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PREPARED BY : ER. D. MOHAPATRA

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CHAPTER-01 : RADAR AD NAVIGATION AIDS

- RADAR means Radio Detection and Ranging. It is a device which can detect the presence of Target and measure its Range.
- Radar is an electromagnetic system for detection and location of reflecting objects such as aircrafts, ships, vehicles, people and natural environment etc.
- It operates by transmitting a particular type of wave form (for e.g. pulse modulated sine wave) into space and detects the nature of echo signal reflected form an objects or targets.
- Radar can't recognize colour of objects but it can recognize darkness, fog, smoke, rain, snow etc.

1.1. Basic Radar, advantages & applications

- The **basic** principle behind **radar** is simple - extremely short bursts of radio energy (traveling at the speed of light) are transmitted, reflected off a target and then returned as an echo.
- **Radar** makes use of a phenomenon we have all observed, that of the ECHO PRINCIPLE.
- **Radar** is a detection **system** that uses radio waves to determine the range, angle, or velocity of objects.
- The term **RADAR** was coined in 1940 by the United States Navy as an acronym for "RAdio Detection And Ranging".
- The term **radar** has since entered English and other languages as a common noun, losing all capitalization.

Advantages :

- The main **advantage of RADAR**, is that it provide superior penetration capability through any type of **weather** condition, and can be used in the day or night time.
- **Radar** uses electromagnetic wave that does not require a medium like Sonar (that uses water) so can be used in space and air.

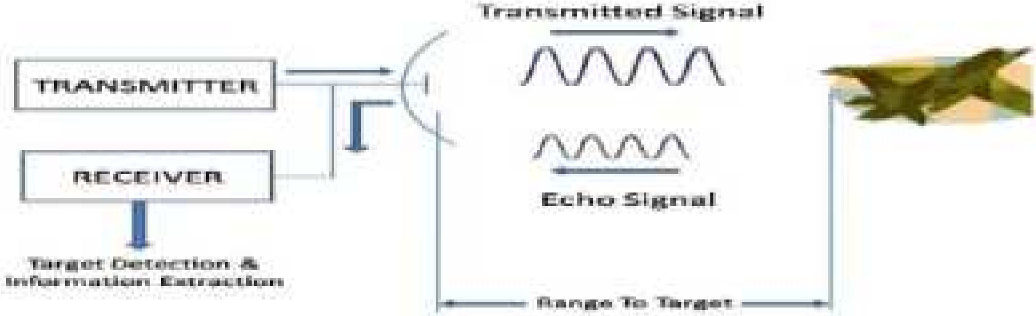
Applications :

The modern **uses** of radar are highly diverse, including

- air and terrestrial traffic control,
- radar astronomy,
- air-**defense** systems,
- antimissile systems,
- marine radars to locate landmarks and other ships,
- aircraft anti collision systems,
- ocean surveillance systems,
- outer space surveillance and rendezvous systems

1.2 . Working principle of Simple Radar system , its types

- A Simple Radar System consists of Transmitter, Receiver and Antenna. A Transmitter generates an EM Signal which is radiated into space by Transmitting Antenna.
- A portion of the transmitted energy is intercepted by the target and re-radiated in many directions.
- The radiation directed towards the Radar is collected by the receiving Antenna and delivers into receiver.



[BLOCK DIAGRAM OF A SIMPLE RADAR SYSTEM]

- At the receiver the Signal is processed to detect the presence of target and determines its location.
- A Single Antenna is generally used in a time shared basic for both Transmitting and Receiving when the radar waveform is a repetitive series of pulses.
- The range or distance to a target is found by measuring the time it takes for the radar signal to travel to the target and return back to the Radar.
- Radar can also provide information about nature of target being observed. If the target is in motion, there is a shift in the frequency of the echo signal due to the Doppler Effect.
- This frequency shift is proportional to the velocity of the target related to the Radar which is known as Radar velocity.

- **NOTE:** Doppler frequency shift is widely used in Radar as the basic for separating desired moving target from fixed(Unwanted) clutter echoes reflected from natural environments such as see, Lake Etc.
- The range of the target is determined by the time T_R; It is the time taken by the pulse to travels to the target and returns back.
- The EM Wave in the space travel in the speed of light i.e. 3×10^8 m/s. Thus the time taken for the signal to travel to the target located at a Range 'R' and returned back to the Radar can found as: -

$V=S/T \Rightarrow T=S/V$

$$T_R=2R/C \rightarrow R=CT_R/2$$ [V=Velocity=C; S=Distance=R; T=Time=T_R]

NOTE:-

$R_{KM} = 0.15\ T_R\ (\mu s)$ $R_{Mt} = 150\ T_R\ (\mu s)$ $R_{Yard} = 164\ T_R\ (\mu s)$ $R_{Feet} = 492\ T_R\ (\mu s)$

$R_{nmi} = 0.081\ T_R\ (\mu s)$ [nmi= Nautical Miles] $R_{smi} = 0.081\ T_R\ (\mu s)$ [smi= Statute Miles]

Un-Ambiguous Range:-

- Once the signal is radiated into space by Radar, Sufficient time must elapse to allow all echo signals to return to the Radar before the next pulse is transmitted. The rate at which the next pulse transmitted is determined by the longest range at which targets are accepted.

- If the time between pulses T_P is too short an echo signal from long range target might arrive after the transmission of next pulse and we mistakenly associated with that pulse rather than the actual pulse transmitted earlier. This can result an incorrect or ambiguous measurement of Range.

- Echo that arrives after the transmission of next pulse are called second-time around echo. Such an echo would appear to be at a closer range than the actual and its range measurement is called misleading, if it were not known to be second-time around echo.
- Hence the range beyond which the target appears as second-time around echo is called Maximum Unambiguous Range.

$$R_{Unamb} = CT_P/2 = C/2F_P$$

Where, T_P = Pulse Repetition Period. & F_P = Pulse Repetition Frequency.

☎ *TYPES Of RADAR*:-

➤ There are basic two types of Radar Detecter

- Pulse Radar System
- Continuous Wave (CW) Radar System

➤ Continuous Wave Radar System again classified into two catagories,such as :

- CW Doppler Radar Frequency
- Modulated CW Radar (FM-CW Radar).

1.3 . Radar range equation & Performance factor of radar

- Radar Equation relates the Range of Radar to the characteristic of Transmitter, Receiver, Antenna,Target, and Environment etc.
- It is used not just as a man for determining the maximum distance from Radar to a Target. But it can serve both as a tool for understanding Radar Operation and a Basic form of Radar Design.
- In this section the simple form of Radar Equation is derived.
- For an isotropic antenna; If the Power of Radar Transmitter is denoted by P_t then the Power Density (watts per unit area) at a distance 'R' is equal to the Transmitted Power Divided by the Surface Area($4\pi R^2$) of an Imaginary Sphere with Radius 'R'. Where P_I = Power Density from Isotropic Antenna.

$$P_I = \frac{Pt}{4\pi R^2} \quad \text{..} \quad (1)$$

Generally Radar uses Directive antennas to channels. In this case the radiated power P_t is in some particular direction. If the gain (G) of an antenna is a measure of increased power radiated in the direction of target as compared with power that would have been radiated. And is defined as,

$$G = \frac{\text{Maximum Power Density Radiated by Directive Antenna}}{\text{Power radiated by a loss less Isotropic Antenna with same Power Input}}$$

➤ So, The Power Density at the target form an Directive Antenna with a transmitting gain 'G' is

$$P_D = \frac{Pt\,G}{4\pi R^2} \quad \text{..} \quad (2)$$

➤ The target intercepts a portion of radiated power and re-radiated it in the various directions. The measure of the amount of incident power intercepted by the target and re-radiated back in the Radar Cross Section (σ) and is defined by the relation.

$$\text{Power Density of the echo signal at Radar} = \frac{Pt\,G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} = \frac{Pt\,G\,\sigma}{(4\pi R^2)^2} \quad \text{..................} \quad (3)$$

➤ The Radar cross section (σ) as unit of area, it is the characteristic of a particular target and a measure of its size as seen by the Radar.

➤ Like target the Receiving Antenna intercepts a portion of the re-radiated power which is proportional to the Cross Sectional Area of the Receiving Antenna (A_e). The radar antenna captures a portion of the echo power. If the effective area of the cross sectional area of receiving antenna is denoted as A_e. The power receiving by the Radar is

$$P_r = \frac{Pt\,G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} \times Ae \rightarrow P_r = \frac{Pt\,G\sigma\,Ae}{(4\pi)^2 R^4} \quad \text{......................... (4)}$$

- The Maximum Radar Range i.e. R_{max} is the distance beyond which the target cannot be detected. It occurs when the received echo signal power P_r just equal to the Minimum Detectable Signal (S_{min}).

$$S_{min} = \frac{Pt\,G\,\sigma\,Ae}{(4\pi)^2 Rmax^4} \rightarrow (R_{max})^4 = \frac{Pt\,G\,\sigma\,Ae}{(4\pi)^2 Smin}$$

$$\Rightarrow (R_{max}) = [\frac{Pt\,G\,\sigma\,Ae}{(4\pi)^2 Smin}]^{\frac{1}{4}} \quad \text{.................................(5)}$$

- That is the Fundamental of the Radar Equation.

NOTE: - The importment antenna parameters are Transmitting Gain & the Receiving Effective Area.

- Antenna theory give the relation between Transmitting gain & receiving affective area of antenna i.e.,

$$G = \frac{4\pi\,Ae}{\lambda^2} \quad \& \quad A_e = \frac{G\,\lambda^2}{4\pi} \quad \text{............................ (6)}$$

- Since the Radar generally use the same antenna both for Transmission and Reception, So we use these values in fundamental equation of Radar.

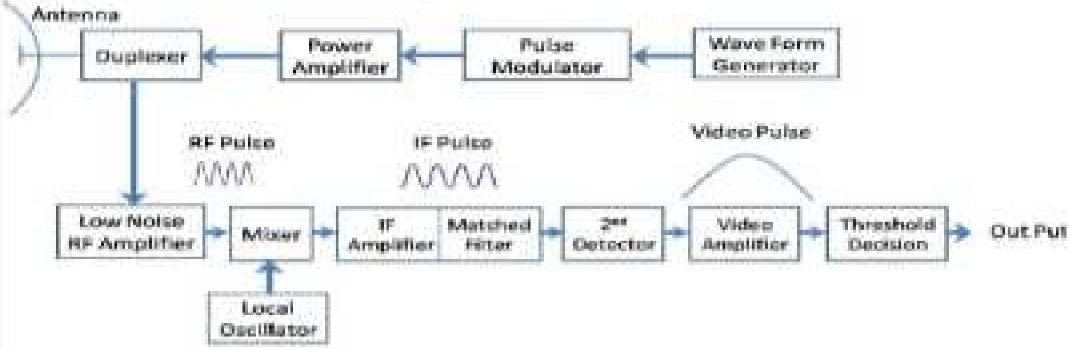
$$R_{max} = \frac{Pt\,4\pi\,Ae}{\lambda^2} \times \frac{Ae\,\sigma}{(4\pi)^2 Smin} \Rightarrow R_{max} = [\frac{Pt\,Ae^2\,\sigma}{4\pi\,\lambda^2 Smin}]^{\frac{1}{4}} \quad \text{.........(7)}$$

$$R_{max} = [\frac{Pt(\frac{G\lambda^2}{4\pi})^2\sigma}{4\pi\lambda^2 Smin}]^{\frac{1}{4}} \quad \& \quad R_{max} = [\frac{PtG^2\lambda^2\sigma}{(4\pi)^3 Smin}]^{\frac{1}{4}} \quad \text{...................... (8)}$$

- These simplified versions of Radar equation don't adequately describe the performance of actual Radars, as many important factors are not included. Also Idealized conditions have been employed i.e. neither the Effect of Ground nor Absorption and Interference is taken into account. Hence, the maximum range in practice is often less than that of indicated by the Radar Range Equation.

1.4 . Working principle of Pulsed Radar system

☎ *PULSE RADAR SYSTEM:-*



[BLOCK DIAGRAM OF A **PULSE MODULATED RADAR** SYSTEM]

- The operation of a typical Pulse Radar System is described by the help of block diagram.

- Generally it consists of Antenna, Transmitter and Receiver which are explained below

1. ANTENNA: -

- The function of antenna during transmission is to concentrate the radiated energy into a shaped beamwhich points in the desired direction in the space.
- On reception the antenna collects energy contained in the echo signal and deliveries it to the receiver.
- The two important input parameters of Antenna i.e. Transmitting Gain (G) and Effective Receiving Area (A_e) are proportional to each other.
- An antenna with large effective receiving aperture implies a large transmitting gain.
- Different type of antenna can be used in Radar such as mechanically steered parabolic reflector, electrically steered planned array antenna or electrically steered phase array antenna etc.

2. TRANSMITTER: -

- The Transmitter may be an oscillator such as a Magnetron i.e. pulsed [turned ON and OFF] by the modulator to generate a repetitive train of pulse.
- The Magnetron most widely used for a various microwave generator for Radar.
- A Typical Radar for the detection of aircraft has the following points: -
  - Ranges nearly equal to 100 to 200nmi.
  - Transmitting power in the order of mega watt & Average power in order of several kilowatt;
  - Pulse Width in the order of micro second.
  - Pulse repetition frequency in the order of several 100 pulses per sec.
- Transmitting section consists of Waveform Generator, Pulse Modulator, Power Amplifier & Duplexer.
- The waveform generator generates repetitive train of pulse & is fed to pulse modulator for modulation.
- The pulse modulator modulates the train of pulses and gives the pulse modulated signal to the power amplifier for amplification.
- The power amplifier amplifies the pulse modulated signal and fed to the duplexer. Generally audio frequency amplifier is used for this purpose.
- The duplexer allows a single antenna to be used on a time sharing basis for transmitting and receiving.
- The duplexer is generally a gaseous device that produces a short circuited at input to the antenna During Transmission. So that the high power is flows to the antenna not to the receiver.
- The duplexer protects from damages caused by the high power of the transmitter. It also serves to channel that the returned echo signal to the receiver and not to the transmitter.
- The duplexer might consist of two gassed discharged devices one known as TR (Transmit Receiver) and ATR (Anti-Transmit Receiver).
- The TR protects the receiver during transmitting and the ATR directs the echo signal to the receiver during reception.

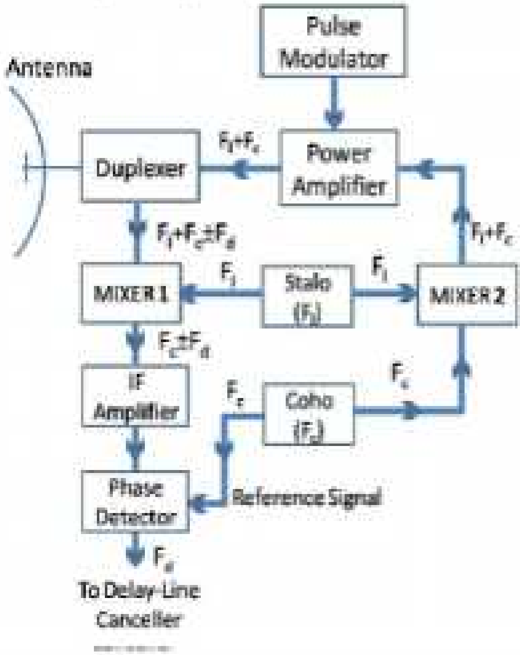
3. RECEIVER SECTION: -

- The receiver is usually super heterodyne type. It consists of different part as explained bellow: -
- The 1st stage of the receiver is low noise R.F. transistor amplifier which reduces the noise level.
- The mixer and local oscillator converts the R.F. signal to intermediate frequency where it is amplified by the IF amplifier.
- The signal Bandwidth of a super heterodyne receiver is determined by the bandwidth of the IF stage.
- The IF amplifier is designed as a Matched Filter that is one which maximizes the output peak-signal-to-mean-noise ratio.
- Thus the basic function of matched filter is to maximize the detectability of weak echo signal a ttenuates the unwanted signal.
- The IF amplifier is followed by a critical diode which is called the second detector or demodulator. Its purpose is to assist extracting the modulating signal from the modulated signal.
- The combination of IF amplifier, 2nd detector and video amplifier act as an envelope detector to pass pulse modulation (envelop) and reject the carrier frequency.
- To detect the Doppler shift of the echo signal the enveloped detector replaced by phase detector which is different from the envelope detector.
- The combination of the IF amplifier and video amplifier is designed to provide sufficient amplification or gain to raise the level of the input signal to a magnitude where it can be seen in a display.
- At the end of the receiver a decision is made whether a target is present or not. The decision is based on the magnitude of the receiver output.
- If the output is large enough to exceed a pre-determined threshold, the decision is that the target is present. If it does not cross the threshold only noise is assumed to present.
- The display unit is usually a Cathode Ray Tube; the most common form of the CRT is Plane Position Indicator (PPI) which maps location of the target is in Azimuth angle & Range in polar co-ordinates.
- B-scope display is similar to the PPI except that it utilizes the rectangular co-ordinate rather than the polar co-ordinates to display Range Vs Angle.
- Another for display is A-scope which plots target Amplitude Vs Range for some fixed direction.

1.5 & 1.8 . Function of radar indication and Working principle of moving target indicator(MTI)

- This Radar uses Doppler Effect for its operation many times it is not possible to distinguish a moving target in the presence of static or permanent echoes of comparable appearance on the Radar screen.

- We have seen that in a PPI display, there is a lot of clutter due to this stationary target echoes. When it is desired to remove the clutter due to the stationary target an MTI Radar is employed.
- The basic principle of MTI Radar is to compare a set of received echo with those received during the previous. Sweep and Cancelling out those whose phase has remain unchanged.
- Moving target will give change of phase and are not cancelled thus clutter due to the stationary target are remove from display and this allows easier detection of moving target.
- The side block diagram is the simple block diagram of simple MTI Radar.
- The Transmitter frequency in the MTI Radar System is the sum of the o/p of two oscillators produced in mixer 2.



[BLOCK DIAGRAM OF A **MTI RADAR** SYSTEM]

- The First oscillator is the Stalo (Stable Oscillator) and the Second one is Coho (Coherent Oscillator) which operating same frequency as the intermediate frequency & providing coherent signal.
- The Coho is used for generating the R.F. signal as well as reference signal for the phase detector.
- The output of the duplexer is the combination of transmitted frequency and Doppler shift frequency.
- At the mixer-1 the Stalo frequency (f_L) cancels out and feeds a signal of frequency $f_c\pm f_d$ to I.F amplifier for amplification.
- The reference signal from the Coho and the I.F echo signal are both feed into the mixer called phase detector. The phase detector differs from the normal amplitude detector, since its output is proportional to the phase difference between the two input signals.
- Since the output of this detector is phase sensitive and output will obtain for all fixed or moving target.
- The phase difference between transmitter & receiver signal will be constant for a fixed target where as it will vary for a moving target. This variation of moving target is due to the Doppler frequency shift.
- The delay line canceller not only eliminate the DC component caused by clutter but also it unfortunately rejects the any moving target whose Doppler frequency happens to be same as the PRF (Pulse Repetition Frequency) or multiple of PRF. ($f_d = nf_p$)

- Those related target velocities which result is zero MTI response are called blind speed and is given by

$$V_n = n\lambda/2T = n\lambda f_p/2$$ Where n = 1, 2, 3……

An MTI RADAR operates at frequency 5GHz with a PRF of 800pps. Calculate the lowest three blind speeds of this RADAR.

