MODULE - IV

Multiple Choice Type Questions

1. Fibre's absorption occurs due to [WBUT 2009, 2013]
   a) impurities of the material
   b) core diameter
   c) clad refractive index
   d) none of these

Answer: (a)

2. The wavelength that is choose for optical communication is [WBUT 2009, 2012, 2016, 2018]
   a) 1550 nm
   b) 1880 nm
   c) 2880 nm
   d) 780 nm

Answer: (a)

3. For total coverage round of the earth, the minimum no. of satellite needed is [WBUT 2009, 2012, 2013, 2015, 2016]
   a) 4
   b) 7
   c) 3
   d) 2

Answer: (c)

4. The term transponder is related to [WBUT 2009, 2013, 2015, 2018]
   a) satellite communication
   b) fibre optic communication
   c) GSM communication
   d) CDMA communication

Answer: (a)

5. Population inversion is a property found in [WBUT 2009, 2013, 2016, 2018]
   a) LED
   b) photodiode
   c) FET
   d) LASER

Answer: (d)

6. Which one is better for satellite telemetry system? [WBUT 2010, 2016, 2018]
   a) CDMA
   b) FDMA
   c) TDMA
   d) None of these

Answer: (c)

7. For step index fibre of core diameter of 50×10^{-6} m and NA of 0.352, what is the number of modes for $\lambda = 55\mu\text{m}$? [WBUT 2010, 2016]
   a) 2
   b) 4
   c) 8
   d) 16

Answer: (a)

8. Pick the odd one out: [WBUT 2011, 2013, 2017]
   a) transponder
   b) earth station
   c) GSM
   d) equatorial orbit

Answer: (c)

9. For step index fibre the NA across the core is [WBUT 2011]
   a) variable
   b) constant
   c) dependent on core radius
   d) none of these

Answer: (b)

10. High-quality glass fibres have least losses in the wavelength range of (nm) [WBUT 2011]
a) 820-880
b) 1200-1320
c) 1550-1610
d) 1620-1710

Answer: (a)

11. For WDM the main optical element is [WBUT 2012, 2015]
a) grating
b) beam splitter
c) mirror
d) none of these

Answer: (a)

12. The numerical aperture may be expressed in terms of the relative refractive indices core and cladding as [WBUT 2012]
a) $(n_1 - n_2)/n_1$
b) $n_1 n_2$
c) n_1/n_2
d) $(n_1 + n_2)/n_1$

Answer: (a)

13. A television (TV) transmission is an example of which type of transmission? [WBUT 2014]
a) half duplex
b) simplex
c) full duplex
d) none of these

Answer: (b)

14. The multiple access technique suitable only for digital transmission is [WBUT 2014]
a) FDMA
b) TDMA
c) both (a) and (b)
d) packet access

Answer: (b)

15. INTELSAT stands? [WBUT 2014]
a) India Telecommunications Satellite
b) Inter Telecommunication Satellite
c) International Telecommunication Satellite
d) none of these

Answer: (c)

16. The carrier to noise ratio for a satellite depend upon [WBUT 2014]
a) effective isotropic radiated power
b) bandwidth
c) free space path losses
d) all of these

Answer: (d)

17. The wave length that is choose for optical communication is [WBUT 2015]
a) 1550 nm
b) 1880 nm
c) 2880 nm
d) 780 nm

Answer: (a)

18. The wavelength that is in optical communication system is [WBUT 2016]
a) 1880nm
b) 2880nm
c) 780nm
d) 1550nm

Answer: (d)

19. Attenuation in optical fibre is measured in [WBUT 2017]
a) dB/km
b) dB/hr
c) KdB/m
d) dBm/m

Answer: (a)

20. Uplink frequency is .... downlink frequency in satellite telemetry. [WBUT 2017]

a) greater than   b) smaller than   c) equal to   d) independent of

Answer: (a)

21. The order of optical frequency is [WBUT 2018]

a) MHz   b) GHz   c) kHz   d) TeraHz

Answer: (d)

Short Answer Type Questions

1. a) What is Geostationary satellite?

b) On what parameters of a system does the carrier level depend in satellite telemetry? Why is the receiver gain to temperature ratio as a factor so important in a receiver system? [WBUT 2009, 2013, 2015]

Answer:

a) A **geosynchronous satellite** is a satellite in geosynchronous orbit, with an orbital period the same as the Earth's rotation period. Such a satellite returns to the same position in the sky after each sidereal day, and over the course of a day traces out a path in the sky that is typically some form of analemma. A special case of geosynchronous satellite is the **geostationary satellite**, which has a geostationary orbit – a circular geosynchronous orbit directly above the Earth's equator.

b) 1st Part:

The carrier level in satellite telemetry depends on the (1) power flux density & (2) effective aperture.

2nd Part:

The receiver gain G_r is related to α_e (effective aperature) and the signal wave length λ, by the relation $G_r = 4\pi\alpha_e / \lambda^2$ .... (1)

So that $C = \{(P_P G_P)/4\pi D^2\}(G_r\lambda^2/4\pi)$ .... (2)

Noise density is defined as $N_0 = k_B T$, T is the system temperature so that noise $N = N_0 B_w$ .... (3)

For non-quantum type thermal noise and since this is the predominant noise we may write

$C = (C/N)N = (C/N)k_B T B_w$ .... (4)

or, $C/N = \{(P_P G_P)/4\pi D^2\}(G_r\lambda^2/4\pi).(1/k_B T B_w)$ .... (5)

$= \{(P_P G_P)/(4\pi D/\lambda)^2\}(G_r/T)(1/(k_B B_w))$ .... (6)

$P_P G_P$ = equivalent isotropic radiated power = P_{erip}

$(4\pi D/\lambda)^2$ = free space loss, L_f

Since $N_O = N/B_w$ so we can write equation (6) as

$$(C/N_o) = (P_{erip}/L_f)(G_r/T)(1/k_B) \quad \text{.... (7)}$$

The equation (7) is independent of bandwidth. So in satellite receiving system (G_r/T) i.e. receiver gain to temperature ratio is an important factor and it is given in units of dB/k.

2. Draw the detail block diagram of an Earth station & explain the functions of each block. **[WBUT 2010, 2013, 2014, 2016]**

Answer:

Earth Station Block Diagram

A simplified block diagram of an E is given in figure below. From a lay-out viewpoint the station equipment may be grouped a follows:

1. Outdoor equipment, located out of the station central equipment room, which includes all RF front-end equipment, namely antenna, HPA, LNA,

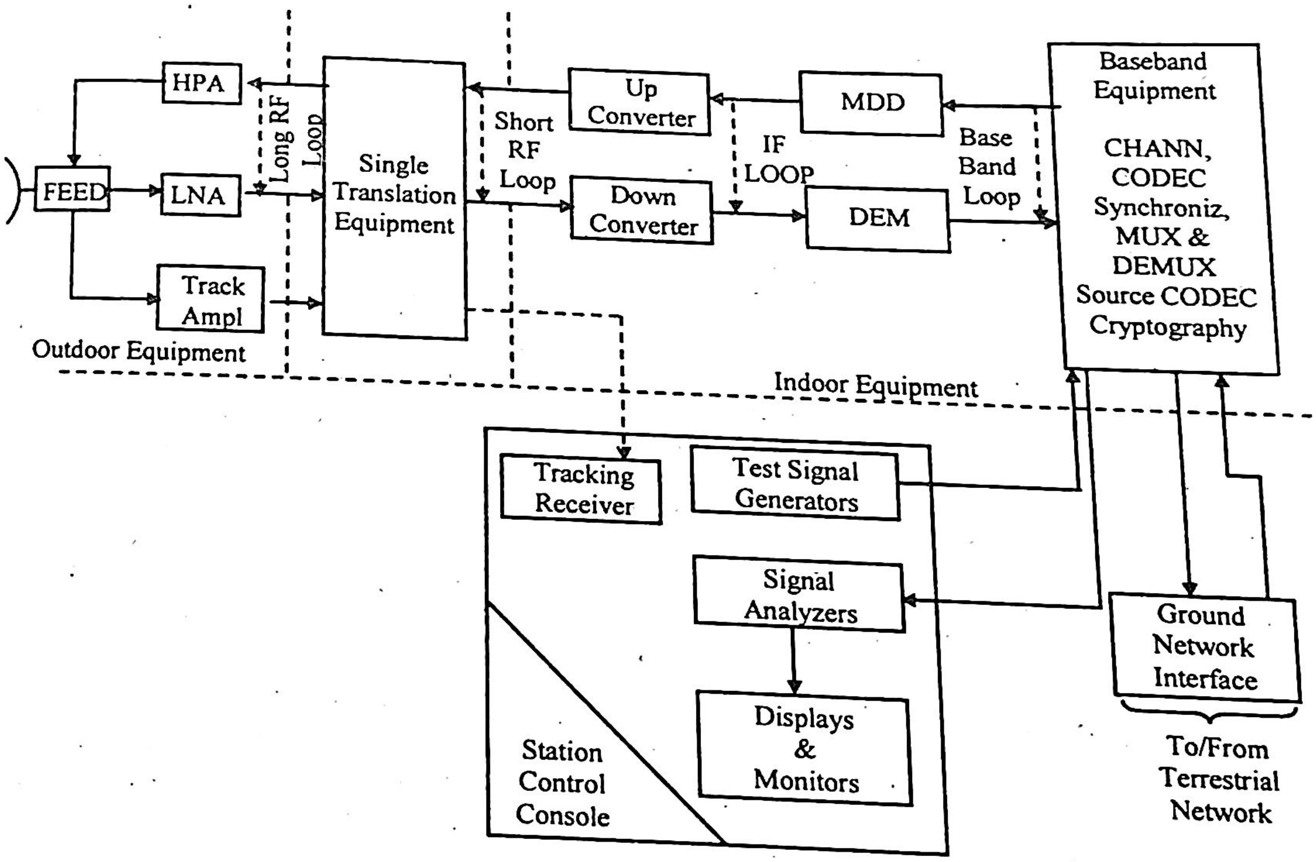


Fig: Earth station block diagram

And tracking RF amplifier (if different from the communication signal LNA). The RF front-end determines the station EIRP, the received signal-to-noise density ratio and therefore the channel quality and availability. To minimize the power losses beyond the

HPA and the noise temperature increase generated before the LNA and the tracking amplifier, this equipment is generally located inside an antenna-mounted box (in small to medium antennas) or inside a real antenna equipment room (in big antennas). It is therefore possible to speak of an "antenna complex", including all RF front-end equipment.

2. Signal translation equipment, for signal transport from the antenna to the central equipment room. Although configurations with double-frequency conversion were used in some earth stations, the most common configuration today foresees that use of single conversion; therefore the same frequency transmitted to and from the satellite in the uplink and downlink is also sent through the signal translation equipment connecting the outdoor equipment (i.e., the antenna complex) to the indoor equipment (in the central equipment room).

3. Indoor equipment, located inside the central equipment room. The indoor equipment transforms the signal, on the transmitting side, to another one, carrying the same information, more suitable for an optimal transmission through the channel. The reciprocal transformation is performed on the receiving side, in order to recover the original signal with the best possible quality and availability. Modemodulation, channel coding, companding, synchronization, source coding (including multiplexing and demultiplexing) and cryptography equipment are included in this section. Of these only modem, syllabic companding and channel-coding equipment may have an impact on the link budget. However, once the modulation technique has been selected, the range of possible performances is significantly smaller than for front-end parameters. It is therefore justified to say that the link budgets are mostly determined by the RF front-ends. The modem implementation margin typically ranges within 0.5–1.5 dB and determines the detection threshold point, which is important in determining link availability. A wider (5–10 dB) range of values is possible for the channel-coding gain, which, however, is not always present (since channel codecs are not always used) and implies the penalty of a significant transmission rate increase, i.e., decreased bandwidth efficiency.

4. Station control console, where all measurement results and command points are centralized, in order to minimize the level of expensive human resources needed for station operation. The addition of expert systems at this level may prove convenient in the future, in order to further reduce the number of required personnel. Performing various loopback loops in the ES allows isolation of the part(s) of the station responsible for a detected anamoly. Typical loops are:

- Baseband, including only the baseband terminal
- IF, including the modem
- Short-RF, connecting the output of an up-converter to the input for a down-converter
- Long-RF, where the HPA output is fed, through a suitable coupling device, to the LNA input.

5. Ground network interface equipment, comprising a radio link-coaxial cable-optical fibre transmissive medium, plus terrestrial standard multiplex-demultiplex. This interface may be digital (TDM) or analog (FDM). In TDM one must care about satellite clock-

terrestrial clock misalignment, while in FDM the situation is easier because the signal is completely reconditioned by the new multiplex pilots. Also mixed interfaces are possible, with analog-to-digital conversion or vice versa.

