwidth and data transfer rates to accommodate web – based applications and audio and video files.

   Example: UMTS (Universal Mobile Telecommunication System), WCDMA-FDD, CDMA 2000.
4. Third – generation wireless technology is the advanced wireless technology. This technology enhances the features that were available in second generation and adds further advanced features. This technology is widely used in mobile phones and data cards.
5. Evolution of 3G describes updating cellular telecommunications network around the world to use 3G technologies. Japan was the first country to commercially launch 3G in 2001. The transition to 3G was completed during 2005/2006 in Japan. In 2005, there were 23 networks worldwide, operating 3G technology. Some are only for test use and some operators are providing services to consumers.

6. The main reason for the evolution of 3G was due to the limited capacity of the 2G networks.
7. 2G networks were built for voice calls and slow data transmission. But these services were unable to satisfy the requirements of present wireless revolution.
8. International Telecommunication Union (ITU) has defined the demand for 3G in the International Mobile Telecommunication (IMT) – 2000 standards to facilitate growth, increase bandwidth, support diverse applications.
9. The development like 2.5G or GPRS (General Packet Radio Service) and 2.75G or EDGE (Enhanced Data rates for GSM Evolution) technologies resulted in the transition to 3G. These technologies act like bridge between 2G and 3G.

5.9.1. Sailent Features of 3g Systems

The ITU (International Telecommunication Union) has proposed 3G telecommunications standards to provide cost efficient high quality, wireless multimedia applications and enhanced wireless communications. The features of 3G can be divided into two categories. One is data rates and the other is security.

FEATURES OF 3G SYSTEMS:

1. Data transmission speed increased from 144 Kbps – 2 Mbps.
2. The main feature of 3G technology is that it supports greater voice and data capacity and high data transmission at low cost.
3. Providing faster communication.
4. Send/receive large Email messages.
5. High speed web.
6. **More security:** 3G offers greater security.
7. Large capacities and broadband capabilities.
8. 11 sec – 1.5 min time to download a 3 min MP3 song.
9. The data are sent through the technology called Packet Switching. Voice calls are interpreted through Circuit Switching.
10. With the help of 3G, we can access many new services too. One such service is the GLOBAL ROAMING.
11. Besides voice clarity it also has entertainments such as Fast Communication, Internet, Mobile T.V, Video Conferencing, Video Calls, Multi Media Messaging Service (MMS), 3D gaming, Multi-Gaming etc are also available with 3G phones.
12. **Download and upload:** 5.8 Mbps.
13. **Bandwidth:** 5 – 20 MHz.
14. 3G mobiles can operate on 2G and 3G technologies.

5.10. List the advantages of 3G over earlier versions

5.10.1. Advantages of 3g Over Earlier Versions

All the functions performed in a normal 2G mobile device can be performed in 3G at a higher speed. 3G provides faster connectivity, faster internet access and music with improved quality.

Advantages:

1. Entertainments such as Fast Communication, Internet, Mobile T.V., Video Conferencing, Video Calls, Multi Media Messaging Service (MMS), 3D gaming, Multi-Gaming etc are also available with 3G phones.
2. Voice quality is high.
3. Better battery life.
4. Phone size is less.
5. Security is high.
6. Capacity is high.
7. Good handoff reliability.
8. TV streaming/Mobile TV/Phone calls is possible.
9. Provides interoperability among service providers.

Disadvantages:

1. The cost of cellular infrastructure, upgrading base stations is very high.
2. Expensive fees for 3G licenses services.
3. It was challenge to build the infrastructure for 3G.
4. High bandwidth requirement.
5. 3G phones are expensive.
6. Requires wider bandwidths.
7. Power consumption is high.

5.10.2. Applications of 3G

Few applications of 3G are:

1. Entertainments such as Fast Communication, Internet, Mobile T.V., Video Conferencing, Video Calls, Multi Media Messaging Service (MMS), 3D gaming, Multi-Gaming etc are also available with 3G phones.
2. The 3G mobile can be used as a modem for a computer which can access internet and can download games and songs at high speed.
3. 3G technology provides high quality voice calls and video calls.
4. View like TV broadcasting in mobile. Get weather updates and new headlines in mobiles.

5. 3G increases bit rate which helps the service providers to provide high speed internet facility and many applications to its customers.
6. 3G devices can provide data transmission speed upto 2 Mbits/s when used in stationary mode.
7. Provides multimedia services such as sharing of digital photos and movies.
8. This technology provides real time multi player gaming and location based services.
9. 3G allows users to be online all the time.
10. 3G also include mobile office services, like virtual banking and online selling.
11. Teleconferencing at work is one of the best applications.
12. Global Positioning System (GPS).
13. Location based services.
14. Telemedicine.
15. Video on demand

5.11. List the basic concepts of 4G aspects

4G technology refers to short name of fourth generation which was started from late 2000s. Then with the case of fourth generation that is 4G in addition to that of the services of 3G some additional features such as Multi Media Newspapers, also to watch T.V. programs with the clarity as to that of an ordinary T.V. In addition, we can send data much faster than that of the previous generations.

Example: LTE (Long Term Evolution), WiMAX (Worldwide Interoperability for Microwave Access).

Features of 4G:

1. The next generations of wireless technology that promises higher data rates and expanded multimedia services.
2. Capable to provide speed 100 Mbps – 1 Gbps.
3. High QOS and high security.
4. Provide any kind of service at any time as per user requirements, anywhere.
5. More security.
6. High speed.
7. High capacity.
8. Low cost per-bit etc.
9. Also known as Mobile Broadband Everywhere.

10. One of the basic term used to describe 4G is MAGIC.
    - Mobile Multimedia.
    - Anytime Anywhere.
    - Global Mobility Support.
    - Integrated Wireless Solution.
    - Customized Personal Services.

Drawbacks of 4G:

- Battery uses is more.
- Hard to implement.
- Need complicated hardware.
- Expensive equipment required to implement next generation network.