- Given that : f = 5GHz = 5×10^9Hz , PRF = 800pps

As $\lambda = c/f = (3\times10^8) / (5\times10^9) = 3/50 = 0.06$m

$V_{n1} = n\lambda f_p/2 = (1\times0.06\times800)/2 = 24$m/s , $V_{n2} = (2\times0.06\times800)/2 = 48$m/s & $V_{n3} = (3\times0.06\times800)/2 = 72$m/s

1.6 . Define Doppler effect & Working principle of C.W Radar

❖ DOPPLER EFFECT:-

- The aperant frequency of electromagnetic or sound waves depends on the relative radial motion of the source or observer. If the source and observer one moving away from each other then the aperant frequency will decrease and when they moving towards each other then the aperant frequency will increase. This phenomenon was postulated by C. Doppler. So it is known as **Doppler Effect**.

- If 'R' is the distance from the Radar to target then the total number of wavelength (λ) contained in the two way path between the Radar and target is 2R/λ.
- Each wavelength corresponds to a phase change of 2π radian then the total phase change in the two way propagation path is equal to (2Π x 2R/λ) i.e. **Φ=4ΠR/λ.**
- If the target is in motion w.r.t. the Radar then R and Φ are continuously changes. A change in Φ w.r.t. time is equal to frequency and this is known as Doppler Angular Frequency (W_d).

$$W_d = 2\pi f_d = \text{—} = \text{—}\ \text{—}) = \text{—}\ \text{—} = \text{—}\ V_r$$

Where f_d = Doppler Frequency Shift & V_r = Radial Velocity of the Target w.r.t. Radar

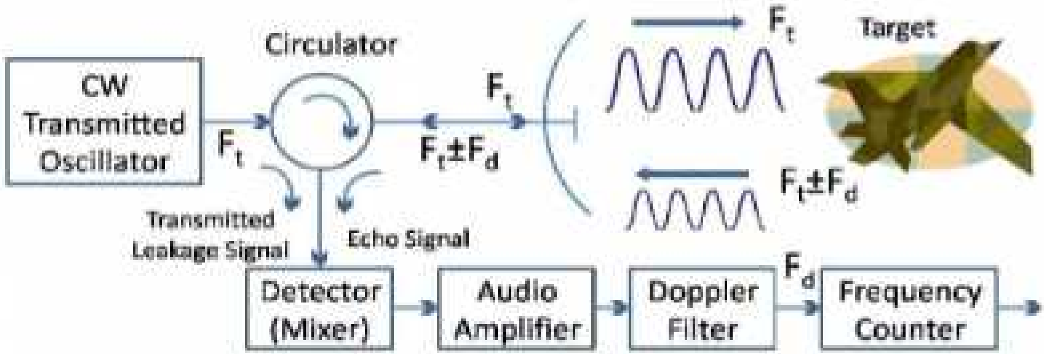
- From the above expression, $f_d = 2V_r/\lambda$. Put $\lambda = C/f_t$,We get $f_d = 2V_r f_t/C$.

  Where f_t=Radar frequency or Transmitted frequency.
- If f_d in Hz, V_r in nmi & λ in meter then $\mathbf{f_d = 1.03V_r/\lambda}$.
- *With a CW Transmit frequency of 5GHz, Calculate the Doppler frequency seen by the Stationary Radar when the Target radial velocity is 100Km/hr.*

  Given that f_t = 5 GHz = 5×10^9 Hz ; V_r =100Km/hr = 100x1000/3600 = 27.8m/s ; c = 3×10^8 m/s.

  As $\lambda = c/f = (3\times10^8) / (5\times10^9) = 0.06$m

☎ 1. *CW Doppler RADAR:-*



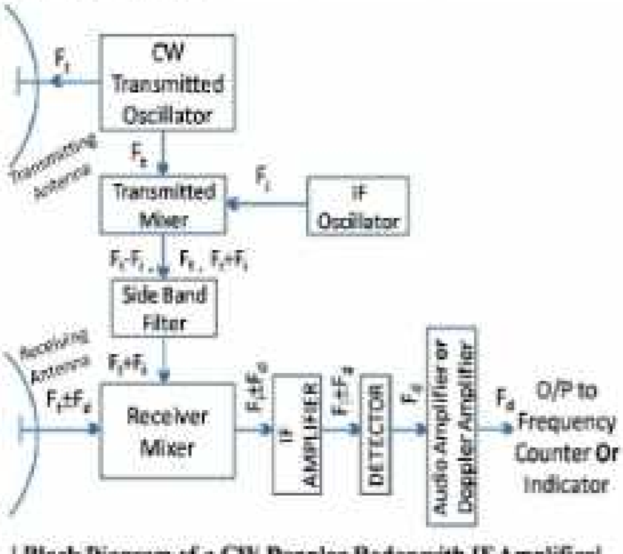
[BLOCK DIAGRAM OF A CW DOPPLER RADAR]

- The CW Transmitter generates a continuous sine wave rather than pulse (Unmodulated) of frequency f_t which is radiated by the antenna. Since, here the transmission is continuous the Circulator is used to provide isolation between transmitter & receiver. For continuous wave the use of duplexer is pointless.
- A Portion of radiated energy is intercepted by the target and scattered. Some of it in the direction of Radar where it is collected by receiving antenna.
- If the target is in motion with a velocity of V_R relative to the Radar, the received signal will be shifted in frequency from the transmitted frequency f_t by an amount of $\pm f_d$.
- The plus (+) sign associated with the Doppler frequency applied, if the distance between the target and the Radar is decreasing (when they moving towards each other) i.e. when the received signal frequency is greater than the transmitted signal frequency. The minus (-) sine applied if the distance is increasing i.e. target is away going from the Radar.
- Hence the received echo signal at the frequency $f_t \pm f_d$ enters to the Radar via antenna.

- This signal is heterodyne in the detector (mixer) with a portion of transmitted signal f_t to produce a Doppler bit of frequency f_d. The sign of the f_d is losses in this process. So we cannot predict whether the target is going away from the Radar or coming towards the Radar.
- The purpose of the Doppler amplifier is to eliminate echoes from stationary target and to amplify the Doppler echo signal to a level where it can operate an indicating device like frequency counter.
- The counter is a normal one except that the output is shown as km or miles/hour rather than the actual frequency in Hz.
- The main disadvantage of simple CW system is its lake of sensitivity. The type of diode detector that is used to accommodate the high incoming frequency and is not a good device for the audio output frequency. Thus an increment is in the following ways.

☎ *CW Doppler RADAR With IF AMPLIFIER:-*

- A small portion of a transmitter output is mixed with output of local oscillator and the sum is fed to the receiver mixer by the help of sideband filter.
- The receiver mixer also receives the Doppler shifted signal from receiving antenna and produces an output difference frequency i.e. typically 30MHz (Generated by the IF oscillator) $\pm f_d$.
- The output of this mixer is amplified by the amplifier and demodulates again by the detector.
- The signal from the 2nd detector is just the Doppler frequency (f_d).



[Block Diagram of a CW Doppler Radar with IF Amplifier]

- This signal is again amplified by the Doppler amplifier so as to raise the signal level such as to meet the frequency counter or indicator. Its sine is lost so that it not possible to tell whether the target is approaching or receiving.
- Separate receiving and transmitting antenna have been used. A Circulator could be used as shown in simple CW Radar system. Separate antenna is used to increase the isolation between transmitter and receiver section of the Radar.

ADVANTAGES: -

- CW Radar is capable of giving accurate measurement of relative velocity using low transmitting power, simple circuitry low power consumption and equipment whose size is much smaller than that of pulsed Radar equipment.
- It is unaffected by the presence of stationary target.
- With some additional circuitry CW Radar can measure the direction of the target along with its speed.

LIMITATION: -

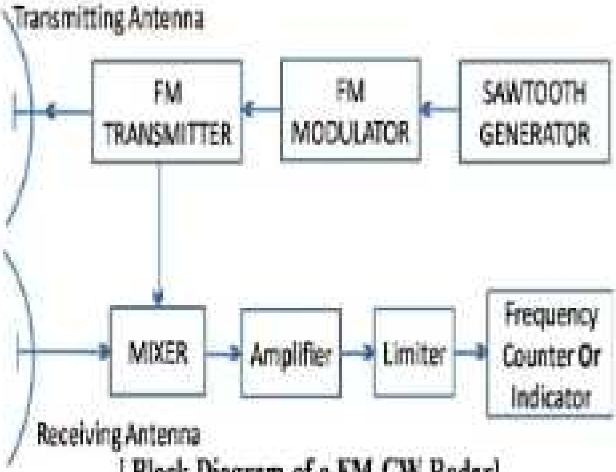
- It is limited to the maximum power it transmits and this naturally places a limit on its maximum range.
- It is easily confused by the presence of a large number of targets (Although it is capable of delaying with more than one target if special filters are included).

APPLICATION:-

- It is used in aircraft navigation for speed measurement.
- Another application is in a rate of climb meter for vertical take of planes such as Harrier.
- It is most commonly used in Radar speed meter used by police.

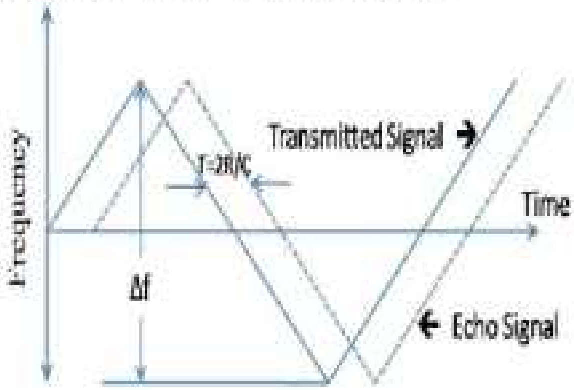
2. *FM CW RADAR:-*

- The greatest limitation of Doppler radar i.e. it is unable to measure the range is over come if the transmitted carrier is frequency modulate.
- If this is done it would be possible to eliminate difficulty with CW Radar i.e. its inability to distinguish one cycle from other.
- The popular method in CW Radar is to linearly frequency modulated the waveform the modulation is triangular which gives up eventually and comes down.



[Block Diagram of a FM-CW Radar]

- The transmitted signal is shown by the solid triangular waveform and the receiver signal is shown by dashed line. Delay time, T=2R/C , Δf = Frequency deviation , F_m = Modulation frequency.
- The target is stationary w.r.t. the plane. A frequency difference proportional to the height of the plane will exist between the receiver and transmitter signal is now being received was sent at a time when the instantaneous frequency was different.
- The rate of change of frequency with time due to the FM process is known the time difference between the sent and received signal may be calculated.
- The above diagram is the block diagram of a common application of the FM CW Radar system. It is also known as air borne altimeter as it is employed for measurement of altitude in air craft. Here we use a saw tooth generator as we employing saw tooth frequency modulation for simplicity.



[SAW TOOTH WAVE FORM IN FMCW RADAR]

- A FM transmitter is used in which frequency modulation of the signal can be done and its output is given to the mixer. The output of the mixer which produces the frequency difference (beat frequency) as amplified by amplifier and limited to remove any amplitude fluctuation by limiter.
- This signal is fed to a frequency counter and to an indicator whose output is calibrated in meter or feet.

APPLICATION:-

- FM CW Radar is mostly used in altimeter in aircraft due to shorter range & lower power requirement as compared to pulse Radar. Smaller size for air craft installation & smaller transmitter power.

1.7 . Radar aids to Navigation

Radar Aids to Navigation:-

- The position of air craft or a ship can be found by use of radio navigation aids. This is achieved by installation of radio transmitter and receiver at known location on the earth surface as well as at air craft or ship which works in conjunction with those on earth.
- The rectilinear propagation and constant velocity of electromagnetic waves held this system to provide navigation parameter like distance, direction, etc, by direct and indirect measurement of delay occurring between transmission and reception of these waves.
- The measurement of direction, distance and the difference between two transmitters give an indication of the position of an air craft or ship leading to correct navigation.
- Direction finding through radio is one of the very earliest methods of electronic navigational aids widely used in ship and air craft even today.

1.9 . Aircraft landing system

☎ Aircraft Landing System: -

- Generally there are two types of landing system are used.
    1. I.L.S. (Instrumental Landing System)
    2. M.L.S. (Microwave Landing System)
- Instrument landing system is used for runway navigation in IFR condition in which by using some specified component the landing can be made.
- If this type of system there are two category. In first category it guided on aircraft up to 200ft. In second category it guided an aircraft up to a level of 100ft below which it cannot guided.
- I.L.S. system contains following Components: -
    - i.) Localizer: - In front the pilot with aero plane horizontal position w.r.t. runway centre line.
    - ii.) Glide Slope: - In front the pilot aero plane vertical position w.r.t. ground.
    - iii.) Outer Marker: - It stands in the same line with localizer and the runway center line four to seven miles before the runway. When the aero plane approaches the runway from the right direction it gives a signal by blinking the outer marker line.
    - iv.) Middle Marker: - It is positioned 0.8 miles before the runway when the aero plane is above the middle marker the receiver blinks giving a chance to the pilot weather land or not.
    - v.) Inner Marker: - It is present in the runway when the aero plane touches the runway and stands over it. The receiver blinks the light of inner marker.
    - vi.) Approach Light: - It includes medium or high intensity system for both inside and outside the aero plane.

1.10 . Navigation Satellite System.(NAVSAT) & GPS System

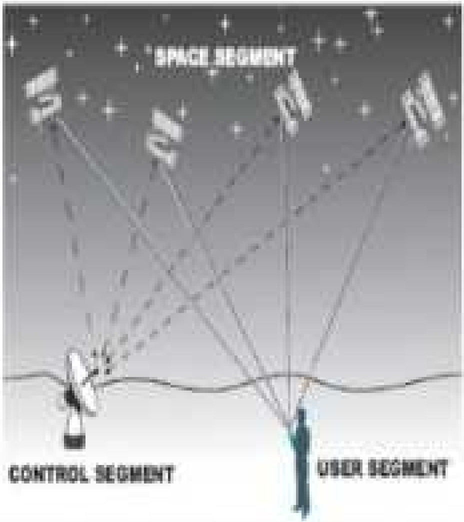
☎ NAVSAT:-

- NAVSTA stands for Navy-Navigation Satellite System. It is developed by USA in 1967 to monitor the military activities and guiding of aero plane & warship. Satellite system means finding out the position of an object from different angles through satellite placed artificially.

Concept & Feature

- NASAT uses the Doppler shift of radio signal transform satellite to measure the relative velocity between the satellite and navigator by knowing the satellite orbit position the navigator position can be determined from the time rate of change of rate to the satellite.
- NAVSAT consists ten orbit satellite and three orbiting space. A network of working station continuously monitors the satellite information. Each satellite is a circular polar orbit at an altitude of 6n. Usually five satellites are operating in the system.
- Generally four satellite can make the constellation and another one is used as a spare to find out the position of a navigator at least information for four satellite taken.
- Each satellite contain receiver to receive the compound from the ground well equipped decoder and memory, control circuit encoder to transmit digital data to phase modulation, ultra stable 5Hz oscillator and a 1.5W transmitter to broadcast the carrier frequency of 150MHz to 400MHz.

☎ GPS (Global Positioning System) :-



- GPS stands for global positioning system which is started in 14th Feb. 1989.
- A GPS system has three segments.
  - Space Segment
  - Control Segment
  - User Segment

❖ *Space segment:-*

- In space segment system it contains 24 operational satellite which are revolving around the earth in 6th different orbit there are used an spare and there are arranged in such a manner at least four satellite are in view to an user at any time on a worldwide base.
- Out of four satellites three are for dimension one for time.
- GPS Satellite Transmits Pseudo Random Noise (PRM) frequency with cars acquisition and precision code. This can be achieved by CDMA process to identify transmit a particular providing a unique PRM number.

❖ *Control segment:-*

- It includes a master control station & number of monitury & general antenna allocated throughout the world. They are all interlinked & all the information received is processed by master control system.
- After calculation of accuracy master control system it is transmitted to the antenna by which a position can identify through satellite.

❖ *User Segment:-*

- User segment contain high, medium and low receiver the user equipment is so designed so that it receives the signal and process all at a time or sequentially then the processer converted signal into 3-dimensaonal navigational information.

FOUR STEPS FIND THE POSITION:

- Measuring travel time of satellite signal.
- Measurement of distance from satellite.
- Measurement of position of satellite.
- Trilateration.

LIMITATION OF GPS

- Line-Of-Sight Essential – Signal cannot pass through building, it happens in urban area, i.e. Sydney city circle.
- Long position time – Around 15 minutes, depends on how accuracy.
- Battery - Run out of the battery in GPS receiver, since long calculation time, 4 AA batteries can last for 4 hours only.
- Need improvement? Cellular Network!

Short Questions With Answers

1. What is a radar?

A: Radar is an electromagnetic system for the detection and location of reflecting objects such as aircraft, ships, spacecraft, vehicles, people, and the natural environment. It operates by radiating energy into space and detecing the echo signal reflected from an object or target.

2. What do you mean by maximum unambiguous range?

A: Echoes that arrive after the transmission of the next pulses are called the second time around echoes.The range beyond which the targets appear as secondtime- around echoes is called the maximum unambiguous range,Run, and is given by Run=cTp/2=c/2fp

3. What is the fundamental range equation?

A: Rmax=(PtGAe A Smin)^(1/4)

Pt=transmitted power , W

G= Antenna gain

Ae= Antenna effective aperture

Smin=Minimum detectable signal

4. What is a PPI?

A:A typical radar display for a surveillance radar is the PPI or Plan Position Indicator.The PPI is a presentation that maps in polar coordinates the location of the target in azimuth and range.

5. What are the applications of radar?

A: ƒ Military

ƒ Remotesensing

ƒ Air traffic control (ATC)

ƒ Law enforcement and highway safety

ƒ Aircraft safety and Navigation

ƒ Ship safety

ƒ Space

6. What are the main reasons for the failure of the simple form of the radar equation?

A:The failure of the simple form of the radar equation is due to

a. the statistical nature of the minimum detectable signal

b. fluctuations and uncertainties in the targets radar cross section

c. the losses experienced throughout the radar system

d. Propagation effects caused by the earth surface and atmosphere

7. Define minimum detectable signal?

A:The weakest signal that can just be detected by the receiver is the minimum detectable signal.

8. What is called a false alarm?

A:If the target were set too low, noise might exceed it and be mistaken for a target. This is called the false alarm.

9. What is called a missed detection?

A:If the threshold were set too high , noise might not be large enough to cause false alarms, but weak target echoes might not exceed the threshold and would not be detected .This is called as missed detection.

10. What is called threshold detection?

A:If the receiver output is not of sufficient amplitude to cross the threshold, only noise is said to be present. This is called threshold detection

11. What is called a thermal noise?

A:If the radar were to operate in a noise free environment so that no external sources of noise accompany the target signal, and if the receiver itself were so perfect that it did not generate any excess noise, there would still be noise generated by the thermal agitation of the conduction electrons in the ohmic portion of the receiver input stages. This is called as thermal or Jhonson noise.

12. What is said to be the rayleigh region?

A:Radar cross section depends on the characteristic dimensions of the object compared to the radar wavelength. When the wavelength is large compared to the objects dimensions, scattering is said to be rayleigh scattering.

13. Give some examples of simple targets?

A:Some examples of simple targets are sphere, cylinder, flatplate, rod, ogive and cone.

14. Define the term fluctuations?

A:change in the resultant phase and amplitude of the composite echo signal which results in target cross section fluctuations.