3. a) What do you mean by the 'figure of merit' of the optical fibre? How does the channel bandwidth vary with the fibre length?
b) In a fibre-optical cable the refractive indices of the core, cladding and air are 1.59, 1.56 and 1.00 respectively. Calculate the critical incidence angle and the numerical aperture. **[WBUT 2010, 2012, 2013, 2015]**

Answer:

a) A figure of merit that indicates the ability of an optical fiber to handle high-frequency signals over given distances with specified limits on distortion and bit error ratios (BERs) is known as the figure of merit of that optical fiber. Example of optical fiber merit figure is: the pulse repetition rate (PRR) times the optical fiber length when pulse dispersion is the specified limiting factor in signal distortion rather than attenuation.
Bandwidth distance product(BDP) is often used as a figure of merit of the fibre which can be written as $BDP = \left(R_{b\max}/2\right) L_f$

It would be seen from the above equation that with increasing fibre length,bandwidth must be reduced.

b) Data given,
(i) Core refractive index $(n_1) = 1.59$
(ii) Cladding refractive index $(n_2) = 1.56$
(iii) refractive index of air $= 1.00$
Numerical aperture

$$NA = \sqrt{n_1^2 - n_2^2} = \sqrt{1.59^2 - 1.56^2} = \sqrt{2.5281 - 2.4336} = \sqrt{0.0945} = 0.3074$$

Acceptance angle

$$\theta_a = \sin^{-1} NA = \sin^{-1}(0.3074) = 17.90°$$

c) Determine the orbital velocity of a satellite moving in a circular orbit at a height of 150 km above the surface of earth given that gravity constant $G = 6.67 \times 10^{-11}\,\text{N-m}^2/\text{kg}^2$, **mass of the earth** $M = 5.98 \times 10^{24}\,\text{kg}$, **radius of earth** $R = 6370\,\text{km}$. **[WBUT 2010, 2014, 2018]**

Answer:

Gravity constant

$$G = 6.67 \times 10^{-11}\,\text{N-m}^2/\text{kg}^2$$

Mass of earth

$$M = 5.98 \times 10^{24}\,\text{kg}$$

Radius of earth

$$R_{earth} = 6370\,\text{km}$$

$$R = R_{earth} + \text{height} = 6370 + 150 = 6520\,\text{km} = 6.52 \times 10^6\,\text{m}$$

Let orbital velocity v

$$v=\sqrt{\frac{G\cdot M_{earth}}{R}}=\sqrt{\frac{6.67\times10^{-11}\times5.98\times10^{24}}{6.52\times10^{6}}}==\sqrt{\frac{6.67\times5.98}{6.52}\times10^{-11+24-6}}$$

$$=\sqrt{\frac{6.67\times5.98}{6.52}\times10^{7}}=\sqrt{6.117\times10^{7}}=\sqrt{61.17\times10^{6}}=7.821\times10^{3}\text{ m/s}$$

4. a) What is FDD and TDD?
b) Calculate the total number of available channels in FDMA system, if the total allocated BW is 13 MHz, guard BW 10kHz and channel BW 30kHz. **[WBUT 2016]**

Answer:

a) *Refer to Question No. 9(d) of Long Answer Type Questions.*

b) Given,

Total spectrum allocation, $B_t=13\text{MHz}=13\times10^{6}\text{Hz}$

Guard band allocated $B_{Guard}=10\text{kHz}=10\times10^{3}\text{Hz}$

Channel BW $B_C=30\text{kHz}=30\times10^{3}\text{Hz}$

The number of channels available in FDMA system is given by

$$N=\frac{B_t-2B_{Guard}}{B_C}=\frac{(13\times10^{6})-2(10\times10^{3})}{30\times10^{3}}$$

$$=\frac{10^{3}(13\times10^{3}-20)}{30\times10^{3}}=\frac{10^{3}(13000-20)}{30\times10^{3}}$$

$$=\frac{10^{3}\times12980}{30\times10^{3}}=432\text{ channels}$$

5. Explain the operation of close loop clock recovery circuit. **[WBUT 2017]**

Answer:

Clock recovery in serial communication of digital data, is the process of extra timing information from a serial data stream to allow the receiving circuit to decod transmitted symbols. Clock recovery is a common component of systems communic over wires, optical fibers, or by radio.

At the receiving end of a data transmission link, the received signal is amplified, fi and equalized. Then a "slicer" circuit reshapes it and retains just the level transitio the levels that represent the nominal values of the received signal in that interval be two consecutive transitions. The clock and data recovery (CDR) processes the "s signal to extract the clock signal embedded in its transitions (clock recovery) sample and retime the pulses of the "sliced" signal (data recovery).

The CDR is always designed with the architecture of a PLL. The input of the circui phase of a reference signal (a clock or a serial data signal) and the output is the pha signal (a serial data stream or a simple clock). The output is locked -as much circuit can- to the input signal. The input signal is contrasted with the output sig

phase comparator, whose output is the error signal. The error signal is processed and then used to control another circuit block that produces the output clock signal.
In this scheme, the output clock is always phase locked to the input signal, and that it is used to regenerate the input signal in the slave CDRs. In the phase aligner CDRs it is the local clock that regenerates (a phase aligned version of) the received signal.

Long Answer Type Questions

1. a) Draw the scheme of a WDM system for optical fibre telemetry. **[WBUT 2009, 2013, 2016]**

b) What is a cut-off parameter? How is it introduced in fibre cable mode calculation? **[WBUT 2009]**

c) What is dispersion? Calculate the total time dispersion in a multimode step-index fibre. **[WBUT 2009]**

Answer:

a) Wavelength Division Multiplexing is a technology where several numbers of optical carried signals are multiplexed onto a single optical fiber by using different wavelengths at laser light. This technique enables bidirectional communications over one strand of fiber as well as multiplication of capacity.

In the early days of optical fiber communications, optical link design engineers only needed to be concerned with the operation of a few component types. Mainly these included light sources, optical fibers, photo detectors, connectors, splices and couplers. The links carried a single wavelength and the data rates were low enough that the design did not require a great deal of special signal processing to compensate for distortion effects. However, the push to increase the data rate, provide longer transmission distances and send many wavelengths simultaneously over the same fiber has resulted in the development of numerous, highly sophisticated passive and active optical components to meet the new and ever-increasing link performance demands. The design, installation and operation of WDM links now have become more complex with the use of these new components.

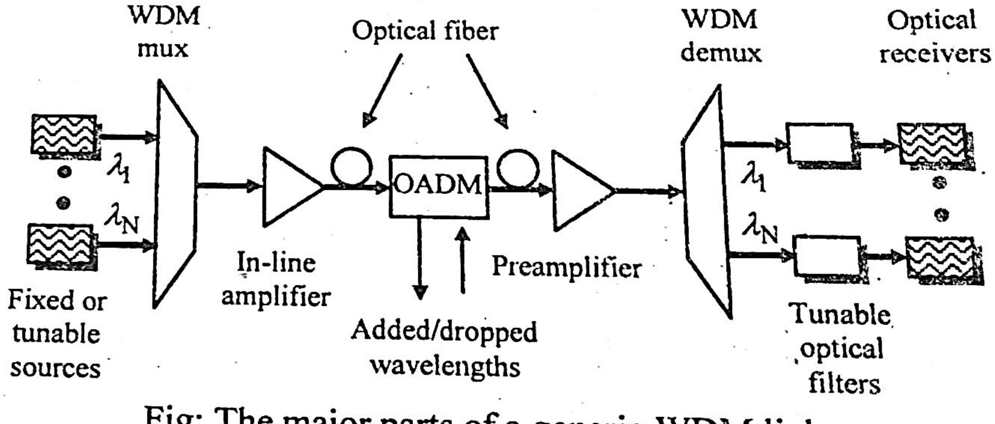


Fig: The major parts of a generic WDM link

Within the link there may be optical amplifiers, add/drop multiplexers for inserting or subtracting individual wavelengths along the path and other devices to enhance the link performance. At the end of the link there is a demultiplexing device for separating the wavelengths into independent signal streams and an array of tunable optical receivers.

A major application of WDM technology is to increase the capacity ... Owing to the large amount of traffic carried on these long links, high-performance wideband components are required. Metro WDM links have a different set of applications which point to the need for lower-cost narrowband components. One important point is that WDM-based networks are bit-rate and protocol-independent, so they can carry various types of traffic at different speeds concurrently.

b) The number of modes of a fibre can support the fibre characteristics which depends on the wavelength is given in terms of normalized frequency v, which is also called cut-off parameter. It is defined as

$$v = (\pi d/\lambda)\left(n_1^2 - n_2^2\right)^{\frac{1}{2}}$$

$NA =$ can be written as $NA = \left(n_1^2 - n_2^2\right)^{\frac{1}{2}} / n_a$

If $n_a = 1$ then v in terms of NA is given as $v = (\pi d/\lambda)\, NA$

We can see that if v increases with the increases of core diameter and decrease of wavelength and also, the number of modes M supported by the fibre is given by

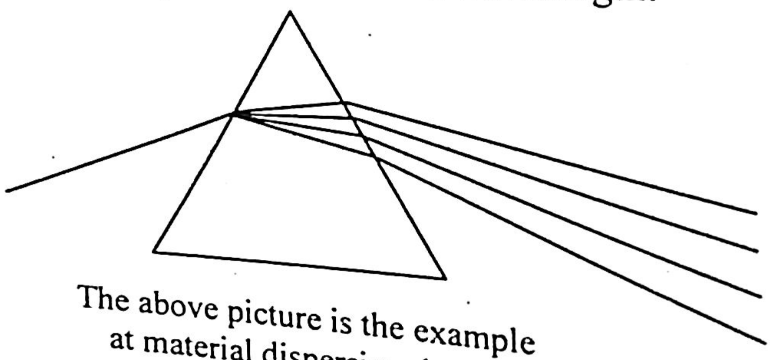
$M \cong v^2/2$ for large number of modes.

c) Dispersion: In optics, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency or alternatively when the group velocity depends on the frequency.

The above picture is the example at material dispersion due to variation refractive index of core as a function of wavelength.

Dispersion is most often described for light waves, but it may also occur for waves that interacts with a medium or passes through an inhomogeneous geometry.

The most common example of dispersion is rainbow, in which dispersion causes the splitting at white light into components at different wavelength.



The above picture is the example at material dispersion due to variation refractive index at core as a function at wavelengths

Multimode dispersion (also called **intermodal dispersion**) arises in multimode cable because of the different velocities and path lengths of the different rays (modes). These differences result in different arrival times for rays launched into the fiber coincidentally. Multimode dispersion is predominant in multimode cable and non-existent in single mode cable. Values of multimode dispersion can be calculated by comparing the transit time of two rays, one having minimum propagation delay and the other having maximum propagation delay. This direct calculation of multimode dispersion, however, requires knowledge of the refractive index profile of the fiber, information that is not readily available to the link designer. Manufacturers usually specify the coefficient of multimode dispersion, from which the total multimode dispersion can be found using

$$t_{mo} = c_{mo} D^{\gamma}$$

Where t_{mo} = multimode dispersion in ns

c_{mo} = distance in km

D = distance in km

γ = length dependence factor (typically $0.5 \le \gamma \le 1$, where γ varies with fiber size, numerical aperture, and wavelength)

2. What is the difference between splices and connectors? Where are connectors used in an optical fibre telemetry/communication system? What are the basic mismatch conditions that may develop associated with the connectors?

[WBUT 2009, 2010]

Answer:

1st part:

There are two types of splicing:

1. Mechanical splicing
2. Fusion splicing

The schematic of a **mechanical splice** shows how two pieces of stripped, cleaved and cleaned fibres are inserted into the splicing device, where their ends are directed towards each other. They come into optical contact and are held by an adhesive or clamp. The heart of the device is an alignment guide; the better the fibre's alignment, the higher the quality of the splice, that is less is the connection loss. A number of arrangements are used for alignment guides, with the V-groove being the most popular. Many different designs of mechanical splices are commercially available.

Fusion connects two fiber ends by melting them. This process is similar to welding metallic wires and is usually accomplished by the use of an electric arc.

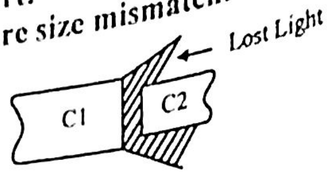
Connectors are special devices attached to the end of optical fibers that can easily be coupled or uncoupled to other connectors or devices. Connectors are required when a fiber must be periodically disconnected, for example for testing or switching purposes. Connectors are typically used at the termination points of optical fiber cables, such as at the transmitter or receiver. They are also employed on test and measurement equipment, at the interfaces between networks, on patch panels where signals may be routed through different pathways and inside office buildings.

2nd part:

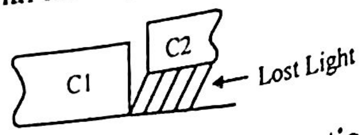
Connectors in an optical fibre telemetry/communication system are used (a) to connect fibre optic cables to one another (b) at the repeater units and (c) at transmitting end of a cable to arrange for light source to send light to the cable & (d) to connect the cable to the receiving photodetector.

3rd part:

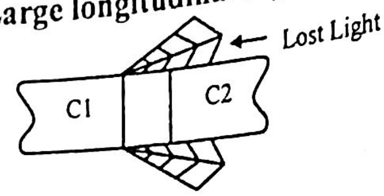
(i) Core size mismatch:



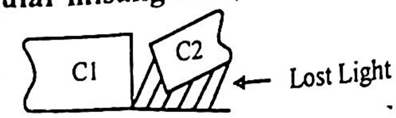
(ii) Axial misalignment:



(iii) Large longitudinal separation or too much end separation:



(iv) Angular misalignment:



(v) Improper fibre end preparation:

3. When the mean optical power launched into an 8 km length of fibre is 1 the mean optical power at the fibre output is 3 μW. Determine:

i) the overall signal attenuation or loss in decibels through the assuming there are no connectors or splices.

ii) the signal attenuation per kilometer for the fibre

iii) the overall signal attenuation for a 10 km optical link using the sa with splices at 1 km intervals, each giving an attenuation of 1 dB.

iv) the numerical input/output power ratio in (iii).

[WBUT 201

Answer:

i) Using formula

$$\text{number of decibels (dB)} = 10\log_{10}\frac{P_1}{P_0}$$

the overall signal attenuation in decibels through the fiber is

$$\text{Signal Attenuation} = 10\log_{10}\frac{120\times10^{-6}}{3\times10^{-6}} = 10\log_{10}40 = 16.0\,dB$$

ii) The signal attenuation per kilometer for the fiber may be simply obtained the result in (a) by the fiber length which corresponds to it using

$$\alpha_{dB}L = 10\log_{10}\frac{P_i}{P_o}$$

$$\alpha_{dB}L = 16.0\,dB$$

$$\alpha_{dB} = \frac{16.0}{8} = 2.0\,dB\,km^{-1}$$

iii) As $\alpha_{dB} = 2dB\,km^{-1}$, the loss incurred along 10 km of the fiber is given by
$\alpha_{dB}L = 2\times 10 = 20\,dB$
The link also has nine splices (at 1 km intervals) each with an attenuation of 1dB. Therefore, the loss due to the splices is 9 dB.
Hence, the overall signals attenuation for the link is:
Signal attenuation = 20 + 9 = 29 dB

iv) To obtain a numerical value for the input/output power ratio,

$\frac{P_i}{P_o} = 10^{dB/10}$ formula may be used

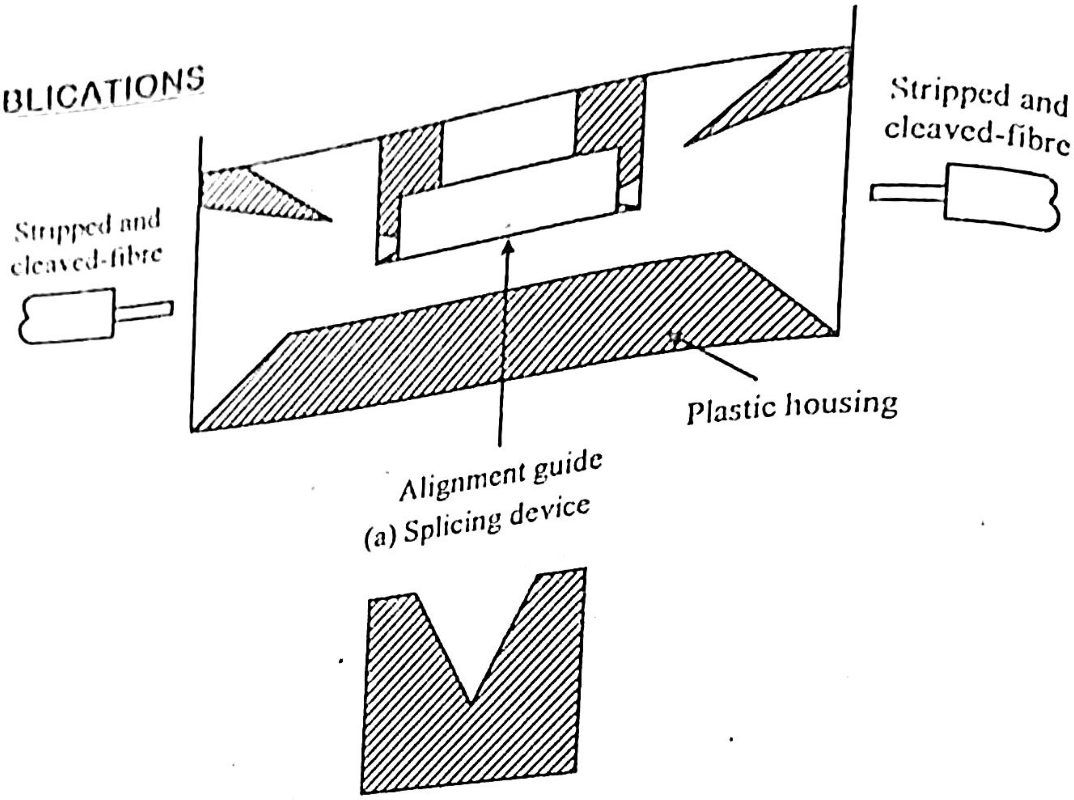
$$\frac{P_i}{P_o} = 10^{29/10} = 794.3$$

4. a) What are the differences between connectors and splices? Where connectors are used in optical fibre telemetry system? [WBUT 2010, 2014, 2016]
b) Explain different techniques for splicing with suitable diagram. [WBUT 2010, 2014]
c) Draw and explain detail circuit diagram of the transmitter and receiver of optical fibre telemetry system. [WBUT 2010, 2014, 2016]
d) What are the advantages and disadvantages of satellite communication system? [WBUT 2010, 2014, 2016, 2018]

Answer:

a) ***Refer to Question No: 2(a) of Long Answer type Questions.***

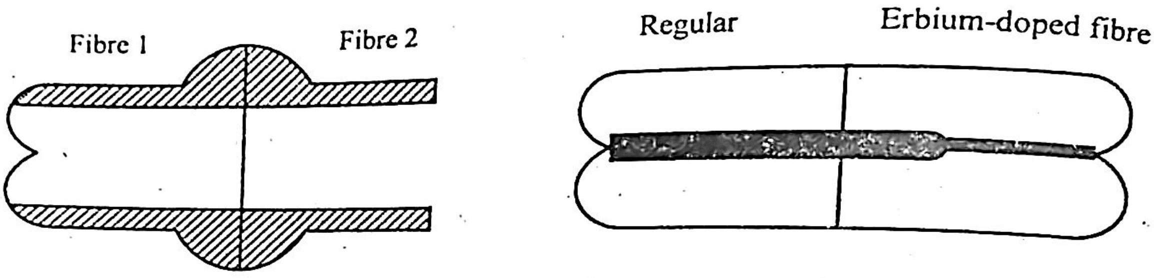
b) High-precision optical-fibre geometry and improvements in mechanical splice technology make mechanical splices very competitive products. Splices with insertion loss as low as 0.2dB per splice are quite common and many manufacturers claim that their splices provide 0.1dB. Their reflection loss varies from – 45dB to – 55dB. Some are preloaded with index-matching gel (glue), whose function is to minimize reflection loss and fix fibre ends. Other mechanical splices use UV curing for adhesion. Some types of mechanical splicing do not use any adhesive but, fix fibre ends mechanically.
The cost of an individual mechanical splice is relatively high. It varies from several hundred rupees to several thousand rupees. Typically, an experienced professional can execute a splice in 30 – 40 seconds. Mechanical splicing is usually used for quick repair when only a small number of splices are required.



(a) Splicing device

(b) V-groove element

Fig: 1 Schematic of a mechanical splicing



(a) Regular fusion splicing

(b) Fusion splicing of erbium fibre

Fig: 2 Schematic of fusion splicing

Fusion splicing connects fibres without a gap, therefore, no reflection loss is introdu Insertion loss, is in the range of 0.01dB to 0.15dB. Fusion splicing is done by spe machines called **fusion splicers**. A fusion splicer is a fully automated desk-size appara controlling the quality of splices during its operation. The cost of fusion splicers var from several thousand dollars to tens of thousands of dollars. The one which is wide used ranges from $25,000 to $40,000. This costly investment can be justified for lar number of splices or for a high-quality splice.

Fusion splicers are commercially available as shown in fig 2. with passive or active fibr alignment. Passive alignment is done mechanically, usually with very precise V-grooves This operation is very similar to the alignment for mechanical splicing. Tightening of standards on fibre geometry has increased the popularity of these splicers. They are less costly, easy to operate and less bulky than active-alignment splicers but one cannot except exceptionally low splicing loss from them. Mass-fusion splicers and mini-splicers are based on passive alignment, with typical loss from 0.03dB to 0.07dB when they are operated automatically and up to 0.15dB when they are operated manually.

c) A fiber-optic communications system is a particular type of telecommunications, system. The features of a fiber-optic communications system can be seen in Figure, which displays its basic block diagram.

Information to be conveyed enters an electronic transmitter, where it is prepared for transmission very much in the conventional manner – that is, it is converted into electrical form, modulated and multiplexed. The signal then moves to the optical transmitter, where it is converted into optical form and the resulting light signal is transmitted over optical fiber. At the receiver end, and optical detector converts the light back into an electrical signal, which is processed by the electronic receiver to extract the information and present it in a usable form (audio, video or data output).

Figure shows that this telecommunications system includes electronic components and optical devices. The electronic components deal with information in its original and electrical forms. The optical devices prepare and transmit the light signal. The optical devices constitute a fiber-optic communications system.

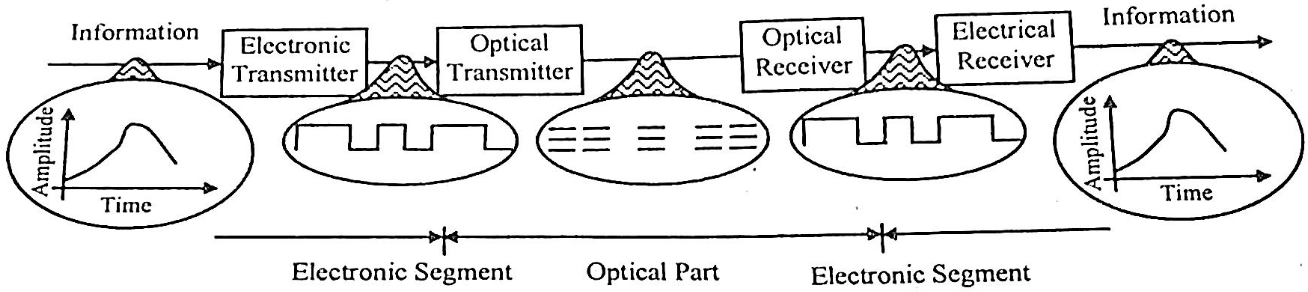


Fig: Basic block diagram of a fibre-optic communication

d) ***Advantages***

1. It can transmit high traffic capacities over long distances either over land or water.
2. Because of its unique geometry it is inherently a broadcast medium. It has a natural ability to transmit simultaneously from one point to an arbitrary number of other points within its coverage area.
3. Terrestrial relays are point-to-point while satellite relays are point to multi-point.
4. Satellite circuits can be installed rapidly. Once the satellite is in position, the earth stations can be installed and communication can be established in days or in hours. A station may be removed relatively quickly from one location and installed elsewhere.

   The terrestrial circuits of any kind require a time-consuming installations.
5. Mobile communication is well suited and can be easily achieved by satellite communication as it has a unique degree of flexibility interconnecting mobile vehicles. Satellite communication is cost-effective option in hilly terrains.
6. Radio navigation is possible with satellites using global positioning system (GPS). Satellite communication is very useful for search, rescue and navigation.

Disadvantages

1. The communication path between the terrestrial transmitter and the terrestrial receiver is approximately 75000 Km long. This introduces a round-trip delay of

about 1/4 seconds between transmission and reception. This produces an annoying effect.
2. Repair is nearly impossible after launching of satellite.
3. On-board equipments are subject to extreme environmental stress.
4. Initial cost is high.
5. High free space loss is there in satellite communication. However satellite costs are independent of distance whereas the terrestrial network costs are proportional to distance.

5. a) Explain the functioning of TT & C subsystems of a satellite communication system with necessary sketches. **[WBUT 2010, 2012]**
b) Mention the different subsystems in
i) satellite stations and
ii) earth stations
How do they work for data transfer and other functions? **[WBUT 2010, 2015]**

Answer:

a) Telemetry, Tracking and Command (TT&C) subsystem: This is a system for monitoring the state of the on-board equipment, for transmitting telemetry signals to a control earth station, and for receiving and executing commands from the ground control centre. The telemetry system multiplexes data from many sensors on the spacecraft and transmits them via a digital communications link to the controlling earth station. This station incorporates a satellite tracking system to monitor changes in the satellite orbit. If required, the control station is able to transmit remote control functions to the satellite via an uplink telemetry system. Control functions on the satellite might include firing the apogee motor or using thruster jets to correct satellite attitude and position. Other functions include control of certain on-board communications subsystems, such as operating switching matrices to direct communications signals to specified antennas.