15. What is called frequency diversion?

A:It means that more than one transmitter, each at a different frequency is utilized in parallel with each transmitter channel operating as a separate radar.

16. What is called frequency agility?

A:Pulse to Pulse change in frequency is called frequency agility.

17. What is called as revisit time?

A:It is the time that an antenna takes to return to view the same region of space. It is also called as scan time.

18. What is a radome?

A:A typical ground based metal space frame radome might have a two-way transmission loss of 1.2 db at frequency ban from L to X band.

19. Define a scan to scan fluctuation?

A:The echo pulses received from a target on any one scan are of constant amplitude throughout the entire scan, but are independent from scan to scan. A target echo fluctuation of this type is called scan to scan or slow fluctuations.

20. What are complex targets?

A:The radar cross section of complex targets such as aircraft, missiles, ships, ground vehicles, fabricated structures, buildings and terrains can vary considerably depending on the viewing angle and frequency.

Long Questions

1. What is radar? Derive the expression for Radar range equation. Justify that shorterthe wave length, range will be higher.(S-24)
2. For maximum unambiguous range of 1000 KW, calculate the PRF required for radar?
3. What is the effect of noise in Radar Receiver Signal? How does it affect radar rangeequation?
4. What is meant by radar cross section of Targets? What are the differences betweenSimple targets & Complex targets?
5. Draw the block diagram of MTI radar and explain the working of its each block.(S-24)
6. What is meant by blind speed? An MTI Radar is operating at 10 GHz with a PRF of1000Hz. Calculate the lowest three blind speeds?

CHAPTER-02 : SATELLITE COMMUNICATION

2.1. Basic Satellite Transponder & Kepler's Laws

The use of satellites as platforms for remote sounding is based on some very fundamental physics.

Newton's Laws of Motion and Gravitation (1685)

→ The basis for classical mechanics

Laws of Motion:

(1) Every body continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by a force impressed upon it.

(2) The rate of change of momentum is proportional to the impressed force and is in the same direction as that force. Momentum = mass × velocity, so Law (2) becomes

$$F = \frac{d(mv)}{dt} = m\frac{dv}{dt} = ma$$

(3) For every action, there is an equal and opposite reaction.

Law of Gravitation: The force of attraction between any two particles is

- Proportional to their masses
- Inversely proportional to the square of the distance between them

$$F = \frac{Gm_1m_2}{r^2}$$

(Treating the masses as points)

Where G = gravitational constant = 6.673 × 10^{-11} Nm^2/kg^2

These laws explain how a satellite stays in orbit.

Law (1): A satellite would tend to go off in a straight line if no force were applied to it.

Law (2): An attractive force makes the satellite deviate from a straight line and orbit Earth.

Law of Gravitation: This attractive force is the gravitational force between Earth and the satellite.Gravity provides the inward pull that keeps the satellite in orbit. Assuming a circular orbit, the gravitational force must equal the centripetal force

$$\frac{mv^2}{r} = \frac{Gmm_E}{r^2}$$

Where

v = tangential velocity
r = orbit radius = $R_E + h$ (i.e. not the altitude of the orbit)
R_E = radius of Earth
h = altitude of orbit = height above Earth's surface
m = mass of satellite
m_E = mass of Earth

$\therefore v = \sqrt{\frac{Gm_E}{r}}$ So v depends only on the altitude of the orbit (not on the satellite's mass).

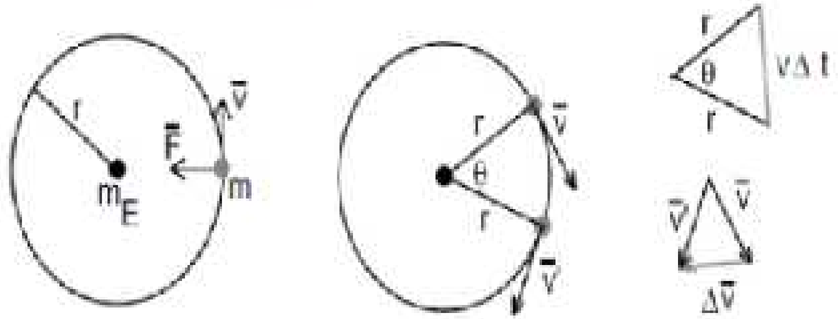
The period of the satellite's orbit is

$$T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{r}{Gm_E}} = 2\pi\sqrt{\frac{r^3}{Gm_E}}$$

Again, this is only dependent on the altitude, increasing as the orbit's altitude increases.

$$\frac{\Delta v}{v} = \frac{v\Delta t}{r}, \text{ so } a = \lim_{\Delta t \to 0}\frac{\Delta v}{\Delta t} = \frac{v^2}{r}$$

The acceleration of the satellite is determined using



Kepler's Laws for Orbits

So far, we have assumed that satellites travel in circular orbits, but this is not necessarily true in practice. Newton's Laws can be used to derive the exact form of a satellite's orbit.

However, a simpler approach is to look at Kepler's Laws, which summarize the results of the full derivation. Kepler's Laws (1609 for 1,2; 1619 for 3) were based on observations of the motions of planets.

(1) All planets travel in elliptical orbits with the Sun at one focus.

→ defines the shape of orbits

(2) The radius from the Sun to the planet sweeps out equal areas in equal times.

→ determines how orbital position varies in time

(3) The square of the period of a planet's revolution is proportional to the cube of its semi major axis.

→ suggests that there is some systematic factor at work

For satellites, substitute "satellite" for planet, and "Earth" for Sun.

2.2. Satellite Orbital patterns and elevation(LEO,MEO & GEO) categories

LEO Basics (Lower Earth Orbit)

With Low Earth Orbit extending from 200 km to 1200 km it means that it is relatively low in altitude, although well above anything that a conventional aircraft can reach.

However LEO is still very close to the Earth, especially when compared to other forms of satellite orbit including geostationary orbit.

The low orbit altitude of leads to a number of characteristics:

- Orbit times are much less than for many other forms of orbit. The lower altitude means higher velocities are required to balance the earth's gravitational field. Typical velocities are very approximately around 8 km/s, with orbit times sometimes of the order of 90 minutes, although these figures vary considerably with the exact details of the orbit.
- The lower orbit means the satellite and user are closer together and therefore path losses a less than for other orbits such as GEO
- The round trip time, RTT for the radio signals is considerably less than that experienced by geostationary orbit satellites. The actual time will depend upon factors such as the orbit altitude and the position of the user relative to the satellite.
- Radiation levels are lower than experienced at higher altitudes.
- Less energy is expended placing the satellites in LEO than higher orbits.
- Some speed reduction may be experienced as a result of friction from the low, but measurable levels of gasses, especially at lower altitudes. An altitude of 300 km is normally accepted as the minimum for an orbit as a result of the increasing drag from the presence of gasses at low altitudes.

Applications for LEO Satellites

A variety of different types of satellite use the LEO orbit levels. These include different types and applications including:

- Communications satellites - some communications satellites including the Iridium phone system use LEO.
- Earth monitoring satellites use LEO as they are able to see the surface of the Earth more clearly as they are not so far away. They are also able to traverse the surface of the Earth.
- The International Space Station is in an LEO that varies between 320 km (199 miles) and 400 km (249 miles) above the Earth's surface. It can often be seen from the Earth's surface with the naked eye.

MEO Basics (Middle Earth Orbit)

A medium earth orbit (MEO) satellite is one with an orbit within the range from a few hundred miles to a few thousand miles above the earth's surface. Satellites of this type orbit higher than low earth orbit (LEO) satellites, but lower than geostationary satellites.

The orbital periods of MEO satellites range from about two to 12 hours. Some MEO satellites orbit in near perfect circles, and therefore have constant altitude and travel at a constant speed.

Other MEO satellites revolve in elongated orbits. The perigee(lowest altitude) of an elliptical-orbit satellite is much less than its apogee (greatest altitude). The orbital speed is much greater near perigee than near apogee.

As seen from a point on the surface, a satellite in an elongated orbit crosses the sky in just a few minutes when it is near perigee, as compared to several hours when it is near apogee.

Elliptical-orbit satellites are easiest to access near apogee, because the earth-based antenna orientation does not have to be changed often, and the satellite is above the horizon for a fairly long time.

A fleet of several MEO satellites, with orbits properly coordinated, can provide global wireless communication coverage. Because MEO satellites are closer to the earth than geostationary satellites, earth-based transmitters with relatively low power and modest-sized antennas can access the system.

Because MEO satellites orbit at higher altitudes than LEO satellites, the useful footprint (coverage area on the earth's surface) is greater for each satellite. Thus a global-coverage fleet of MEO satellites can have fewer members than a global-coverage fleet of LEO satellites.

One very popular orbit format is the geostationary satellite orbit. The geostationary orbit is used by many applications including direct broadcast as well as communications or relay systems.

The geostationary orbit has the advantage that the satellite remains in the same position throughout the day, and antennas can be directed towards the satellite and remain on track.

This factor is of particular importance for applications such as direct broadcast TV where changing directions for the antenna would not be practicable.

It is necessary to take care over the use of the abbreviations for geostationary orbit. Both GEO and GSO are seen, and both also used for geosynchronous orbit.

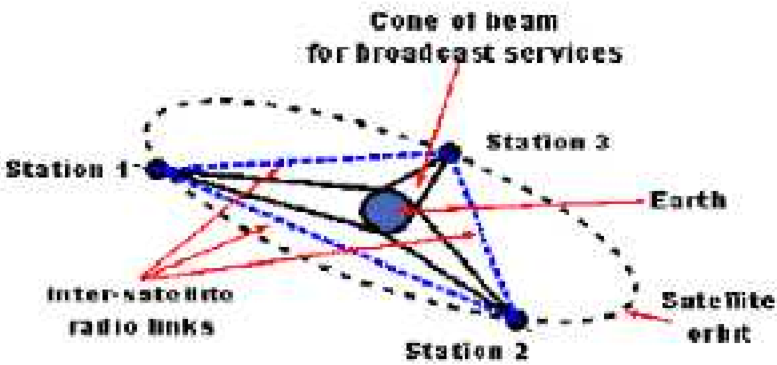
GEO (Geo stationary Earth Orbit)

The idea of a geostationary orbit has been postulated for many years. One of the possible originators of the basic idea was a Russian theorist and science fiction writer, Konstantin Tsiolkovsky.

However it was Herman Oberth and Herman Potocnik who wrote about orbiting stations at an altitude of 35 900 km above the Earth that had a rotational period of 24 hours making it appear to hover over a fixed point on the equator.

The next major step forwards occurred when Arthur C Clarke, the science fiction write, published a serious article in Wireless World, a major UK electronics and radio publication, in October 1945. The article was entitled "Extra-Terrestrial Relays: Can Rocket Stations Give World Coverage?"

Clarke extrapolated what could be done with the German rocket technology of the day and looked at what might be possible in the future. He postulated that it would be possible to provide complete global coverage with just three geostationary satellites.



2.3. Concept of Geostationary Satellite, calculate its height, velocity & round trip time delay & their advantage & disadvantage

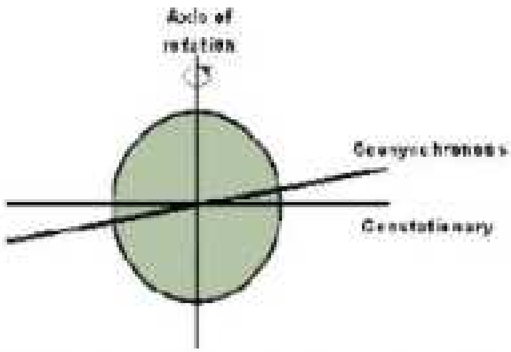
Geostationary Orbit basics

As the height of a satellite increases, so the time for the satellite to orbit increases. At a height of 35790 km, it takes 24 hours for the satellite to orbit. This type of orbit is known as a geosynchronous orbit, i.e. it is synchronized with the Earth.

One particular form of geosynchronous orbit is known as a geostationary orbit. In this type of orbit the satellite rotates in the same direction as the rotation of the Earth and has an approximate 24 hour period. This means that it revolves at the same angular velocity as the Earth and in the same direction and therefore remains in the same position relative to the Earth.

In order to ensure that the satellite rotates at exactly the same speed as the Earth, it is necessary to clarify exactly what the time is for the rotation of the Earth. For most timekeeping applications, the Earth's rotation is measured relative to the Sun's mean position, and the rotation of the earth combined with the rotation around the Sun provide the length of time for a day. However this is not the exact rotation that we are interested in to give a geostationary orbit - the time required is just that for one rotation. This time period is known as a sidereal day and it is 23 hours 56 minutes and 4 seconds long.

Geometry dictates that the only way in which an orbit that rotates once per day can remain over exactly the same spot on the Earth's surface is that it moves in the same direction as the earth's rotation. Also it must not move north or south for any of its orbit. This can only occur if it remains over the equator.



Geostationary orbit can only be over the Equator

Different orbits can be seen from the diagram. As all orbital planes need to pass through the geo-centre of the Earth, the two options available are shown. Even if both orbits rotate at the same speed as the Earth, the one labelled geosynchronous will move north of the equator for part of the day, and below for the other half - it will not be stationary. For a satellite to be stationary, it must be above the Equator.

Geostationary Satellite Drift

Even when satellites are placed into a geostationary orbit, there are several forces that can act on it to change its position slowly over time.

Factors including the earth's elliptical shape, the pull of the Sun and Moon and others act to increase the satellite orbital inclination.

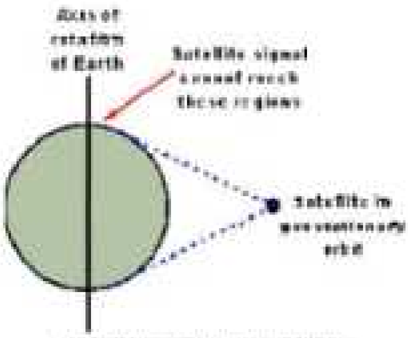
In particular the non-circular shape of the of the Earth around the Equator tends to draw the satellites towards two stable equilibrium points, one above the Indian Ocean and the other very roughly around the other side of the World.. This results in what is termed as an east-west libration or movement back and forth.

To overcome these movements, fuel is carried by the satellites to enable them to carry out "station-keeping" where the satellite is returned to its desired position. The period between station-keeping manoeuvres is determined by the allowable tolerance on the satellite which is mainly determined by the ground antenna beamwidth. This will mean that no re-adjustment of the antennas is required.

Often the useful life of a satellite is determined by the time for which fuel will allow the station-keeping to be undertaken. Often this will be several years. After this the satellite can drift towards one of the two equilibrium points, and possibly re-enter the Earth's atmosphere. The preferred option is for the satellites to utilise some last fuel to lift them into a higher and increasing orbit to prevent them from interfering with other satellites.

Geostationary Orbit Coverage

A single geostationary satellite obviously cannot provide complete global coverage. However, a single geostationary satellite can see approximately 42% of the Earth's surface with coverage falling off towards the satellite is not able to "see" the surface. This occurs around the equator and also towards the polar regions.



Geostationary satellite coverage

For a constellation of three satellites equally spaced around the globe, it is possible to provide complete coverage around the equator and up to latitudes of 81° both north and south.

The lack of polar coverage is not a problem for most users, although where polar coverage is needed, satellites using other forms of orbit are needed.

Height, velocity & round trip time delay

Height of GEO satellite can be given as

r (orbit radius) = R_E(Radius of the Earth)+ h

Round trip time delay is given as following

$$T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{r}{Gm_E}} = 2\pi\sqrt{\frac{r^3}{Gm_E}}$$

And the velocity can also be given as

$F = GMm/R^2$

$\Sigma F = m\,a = m\,\omega^2 R$

$GMm/R^2 = m\,\omega^2 R = m\,(2\pi/T)^2 R$

$GM/R^2 = (2\pi/T)^2 R$

substitute:
$G = 6.673\ E\text{-}11\ Nm^2/kg^2$
$T = 86400$ seconds
$M = 5.9736\ E24$ kg

and we get:
$R = 4.2241727486054976303\ E7$ meters
if radius of earth is 6371 km, height of stationer is 42242 - 6371 = 35871 km from surface.
$v = (2\pi/T)R = (2\pi/86400)\ 4.2241727486054976303\ E7$

$v = 3071.91$ m/s

2.4. Working of the Satellite sub system

A Complete Satellite consists of several subsystems, but the most important of them are as follow:

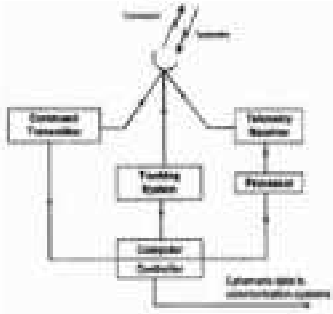
1) Power Supply System.
2) Attitude and Orbit Control System.
3) Telemetry, Tracking and Command System.
4) **Communication** Subsystem.

Telemetry, Tracking and Command System

Data received from the Satellite about status of attitude, orbit and other involve parameters is processed at the ground station. Telemetry, Tracking and Command Subsystem is a part of satellite management task and it is involves an Earth Station. The main function of the TT&C Subsystem are as follow:

a) Measuring of angle and range for the localization of the satellite.
b) Transmission of housekeeping information.
c) Status of a satellite to the ground control station.
d) Receiving command signals for the station keeping operations of the on-board equipments.

Following diagram typical arrangement of a Telemetry, Tracking and Command System.



Telemetry, Tracking and Command System Block Diagram

Telemetry: Telemetry system collects the data from many sensor and sends this data to the controlling Earth stations. The sensors are mounted on the satellite and they monitor:

- The pressure in fuel tanks.
- Voltages and currents in the communication electronics.
- Temperature of other subsystems.
- Position of switches and attitude.

Typically 100 sensors are required to monitor these data. When the satellite is in transfer orbit, the telemeter transmitter is connected to a TWTA in the satellite repeater. The telemetry data is digitized in nature and transmitted as frequency or phase shift keying of a low power telemetry carrier using time division techniques.

Monitoring: This subsystem deals with the monitoring of the maintenance and working of the components soldered with the Satellite like pressure sensors measures the pressure on the fuel tank of the satellite and sends the information to the monitoring subsystem on the Earth Station.

It determines the slant range for accurate determination of a satellite orbit. It can be done in following ways:

1) By transmitting a command carrier modulated by multiple tones from the Earth Station to the satellite. The carrier is received by the command receiver in the satellite, demodulated and then goes to the telemetry or beacon transmitter for the re-transmission toward the Earth Station where the phase difference of the received signal is measured with respect to the transmitted signal.

2) Velocity and acceleration sensors that can be used in the satellite to sense the change observed in the orbit. The data can be sent to the Earth Station through telemetry, where commands are generated and then sent to the satellite for the orbit correction.

Command: In command subsystem the earth station deals with the problem and sends back the command to the satellite through an electrical signal on air. If it wants to turn off the transponders it can easily send the command and the respective operation will be done at the satellite side.

This subsystem uses many sensors which senses the situation and sends data to the earth station. Sensors like pressure sensor, temperature sensor, altide sensor etc.

Every thing happening in space is controlled by subsystem which is established on the earth station. It helps in reducing the cost of the maintenance by controlling everything from earth station.

2.5. Satellite frequency allocation and frequency bands

What is Frequency Management

• Combination of administrative, scientific and technical procedures to ensure efficient operation of the various radiocommunication services without causing harmful interference. It has national and international aspects.

Allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned.