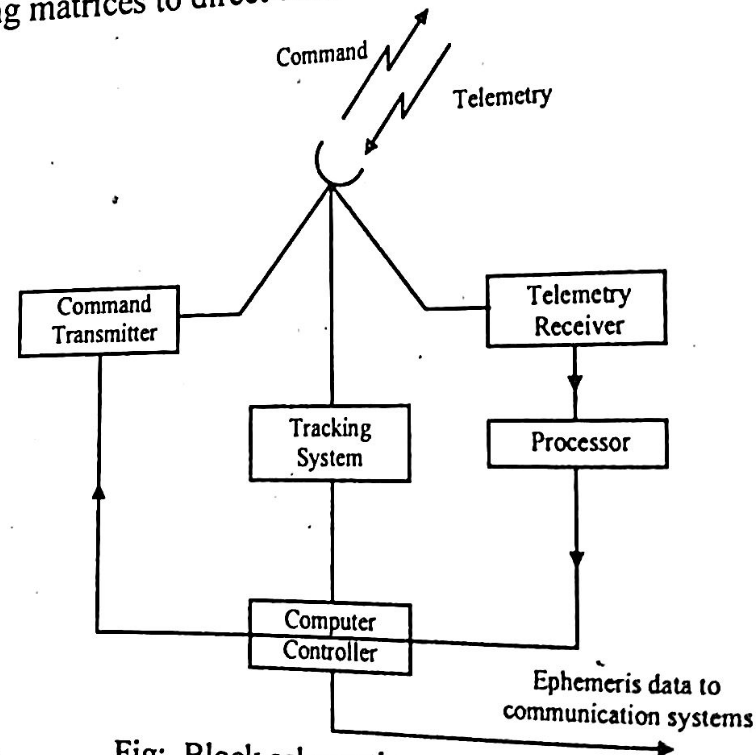
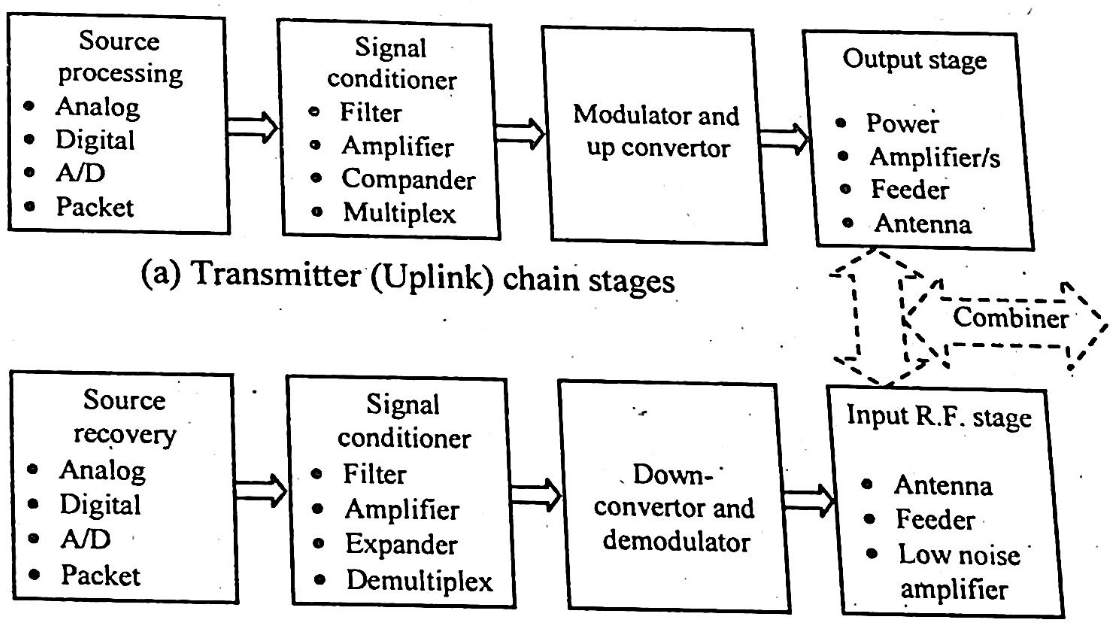


Fig: Block schematic arrangement of the basic TT&C subsystem

Tracking System
This system is used to determine the satellite's orbit during lunching and then to track it. The change of orbit due to various disturbing forces, mentioned earlier from the last known position can be sensed by the velocity and acceleration sensors on the spacecraft, and by measuring the Doppler shift of the telemetry carrier from the earth station the rate at which the range is changing can be known. In Doppler shift method, a single pulse or a sequence of pulses are transmitted towards the satellite from the controlling earth station and then time delay is measured from the received pulse. When sufficient number of earth stations are observing the satellite, its position can be established by triangulation form and the earth station look angles are determined by simulations range measurements.

b) Earth Station Technology: The configuration of earth stations can be broadly divided into four subsystems.
Basic subsystems of an earth station are:
1. Antenna systems which is connected to
2. receiving end
3. transmitting subsystems through a diplexer subsystem
4. Ground control equipment
The first earth station can have different configuration, for example, in the case of a TV transmitter there is no receiver section as such and it just transmits the signal spectrum generated by the studio whereas in the case of a telephone network the hub station transmits as well as receives the modulated carriers. Similarly a satellite control station also receives telemetry signals and transmits the control commands.



(a) Transmitter (Uplink) chain stages

(b) Receiver (Downlink) chain stages

The design of earth station depends on:
1. Application
2. Intermediatory processing
3. EIRP required

4. Back-off requirements
Consider the case of a telephone network application; it is meaningless and uneco to transmit every call on a separate carrier. Hence the subscriber channels are mul in groups, super groups, master groups, etc. to build a base band. This base band amplified, modulated, power amplified, filtered and fed to the antenna whereas case of a satellite control station the process is more complicated and requires c subsystems. This is necessary because any error or tracking calculations are ti space dependent. The computers in the control station have not only to calculate th or changes but also calculate the corrective action to be taken in split of millisecon data thus generated has to be put in a frame that contains the header giving information about the destination, source and error check information. This fra digital symbols is then modulated power-amplified and transmitted. The corrective taken at the satellite has to be checked at the control station and hence loop back has created to receive the new telemetry, ranging information for further processing.

Earth stations can, therefore, be classified on the basis of services provided such as:
1. Two-way TV telephony and data
2. Two-way TV
3. TV receiver only
4. TV receiver only and two-way telephony and data
5. Two-way data

From the classification, it is obvious that the technology of earth station will v considerably on the performance and service requirements of the earth station. T transmit chain of satellite earth station performs the following functions:
1. Building of base band
2. Modulation of carrier
3. Up conversion of IF to RF
4. Power amplification of RF carrier

Tracking, Telemetry and Command Subsystem
The tracking, telemetry and command (TT&C) subsystem monitors and controls the satellite right from the lift-off stage to the end of its operational life in space. The tracking Part of the subsystem determines the position of the spacecraft and follows its travel using angle, range and velocity information. The telemetry part gathers information on the health of various subsystems of the satellite. It encodes this information and then transmits the same towards the earth station. The command element receives and executes remote control commands from the control centre on Earth to effect changes to the platform functions, configuration, position and velocity. The TT&C subsystem is therefore very important, not only during orbital injection and the positioning phase but also throughout the operational life of the satellite.

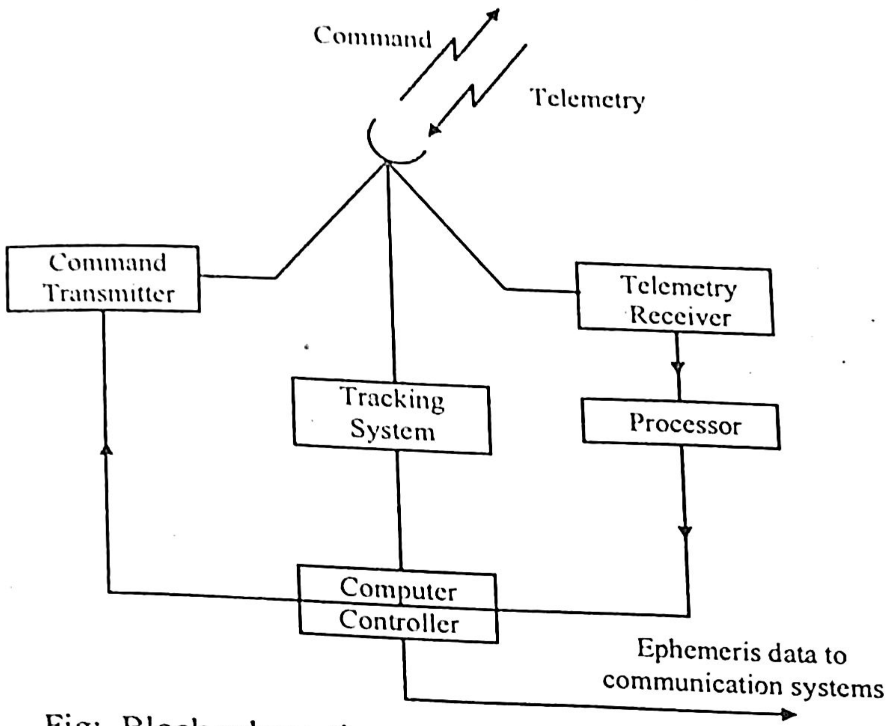


Fig: Block schematic arrangement of the basic TT&C subsystem

Payload

Payload is the most important subsystem of any satellite. Payload can be considered as the brain of the satellite that performs the intended function of the satellite. The payload carried by a satellite depends upon the mission requirements. The basic payload in the case of a communication satellite, for instance is a transponder, which acts as a receiver/amplifier/transmitter. Thus, a transponder can be considered to be a microwave relay channel that also performs the function of frequency translation from the uplink frequency to the relatively lower downlink frequency.

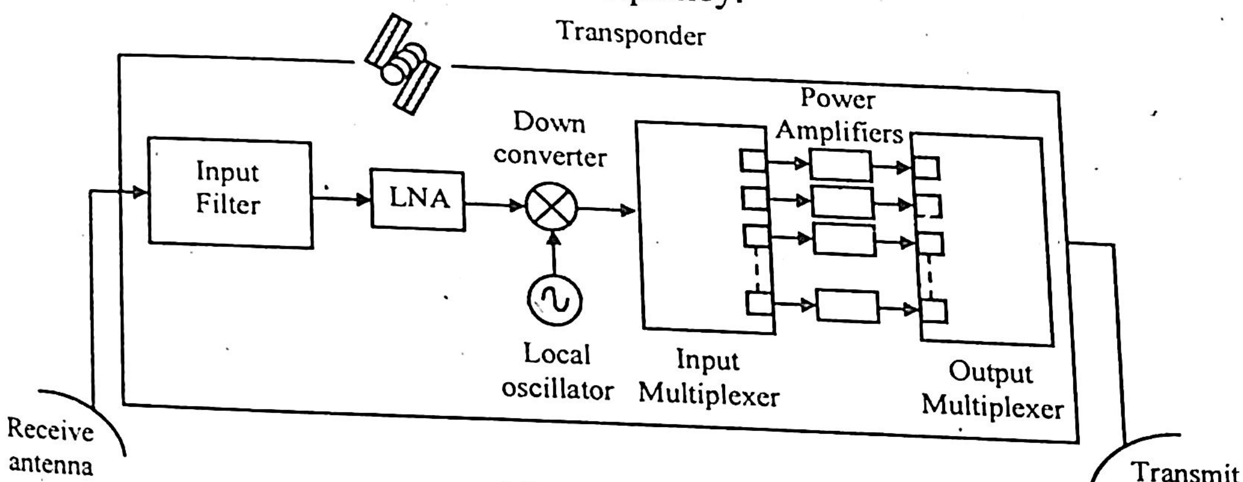


Fig: Transponder

6. a) What do you mean by dispersion? How does dispersion affect the transmission through an optical fibre? What precautions are needed to avoid or minimize the dispersion? Explain.

b) What is WDM? Explain with necessary sketch. Explain briefly with diagram how the WDM is used in optical fibre telemetry system. **[WBUT 2011]**

Answer:

a) **Dispersion:** *Refer to Question No. 1(c) of Long Answer Type Questions.*

Dispersion is a main cause of energy loss in case of the optical fiber and is brought by light rays with different critical angles causing rays to have different path lengths. This can be overcome by using a fiber cladding.
Light propagation in a fiber is model and similar to waveguide propagation. In practice, however, cable diameters are very much larger than the optical wavelength, and therefore produce multimode propagation, with each mode having its own velocity. This leads to a dispersion or spread of energy in time as the light travels down the fibers thus limiting the maximum signalling speed over a given length of cable.
Because of fiber attenuation and material dispersion, optoelectronics (at th moment) is mainly concentrated in the near infrared or short wavlength (780 to 900 nm: typically 850 nm) and the long wavelength region (1200 nm to 1600 nm: typically 1300 nm and 1550 nm). Rayleigh scattering largely controls the short wavelengths losses, while absorption of the glass materials controls long wavelength losses. Minimum loss is the region of about 1300 nm which is also the wavelength at which first-order material dispersion goes through zero. Although designers would prefer to use the long wavelength region because their low fiber attenuation and comparatively low material dispersion permit higher bandwidths, the cost of doing so usually limits their choice.

b) *Refer to Question No. 1(a) of Long Answer Type Questions.*

7. a) How does energy loss occur in fibre optic cable? What are the different types of such loss mechanism in fibre optic cable? How can they be compensated?
b) What are the different sources of light used in optical fibre telemetry system? Compare the advantages and disadvantages. **[WBUT 2012]**

Answer:

a) Attenuation coefficients are a function of the optical wavelength, and so the amount of optical power available to the photodetector at the end of a fibre length depends primarily upon the attenuation coefficient of the fiber.
Most of the energy losses in optical fibres occur because of light scattering but this particle scattering (i.e., Rayleigh scattering, Figure) is very small compared with the wavelength of the radiation being considered and is due to microscopic imperfections in the glass.

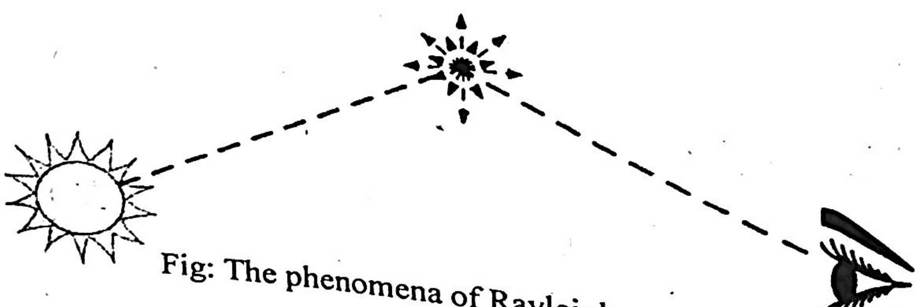


Fig: The phenomena of Rayleigh scattering

A feature of Rayleigh scattering is that the scattered flux is inversely proportional to the fourth power of the wavelength. The degree of scattering increases as the light wavelength approaches the size of the imperfections thereby giving greater attenuation at shorter wavelengths.

The blue colour of the sky is caused by the scattering of sunlight off the molecules of the atmosphere. This Rayleigh scattering is more effective at short wavelengths. Therefore, the light scattered down to the earth at a large angle with respect to the direction of the sun's light is predominately in the blue end of the spectrum.

Dispersion is one of the main cause of energy loss and is brought by light rays with different critical angles causing rays to have different path lengths. This can be overcome by using a fiber cladding.

Light propagation in a fiber is model and similar to waveguide propagation. In practice, however, cable diameters are very much larger than the optical wavelength, and therefore produce multimode propagation, with each mode having its own velocity. This leads to a dispersion or spread of energy in time as the light travels down the fibers thus limiting the maximum signalling speed over a given length of cable.

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Other losses: Other than opaque obstructions on the surface of a fiber, there is always a loss due to reflection from the entrance and exit surface of any fiber. This loss is called the Fresnel loss and is equal to about 4 percent for each transition between air and glass. There are special coupling gels that can be applied between glass surfaces to reduce this loss when necessary.

b) *Optical Sources in a Optical Fibre Telemetry Laser LD etc.*

Wireless telemetry allows signal transmission to take place without laying down a physical link in the form of electrical or fibre-optic cable. This can be achieved using either radio or light waves to carry the transmitted signal across a plain air path between a transmitter and a receiver.

Optical wireless transmission was first developed in the early 1980s. It consists of a light source (usually infrared) transmitting encoded data information across an open, unprotected air path to a light detector. Three distinct modes of optical telemetry are possible, known as point to point, directed, and diffuse.

- Point-to-point telemetry uses a narrowly focuswed, fine beam of light, which is used commonly for transmission between adjacent buildings. A data transmission speed of 5 Mbit/s is possible at the maximum transmission distance of 1000 m. However, if the transmission distance is limited to 200 m, a transmission speed of 20 Mbit/s is possible. Point-to-point temetry is used commonly to connect electrical or fibre-optic Ethernet netwoks in adjacent buildings.

- Directed telemetry transmits a slightly divergent beam of light that is directed toward reflective surfaces, such as walls abd ceilings in a room. This produces a wide area of coverage and means that the transmitted signal can be received at a number of points. However, the maximum transmission rate possible is only 1 Mbit/s at the maximum transmission distance of 70 m. If the transmission distance is limited to 20 m, a transmission speed of 10 Mbit/s is possible.
- Diffuse telemetry is similar to directed telemetry but the beam is even more divergent. This increases the area of coverage but reduced transmission speed and range. At the maximum range of 20 m, the maximum speed of transmission is 500 kbit/s, although this increases to 2 MBit/s at a reduced range of 10 m.

In practice, implementations of optical wireless telemetry are relatively uncommon because the transmission of data across an open, unprotected air path is susceptible to random interruption.

Different Sources and their Advantages

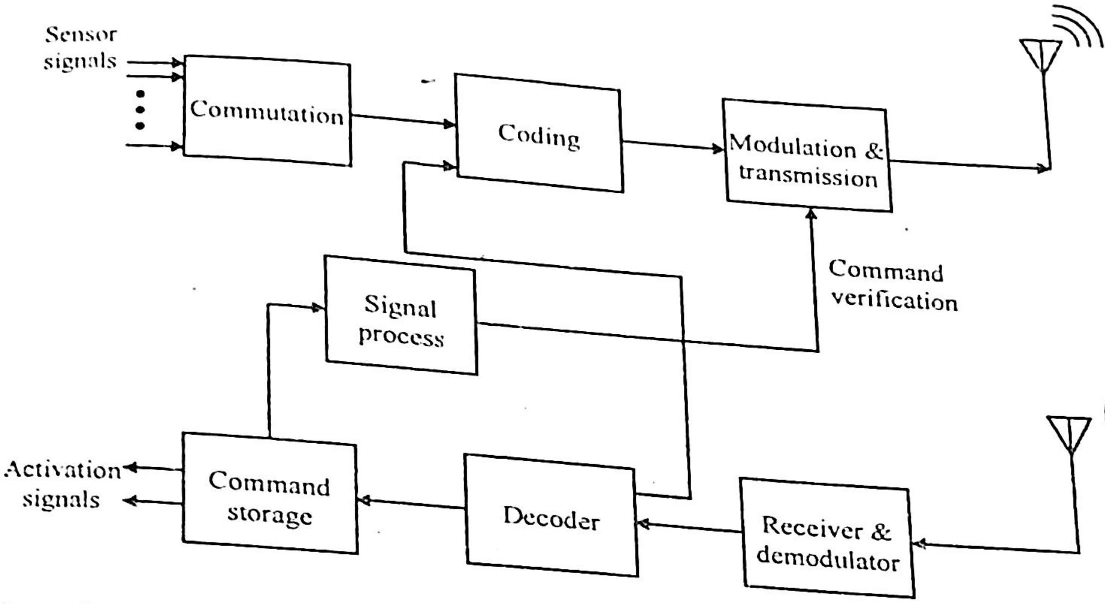
Sources: In FOS semiconductor based light sources offer the best advantages in terms of size, cost, power consumption and reliability. Light emitting diodes (LEDs) and laser diodes (LDs) are the right type of sources for FOS although in laboratory experiments the He-Ne laser is frequently used. Features of LED include very low coherence length, broad spectral width, low sensitivity to back reflected light and high reliability. They are useful in intensity type of sensors only. LDs on the other hand exhibit high coherence, narrow linewidth and high optical output power, all of which are essential in interferometric sensors. Single mode diode lasers are made using distributed feedback or external cavity schemes. High performance Mach-Zehnder and Fabry-Perot type sensors need single mode lasers. LDs in general are susceptible to reflected (feedback) light and temperature changes. They are also less reliable and more expensive. Coupling of light from source to fiber is an important aspect and may call for special optical devices. Use of pigtailed source can alleviate this problem but such devices cost more. Fiber lasers and amplifiers are fast becoming commercial products and may play an important role in future FO sensors.

c) Draw the block diagram of a typical *TT* and *C* system for space craft and explain it. **[WBUT 2012]**

Answer:

In satellite communication, a typical TT&C system for the spacecraft is shown in Fig. As the condition of the satellite is to be known from the ground, all the while many points on or around the spacecraft are selected and variables like temperature, pressure, voltages, currents at some points are measured and status of solenoids, switches and contacts are ascertained. Sensor outputs for all the variables are converted by AD converters and then sampled. The telemetry transmission scheme generally uses PCM, TDM and PSK systems.

For tracking purposes beacon transmitters are provided on the spacecraft, which also serve for telemetry ranging and command verification. Large antenna and monopulse technique is used for angle measurement.



For ranging, the command (uplink) carrier is phase-modulated by pairs of low frequency waves, which are detected on the craft and used to remodulate the downlink telemetry carrier. The phase of this received signal is compared with that of the transmitted one for the range calculation. Pairs of modulating waves are used to avoid/resolve the ambiguities in the ranges, if any. Time difference measurement of the two signals can also provide the range. Commands are necessary for functions like attitude changes, gain control, station keeping, transponder/repeater switching, redundancy control etc. command systems are designed according to the overall TT&C requirement, number of commands required and security, i.e., protection against error and fake commands. The system should consist of (i) enabling, (ii) verification, (iii) execution signals other than the specific command signals. Enabling is permitting the system operation, verification is for fault-free operation and that is effected by transmitting the telemetry link to the earth and execution is carrying out the command.

8. When the mean optical power launched into an 8 km length of fiber is 120 μW, the mean optical power at the fiber output is 3 μW. Determine:
i) The overall signal attenuation or loss in decibels through the fiber assuming there are no connectors or splices.
ii) The signal attenuation per kilometer for the fiber.
iii) The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1 km intervals, each giving an attenuation of 1 dB.
iv) The numerical input/output power ratio in (c).

[WBUT 2014]

Answer:
The overall signal attenuation in decibels
ii) through the 8km fiber is

Signal attenuation $= 10\log_{10}\frac{P_i}{P_o} = 10\log_{10}\frac{120\times10^{-6}(W)}{3\times10^{-6}(W)} = 10\log_{10}40 = 16.02\text{dB}$

Hence,
$$\alpha(dB/km) = \frac{16.02}{8} = 2.0025\text{dB/km}$$

i) As $\alpha(dB/km)2.0025dB/km$, the loss incurred along 10km of the fiber is given
$$\alpha(dB/km)L = 2.0025\times10 = 20.025\text{dB}$$

iii) The total loss incurred along to 10km of the fiber 20.025dB.
According to the problem, the link has nine splices (at 1km intervals), each attenuation of 1dB. Hence, the loss due to the splices is 9 dB.
Thus the overall signal attenuation for the link is
Signal attenuation = 20.025 + 9 = 29.025 dB

iv) Input/output power ratio as follows:
$$\frac{P_i}{P_o} = 10^{(dB/10)}$$
$$\frac{P_i}{P_o} = 10^{(29.025/10)} = 10^{2.9025} = 798.91$$

9. a) What is multiple access technique? What are the factors on whi selection of multiple access technique depends on?
b) Calculate the total number of available channel in FDMA system, if th allocated BW is 12.5 MHz, guard BW 10 kHz and channel BW 30 kHz.
c) What do you mean by CDMA? What is spread spectrum technology?
d) What is FDD and TDD?
e) Draw one TDMA frame structure.

[WBUT

Answer:
a) 1st Part:
Multiple Access is a technique with which multiple terminals share the bandwidtl transmission medium. Multiple access techniques are of permanent importance i systems where the channel bandwidth is very limited.
Multiple Access are used to share the available channels by a large number of subs (users). There are four basic forms or types of multiple access techniques.
i) FDMA, ii) TDMA, iii) SSMA, iv) SDMA.

2nd Part:
i) capacity of MA system
ii) RF power & bandwidth
iii) inter-connectivity
iv) growth adaption
v) multiple service transmission
vi) terrestrial interface.

b) Given,
Total spectrum allocation, $B_{+} = 12.5\text{MHz} = 12.5\times10^{6}\text{ Hz}$
Guard band allocated $B_{Guard} = 10\text{kHz} = 10\times10^{3}\text{ Hz}$
Channel BW $B_C = 30\text{kHz} = 30\times10^{3}\text{ Hz}$
The number of channels available in FDMA system is given by

$$N = \frac{B_t - 2B_{Guard}}{B_C} = \frac{(12.5\times10^{6}) - 2(10\times10^{3})}{30\times10^{3}}$$

$$= \frac{10^{3}(12.5\times10^{3} - 20)}{30\times10^{3}} = \frac{10^{3}(12500 - 20)}{30\times10^{3}}$$

$$= \frac{10^{3}\times12480}{30\times10^{3}} = 416 \text{ channels}$$

c) 1st Part:
In code division multiple access (CDMA) systems, the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal. The spreading signal is a pseudo-noise (PN) code sequence that has a chip rate, which is few orders of magnitudes greater than the message data rate. In this system, each cell is a cluster (cluster size N = 1) and shares the same bandwidth. All users use the same carrier frequency and may transmit simultaneously. Each user has its own PN code, which is almost orthogonal to all other codewords. The receiver needs to know the code used by the transmitter for detection of the message signal.
CDMA offers many advantages over TDMA and FDMA. A US digital cellular system based on CDMA, which promised increased capacity was standardized as Interim standard 95 (IS – 95). IS – 95 allows each user within a cell to use the same radio channel and users in adjacent cells also use the same radio channel. This is possible because the system uses direct sequence spread spectrum CDMA system. CDMA system thus completely eliminates the need for frequency planning/reuse. For graceful transition from AMPS to CDMA, each IS-95 channel occupies 1.25 MHz of spectrum on each one-way link.
On the forward link, the BS transmits the user data for all mobiles in the cell by using a different spreading sequence for each mobile. A pilot code is also transmitted at a higher power level thereby allowing mobile units to use coherent carrier detection. On the reverse link, all mobiles respond in an asynchronous manner and ideally have a constant power level due to power control applied by BS.

IS-95 uses 824-849 MHz band for reverse channel and 869-894 MHz for forward channel. A forward and reverse channel pair is separated by 45 MHz.
Maximum user data rate is 8.6 Kbps. User data is spread to a channel chip rate of 1.2288 M chips/sec (spreading factor of 128). The spreading process is different in the forward and reverse channels as per the original CDMA specifications.
In India, CDMA service provides offer two-services – WLL (M) and fixed wireless terminal (FWT).