Radio Frequency Spectrum

• Radio Frequency Spectrum (RFS) and associated satellite orbits, including Geostationary-Satellite Orbit (GSO) are limited natural resources. Radio waves are defined as electromagnetic waves of frequencies arbitrarily from 3 kHz to 3000 GHz, propagated in space without artificial guide.

Radio frequency waves do not respect geographical boundary, and these cannot be confined to national boundaries. Radio waves are susceptible to harmful interference and requires application of complex engineering tools to ensure interference-free operation of various wireless networks.

The utilisation of radio frequency spectrum is governed by international treaties, namely, the Constitution, the Convention and the Radio

Regulations of the International elecommunication Union (ITU) as well as by the bilateral agreements between two countries.

• All frequency bands are available for use in all countries, including India, in accordance with international table of Frequency allocations and associated radio regulatory provisions. National Frequency Allocation Plan forms the basis for development, manufacturing and spectrum utilisation activities in the country.

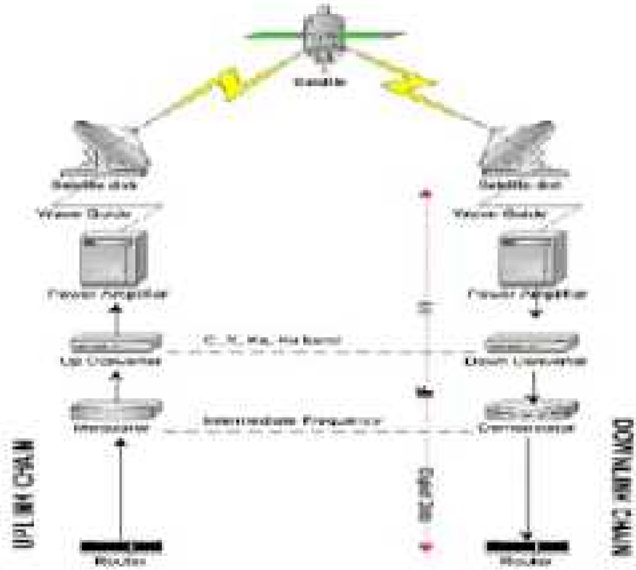
Frequency Allocations For Satellite Services or Fixed Satellite Service (FSS) (Frequency Bands)

5925-6425 MHz FOR UP-LINK (C-BAND)
3700-4200 MHz FOR DOWNLINK (C BAND)
6725-7075 MHz FOR UPLINK (UPPER EXT C)
4500-4800 MHz FOR DOWNLINK (UPPER EXT C)
6425-6725 MHz FOR UPLINK (LOWER EXT-C)
3400-3700 MHz FOR DOWNLINK (LOWER EXT-C)
10.95 - 11.2 GHz (down-links)
11.45 - 11.7 GHz (down-links)
11.7 - 12.2 GHz (down-links) (Region 2 only)
12.5 - 12.75 GHz (down-links) (Region 1 only)
14.0 - 14.5 GHz (up-links)
17.7 - 21.2 GHz (down-links)
27.5 - 31.0 GHz (up-links)

2.6. General structure of satellite Link system (Uplink, Down link, Transponder, Crosslink)

DIGITAL SATELLITE UPLINK CHAIN

1. Digital data is sent to the modulator which takes the data and converts it into a modulated signal in the Intermediate Frequency range (70-140 Mhz). The modulators use standards such as *Digital Video Broadcast* to organize communication over the microwave link.
2. The *Intermediate Frequency* is piped to an "up converter" (usually via shielded coaxial cable) which mixes the *intermediate frequency* with a higher frequency to produce a final frequency which carries the modulated data.
3. Noise is removed from the signal via either a band pass filter or other means and then it is amplified in a Klystron, Travelling Wave Tube or Solid State amplifier.
4. The final cleaned signal is transmitted down the wave guide to the dish.
5. The *feed horn* at the focal point of the dish emits the high frequency radio transmission, which the dish focuses into a directional transmission at the satellite.
6. Computer data is sent through a serial cable to a modulator. The modulator takes the data and produces a radio freqency from it. This frequency is usually in what is called the 'L-band' range (70-140Mhz). The modulator passes the information over coaxial cable to an 'up converter', which converts the radio frequency from 'L-band' up to microwave fregencies in the C, S, X, Ka, and Ku band ranges (frequencies above 1,000 Mhz). Once the final signal has been produced, it's amplified to increase its total effective output power. The signal is then sent out a dish via the feed horn.



DOWNLINK CHAIN

Downlink is a telecommunication term pertaining to data which is sent out or downwards from a higher level or portion of a network.

Traditionally, it refers to a satellite communications process where data is sent from a satellite down to an earthbound terminal or device, hence the word "down."

It is also used in other fields of networking like cellular and computer networking, where it is used in a similar manner but may or may not involve the directional meaning of up or down.

In satellite communications, downlink simply refers to the process when a satellite beams down information toward earthbound terminals or devices. The opposite of this is uplink, where the satellite receives data from an earthbound terminal.

In cellular networking, downlink can be seen from the user perspective as receiving some sort of message or data. A cellular device or phone receives direct communication from a cellular base station.

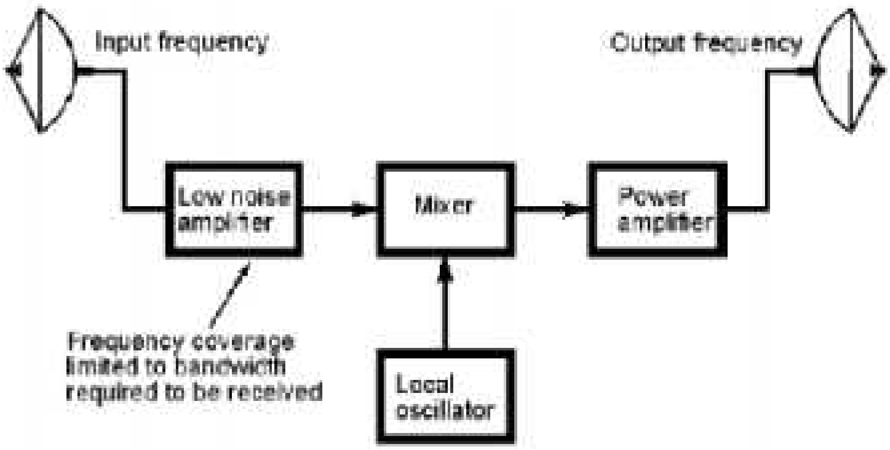
An example of this is receiving a text message or an image from someone—that message is received the through a downlink communication process.

The term is used in the same way in computer networking. Edge terminals or nodes receive data from the network core or from higher level network nodes such as routers and servers, and is commonly known as downloading. Therefore, the downloading of images and videos is done through the downlink process.

TRANSPONDER

An earth station transmits information to the satellite. The satellite contains a receiver, which picks up the transmitted signal, amplifies it and translates it to another frequency. This new frequency is then retransmitted to the receiving stations back on earth.

The original signal being transmitted from the earth station to the satellite is called the uplink. The retransmitted signal from the satellite to the receiving stations is called downlink. Usually the down link frequency is lower than the uplink frequency. A typical up link frequency is 6GHz and a common down link frequency is 4 GHz.



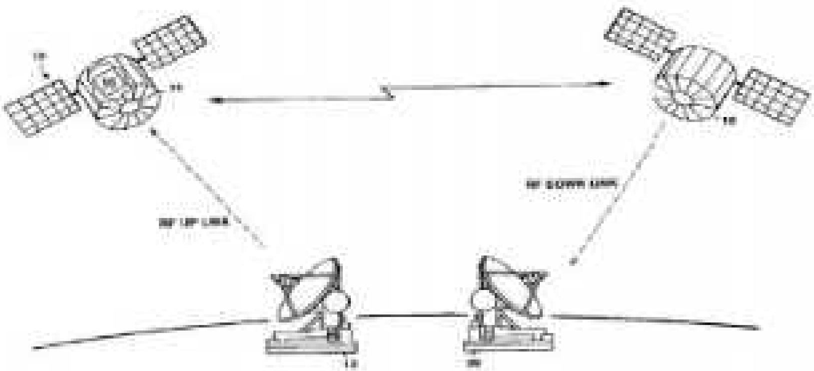
The transmitter – receiver combination in the satellite is known as **transponder.** The basic function of a transponder is amplification and frequency translation.

The reason for frequency translation is that the transponder cannot transmit and receive on the same frequency. Transponders are wide bandwidth units so that they may receive and retransmit more than one signal. An amplified, translated and receiver's bandwidth will be amplified, translated and retransmitted on a different frequency.

A typical communications satellite has 12, 2 or more transponders. Each transponder represents an individual communications channel.

CROSSLINK

A crosslink is when satellites communicate directly with eachother, instead of communicating with a ground station which, in turn, communicates with other satellites. Frequencies that are quickly attenuated in the atmosphere are commonly used, making the link undetectable and unjamable from the ground.

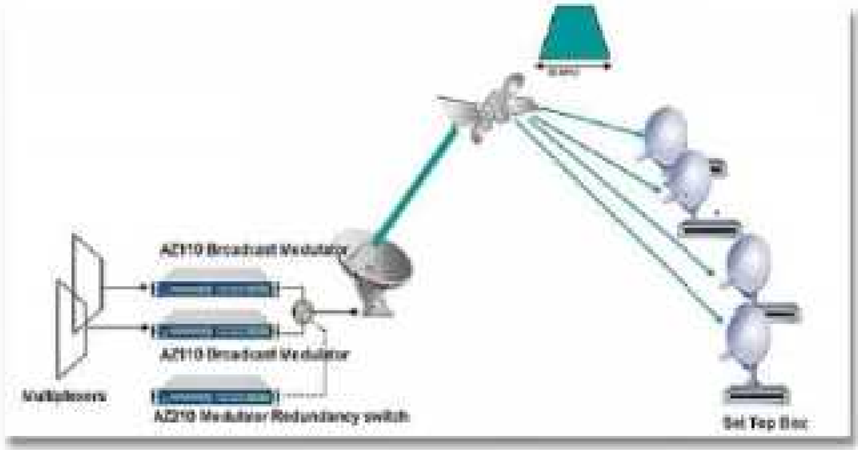


2.7. Working principle of direct broadcast system (DBS)

Systems for transmitting television and other program material via satellite directly to individual homes and businesses. Direct broadcasting satellite (DBS) systems operate at microwave frequencies, in a portion of the Ku band; in North and South America these systems operate in the frequency range 12.2–12.7 GHz.

Although direct broadcasting satellites had been operating in Europe and Japan for a number of years, the first United States direct broadcasting satellite was launched on December 17, 1993, and the second in July 1994, followed by additional satellites in subsequent years.

DBS systems use a satellite in geostationary orbit to receive television signals sent up from the Earth's surface, amplify them, and transmit them back down to the surface. The satellite also shifts the signal frequency, so that a signal sent up to the satellite in the 17.3–17.8-GHz uplink band is transmitted back down in the 12.2–12.7-GHz downlink band. The downlink signal is picked up by a receive antenna located atop an individual home or office; these antennas are usually in the form of a parabolic dish, but flat square phased-array antennas are sometimes used, and may eventually become commonplace.



The receive antenna may be permanently pointed at the satellite, which is at a fixed point in the sky, in a geostationary orbit.

It is difficult to build receivers to operate at the microwave downlink frequencies, so the signal from the dish antenna is first passed to a downconverter, usually mounted outdoors on the antenna, that shifts it to (typically) the 0.95–1.45-GHz band.

This signal is then conducted by cable to the receiver atop the television set. The receiver contains the channel selector, as well as a decoder to permit the user to view authorized channels. The receiver is connected by an additional cable to the television set

A typical direct broadcasting satellite contains 16 transponders, or amplifiers, the maximum permitted under present regulations, each with a radio-frequency power output in the range 120–240 W. Two or more direct broadcasting satellites may be located at any of the orbital locations assigned to the United States, for a maximum of 32 transponders.

DBS satellites in the United States typically use digital signals; a single 24-MHz satellite transponder can carry an error-corrected digital signal of 30 megabits per second or greater. A wide variety of communications services can be converted to digital form and carried as part of this digital signal, including television, high-definition television (HDTV), stereo audio, one-way videoconference, information services (such as news retrieval services), and digital data.

Modern digital signal compression technology greatly increases the capacity of a satellite transponder. It is possible to compress up to perhaps 10 television signals into the bandwidth of a DBS transponder, depending on the amount of motion in the picture and the amount of screen resolution required. Since some common programming (for example, sports) contains a good deal of motion, the average compression factor for a DBS system will typically be lower than 10. See Data compression

DBS systems, like all satellite systems operating in the K_u band, are subject to attenuation of their signals by rain. The combination of satellite power and receive-dish antenna size is chosen to enable reception for all but the heaviest rainfall periods of the year, corresponding to an outage period of perhaps 7 h per year at any particular location. The DBS customer can further reduce this expected outage period by purchasing a slightly larger dish antenna.

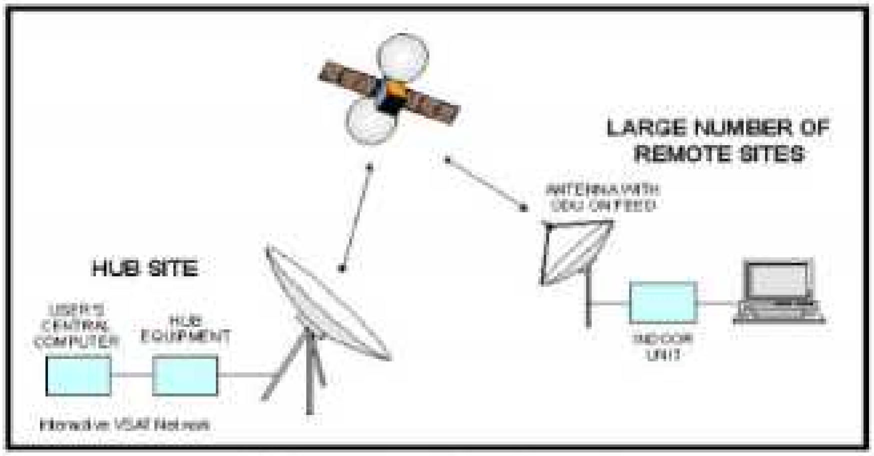
2.8. Working principle of VSAT system

A very small aperture terminal (VSAT) is a small telecommunication earth station that receives and transmits real-time data via satellite. A VSAT transmits narrow and broadband signals to orbital satellites. The data from the satellites is then transmitted to different hubs in other locations around the globeT.

VSAT end users have a box that acts as an interface between the computer and the external antenna or satellite dish transceiver. The satellite transceiver sends data to and receives data from the geostationary satellite in orbit.

The satellite sends and receives signals from an earth station, which acts as the hub for the system. Each end user is connected to this hub station through the satellite in a star topology. For one VSAT user to communicate with another, the data has to be sent to the satellite.

Then the satellite sends the data to the hub station for further processing. The data is then retransmitted to the other user via a satellite. The majority of VSAT antennas range from 30 inches to 48 inches. Data rates typically range from 56 Kbps up to 4 Mbps.



VSATs are most commonly used to transmit:

- Narrowband data. This includes point of sale transactions such as credit card, polling or radio-frequency identification (RFID) data, or supervisory control and data acquisition (SCADA) data.
- Broadband data, for the provision of satellite Internet access to remote locations, Voice over Internet Protocol (VoIP) or video

VSATs are also used for transportable, on-the-move communications (using phased array antennas) and mobile maritime communications.

2.9. Define multiple accessing & name various types

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 several different ways to allow access to the channel. These include the following.

- Frequency Division Multiple-Access (FDMA)
- Time Division Multiple-Access (TDMA)
- Time/Frequency Multiple-Access
- Random Access
- Code Division Multiple-Access (CDMA)
  - Frequency-Hop CDMA
  - Direct-Sequence CDMA
  - Multi-Carrier CDMA (FH or DS)

2.10. Time Division Multiple Accessing(TDMA) & Code Division Multiple Accessing (CDMA) – block diagram, its advantages & dis-advantages

Time Division Multiple Accessing (TDMA) & its advantages & Dis-advantages.

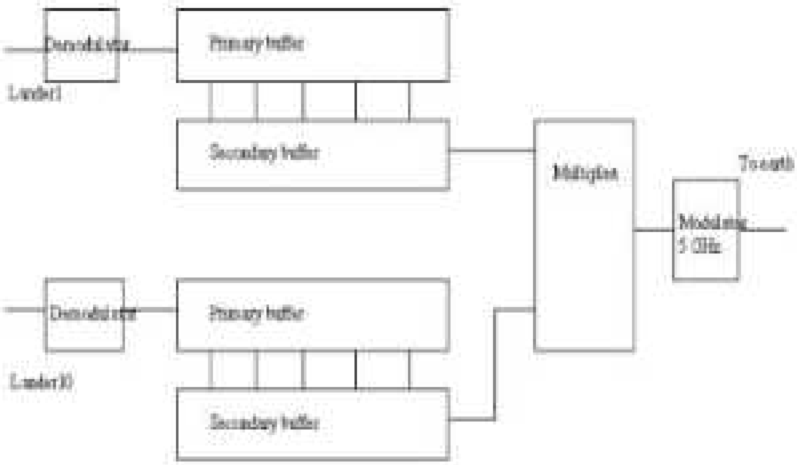
Time division multiple access (TDMA) is a channel access method (CAM) used to facilitate channel sharing without interference. TDMA allows multiple stations to share and use the same transmission channel by dividing signals into different time slots.

Users transmit in rapid succession, and each one uses its own time slot. Thus, multiple stations (like mobiles) may share the same frequency channel but only use part of its capacity.Examples of TDMA include IS-136, personal digital cellular (PDC), integrated digital enhanced network (iDEN) and the second generation (2G) Global System for Mobile Communications (GSM).

TDMA allows a mobile station's radio component to listen and broadcast only in its assigned time slot. During the remaining time period, the mobile station may apply network measurements by detecting surrounding transmitters in different frequencies.

This feature allows interfrequency handover, which differs from code division multiple access (CDMA), where frequency handover is difficult to achieve. However, CDMA allows handoffs, which enable mobile stations to simultaneously communicate with up to six base stations.

TDMA is used in most 2G cellular systems, while 3G systems are based on CDMA. However, TDMA remains relevant to modern systems. For example, combined TDMA, CDMA and time division duplex (TDD) are universal terrestrial radio access (UTRA) systems that allow multiple users to share one time slot.



Advantages of TDMA:

- TDMA can easily adapt to transmission of data as well as voice communication.
- TDMA has an ability to carry 64 kbps to 120 Mbps of data rates.
- TDMA allows the operator to do services like fax, voice band data, and SMS as well as bandwidth-intensive application such as multimedia and videoconferencing.
- Since TDMA technology separates users according to time, it ensures that there will be no interference from simultaneous transmissions.
- TDMA provides users with an extended battery life, since it transmits only portion of the time during conversations.
- TDMA is the most cost effective technology to convert an analog system to digital.