2nd Part:
Spread spectrum is designed to trade off bandwidth efficiency for reliability, integrity and security. If a receiver is not tuned to the right frequency, a spread spectrum signal looks like background noise. There are two type of spread spectrum radio; frequency hoping and direct sequence.

i) Frequency Hopping Spread Spectrum Technology
FHSS uses a narrowband carrier that changes frequency in a pattern known to both transmitter and receiver. Properly synchronized, the net effect is to maintain a single logical channel. To an unintended receiver, FHSS appears to be short duration impulse noise. It can provide greater scalability features than DSSS. In addition, while DSSS communication link could be shut down by a sufficiently strong interference, the FHSS link would merely be interrupted.

ii) Direct Sequence Spread Spectrum Technology
DSSS generates a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip. The longer chip, the greater the probability that the original data can be recovered and of course, the more bandwidth required. Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission. To an unintended receiver, DSSS appears a low power wide band noise and is rejected by most narrowband receivers.

d) Frequency division duplex (FDD) is a technique where separate frequency bands are used at the transmitter and receiver side. Because the FDD technique uses different frequency bands for send and receive operations, the sending and receiving data signals don't interfere with each other. This makes FDD a better choice than Time Division Duplex (TDD) for symmetric traffic such as voice applications in broadband wireless networks.
Time division duplex (TDD) refers to duplex communication links where uplink is separated from downlink by the allocation of different time slots in the same frequency band. It is a transmission scheme that allows asymmetric flow for uplink and downlink data transmission. Users are allocated time slots for uplink and downlink transmission. Time division multiplexing separates uplink and downlink signals by matching full duplex communication over a half-duplex communication link. This method is highly advantageous in case there is an asymmetry of uplink and downlink data rates. TDD divides a data stream into frames and assigns different time slots to forward and reverse transmissions, thereby allowing both types of transmissions to share the same transmission medium.

As with multiplexing, there are two ways to provide duplexing – frequency-division duplexing (FDD) and time-division duplexing (TDD). The simplest and perhaps best way to provide full duplex is to use FDD, which utilizes two separate channels, one for send and another for receive. Figure (i) shows the concept. The communicating parties are called station 1 and station 2. Station 1 uses the channel around f_1 for receiving only and the channel around f_2 for transmitting. Station 2 uses f_1 from transmitting and f_2 for receiving. By spacing the two channels far enough apart, the transmitter will not interfere with the receiver. Selective filters keep the signals separated. The big advantage of this method is the extra spectrum space required. Spectrum space is scarce and expensive. Yet most cell phone systems use this method because it is the easiest to implement and the most reliable.

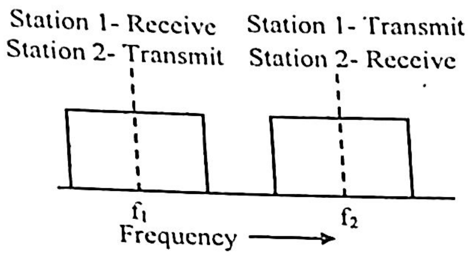


Fig: (i) Frequency division duplexing (FDD)

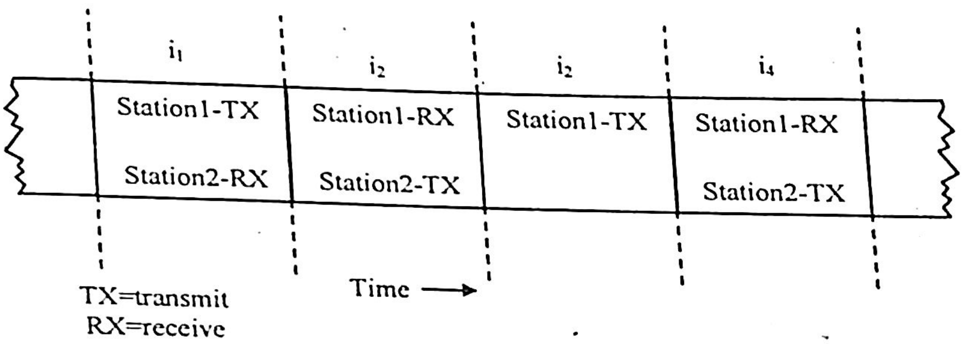


Fig: (ii) Time-division duplexing (TDD)

Time-division duplexing (TDD) means that signals are transmitted simultaneously on a single channel by interleaving them in different time slots. For example, alternating time slots are devoted to transmitting and receiving. This is illustrated in figure (ii). During time slot t_1, station 1 is transmitting (TX) while station 2 is receiving (RX). Then during time slot t_2, station 1 is receiving while station 2 is transmitting. Each time slot may contain one data word, such as 1 byte from an A/D converter or a D/A converter. As long as the serial data rate is high enough, a user will never know the difference.
The primary benefit of TDD is that only one channel is needed. It saves spectrum space and cost. On the other hand, the TDD method is harder to implement. The key to making it work is precise timing and synchronization between transmitter and receiver. Special synchronization pulses of frame sequences are needed to constantly ensure that timing will not result in collisions between transmit and receive. Several of the newer third-generation cell phone systems may use TDD.

c) In TDMA, a channel means a particular time slot that is cyclically repeating to every user. A TDMA frame consists of many time slots. The transmission from different users is interlaced into a repeating frame structure as shown in figure below.

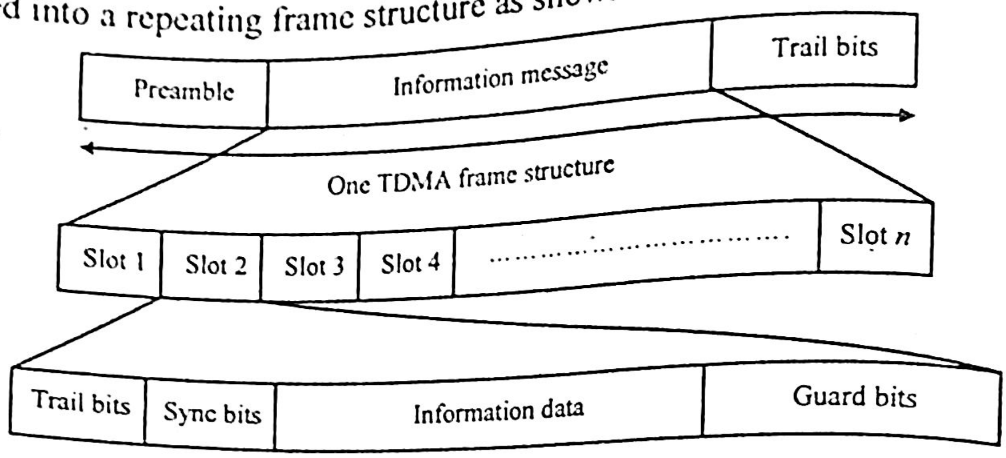


Fig: TDMA frame structure

10. a) What are the different criteria to choose light sources in an optical fibre communication system?
b) Draw the scheme of the transmitter-receiver system of Wavelength Division Multiplexing and explain the same.
c) Explain the reflection-refraction mechanism of a cable with step-index profile giving a suitable/relevant diagram. **[WBUT 2015]**

Answer:

a) i) Light must be monochromatic, which is not met ideally but the above sources have narrow band emission as shown in Fig. 1(a) and (b).

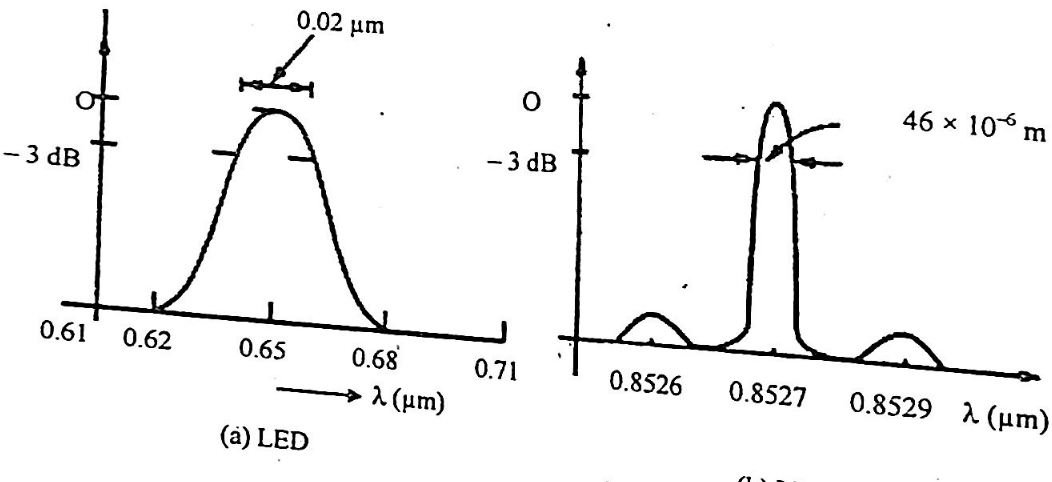


Fig: 1 Power output-wavelength plots:
(a) LED (G_2AsP), (b) Laser diode

ii) Light output from the source should be high otherwise the losses will not be covered and the receivers would not get enough light.
iii) Light source should be amenable to be easily modulated.

b) Wavelength division multiplexing (WDM) technique can be used to multiplex many high-speed channels at different carriers to transmit through the same fibre cable.

Depending on the choice of the channel spacing, there are three different types of WDM system: (i) the coarse WDM, (ii) the dense WDM and (iii) the optical frequency division multiplexing. The coarse type supports two channels at 1.30 and 1.55 μm in the low transmission loss region of the fibre. Both dense WDM and OFDM can support transmission rate of 100 Gb/s. The typical scheme of a WDM system is shown in Fig. 1. Through the fibre, k wavelengths (carrier) are simultaneously carried on, optically amplified for attenuation and component losses. These are then demultiplexed and detected by optical receivers.

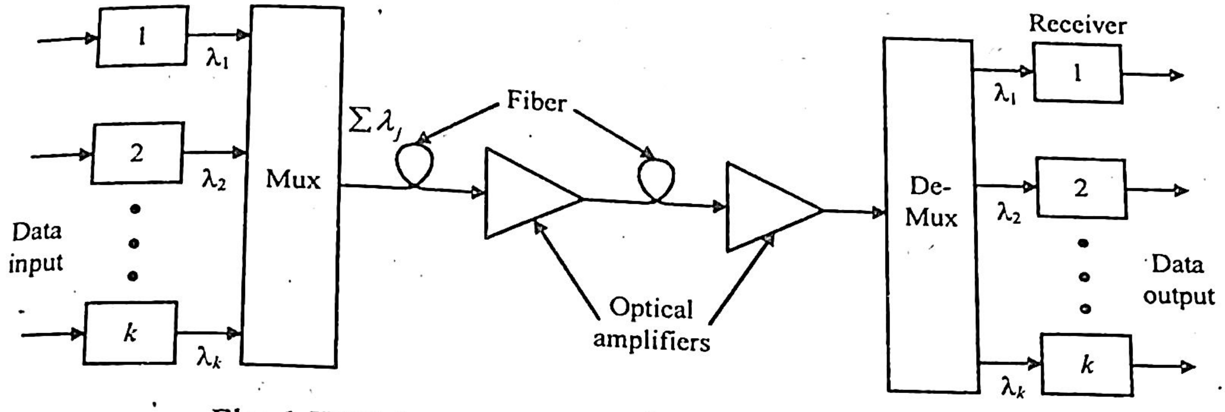


Fig: 1 WDM transmitter-receiver system with channel

Multiplexer and demultiplexers are for 1 to 10 nm, usually passive type like diffraction gratings or multiplayer interference filters. For channel spacing of the order of 0.1 nm cascaded interferometers are used specifically Mach-Zehnder or Fabrey-Perot types. Wavelength selective coupling devices are also common such as a star coupler. Optical amplifiers like erbium-doped fibre amplifiers provide high fibre-to-fibre gain of more than 20 dB and high output power, more than 10 mW, at a bandwidth of about 30 nm, around 1.535 to 1.565 μm wavelength range.

c) Fig. 1 shows a cable with step-index profile where the indices are marked.

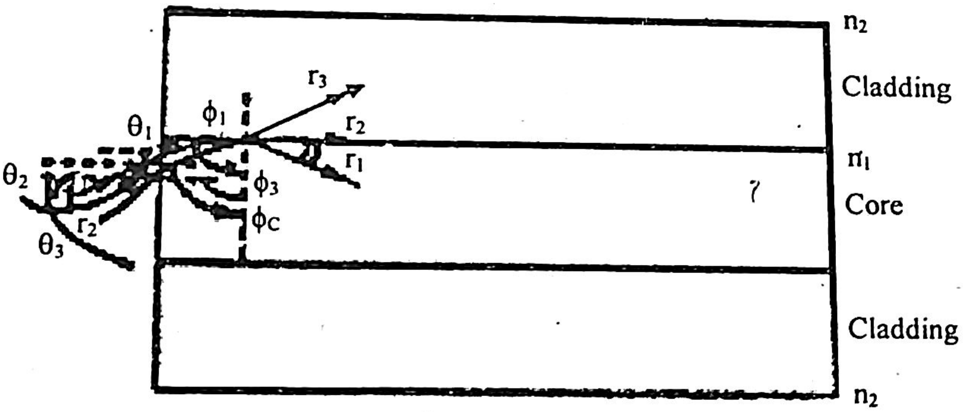


Fig: 1 The cable with step-index profile and reflection-refraction mechanism

It has been shown that with the incident angle θ_2 for ray r_2, the angle ϕ_c (Fig. 1) at the cladding interface is critical for total internal reflection to occur. With $\theta > \theta_2$, as for example θ_3 for ray r_3, the angle $\phi < \phi_c$ and there does not occur total internal reflection

and n_2 arrives in the cladding leaving the core at the interface. Light should, therefore, be incident at an angle $\theta < \theta_2$ for total internal reflection to occur so that $\phi > \phi_c$.
Now, one defines

$$\sin\phi_c = \frac{n_2}{n_1} \qquad .... (1)$$

So that $$\cos\phi_c = \frac{\left(n_1^2 - n_2^2\right)^{\frac{1}{2}}}{n_1} \qquad .... (2)$$

Also $$n_a \sin\theta_2 = n_1 \cos\phi_c \qquad .... (3)$$

where n_a is the index of air, and $\sin\theta_2$ is the sine of the maximum angle of incidence.
Writing $\theta_2 = \theta_{max}$,

$$\theta_{max} = \sin^{-1}\left(\frac{\left(n_1^2 - n_2^2\right)^{\frac{1}{2}}}{n_a}\right) \qquad .... (4)$$

The cone of light with the axial line of the fibre making an angle θ_{max} is called the acceptance cone, and the quantity $\sin\theta_{max}$ is often referred to as the 'numerical aperture'. NA thus

$$NA = \frac{\left(n_1 (2\Delta)^{\frac{1}{2}}\right)}{n_a} \qquad .... (5)$$

The quantity $\Delta = \frac{(n_1 - n_2)}{n_1}$ is called the normalized index difference and is used In propagation studies of the fibre cable. If $n_1 \cong n_2$, as is often the case, one can simplfy relation (5) as

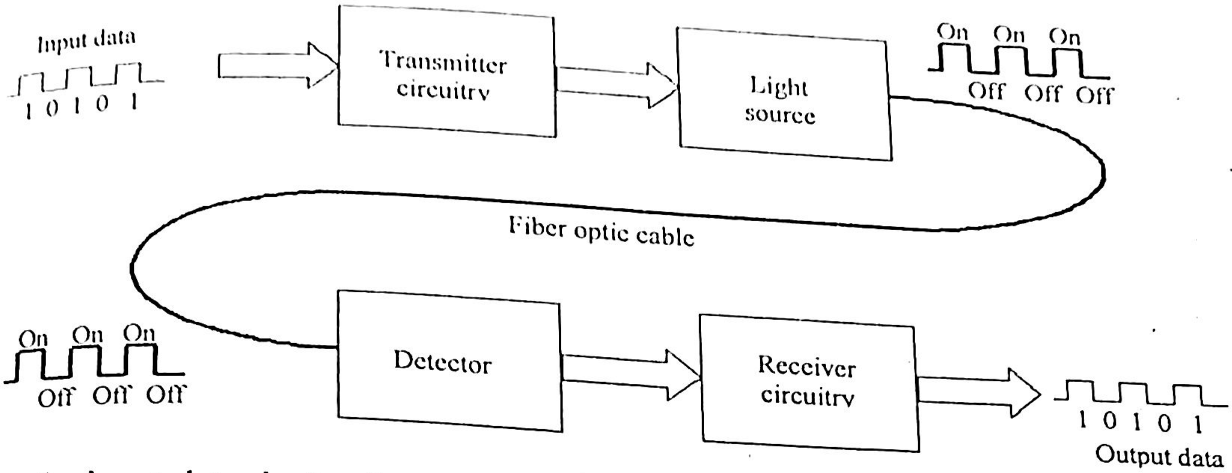
$$NA = \frac{\left(n_1 (2\Delta)^{\frac{1}{2}}\right)}{n_a} \qquad .... (6)$$

Propagation of light in a fibre is similar to the way microwave does in a waveguide. Three bands of wavelengths commonly used in fibre optical communication are $3\times\frac{10^{14}}{1.5}$ to $3\times\frac{10^{14}}{1.4}$ Hz, $\frac{3\times10^{14}}{1.3}$ to $\frac{3\times10^{14}}{1.2}$ Hz and $\frac{3\times10^{14}}{0.9}$ to $\frac{3\times10^{14}}{0.8}$ Hz, because the silica-based fibre used in data communication have lowest losses in these bands.

11. a) Draw the scheme of an optical fibre-based telemetry system. **[WBUT 2017]**

Answer:

Unlike copper wire based transmission where the transmission of electrical signals is done through the cable, the fiber optics transmission involves the transmission of signals in the form of light from one point to the other. Furthermore, a fiber optic communication network consists of transmitting and receiving circuitry, a light source and detector devices like the ones shown in the figure below.



When the input data, in the form of electrical signals, is given to the transmitter circuitry, it converts them into light signal with the help of a light source. This source is of LED whose amplitude, frequency and phases must remain stable and free from fluctuation in order to have efficient transmission. A fiber optic cable carries the light beam from the source to the destination circuitry. A receiver circuit reverts the optical information back to the electrical signal.

The receiver circuit consists of a photo detector along with an appropriate electronic circuit, which is capable of measuring magnitude, frequency and phase of the optic field. This type of communication uses the wave lengths near to the infrared band that are just above the visible range. Both LED and Laser can be used as light sources based on the application.

b) What are the different types of loss mechanisms in fibre optical cable? How can they be compensated? **[WBUT 2017]**

Answer:

Refer to Question No. 7(a) of Long Answer Type Questions.

c) Compare the advantages and disadvantages of different sources of light used in optical fibre telemetry system. **[WBUT 2017]**

Answer:

Refer to Question No. 7(b) of Long Answer Type Question.

12. a) Draw the scheme of an optical fibre-based communication system.
b) What are the different types of loss mechanisms in fibre optical cable? How can they be compensated?
c) What is the critical angle of incidence and on what factors does it depend?

d) What is Geostationary satellite? Describe a typical TT and C system for spacecraft. [WBUT 2018]

Answer:

a) *Refer to Question No. 11(a) of Long Answer Type Questions.*

b) *Refer to Question No. 7(a) (2^{nd} & 3^{rd} part) of Long Answer Type Questions.*

c) Critical angle is defined as the angle of incidence that provides an angle of refraction of 90-degrees and depends on the interfacing media. For the water-air boundary, the critical angle is 48.6-degrees. For the crown glass-water boundary, the critical angle is 61.0-degrees. The actual value of the critical angle is dependent upon the combination of materials present on each side of the boundary.

The factors which affect the critical angle are: (i) The wavelength of light, and (ii) The temperature of the media.

i) Effect of wavelength of light: The critical angle for a pair of media is less for the violet light and more for the red light. Thus critical angle increases with increase in wavelength of light.

ii) Effect of temperature: The critical angle increases with increase in temperature because on increasing the temperature of medium, its refractive index decreases.

d) 1^{st} part: *Refer to Question No. 1(a) of Short Answer Type Questions.*
2^{nd} part: *Refer to Question No. 7(c) of Long Answer Type Questions.*

13. Write short notes on the following:

a) Satellite telemetry and MA techniques [WBUT 2010]
b) Optical detectors used in telemetry system [WBUT 2010, 2015]
c) Remote control system [WBUT 2012, 2016]
d) Earth Station [WBUT 2012]
e) TT and C services [WBUT 2014, 2016]
f) Different losses in optical fiber telemetry system [WBUT 2014]
g) CDMA [WBUT 2014]

Answer:

a) Satellite telemetry and MA techniques:

The selection of proper multiple access (MA) technique in satellite telemetry is to meet the requirement of the services to be rendered commercially. This, in turn, is dependent on (i) capacity of MA system, (ii) RF power and bandwidth, (iii) inter-connectivity, (iv) growth adaptation, (v) multiple service transmission, (vi) terrestrial interface. The other two aspects are security and cost effectiveness.

(i) Capacity of MA is defined in terms of number of channels (data/voice) that can be accommodated using the power and bandwidth of a single transponder.

(ii) Interconnectivity depends on the network geometry for the various services to be rendered. In multimode geometry it is convenient for MA technique to provide interconnectivity among different users at varying data rates and quality levels. This makes the satellite service better cost effective as compared to point to point network or connectivity.

(iii) In fact, power and bandwidth are resources and should be used economically, i.e. the design should both be power-limited and bandwidth limited.

(iv) The design should envisage a growth rate and provision to adapt to traffic growth and changes in traffic patterns should be there.

(v) Terrestrial interface between the earth station and the user is to be made as economical as possible and to add more the digital technique available can be used here to have better quality as well.

(vi) The digital technique flushing the communication services has revolutionized them providing multiservice transmission. The integrated service digital network (ISDN) is being used for multiple services and this should be accommodated in the design stage.

In satellite telemetry, it is only too natural that its geometric advantage be exploited and multiple access technique should be adopted towards the goal that more than one pair of earth stations can use a satellite transponder simultaneously. A transponder may be accessed by a single or multiple carries which may, in turn, be modulated by single or multiple channel basebands consisting of voice, video and data.
There are three fundamental types of MA systems known as reservation protocols:

(i) Frequency division multiple access (FDMA) where multiple carriers access the transponder – the bandwidth of each carrier can be small as required for single signal channel. It can use either analogue or digital transmission in burst or continuous mode.

(ii) Time division multiple access (TDMA) where a single carrier frequency is used for transponder and the full transponder bandwidth can be used which is time-shared by users on time slot basis. It uses only digital transmission and in burst mode only.

(iii) Code division multiple access (CDMA), suitable also for digital transmission allows the users to transmit simultaneously in the full transponder bandwidth at the same time and the signal, for each user, is transformed using a unique code sequence.Of these, the first two techniques are very common and offer following characteristics: FDMA has two variations the multiple channel per carrier and the single channel per carrier. MCPC and SCPC respectively. In the former, the carriers can have varying bandwidths depending on the number of channels per frequency slot, a large portion also goes for guardbands (= 10%) for spectral separation. In analogue transmission mode frequency division multiplexing is done and then modulated on FM carrier. For digital transmission time division multiplexing combines the multiple digital channels and typically PSK is used for modulation.

Analogue or digital transmission can be used for FDMA-SCPS system as well but usually in burst operating mode where voice activated carriers are used.
The TDMA using full transponder bandwidth has no transponder nonlinearity and can operate at full power. There is no loss in spectral utilization. It also uses a single carrier.

b) Optical detectors used in telemetry system:
Usually chosen light sources are LEDs (light emitter diodes) and semiconductor laser diodes, often abbreviated as LDs.

On the receiving side, the light pulses are detected by a photodiode and a circuit arrangement with it is made to obtain electrical pulses as appropriate. The photodiode is again a light-sensitive p-n junction diode and is operated in the reverse-biased condition. PIN avalanche diode is also used but p-n junction diodes are more popular for generalized applications. It has comparatively low conversion efficiency or responsivity but is quite fast in response. Both are increased by adding an undoped intrinsic layer between the p and n semiconductors to form PIN diode. With the intrinsic layer exposed to light and reverse biasing, the responsivity increases but so also response time.

To increase responsivity and decrease response time, avalanche photodiode is produced and used. Its popularity, however, is to a certain extent limited because of high cost and complicated circuitry associated with it. It uses the break-down principle similar in zener and IMPATT microwave diodes. A large reverse voltage is applied and with photons incident on it, avalanche effect takes place and a large current flows. Because of high reverse current, amplification is often not necessary as it has an inherent multiplication factor of 100 to 300.

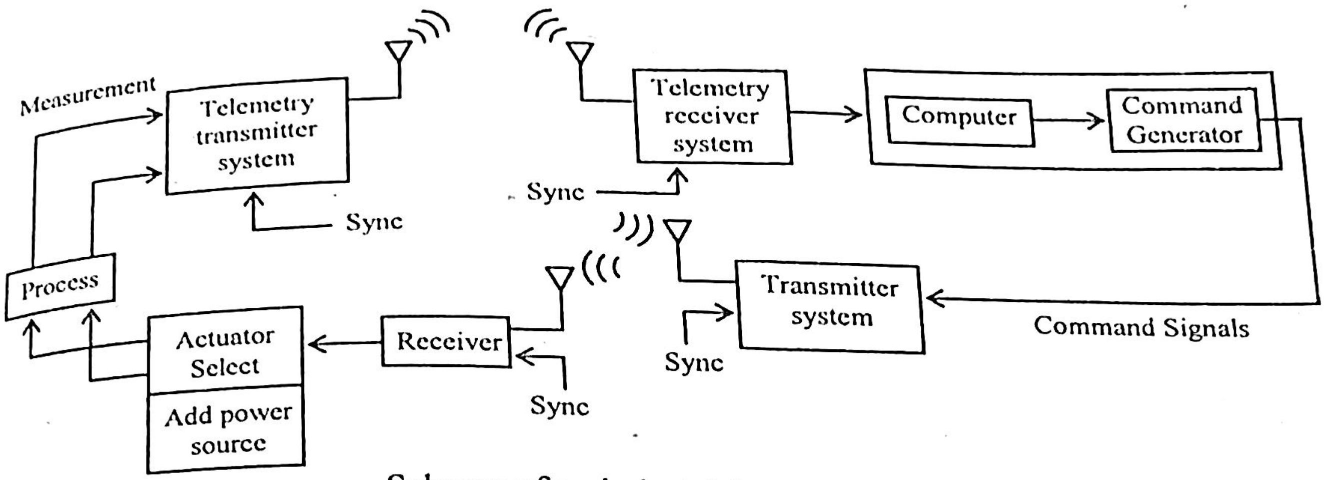
c) Remote Control System:

Remote control system can be defined as a closed loop system consisting of (a) sensors, (b) a signal conditioning system, (c) a transmission system to send the information (conditioned) to a remote station (control), (d) a control centre or point where automatic decision making (controller/computer) is done, (e) the devices that would transform decision outputs into appropriate control signals, (f) channels/links to transmit informations (control signals) to actuators at action points, often remote from the control points, and (g) the actuators that are located at action points and are operated by the received control signals to effect desired responses.