Disadvantages of TDMA:

- Disadvantage using TDMA technology is that the users has a predefined time slot. When moving from one cell site to other, if all the time slots in this cell are full the user might be disconnected.
- Another problem in TDMA is that it is subjected to multipath distortion. To overcome this distortion, a time limit can be used on the system. Once the time limit is expired the signal is ignored
- Code Division Multiple Accessing

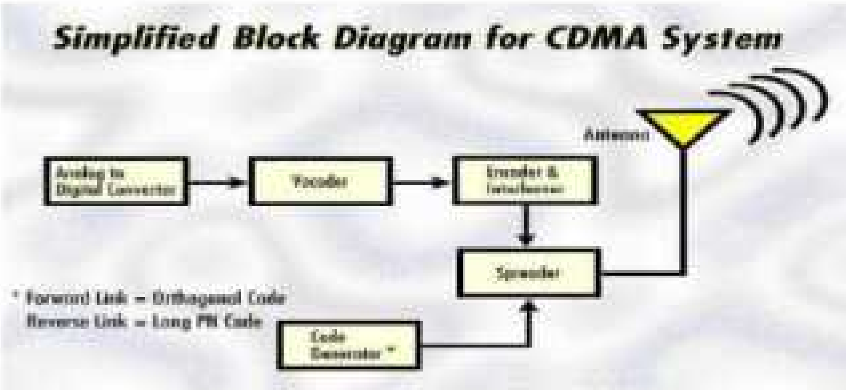
(CDMA) & ITS ADVANTAGES & DIS-ADVANTAGES.

Code division multiple access (CDMA) is a digital cellular network standard that utilizes spread-spectrum technology. This technology does not constrict bandwidth's digital signals or frequencies but spreads it over a fully-available spectrum or across multiple channels via division.

Thus, there is improved voice and data communication capability and a more secure and private line. The CDMA digital standard is a leading communications network standard in North America and parts of Asia. Qualcomm, a US-based wireless communications company, patented CDMA and commercialized this technology.

CDMA technology was initially used in World War II military operations to thwart enemy attempts to access radio communication signals. In the early 1990s, Qualcomm introduced the possibility of using the same concept with publicly-available cellular network technology.

During this time, an alternative mobile networking arena digital standard gained traction, proving to be a challenge to CDMA proponents. Despite adamant negativity and discouragement from prominent industry figures, CDMA's supports successfully convinced these leaders to consider, use and eventually accept the newly introduced CDMA standard.



Essentially, CDMA offers more airspace capacity than the time division multiple access (TDMA) based Global System for Mobile Communications (GSM) standard. Furthermore, CDMA also uses less power. Another advantage boasted by CDMA technology is its ability for soft handoffs between base stations, i.e., less likelihood of cut-off calls. The usual analogy given in comparing CDMA with other channel access methods like FDMA or TDMA is that of people each carrying out a conversation with a friend in a crowded room. The room, in this case, represents a channel (a.k.a. carrier frequency).

TDMA is likened to the method by which communication is carried out by speaking one at a time (hence the name "time division"). FDMA, on the other hand, is likened to the method wherein communication is made by speaking at different pitches (hence, frequency division).

Finally, CDMA is likened to people speaking simultaneously but in different languages. Because only those who speak the same language can understand each other, it is possible for multiple conversations to take place in the room at the same time. The basic concept in CDMA is that users who wish to communicate through it are given a shared code.

While multiple codes may occupy the same channel, only those users having the same code can communicate with each other. Because CDMA and GSM standards each have unique pros and cons, the preferred technology standard choice is now in the hands of potential subscribers.

Advantages of CDMA:

- One of the main advantages of CDMA is that dropouts occur only when the phone is at least twice as far from the base station. Thus, it is used in the rural areas where GSM cannot cover.
- Another advantage is its capacity; it has a very high spectral capacity that it can accommodate more users per MHz of bandwidth.

Disadvantages of CDMA:

- Channel pollution, where signals from too many cell sites are present in the subscriber.s phone but none of them is dominant. When this situation arises, the quality of the audio degrades.
- When compared to GSM is the lack of international roaming capabilities.
- The ability to upgrade or change to another handset is not easy with this technology because the network service information for the phone is put in the actual phone unlike GSM which uses SIM card for this.
- Limited variety of the handset, because at present the major mobile companies use GSM technology.

2.11. Satellite Application- Communication Satellite(MSAT), Digital Satellite Radio

Communication Satellite

It is difficult to go through a day without using a communications satellite at least once. Do you know when you used a communications satellite today? Did you watch T.V.? Did you make a long distance phone call, use a cellular phone, a fax machine, a pager, or even listen to the radio? Well, if you did, you probably used a communications satellite, either directly or indirectly.

Communications satellites allow radio, television, and telephone transmissions to be sent live anywhere in the world. Before satellites, transmissions were difficult or impossible at long distances.

The signals, which travel in straight lines, could not bend around the round Earth to reach a destination far away. Because satellites are in orbit, the signals can be sent instantaneously into space and then redirected to another satellite or directly to their destination.

The satellite can have a passive role in communications like bouncing signals from the Earth back to another location on the Earth; on the other hand, some satellites carry electronic devices called **Transponders** for receiving, amplifying, and re-broadcasting signals to the Earth.

Communications satellites are often in geostationary orbit. At the high orbital altitude of 35,800 kilometers, a geostationary satellite orbits the Earth in the same amount of time it takes the Earth to revolve once.

From Earth, therefore, the satellite appears to be stationary, always above the same area of the Earth. The area to which it can transmit is called a satellite's footprint. For example, many Canadian communications satellites have a footprint which covers most of Canada.

Communications satellites can also be in highly elliptical orbits. This type of orbit is roughly egg-shaped, with the Earth near the top of the egg. In a highly elliptical orbit, the satellite's velocity changes depending on where it is in its orbital path.

When the satellite is in the part of its orbit that's close to the Earth, it moves faster because the Earth's gravitational pull is stronger. This means that a communications satellite can be over the region of the Earth that it is communicating with for the long part of its orbit. It will only be out of contact with that region when it quickly zips close by the Earth.

Digital Satellite Radio.

Satellite radio is just what its name suggests: a radio service that uses satellites circling Earth to broadcast its programming. In 1992, the Federal Communications Commission (FCC) allocated a satellite spectrum (the "S" band, 2.3 GHz) for the broadcasting of satellite-based digital audio radio service (DARS).

It eventually granted two licenses, one to Sirius Satellite Radio (formerly CD Radio) and one to XM Satellite Radio (formerly American Mobile Radio Corporation). The world's biggest satellite radio provider, 1worldspace, is available in Europe and several other countries but not in the United States.

As the satellites orbit the earth, programs are beamed to them from broadcast stations. The satellites then transmit the signal to special antennas on homes, cars and portable radios. Terrestrial repeaters throughout the country also receive the signal and help ensure that it's transmitted to receivers, especially in areas with tall buildings that might block the signal

There are two big pluses for satellite radio listeners. First, every channel, whether it's on XM or Sirius, is largely commercial-free, which should appeal to radio listeners tired of having advertisements screamed into their ears while they sit in traffic.

Most music channels have no advertising at all. Second, no matter where you are in the continental United States, you get the same reception as long as the skies are relatively clear. Unlike traditional radio, which loses reception once you're too far away from a certain station, satellites ensure you receive a signal no matter where you are in America. A driver could trek all the way from New York City to Los Angeles and never have to change the channel.

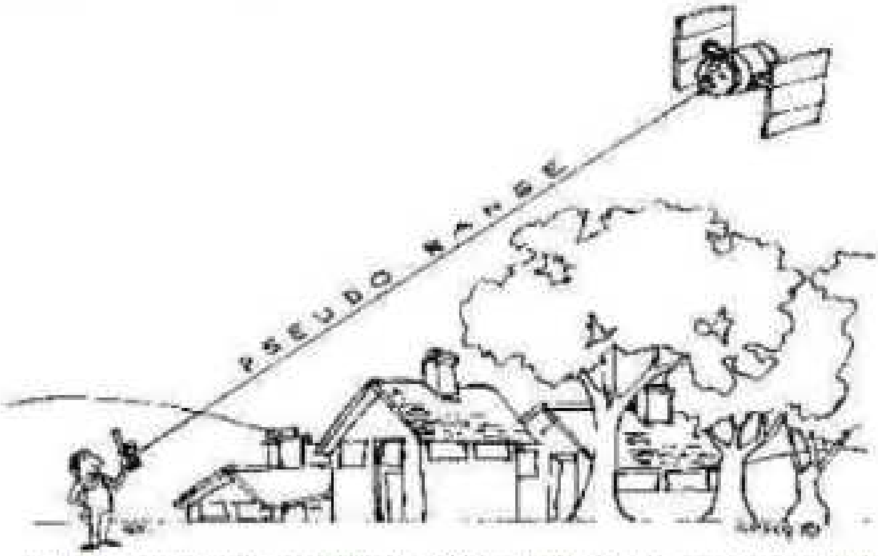
For about $13 a month, plus the cost of equipment and a small activation fee, both Sirius and XM listeners can receive more than 100 channels of satellite radio, including music ranging from classical to heavy metal, plus news, sports, talk and entertainment. But there are some notable differences between the two services, too.

The type of technologies used by XM and Sirius differs slightly, and the specific programming offered by both companies can vary, especially when it comes to news, sports and celebrities with contracts for their own shows. On the next two pages we'll take a look at those differences.

2.12. Working principle of GPS Receiver & Transmitter & applications.

There are two range-type measurements that can be made on the GPS signals:

- Pseudo-ranges, and
- Carrier phase observations.



Both are a product of the operation of the GPS receiver (that is, the acquisition and maintenance of signal tracking), both are used for GPS navigation (position, velocity and time – PVT – determination), and both have a role in the specialised data processing that characterises GPS surveying.

Before studying these measurements it is useful to consider the overall GPS hardware tracking operation (in a much abbreviated form!). The received satellite signal level is actually less than the background noise level, hence correlation techniques are used to obtain the satellite signals.

A typical satellite tracking sequence begins with the receiver determining which satellites are visible above the horizon. Satellite visibility is estimated from predictions of present PVT, and on the stored satellite almanac information residing within the receiver. (If no stored almanac information exists, or only a very poor estimate of PVT is available, the receiver will carry out a "sky search", attempting to randomly locate and lock onto a signal.

The receiver will then decode the Navigation Message and read the almanac information about all the other satellites in the constellation.) A carrier-tracking loop is used to track the carrier frequency while a code-tracking loop is used to track the C/A and/or P code signals. The two tracking loops have to work together in an iterative manner, aiding each other in order to acquire and track the satellite signals.

The receiver's carrier-tracking loop will locally generate an L1 carrier frequency (or L2 if the receiver is capable of tracking this frequency) which differs from the received carrier signal due to a Doppler offset of the carrier frequency.

This Doppler offset is proportional to the relative velocity along the line-of-sight to the satellite. In order to maintain lock on the carrier, the carrier-tracking loop must, in effect, adjust the frequency of the receiver-generated carrier until it matches the incoming carrier frequency.

The amount of this offset is the "beat" frequency which can be processed to give a periodic carrier phase measurement. The derivative of this phase measurement is the "Doppler" measurement, which is used to determine the receiver's velocity.

What role does the code-tracking loop play in this process? In order for the carrier-tracking loop to acquire the incoming satellite signal in the first place the carrier signal must be made visible above the background noise.

This is generally done by the code-tracking loop using the **code-correlating technique** to "reconstruct" the carrier wave (see discussion below under "Carrier Phase Measurements"). A by-product of code-tracking are the pseudo-range measurements.

GPS Transmitter

Phase locked loops (PLLs) are common to many communications systems, including in WiMAX Access Points (AP). By performing an analysis of the phase-noise contributions of the PLLs within a WiMAX AP frequency chain, which is essentially the string of PLLs in the system starting with the frequency reference in the controller and ending with the transmitter local oscillator (LO) in the RF head, it is possible to better understand the impact that each PLL has on overall system performance.

All seven PLLs in this example contribute to the ultimate signal and noise performance at the output of the chain. For practical analysis purposes, the chain begins with the reference oscillator in the site controller.

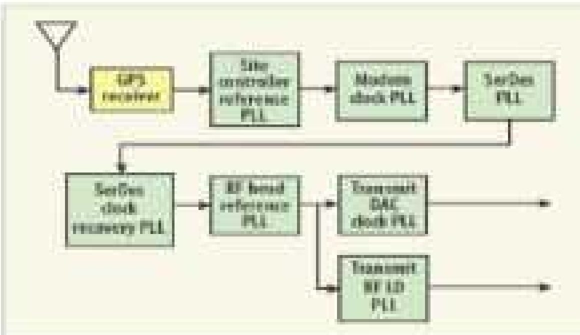
This special loop is locked to the Global Positioning System (GPS) receiver, but the loop bandwidth is so low that the only noise at the site controller reference PLL's output is the phase noise of the oven-controlled crystal oscillator (OCXO).

To review the essentials of PLL design,1-3 a PLL is a control loop that typically locks the phase and frequency of a tunable signal source, such as a voltage-controlled oscillator (VCO), at the output of the loop to the frequency and phase of a presumably stable signal at the input of the loop. Figure 2 shows the major elements of a PLL.

The frequency of the loop output (FOUT) is related to the frequency at the loop input (FIN) by

$$F_{OUT} = F_{IN} \cdot \frac{N}{R} \cdot \frac{1}{P}$$

N = the loop frequency multiplication factor,
R = the reference oscillator divider, and
P = the output divider, which is optional.



1. This block diagram shows the different function blocks of a WiMAX Access Point (AP) transmitter frequency chain block.

Designing for a higher-than-needed frequency and then dividing the output to reach the desired frequency is an approach that can be used to improve noise performance.

Post-loop frequency division can also be used to lower the output frequency that is sometimes needed by the reference divider of a subsequent stage. Most, if not all, PLLs act as phase-noise filters to the input signal (with each PLL exhibiting a unique lowpass response) and also as phase-noise generators. Some important points to note about PLL noise theory are that:

1. Each PLL has a unique lowpass response, most often characterized by the closed-loop 3-dB banwidth.
2. At frequencies above the loop bandwidth, the loop attenuates the phase noise of the input signal and also attenuates the phase noise of the phase detector and charge pump inside the loop.
3. At frequencies below the loop bandwidth, the loop attenuates the phase noise of the VCO or other voltage-controlled element in the loop.

2.13. Optical Satellite Link transmitter & Receiver

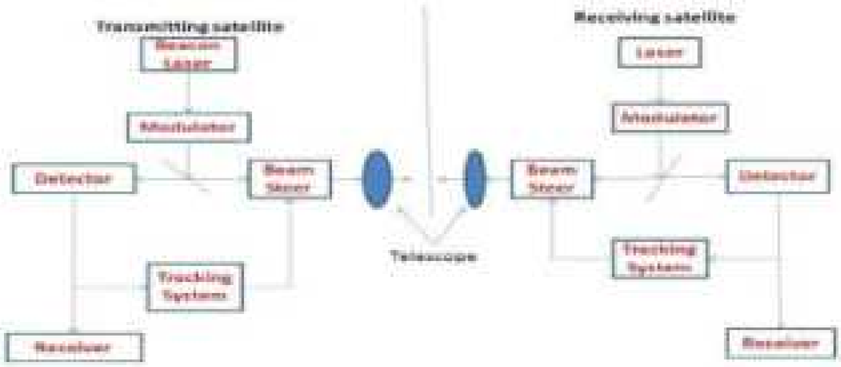


Fig. Block diagram of optical satellite crosslink

- In this modern era, Wireless and Telecommunication have become an integral part of each other to provide wireless communication to common man that helps people located in any part of the world communicate easily.
- Wireless communication technology transmits information over the air using electromagnetic waves like IR (Infrared), RF (Radio Frequency), satellite, etc. For example, GPS, Wi-Fi, satellite television, wireless computer parts, wireless phones that include 3G and 4G networks, and Bluetooth.
- This white paper summarizes the importance of Wireless and Telecommunication, their advantages and disadvantages.
- Telecommunication these days is mostly wireless. It involves transmission of information without wires, cables or any other electrical conductors within a shorter distance or across the globe.
- Wireless communications are growing to new heights because of its huge business benefits. Wireless technology offers speed, flexibility, and network efficiency.
- It has become a powerful tool for tech-savvy generation as it facilitates easy information sharing and boosts productivity. One gets the freedom to roam around freely without worrying about the internet connection and still stay connected.

Advantages

- Wireless networks are cheaper to install and maintain.
- Data is transmitted faster and at a high speed.
- Reduced maintenance and installation cost compared to other form of networks.
- Wireless network can be accessed from anywhere, anytime.
- Working professionals these days can access Internet anywhere and anytime without carrying cables or wires. This also permits professionals complete their work from remote locations.

- Medical professionals working in remote areas can be in touch with medical center located elsewhere through wireless communication.
- Through wireless communication, emergency situations get immediate help and support.

Disadvantages

Wireless communication has its own disadvantages as its advantages.

- It leads to security threats and data exploitation if not secured appropriately.
- An unauthorized person can easily capture wireless signals that spreads through the air and misuse information that is transmitted over the wireless network.
- To secure wireless signals like WPA and WPA2, one must use strong security protocols. Alternatively, you can also use wireless intrusion prevention system to secure the wireless network.

Short Questions With Answers

1. What is DBS?

Satellites are used to provide the broadcast transmissions. It is used to provide direct transmissions into the home. The service provided is known as Direct Broadcast Satellite services.

Example : Audio, TV and internet services.

2. What is GPS?

In the GPS system, a constellation of 24 satellites circles the earth in near- circular inclined orbits. By receiving signals from at least four of these satellites, the receiver position (latitude, longitude, and altitude) can be determined accurately. In effect, the satellites substitute for the geodetic position markers used in terrestrial surveying. In terrestrial the GPS system uses one-way transmissions, from satellites to users, so that the user does not require a transmitter, only a GPS receiver.

1. What is Satellite?

An artificial body that is projected from earth to orbit either earth (or) another body of solar systems.

Types: Information satellites and Communication Satellites

2. Define Satellite Communication.

It is defined as the use of orbiting satellites to receive, amplify and retransmit data to earth stations.

3. State Kepler's first law.

It states that the path followed by the satellite around the primary will be an ellipse.

An ellipse has two focal points F1 and F2. The center of mass of the two body system, termed the barycenter is always centered on one of the foci.

e = [square root of (a2– b2)] / a

4. State Kepler's second law.

It states that for equal time intervals, the satellite will sweep out equal areas in its orbital plane, focused at the barycenter

5. State Kepler's third law.

It states that the square of the periodic time of orbit is perpendicular to the cube of the mean distance between the two bodies.

6. Define apogee.

The point farthest from the earth.

7. Define Perigee.

The point closest from the earth.

8. What is line of apsides?

The line joining the perigee and apogee through the center of the earth.

9. Define ascending node.

The point where the orbit crosses the equatorial plane going from south to north.

10. Define descending node.

The point where the orbit crosses the equatorial plane going from north to south.

11. Define Inclination.

The angle between the orbital plane and the earth's equatorial plane. It is measured at the ascending node from the equator to the orbit going from east to north.

12. Define mean anomaly.

It gives an average bvalue of the angular position of the satellite with reference to the perigee.

13. Define true anomaly.

It is the angle from perigee to the satellite position, measured at the earth's center.

14. What is meant by azimuth angle?

It is defined as the angle produced by intersection of local horizontal plane and the plane passing through the earth station, the satellite and center of earth.

15. Give the 3 different types of applications with respect to satellite systems.

- The largest international system (Intelsat)
- The domestic satellite system (Dom sat) in U.S.
- U.S. National oceanographic and atmospheric administrations (NOAA)

16. Mention the 3 regions to allocate the frequency for satellite services.

- Region1: It covers Europe, Africa and Mangolia
- Region2: It covers North & South Ameriaca and Greenland.
- Region3: It covers Asia, Australia and South West Pacific.

Long Questions

1. Explain Working principle of VSAT system.
2. Write short note on Time Division Multiple Accessing(TDMA) .(S-24)
3. Explain about Code Division Multiple Accessing CDMA.
4. Discuss Working principle of GPS Receiver & Transmitter& applications.
5. Write Short note on Optical Satellite Link transmitter & Receiver.
6. Explain General structure of satellite Link system.(S-24)

CHAPTER-03 : OPTICAL FIBER COMMUNICATION

3.1. Basic Principle of optical communication

- Fiber optics is a branch of science which deals with the study of propagation of light through transparent dielectric medium such as optical fibers.
- Fiber optics is a relative new technology that used to transmit television, voice and digital **data signal** by light waves over flexible hair like threads of glass and plastic.
- Optical fiber is the medium in which the communication signals are transmitted from one location to another in the form of guided light.
- This signal can be voice information, data information, video information and any other information.
- The process of communicating using fiber optics involves the following basic steps.
    I. Creating the optical signal along the fiber.
    II. Relaying the signal along the fiber.
    III. Ensuring that the signal does not become to distort or weak.
    IV. Receiving the optical signal.
    V. Converting it in to electrical signal.

[Simple Block Diagram of a FOCS]

3.2. Compare the advantage and disadvantage of optical fiber metallic cables

ADVANTAGE

- *Attenuation* in a fiber is lower than that of coaxial cable or twisted pair and is constant over a very wide range. So transmission within wide range distance is possible without use of repeaters.
- *Smaller size and lighter weight.* So that it occupy much less space.
- Due to *Electromagnetic Isolation* the system is not vulnerable (risk) to interference, impulse noise or cross-talk.
- Fiber optical cable has much *greater band width* than copper wire.
- Fiber optic cable is *less susceptible* to signal degradation that copper wire.
- Data can be transmitted *digitally* and Data rate is much higher. As for example the data rate is 2 Gbps over some kilometers in case of fiber optics where as for coaxial twisted cable it is about 1 Mbps over one kilometer.
- *Lower power transmitter* can be used instead of the high voltage electrical transmitter used for the copper wire.
- Because of no electricity is passed through optical fiber it is *nonflammable and immune* to light.
- No cross-talk in optical fibers and hence transmission is *more secure* and private as it difficult to tap into fiber.

DISADVANTAGE

- Fiber optics is the cables which are expensive to installation.
- The termination of fiber cable is complex and requires special tools.
- They are more fragile (easily broken) than co-axial cable.

3.3. Electromagnetic Frequency and wave line spectrum

- The **electromagnetic spectrum** is the range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.
- The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below one hertz to above 10^{25} hertz, corresponding to wavelengths from thousands of kilometers down to a fraction of the size of an atomic nucleus.
- This frequency range is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names; beginning at the low frequency (long wavelength) end of the spectrum these are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays at the high-frequency (short wavelength) end.
- The limit for long wavelengths is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length.Gamma rays, X-rays, and high ultraviolet are classified as *ionizing radiation* as their photons have enough energy to ionize atoms, causing chemical reactions.
- In most of the frequency bands above, a technique called spectroscopy can be used to physically separate waves of different frequencies, producing a spectrum showing the constituent frequencies. Spectroscopy is used to study the interactions of electromagnetic waves with matter.
- Electromagnetic waves are typically described by any of the following three physical properties: the frequency *f*, wavelength λ, or photon energy *E*.
- Frequencies observed in astronomy range from 2.4×10^{23} Hz (1 GeV gamma rays) down to the local plasma frequency of the ionized interstellar medium (~1 kHz).
- Wavelength is inversely proportional to the wave frequency,so gamma rays have very short wavelengths that are fractions of the size of atoms, whereas wavelengths on the opposite end of the spectrum can be as long as the universe.
- Photon energy is directly proportional to the wave frequency, so gamma ray photons have the highest energy (around a billion electron volts), while radio wave photons have very low energy (around a femtoelectronvolt).
- These relations are illustrated by the following equations:

$$f=\frac{c}{\lambda}, \quad \text{or} \quad f=\frac{E}{h}, \quad \text{or} \quad E=\frac{hc}{\lambda},$$

where:

- c = 299 792 458 m/s is the speed of light in vacuum
- h = 6.525 070 [illegible]5 × 10^{-34} J·s = 4.135 667 33(10) × 10^{-15} eV·s is Planck's constant.

3.4. Need and advantages of optical fibres and principle of light transmission in a fibre using Ray Theory

&

3.6. Define terms: Velocity of propagation, Critical angle, Acceptance angle & numerical aperture

- In free space the light wave travels at speed $C=3x10^8$ M/s upon entering to a dielectric and non conducting medium the wave now travels at a speed 'V' and is less than that of 'C'.
- The ratio of speed o light in vacuum to that of in a metal is known as **Refractive Index** of the material and is

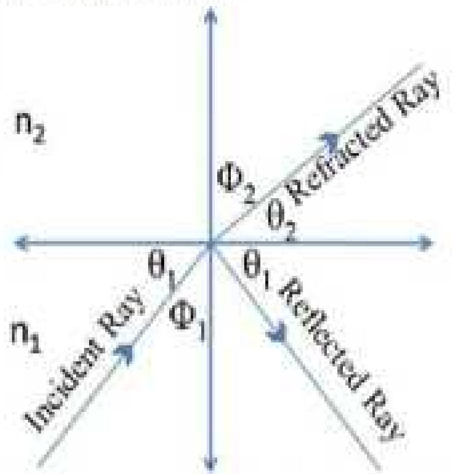
Typical values of Refractive Index is given by
n= 1 for Air, n=1.33 for Water, n=1.50 for Glass, n=2.42 for Diamond etc.

- When a light ray encounters a boundary separating two different media, part of the ray has reflected back in to the 1st medium. Then the remainder is bending or refracted as it enters to the second material.
- The bending or refraction of light ray at the interface as a result of difference in the speed of light in two materials that have different refractive indices.
- The relationship at the interface is known as **Snell's Law** and is given by

$$n_1 \sin \Phi_1 = n_2 \sin \Phi_2$$

$$\rightarrow n_1 \sin (90-\theta_1) = n_2 \sin (90-\theta_2)$$

$$\rightarrow n_1 \cos \theta_1 = n_2 \cos \theta_2$$



[Light Propagation in Optical Fiber]

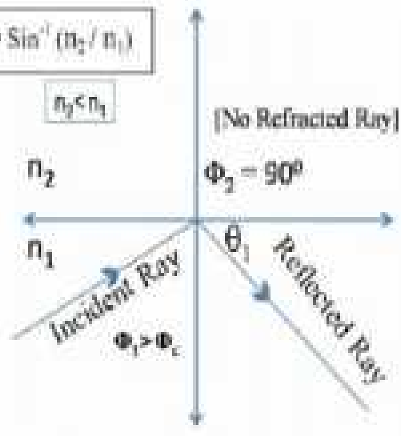
- The angle ϕ_1 between the incident ray and the normal to the surface is known as Angle of Incident.

- According to the Laws of Refraction the incident angle "θ" at which the incident ray strikes to the interface is exactly equal to the angle that the reflected ray makes with the same interface.
- In addition the incident rays the normal to the interface and the reflected ray all lies on the same plane.
- As n_1 is greater than n_2 the angle of refraction is always greater than that of angle of incident.
- If the angle of incident ϕ is increased a point will eventually reached where the light ray in air is parallel to the glass surface. This point is known as Critical Angle (ϕ_c) of the incident.
- The value of critical is given by

$$\sin \theta_c = n_2 / n_1 \rightarrow \theta_c = \sin^{-1} (n_2 / n_1)$$

$n_2 < n_1$

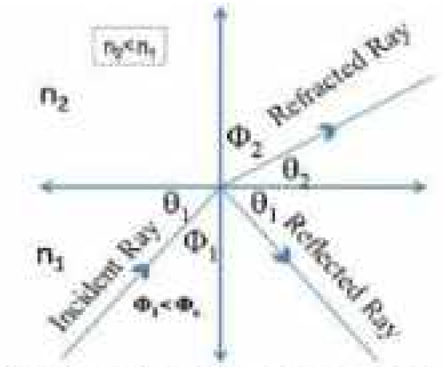
- When $\theta_c = 90^0$ then $\sin 90^0 = n_2/n_1 = 1 \rightarrow n_2 = n_1$
- So we must choose the angle of incidence less than 90^0.
- When the angle of incidence is greater than that of the critical angle. The light is reflected back into the medium and is known as **Total Internal Reflection.**



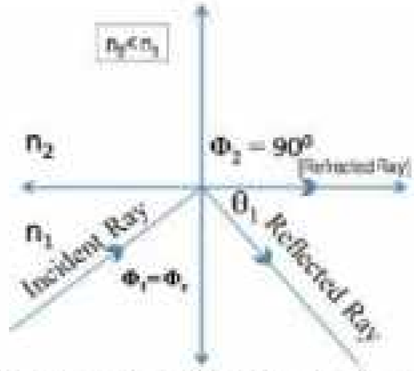
[Total Internal Reflection of Light; When $\Phi_1 > \Phi_c$]

❖ *Acceptance Angle:-*

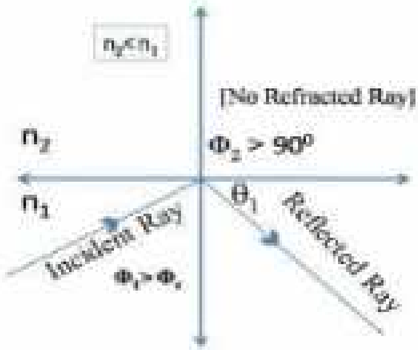
- Any ray which are incidence into the fiber core at an angle greater than θa will be transmitted to the core cladding interface at an angle less than 'ϕ_c' will not be total internal reflection.



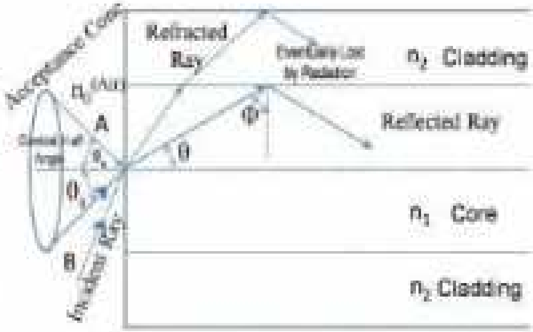
[Light Propagation in Optical Fiber when $\Phi_1 < \Phi_c$]



[Light Propagation in Optical Fiber when $\Phi_1 = \Phi_c$]



Light Propagation in Optical Fiber when $\Phi_1 > \Phi_c$]



[Propagation Mechanism for in an Ideal Step-Index Fiber]

- From the above figure the incident ray 'B' at an angle greater than θa is refracted into the cladding and is eventually loosed by the radiation.
- Thus for rays to be transmitted by total internal reflection within the fiber core, they must be incident on the fiber core with in an acceptance angle and is also defined by **Conical Half Angle** (θa).
- Hence θa is the maximum angle to the axis at which light may enter to the fiber in order to propagate fully and is refer as acceptance angle for the fiber.
- θ is some time refer as maximum or total acceptance angle .
- It may be noted that the output angle to the axis will be equal to the input angle for the ray assuming the ray emerges in to a medium o the same refractive index from which it was input.

❖ ***NUMERICAL APERTURE:-***

- It is possible to continue the ray theory analysis to obtain a relation between the acceptance angle and the refractive indices of the three medium involve such as core, cladding and air.
- This leads to the definition of a more generally used term that the Numerical Aperture of the fiber.
- The figure of the next page shows a light ray incident on the fiber core at an angle θ_1 to the fiber axis which is less than the acceptance angle for the fiber θa.
- The ray enters to the fiber from a medium (Air) that the refractive index 'n_0' and the fiber refractive index 'n_1' which is slightly greater than the cladding refractive index 'n_2'.

3.5. Describe the optical fiber construction

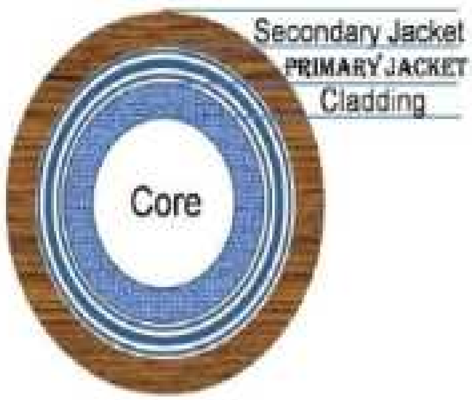
- Optical fiber may be produced with good stable transmission characteristic in long lengths at a minimum cost and with maximum reproducibility.
- The range of optical fiber type with regards to size, refractive indices, operating wave length, material etc is available in order to fulfill many different system applications.
- The fiber may be converted into practical cable which can be handled in a similar manner to a electrical transmission cable without any problem.
- For transmission point of view it is clear that a variation of refractive index inside the optical fiber (Core and Cladding) is the fundamental necessity in the fabrication of fiber for light transmission.
- Hence at least two difference materials which are transparent to light over the current operating wave length range are required.
- In practice these material must exhibit relatively low practical attenuation and they must therefore have low intrinsic absorption and scattering losses.
- A number of organic and inorganic insulating substances are used to meet these conditions. We chose suitable material for the fabrication of optical fibers to either glasses or glass like material & mono crystalline structure.
- It is used full in the case of graded index fiber that the refractive index of the material may be varied by suitable doping with another compactable material.
- This is only achieved in glasses or glass like material and therefore mono crystalline material are not suitable for the fabrication o graded index fiber but may be used for step index fiber.
- It is clear that glasses exhibit the best overall low loss optical fiber. Therefore it is used almost exclusively in the preparation of fibers for telecommunication application.

Structure of Optical Fiber:-

- The working of optical fiber is based on the principal of total internal reflection of light.
- The possible of light being guided through narrow jet of a communication system based on the propagation of light with in a cylindrical wave guided called optical fiber.
- The light entering at one end of the fiber has to travels through the entire length and energy at the other end without much loss.

[Structure of Optical Fiber]

- Optical fiber consists of three section such as
  I. CORE
  II. CLADDING
  III. JACKET
- The CORE of an optical fiber is a hair thin cylindrical fiber of glass any transparent dielectric material like plastic. The Core is coated with a layer of material with lower refractive index this layer is called CLADDING.
- The core and cladding together guide optical energy along the axis of fiber.
- The core diameter generally 5-100 micron while the cladding diameter is around 125 micron.

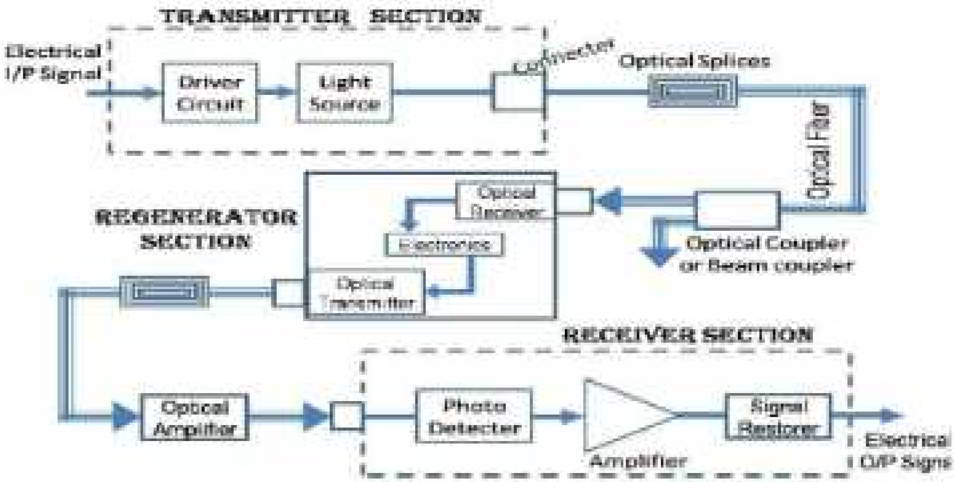


- For greater strength and protection of fiber a soft plastic coating or outer cover which is primary which diameter is around 250 micron is used called JACKET or PRIMARY JACKET.

[Cross-Sectional View of Optical Fiber]

- This is often followed by another layer of hard protective material which is known as SECONDARY JACKET. The entire unit is remaining flexible for use.

3.7. Optical fibre communication system- block diagram & working principle



[Block Diagram of a Fiber Optics Comm. System]

- The block diagram of FOCS contains fallowing components. Light Signal, Transmitter, Optical Fiber, Photo Detecting Receiver, Cable Splices, Connector, Regenerators, Beam Splitters and Optical Amplifier etc.
- Modern fiber optics communication system general includes an optical transmitter to convert an electrical signal to an optical signal to send into the optical fiber.
- In this section the electrical signal is converted into optical signal with the help of light source and associated circuit. We use light sources like semiconductor LED or LASER diodes since their light output can be modulated rapidly by simply varying the bias current at the desired transmission rate.
- Optical fiber cables are the medium for the transmission of signal. It carries the data, audio or video information in the form of optical signal. The cable containing bundles of multiple optical fiber that is routed through underground and buildings.
- An optical receiver is used to recover the signal as an electrical signal. The information transmitted in typically digital information generated by Computer, Telephone System or Television Company.
- In the receiver section a photo diode is there which treated the weakened optical signal and convert it to electrical current referred to as photo current. This photo current in the form of electrical signal is amplified by the amplifier.
- The signal restored will produce the required form of the signal at the output. Cable splices are used to joint between the two fiber optical cables.

- Connectors are connected just the end of the transmitter and receiver to connect with fiber optics cable. Its construction is more complex than that of splices. Beam splitter or optical couplers are used to split the optical signal into different parts for different communication system.
- Different type of optical amplifier is there to amplify the optical signal. Regenerators are used for restoring the signal shape characteristic.
- In a long distance transmission the degradation of optical signal takes place so to restore the signal shape characteristic over a long distance regenerators are used. This is mainly used under sea where the longest cables are employed.

APPLICATIONS

- Used in Voice Communications. (Inter-Office, Intercity, Intercontinental links etc)
- Video Communications. (TV Broadcast, Cable Television, Remote Monitoring, Wired City, Videophones etc)
- Data Transfer (Inter Office Data Link, Local Area Network, Satellite Ground Stations, Computers etc)
- Internet (Email, Access to remote information, Video Conferencing etc)
- Sensor System (Point Sensor, Distributed Sensor, Smart Structure, Robotics etc)
- Also it used in other indirect fields like Entertainment (HDTV), Power System, Transportations, Health Care (Endoscope),Military Defence(Guided Missile), Business Developments (CAD/CAM), Educations (CCTV) etc.