There are two points or stations remote to each other – (1) the action point or site and (2) control point (or control station/command centre/control centre). Remote control system generally belongs to the real time control category. The another category, the non-real time system is the one when assessment/correlation/decision-making takes an amount of time that exceeds an interval called the control response time.

In a feedback control system inside the plant, the communication delay is negligible and the analysis is based on this conjecture. But in a remote feedback control system, an additional delay comes in which may initiate instability in the system. When sampled data is transmitted through the channels for remote control, it is necessary that the sampling time should be less than the shortest response time of the system.

The scope of application for remote control is growing in the industrial organization. The typical scheme of arrangement is given in fig. The remote control system is different from a ordinary telemetry system as there is an additional return loop /link for the remote control known as command link & actuators.



Scheme of an industrial remote control system

Remote control is extensively used in space programme and also in targeting of moving objects detrimental to national peace. In the latter group two specific cases are (i) a command guidance system and (ii) a beam rider system. A block diagrammatic representation of the former is shown in Fig. below.

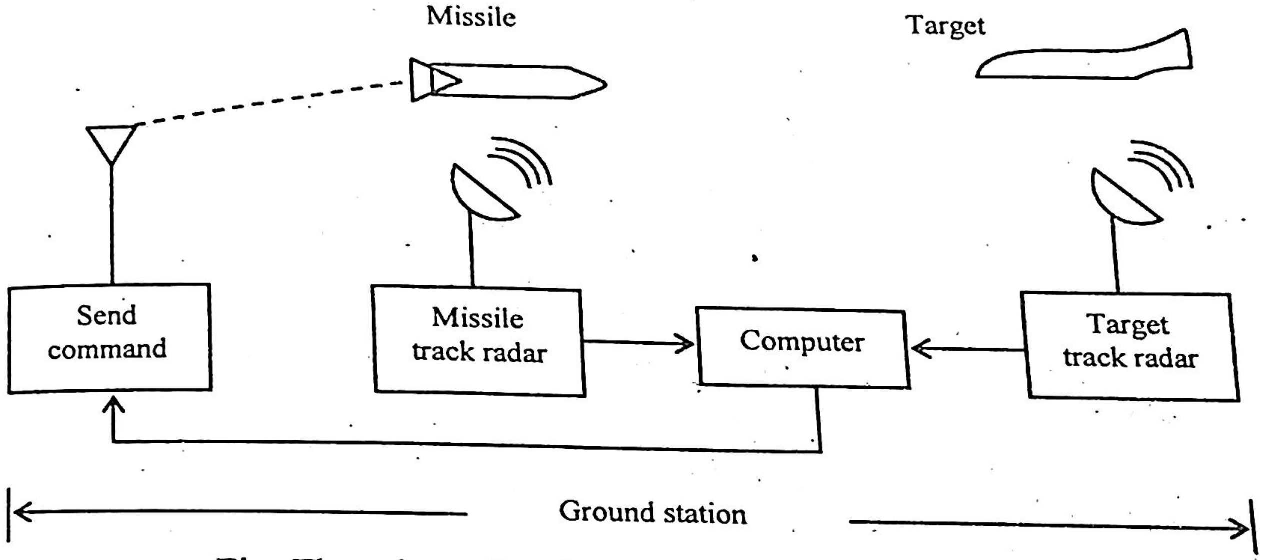


Fig: The schematic of a command guidance system

d) Earth Station:

An earth station is a collection of equipment for communicating with the satellite, regardless of whether it is a fixed, mobile, aeronautical, or marine terminal. An earth station provides a means of transmitting the modulated radio frequency (RF) carrier to the satellite within the uplink frequency spectrum and receiving the RF carrier from the satellite with the downlink frequency spectrum. It is the vital link between satellites and communication users.

The basic configuration of an earth station is shown in Fig. 1. An earth station comprise an antenna, tracking system, receiver, transmitter, multiplexer (combiner) and terrestria links via modem (or codec).

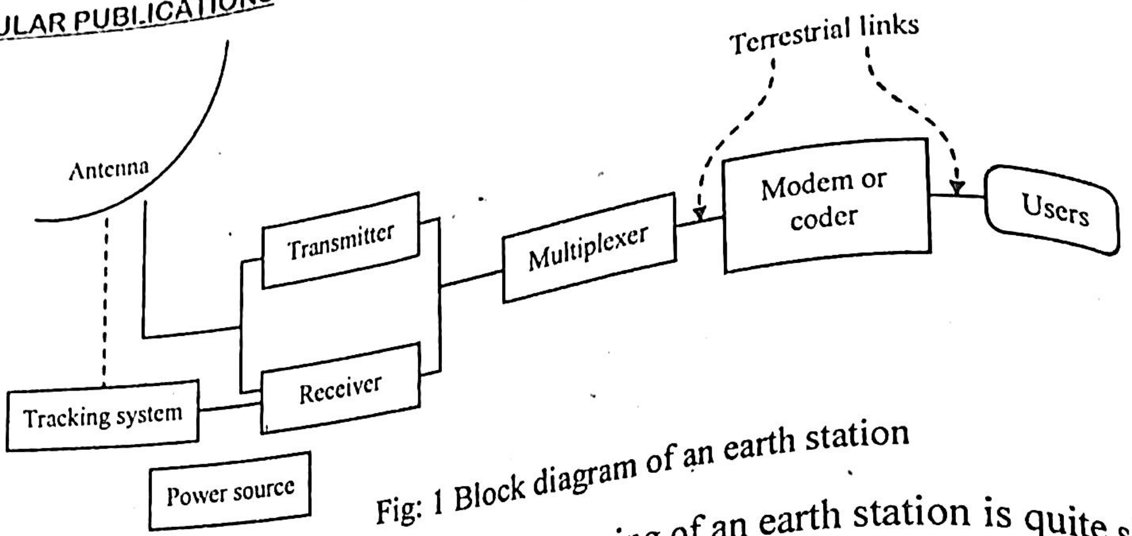


Fig: 1 Block diagram of an earth station

Conceptually, the internal electronic signals processing of an earth station is quite simple. For example, let's consider the processing of baseband signals to form the transmitting signals of the earth station. The baseband signals – such as video (TV), voice (telephone) and data – from users are brought via the terrestrial link (e.g., optical fibre, twisted pair cable, coaxial cable, microwave link) from different sources. the baseband signals are then combined multiplexed) – and encoded with a forward error correction (FEC) scheme in the case of digital satellite communications – and modulated onto the intermediate frequency (IF) carrier to form the earth station's transmission. The transmission can be formatted as a single carrier or multiple contiguous carriers. If the information from a single source is placed on a carrier, the format is called single channel per carrier (SCPC). A distinction should be made between a signal and a carrier. A carrier is an electromagnetic wave of fixed amplitude, phase and frequency that, when modulated by a signal, can be used to convey information through a communication system. The modulated signal can be analog or digital originating from a source, such as a telephone, video, data and so on, and is often referred to as modulating the carrier. The complete set of these carriers is then radio frequency translated for high power amplification and transmission.

Types of Earth Stations

Many different types of earth stations are required for satellite communications. The siz of an earth station's antenna is the primary feature distinguishing one earth station fro another. The types are grouped under three headings: long earth station, small eart station and very small aperture (VSAT) earth station.

Earth stations with large antennas 10 to 60 m in diameter are called long earth statio This type is often required to provide for high-capacity telephone, data or televisi transmission. In general, the larger the antenna, the greater the traffic capacity of t station.

Small earth stations have antennas with diameters between 1 and 10 m. They a commonly sighted on the roofs or in the gardens of domestic and commercial buildin Small earth stations provide capabilities for reception of broadcast television connection for thin-route telephony systems in remote regions.

Very small aperture (VSAT) earth stations are networks of satellite earth terminals, each of which has an antenna diameter between 0.3 and 0.9 m – hence the name very small. VSAT networks are usually arranged in a star configuration in which small-aperture terminals each communicate via the satellite to a large central earth station known as a hub station. Any aperture smaller than VSAT is called an ultra-small-aperture terminal (USAT).

e) TT & C Services:

As mentioned earlier for TT & C services VHF and S band microwave links are in common use. The characteristics of these usages are specified in terms of uplink and downlink frequency range (MHz), maximum multiplicity of sinusoidal tones (Nos.), ranging and propagation errors (metres). Typically, propagation error in VHF, around 100 to 2000m, is much more than S-band usage, around 0 to 300m, although the ranging accuracies are comparable (VHF: around 20-140m, S-band: 5 – 175m). VHF frequency ranges are usually 148-150 MHz and 136-138 MHz for up and down links respectively while for S-band these are 2025-2120 MHz and 2200-2300 MHz respectively. Number of sinusoidal tones in the two cases are 6 and 7 respectively and obviously are comparable. To add more, the microwave frequency bands used in satellite communications can be listed as given in table below.

Table: Microwave bands in satellite communications

Name of band	Frequency range	Comments
P	225 – 390 MHz	
J	350 – 530 MHz	
L	1530 – 2700 MHz	Application in Military, radar/satellite services
S	2500 – 2700 MHz	
C	3400 – 6425 MHz	Satellite downlink 3.7 to 4.2 GHz and uplink 5.925 to 6.425 GHz, loosely named 4 – 6 GHz system
X	7.250 – 8.400 GHz	Aeronautical/Marine usage, including radar
Ku	0.95 – 14.5 GHz	New Comm. satellite services: DL 11.7 to 12.2 GHz, UL 14 to 14.5 GHz, named as 12/14 GHz system Bandwidth 500 MHz; it has been used because C-band is getting over crowded
Kc	17.7 – 21.2 GHz	
K	27.5 – 31 GHz	
Q	36 – 46 GHz	
V	46 – 56 GHz	
W	56 – 100 GHz	

f) Different losses in optical fiber telemetry system:

A fibre optic cable may be 'single-stranded' or a 'multistranded' one. It is made of glass or plastic. Glass is obviously superior compared to plastic as a material for fibre but is costlier and more fragile. Plastic is more lossy (has greater attenuation loss). For short distance transmission, plastic is sometimes preferred to glass. Cladding is provided by the same material but with different refractive index. Thus one can have glass core-glass-cladding type known as PCS type cable. As has already been mentioned, a fibre cable may be made as shown in Fig. 1, with an inner core, a cladding and a jacket. Additional protection is being provided by wrapping such a cable in stranded-steel armour or a special yarn (Kevlar) armour, which then is covered with plastic jacket again. Fibre cable is also available in multicore flat ribbon form for special applications.

It is the attenuation of light energy in the cable that receives attention first. This attenuation or loss is mainly due to (a) absorption, (b) scattering and (c) dispersion. Of these, dispersion has already been discussed and it has been shown that the light intensity is reduced by reducing the pulse height at the receiving end: it occurs due to pulse stretching and as such no loss occurs in the cable. Loss, however, may occur through leaks over the cladding interfaces due to change in reflection angles for some reason or other, such as wavelength change and bending of the cable etc.

Absorption occurs mainly due to impurities in the material (glass or plastic) and is dependent on wavelengths. There are three different types of absorption; resonance, UV and IR. Minute quantities of water molecules present contribute to OH^- ions which show resonance effect at specific wavelengths (UV), i.e., higher frequencies, light can induce conduction of valence electrons. Since energy is absorbed for such a thing to occur, loss occurs in this part of the spectrum. Impurities enhance these losses. In the IR range, absorption leads to heat generation causing losses. There occurs even peaks like resonance but at much longer wavelengths like 3.2, 3.8, 4.4, 8.0 μm.

Impurities frozen during manufacturing generate submicroscopic variations in the fibre density. This variation in density tends to produce scattering that leads to loss of light as the rays entering at some angle are lost in the cladding due to refraction. Total loss in dB over a band of wavelengths used in optical fibre communication are shown in Fig. 1. The loss is expressed in dB as

$$dB \text{ loss} = 10\log(P_{output} / P_{input})$$

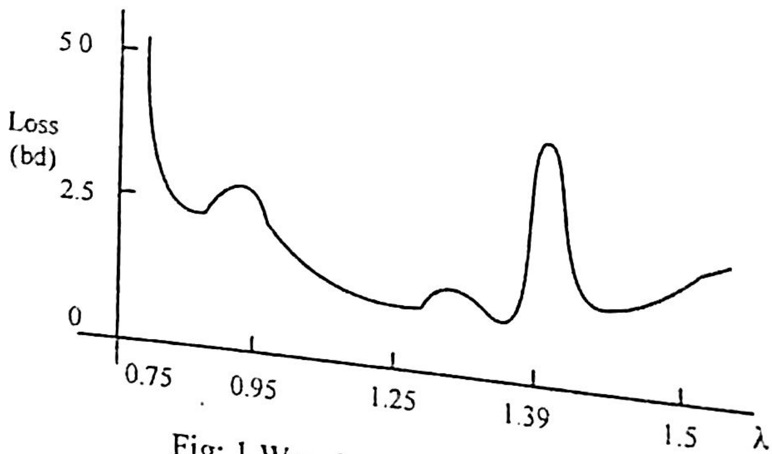


Fig: 1 Wavelength versus loss plot

The loss, so incurred, forces to use repeaters for long fibre optic communication lines. With laser source (ILD) and best circuitry available now, a repeater is required every 30 to 35 km.

g) CDMA: ***Refer to Question No. 9(c) of Long Answer Type Questions.***