3.8. Modes of propagation and index profile of optical fiber

❖ *MODES OF PROPAGATION:-*

- Propagation of light along an optical fiber can be described in terms of a set of guided electromagnetic waves called the MODES.
- Each guided mode corresponds to a patterns of electric and magnetic field distribution that is repeated along the fiber at regular intervals. Only a certain discrete number of modes or patterns are capable of propagating along the fiber.
- For monochromic light the amplitude of a mode traveling along the fiber axis (say the +ve z-direction) is represented as

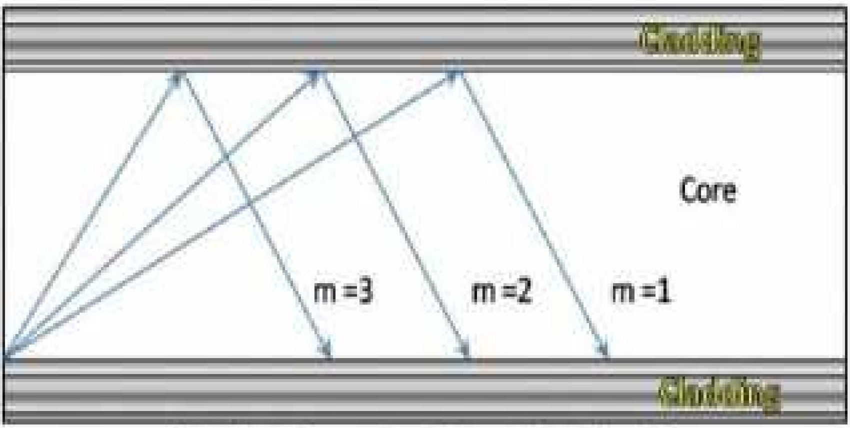
  $\Psi(z,t) = Ae^{j(wt-\beta z)}$,Where w=2πν and β is the z-component of propagation vector k=2π/λ in z-direction.
- For guided modes, β can have only certain discrete values that satisfies the maxwell's equation and the boundary conditions. These modes are identified by solving maxwell's EM wave equation under the boundary condition of the wave guide surface.
- The modes can also be visualized by ray tracing method.
- A guided mode travelling along the fiber can be regarded to be assembly of a group of plane waves along the axis with a common wave front.
- Since with any plane wave can associate a light ray that is normal to the wave front of the wave, group of waves corresponding to a particular mode from a set of ray called a Ray Congruence.
- Each ray of this particular group is incident at the core cladding interface at the same angle. Note that any ray that satisfies the condition (θ ≥ θc) can be transmitted in the fiber yet the constant phase condition is satisfied only in limited cases. i.e. there will be limited number of ray congruence or modes.

- The order of the mode m, is linked to the angle that the ray congruence makes with the fiber axis at the point of incidence. In order that the mode rays satisfy the condition, θ > θc and also converge is in the same phase, the path difference ΔP = mλ.

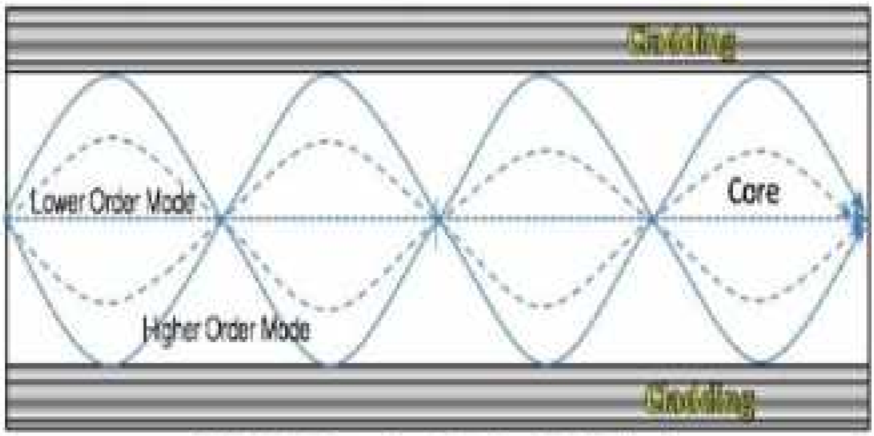
  Where m is an integer called the Mode Number. Note that the phase change on reflection should be included in computing ΔP.

- Through the path difference between meridional ray and skew rays is large yet the phase should be the same for transmission to be possible.
- The angle ϕ which a mode ray makes with the wall of the fiber is given by

  $\sin \phi = (\frac{m}{2}\lambda/d) < 1$, where $(\theta - \phi) = 90^0$, λ = Wavelength of light used & d = Fiber Diameter.
- Through a distinct mode is available with any integer value of m, number of modes are limited as $\sin\theta$ cannot exceed unity for low value of m, value of ϕ is low.
- On the other hand the value of ϕ is more for higher order modes are due to steeper incident ray. What happens for $\phi = 90°$ the wave front boundes back and forth from both the walls without advancing along the axis.



[Mode Information in Steo Index Fiber]



[Mode Information in Graded Index Fiber]

- When the fiber is very thin, the ray with a single low value of ϕ i.e. grazing incidence can enter into the fiber the steeper ray with high value of ϕ will not enter into the fiber.
- This is a monomode transmission if the core diameter is large, angle of incidence can change over a range and as such multimode transmission is possible as shown in figure above.

3.9. Types optical fiber configuration: Single-mode step index, Multi-mode step index, Multi-mode Graded index

- ***Classification of Optical Fiber :-***

➢ There are two methods of classification

1. According to Mode Capacity
2. According to Core Refractive Index

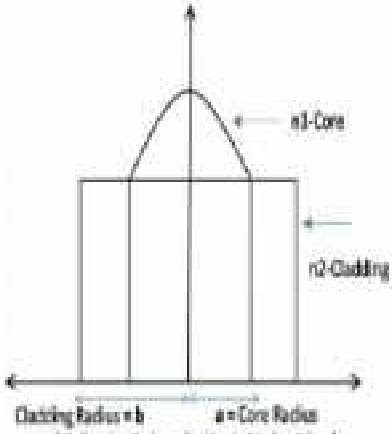
- ***Classification on the Basis of Mode :-***

A. MONOMODE FIBER : - The Monomode fiber allows only one mode to propagate and hence this name fiber of this type have very small core diameter ~ 2 to 10 micron.

B. MULTIMODE FIBER : - The core diameter is more than 50micron. Because of large diameter, It allows many modes to transmit through the fiber.

- ***Classification on the Basis of Core Refractive Index:-***

[Refractive Index of a Step Index Fiber]



[Refractive Index of a Graded Index Fiber]

A. STEP INDEX FIBER: - In step index fiber the core has uniform refractive index n_1, through its core section and the cladding also has slightly less but uniform refractive index n_2 through its cross section. The refractive index profile, the figure shows a step like structure.

B. GRADED INDEX FIBER:- Refractive index of the core is non-uniform being maximum along the axial and gradually decreases towards the core-cladding interface. The cladding refractive index n_2, however is uniform the variation of refractive index of the core n with distance 'x' measure from the axis.

3.10. Attenuation in optical fibers – Absorption losses, scattering, losses, bending losses, core and cladding losses- Dispersion – material Dispersion, waveguide dispersion, Intermodal dispersion

LOSSES IN OPTICAL FIBERS

When light propagates through an optical fiber, a small percentage of light is lost through different mechanisms. The loss of optical power is measured in terms of decibels per km for attenuation losses.

ATTENUATION:

It is defined as the ratio of optical power output (P_{out}) from a fiber of length 'L' to the power output (P_{in}) and is given by,

$$\frac{-10}{L} \log \frac{P_{in}}{P_{out}} \, dB / Km$$

Since attenuation plays a major role in determining the transmission distance, the following attenuation mechanisms are to be considered in designing an optical fiber.

1. Absorption:

Usually absorption of light occurs due to imperfections of the atomic structure such as missing molecules, (OH-), hydroxyl ions, high density cluster of atoms etc., which absorbs light.

2. Scattering:

Scattering is also a wavelength dependent loss, which occurs inside the fibers. Since the glass is used in fabrication of fibers, the disordered structure of glass will make some variations in the refractive index inside the fiber. As a result, if light is passed through the atoms in the fiber, a portion of light is scattered (elastic scattering) .this type of scattering is called Raleigh scattering.

$$\text{Raleigh scattering loss} \propto \frac{1}{\lambda^4}$$

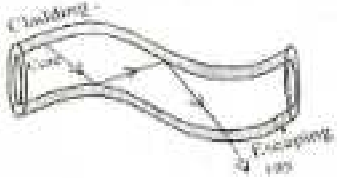
3. Radiative loss:

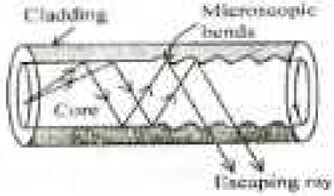
Radiative loss occurs in fibers due to bending of finite radius of curvature in optical fibers. The types of bends are

a. Macroscopic bends
b. Microscopic bends

a. Macroscopic bends:

If the radius of the core is large compared to fiber diameter, it may cause large-curvature at the position where the fiber cable turns at the corner. At these corners the light will not satisfy the condition for total internal reflection and hence it escapes out from the fiber. This is called as macroscopic / macro bending losses. Also note that this loss is negligible for small bends.





b. Microscopic bends:

Micro-bends losses are caused due to non-uniformities or micro bends inside the fiber as shown. This micro bends in fiber appears due to non uniform pressures created during the cabling of the fiber or even during the manufacturing itself. This lead to loss of light by leakage through the fiber.

Remedy:

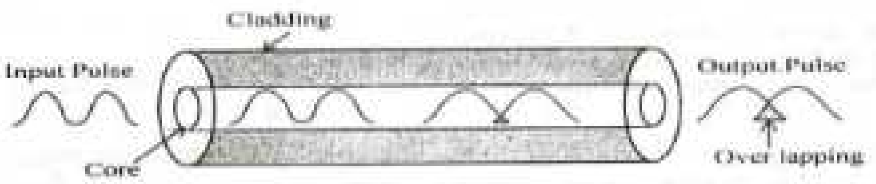
Micro-bend losses can be minimized by extruding (squeezing out) a compressible jacket over the fiber. In such cases, even when the external forces are applied, the jacket will be deformed but the fiber will tend to stay relatively straight and safe, without causing more loss.

DISTORTION AND DISPERSION

The optical signal becomes increasingly distorted as it travels along a fiber. This distortion is due to dispersion effect.

Dispersion:

When an optical signal or pulse is sent into the fiber the pulse spreads /broadens as it propagates through the fiber. This phenomenon is called dispersion as shown in the figure.



From figure we can see that the pulse received at the output is wider than the input pulse. Hence the output pulse is said to be distorted, due to dispersion effect.

The pulse broadening or dispersion will occur in three ways, viz.,

1. Inter-modal dispersion
2. Material dispersion or chromatic dispersion
3. Waveguide dispersion

Intermodal dispersion:

When more than one mode is propagating through the fiber, then the inter modal dispersion will occur. Since, many modes are propagating; they will have different wavelengths and will take different time to propagate through the fiber, which leads to intermodal dispersion.

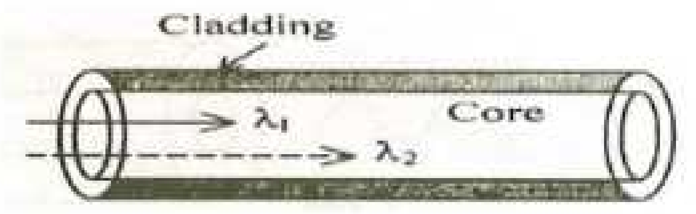
Explanation:

When a ray of light is launched into the fiber, the pulse is dispersed in all possible paths through the core, so called different modes.

Each mode will be different wavelength and has different velocity as shown in the figure. Hence, they reach the end of the fiber at different time. This results in the elongation or stretching of data in the pulse. Thus causes the distorted pulse. This is called intermodal dispersion.

Material dispersion:

In material dispersion, the dispersion occurs due to different wavelength travelling at different speed inside the fibers shown in the figure.



Remedy:

The material dispersion can be minimized at certain wavelengths say 870nm, 1300 nm and 1550 nm; these wavelengths are termed ***Zero Dispersion wavelengths(ZDW).***

Whether light wavelength is lesser than ***Zero Dispersion wavelengths*** , it travels slower and when it is higher than ZDW it travels faster.

Thus the speed is altered and adjusted in such a way that all the waves passing through the fiber will move with constant speed and hence the material dispersion is minimized.

Note: this dispersion will not occur in single mode fibers

Wave guide dispersion:

The wave guide dispersion arises due to the guiding property of the fiber and due to their different angles at which they incident at the core-cladding interface of the fiber.

In general

Inter-modal dispersion > Material Dispersion> Waveguide dispersion

3.11. Optical sources(Transmitter) & types – LED- semiconductor laser diodes &

3.12. LASER-,its working Principle, Block Diagram using Laser feedback control system

- ***LED(LIGHT EMITTING DIODE):-***
- LED stands for Light Emitting Diode. These types of diodes are created by combination of a trivalent or pentavalent material with some other material to produce light in different colour.
- WORKING PRINCIPLE:-
- When these diodes are forward biased there is a process of recombination takes place due to which the free electrons release some energy in the form of light. The materials are so chosen that it creates a proton which is radiated by changing the energy gap and by adding some other materials different visible and invisible light are produced.
- LEDs are two types. Homo junction LED, Hetro junctio LED.

- ***LASER:-***
- Laser stands for Light Amplification Stimulated Emission of Radiation.
- It deals with the technical concentration of light into a very small and powerful beam.
- It was developed by H.Maiman.
- There are four types of LASER.

I. GAS
II. LIQUID
III. SOLID
IV. SEMICONDUCTOR

- A active medium is taken from which laser is emitted. The active medium is polished for 100% internal reflection exceed one side. A power source is connected over the medium. A flash tube with a trigger is used to brust light. Due to continuous flashes the ionization increasing creating lasing and after some period again they are grounded releasing protons.
- The protons strike other electrons and atoms creating a number of proton packs by which they try to escape from the material and they escape from the material and escaped from unfinished part.

3.13. Optical Detectors-PIN and APD diodes & Block diagram using APD Connectors and splices-optical cables-Couplers

❖ *PIN Diode:-*

- It is a depletion layer photo diode PIM stands for P-type intrinsic N-type diode.
- It is used to defect light energy in optical fiber communication system.
- A very lightly dopped N-type semiconductor is sandwiched between two P and N type heavily dopped semiconductor.
- There is a small window over the path which receives the light or proton energy. This is mode so thick that it can observe all the proton energy.
- The Proton energy is observed by the valany band electrons of intrinsic semiconductor and make it a free electron allowing current to flow through it.
- The current depends upon the number of photon energy. Generally silicon materials are used for this type of diode construction.

APD Diode :

- An **avalanche photodiode** (APD) is a highly sensitive semiconductor photodiode that exploits the photoelectric effect to convert light into electricity.
- From a functional standpoint, they can be regarded as the semiconductor analog of photomultipliers.
- The avalanche photodiode (APD) was invented by Japanese engineer Jun-ichi Nishizawa in 1952.

Principle of operation

- By applying a high reverse bias voltage (typically 100–200 V in silicon), APDs show an internal current gain effect (around 100) due to impact ionization (avalanche effect).
- However, some silicon APDs employ alternative doping and beveling techniques compared to traditional APDs that allow greater voltage to be applied (> 1500 V) before breakdown is reached and hence a greater operating gain (> 1000). In general, the higher the reverse voltage, the higher the gain.

- Among the various expressions for the APD multiplication factor (M), an instructive expression is given by the formula

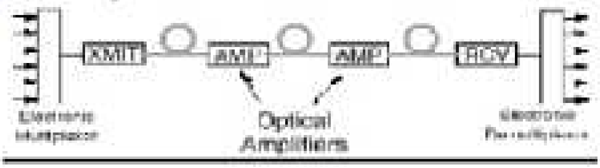
$$M = \frac{1}{1 - \int_0^L \alpha(x)\, dx},$$

- where L is the space-charge boundary for electrons, and 'a' is the multiplication coefficient for electrons (and holes).
- This coefficient has a strong dependence on the applied electric field strength, temperature, and doping profile.
- Since APD gain varies strongly with the applied reverse bias and temperature, it is necessary to control the reverse voltage to keep a stable gain.
- Avalanche photodiodes therefore are more sensitive compared to other semiconductor photodiodes.

3.14. Optical repeater & Single Channel system

- In the world of electronic communications the use of digital transmission revolutionised the technology because we were now able to send information as far as we liked *without* loss or distortion of any kind.
- This comes about because of the nature of the digital signal. The form of the signal is predetermined and predictable.
- Therefore we can regenerate it whenever needed and reconstitute it exactly it into its original form.
- What we do is extract the digital information stream from the old signal and then build a new signal containing the original information. This function is performed by a *repeater*.

Amplified Single-Channel Systems



The wavelength used is now 1550 nm. This is done for two reasons:

1. To exploit the low attenuation window of fibre in the 1500 nm "window"
2. To allow the use of Erbium Doped Fibre Amplifiers (EDFAs)

- The distance between amplifiers is now increased to between 110 and 150 km. (On long distance links this is a very significant cost saving as the cost of maintaining repeater or amplifier "huts" along the route is very high.)
- The speed is generally increased to either 1.2 Gbps or 2.4 Gbps.

While the overall architecture of the system looks much the same as before there are three significant changes:

1. Since we are still using standard fibre which has a large amount of dispersion in the 1550 nm band we need to give some design consideration to the control of dispersion. In older systems, the fibre didn't disperse the signal by very much because we were using the 1310 nm band. The repeaters removed the small dispersion created anyway. Now, by moving to the 1550 nm band, we have brought on a dispersion problem. The amplifiers will cause dispersion to accumulate over the whole length of the link.
2. The link is now both modulation format and speed transparent. It may be upgraded to use higher speeds and the modulation format may be changed (for example from OOK to duobinary or ternary coding) without changing equipment in the field. You only have to change the equipment at each end!
3. Provided the link has been planned properly it can now be upgraded to use WDM technology again without change to the outside plant. Some foresight is needed here in planning the amplifier capacity (power) as the addition of WDM will demand significantly higher levels of power. However, it is possible to plan the link in such a way as to enable upgrading to WDM at a future time without change to outside equipment.

3.15. Applications of optical fibres – civil, Industry and Military application

APPLICATIONS

- Used in Voice Communications (Inter-Office, Intercity, Intercontinental links etc)
- Video Communications (TV Broadcast, Cable Television, Remote Monitoring, Wired City, Videophones etc)
- Data Transfer (Inter Office Data Link, Local Area Network, Satellite Ground Stations, Computers etc)
- Internet (Email, Access to remote information, Video Conferencing etc)
- Sensor Systems (Point Sensor, Distributed Sensor, Smart Structure, Robotics etc)
- Also it used in other indirect fields like Entertainment (HDTV), Power System, Transportations, Health Care (Endoscope),Military Defense(Guided Missile), Business Developments (CAD/CAM), Education (CCTV) etc.

3.16. Concept of Wave Length Division Multiplexing (WLDM) principles

Wave Length Division Multiplexing (WLDM):-

- Wave length division multiplexing is simply known wave division multiplexing (W.D.M).
- In this type of technology transmission of multiple digital signals can be made in difference wave length without any interference.
- Using W.D.M a number of optical signal can be transmitted at a time by a signal fiber cable at the same time with different wave length or frequencies.
- Transmitted in the same medium in different paths only and at the receiving section. They are reached at different time interval.
- The wave lengths are created depending upon the color and combination of these can be transmitted by multimode step index profile creating paths for individual colour.

Short Questions with answers

1. Give four applications of fiber optic sensors.

a) Fiber optic sensors are used as optical displacement sensors, which is used to find the displacement of a target along with its position.
b) It is used as fluid level detector.
c) It is used to sense the pressure, temperature at any environment.
d) It is also used to measure the number of rotations of the fiber coil using the instrument called a gyroscope.

2. Explain the basic principle of fiber optic communication.

Total internal reflection is the principle of fiber optic communication.

> **Principle:** When light travels from a denser to rarer medium, at a particular angle of incidence called the critical angle, the ray emerges along the surface of separation. When the angle of incidence exceeds the critical angle, the incident ray is reflected in the same medium and this phenomenon is called the total internal reflection.

3. Give the application of fiber optical system.

a) It can be used for long distance communication in trunk lines.

b) A large no of telephone signals nearly 15000 can be passed through the optical fibers in a particular time without any interference.

c) It is used in computer networks especially in LAN.

d) It is also used as optical sensor.

4. Mention any four advantages of LED in electronic display.

a) Very small in size.

b) Different colours of display.

c) Works under a wide range of temperature.

d) It is a very wide range of operation.

5. Mention any four advantages of fiber optic sensors.

a) It has no external interference

b) It is used in remote sensing.
c) Safety of data transfer.
d) It is small in size.

6. Mention any two fiber optic sources.

a) Light emitting diode (LED) in LED we have two types 1.planar 2.dome shaped LED.

b) Laser diodes (LD). In laser diodes we have homojunction laser heterojunction laser injection laser diode etc.

7. What is meant by injection luminescence? Give examples.

When the majority careers are injected from P to N and N to P region, they become excess minority carriers. Then this excess minority carrier diffuses away from the junction and recombines with the majority carriers in P and N region and emits light. This phenomenon is known as injection luminescence.

8. What is meant by LED? Give its principle.

An LED is the abbreviation of light emitting diode. It is a semiconductor P N junction diode which converts electrical energy to light energy under forward biasing.

9. What is the principle used in PIN photodiode?

This diode works in reverse bias. Under reverse bias when light is made to fall on the neutral or intrinsic region electron hole pairs are generated. These electrons and holes are accelerated by the external electric field, which results in photo current. Thus light is converted into electrical signal.

10. Give any four examples of intrinsic sensor.

a) Pressure sensor

b) Liquid level sensor

c) Phase and polarization sensor.

d) Optical fiber flow sensor.

11. 10. Give any four examples of extrinsic sensor.

a) Displacement sensor

b) Laser Doppler velocimter sensor

c) Fluor optic temperature sensor

d) Current measurement sensor

12. State the applications of optical fibers in medical field.

a) Fiber optics endoscopes are used in medical diagnosis

b) It is used to visualize the inner organs of the body
c) Fibers as endoscopes are used in various medical fields such as cardioscopy, laparoscopy, cryoscopy etc.

Long Questions

1. Describe the optical fiber construction.
2. Define terms: Velocity of propagation, Critical angle, Acceptance angle & numerical aperture.
3. Explain Optical fibre communication system- block diagram & working principle with advantages and application.(S-24)
4. Explain about the Attenuation in optical fibers.
5. Write short note on the Concept of Wave Length Division Multiplexing (WLDM) principles.
6. Explain about LED in fiber optics.
7. Explain LASER diode in fiber optics.(S-24)
8. Write short note on APD.

CHAPTER-04 : TELECOMMUNICATION SYSTEM

4.1 The operation of Electronic Telephone System. (Telephone Set)

The Basic Telephone Set Fundamental Functions

- The basic telephone set connected to the telephone network we are all very comfortable with using, has 4 basic functions:
- To provide a signal to the telephone company that a call is to be made (off-hook) or a call is complete (on-hook).
- To provide the telephone company with the number the caller wishes to call.
- To provide a way for the telephone company to indicate that a call is coming in or ringing.
- To convert voice frequencies to electrical signals that can be transmitted at the transmitter and convert these electrical signals back to voice frequencies at the receiver.

The Federal Communications Commission (FCC) has set standards for the above features and all manufacturers selling telephones in this country must match these standards or the phone will not work properly.

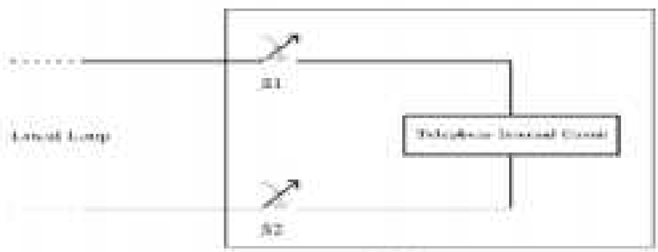
In addition many modern telephones also come with features like speed dial, redial, memory, caller ID, voice mail, etc. These are all additional features that are not necessary to make or receive calls.

Let's look at Telephone Set Function 1: To provide a signal to the telephone company that a call is to be made (off-hook) or a call is complete (on-hook).

The switchhook gets its name from the old telephones that had a hook on the side. On modern phones the switchhook is a button that is depressed when the handset is put on the cradle of the telephone.

According to Telephone Company specifications individual telephone set DC resistance should be 200 Ω but in reality most telephones range between 150 and 1000 Ω of DC resistance.

When a user picks up a connected telephone handset to make a call the switch hooks in the figure below (S_1 and S_2) close (off-hook condition) and the local loop circuit is complete.



Telephone

When a handset is picked up, a DC current ranging between 20 and 120 mA flows on the pair of wires connecting the telephone to the CO. This current flow causes a relay coil to magnetize and it's contacts close.

In the CO current flows through a relay coil attached to the local loop wire pair. The coil energizes, it's contacts close and the CO switch knows a phone is off hook somewhere.

A line feeder in the CO switch looks for the off-hook signal, finds it and sets up a connection. In the CO switch a dial-tone generator is connected to the line so the caller knows they can dial a number.

4.2 The function of Switching System & Call Procedures

Switching system

When there are many devices, it is necessary to develop suitable mechanism for communication between any two devices. One alternative is to establish point-to-point communication between each pair of devices using **mesh topology.**

However, mesh topology is impractical for large number of devices, because the number of links increases exponentially (n(n-1)/2, where n is the number of devices) with the number of devices. A better alternative is to use switching techniques leading to switched communication network.

In the **switched network** methodology, the network consists of a set of interconnected nodes, among which information is transmitted from source to destination via different routes, which is controlled by the switching mechanism. A basic model of a switched communication is shown in Fig. 4.1.1.

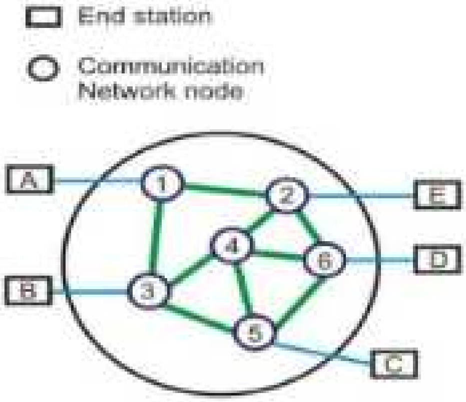
The end devices that wish to communicate with each other are called *stations*. The switching devices are called *nodes*. Some nodes connect to other nodes and some are to connected to some stations.

Key features of a switched communication network are given below:

- Network Topology is not regular.
- Uses FDM or TDM for node-to-node communication.
- There exist multiple paths between a source-destination pair for better network reliability.
- The switching nodes are not concerned with the contents of data.
- Their purpose is to provide a switching facility that will move data from node to node until they reach the destination.

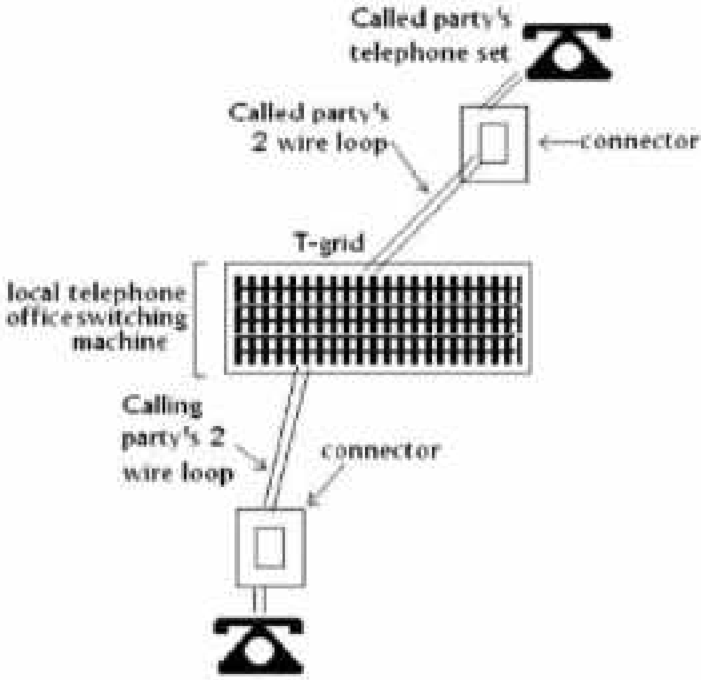
The switching performed by different nodes can be categorized into the following three types:

- Circuit Switching
- Packet Switching
- Message Switching



Basic Call Procedure:

Fig. Shows a simplification diagram illustrating how two telephone sets (subscribers) are interconnected through a central office dial switch. Each subscriber is connected to the switch through a local loop. The switch is most likely some sort of an electronic switching system (ESS machine). The local loop are terminated at the calling and called station s in telephone sets and at the central office ends to switching machines.



[BASIC CALL PROCEDURE]

When the calling party's telephone set goes off hook (i.e., lifting the handset off the cradle), the switch hook in the telephone set is released, completing a dc path between the tip and the ring of the loop trough the microphone .

The ESS machine senses a dc current in the loop and recognizes this as an off-hook condition. Completing a local telephone call between two subscribers connected to the same telephone switch is accomplished through a standard set of procedure that includes the 10 steps listed next.

1. Calling station goes off hook.

2. After detecting a dc current flow on the loop, the switching machine returns an audible dial tone to the calling station, acknowledging that the caller has access to the switching machine.

3. The caller dials the destination telephone number using one of the two methods: Mechanical dial pulsing or, more likely, electronic dual-tone multi frequency (Touch-Tone) signals.

4. When the switching machine detects the first dialled number, it removes the dial tone from the loop.

5. The switch interprets the telephone number and then locates the loop for the destination telephone number.

6. Before ringing the destination telephone , the switching machine tests the destination loop for dc current to see if it is idle (on hook) or in use (off hook). At the same time, the switching machine locates a signal path through the switch between the two local loops.

7. (a) If the destination telephone is off hook, the switching machine sends a station busy signal back to the calling station.

(b) If the destination telephone is on hook, the switching machine sends a ringing signal to the destination telephone on the local loop and the same time sends a ring back signal to the calling station to give the caller some assurance that something is happening.

8. When the destination answers the telephone, it completes the loop, causing dc current to flow.

9. The switch recognizes the dc current as the station answering the telephone. At this time, the switch removes the ringing and ring-back signals and completes the path through the switch, allowing the calling and called parties to begin conversation.

10. When either end goes on hook, the switching machine detects an open circuit on that loop and then drops the connections through the switch.

4.3 The principle of space and time switching.

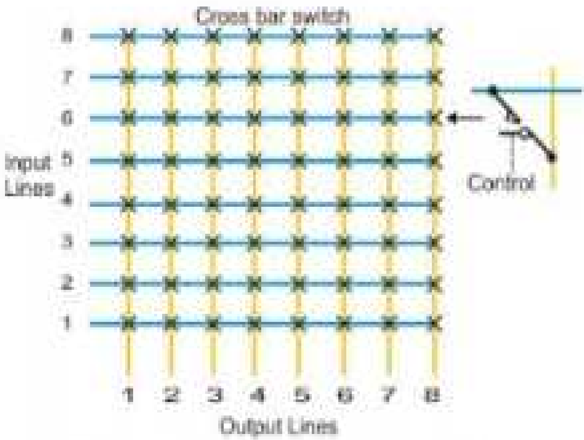
Space Switching

Circuit switching uses any of the three technologies: **Space-Division** switches, **Time-Division** switches or a **Combination of both**.

In Space-division switching, the paths in the circuit are separated with each other spatially, i.e. different ongoing connections, at a same instant of time, uses different switching paths, which are separated spatially.

This was originally developed for the analog environment, and has been carried over to the digital domain. Some of the space switches are crossbar switches, Multi-stage switches (e.g. Omega Switches).

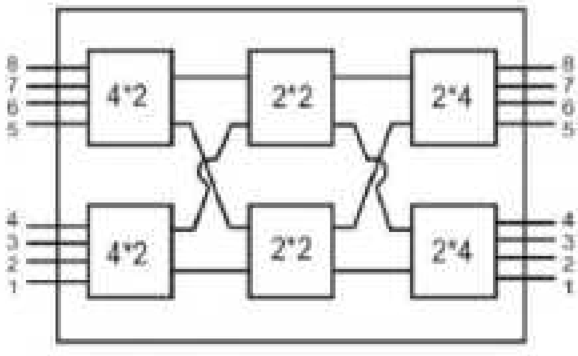
A **Crossbar** switch is shown in Fig. Basic building block of the switch is a metallic crosspoint or semiconductor gate that can be enabled or disabled by a control unit.



[Figure Schematic diagram of a crossbar switch]

Limitations of crossbar switches are as follows:

• The number of cross points grows with the square of the number of attached stations.
• Costly for a large switch.
• The failure of a cross point *prevents* connection between the two devices whose lines intersect at that cross point.
• The cross points are inefficiently utilized.
• Only a small fraction of cross points are engaged even if all of the attached devices are active. Some of the above problems can be *overcome* with the help of *multistage space division* switches.
• By splitting the crossbar switch into smaller units and interconnecting them, it is possible to build multistage switches with fewer cross points.



[Fig- A three-stage space division switch]

Figure shows a three-stage space division switch. In this case the number of crosspoints needed goes down from 64 to 40. There is more than one path through the network to connect two endpoints, thereby increasing reliability. Multistage switches may lead to *blocking*.

The problem may be tackled by increasing the number or size of the intermediate switches, which also increases the cost. The blocking feature is illustrated in Fig. 4.1.6. As shown in Fig. 4.1.6, after setting up connections for 1-to-3 and 2-to-4, the switch cannot establish connections for 3-to-6 and 4-to-5.

Time Division Switching

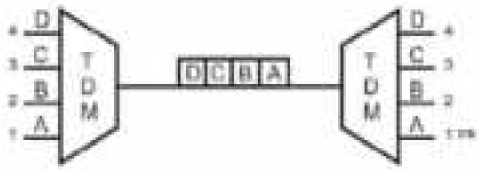
Both voice and data can be transmitted using digital signals through the same switches. All modern circuit switches use digital time-division multiplexing (TDM) technique for establishing and maintaining circuits. Synchronous TDM allows multiple low-speed bit streams to share a high-speed line.

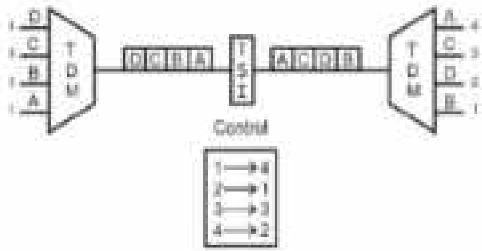
A set of inputs is sampled in a round robin manner. The samples are organized serially into slots (channels) to form a recurring frame of slots.

During successive time slots, different I/O pairings are enabled, allowing a number of connections to be carried over the shared bus. To keep up with the input lines, the data rate on the bus must be high enough so that the slots recur sufficiently frequently.

For 100 full-duplex lines at 19,200 Kbps, the data rate on the bus must be greater than 1.92 Mbps. The source-destination pairs corresponding to all active connections are stored in the control memory.

Thus the slots need not specify the source and destination addresses. Schematic diagram of time division switching is shown in Fig.





Time-division switching uses time-division multiplexing to achieve switching, i.e. different ongoing connections can use same switching path but at different interleaved time intervals.

There are two popular methods of time-division switching namely, Time-Slot Interchange (TSI) and the TDM bus.

TSI changes the ordering of the slots based on desired connection and it has a random-access memory to store data and flip the time slots as shown in Fig. 4.1.8.

The operation of a TSI is depicted in Fig.1 As shown in the figure, writing can be performed in the memory sequentially, but data is read selectively.

In TDM bus there are several input and outputs connected to a high-speed bus. During a time slot only one particular output switch is closed, so only one connection at a particular instant of time as shown in Fig.2

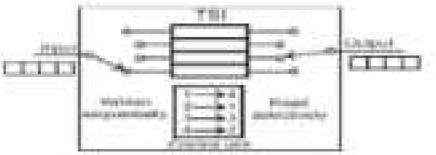


Figure 1 Operation of a TSI

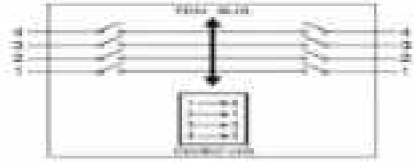


Figure 2 TDM bus switching

4.4. Numbering plan of telephone networks (National Schemes & International Numbering)

INTRODUCTION

The National Numbering Plan was last reviewed during 1993. The plan covered basic as well as other services like cellular mobile, paging etc. Though the 1993 Numbering Plan could cater to the needs of existing and new services for another few years, yet it was felt to rationalise and review the existing National Numbering Plan because of introduction of a large number of new telecom services and opening up of the entire telecom sector for private participation.

The existing Numbering Plan was formulated at a time when there was no competition in the basic telecom services and the competition in cellular mobile services had just started, paging services were in a stage of infancy and Internet services were not available in the country.

The main objectives of the plan are –

i) To plan in conformity with relevant and applicable ITU standards to the extent possible.

ii) To meet the challenges of the changing telecom environment.

iii) To reserve numbering capacity to meet the undefined future needs.

iv) To support effective competition by fair access to numbering resources.

v) To meet subscriber needs for a meaningful and user-friendly scheme. Only the decimal character set 0-9 has been used for all number allocations. Letters and other non-decimal characters shall not form part of the National (Significant) Number [N(S)N]. Dialling procedure as per ITU Recommendation E.164 has been followed.

The Short Distance Charging Area (SDCA) based linked numbering scheme with 10-digit N(S)N has been followed. This would expand the existing numbering capacity to ten times.

NATIONAL NUMBERING SCHEME

Level '0':

Sub level '000':

The prefix '000' shall be used for home country direct service (Bilateral) and international toll free service (Bilateral). The format used is '000 + Country Code + Operator Code' except '000800' which is used for bilateral international toll free service.

Sub level '0010' - INTERNATIONAL CARRIER ACCESS (Prefix) CODE. The prefix '0010' shall be used for selection of international carrier. It will be followed by International Carrier Identification Code (ICIC), Country Code (CC) and N(S)N. The format shall be as under:

Prefix	International Carrier Identification Code	Country Code	National(Significant)Number
0010	ICIC	CC	N(S)N

Initially ICIC shall be a two-digit code. This will be sufficient for allotment to 50 international long distance service providers considering that maximum of two codes may be allotted to each service provider depending upon toll quality and non-toll quality network. However, to take care of all possible future requirements, length of ICIC may be reviewed and changed to 3-digit code as and when required. The allotment of ICIC may start from '10' and codes '00' to '09' may be kept reserved.

Sub level '00' - INTERNATIONAL PREFIX:

The prefix '00' shall be used for International dialling. It will be followed by country code and the N(S)N of the country to which that call is attempted. The format is as per ITU Recommendation E.164:

Prefix	Country Code	National(Significant)Number
00	CC	N(S)N

Sub level '010' - NATIONAL CARRIER ACCESS (Prefix) CODE:

The prefix '010' shall be used for selection of national long distance carrier. It will be followed by (National) Carrier Identification Code (CIC) and N(S)N. The format shall be as under:

Prefix	Carrier Identification Code	National(Significant)Number
010	CIC	N(S)N

Initially CIC shall be a two-digit code. This will be sufficient for allotment to 40 NLDOs (including NLDOs licensed for basic services) and 10 BSOs licensed only for basic services, considering that maximum of two codes may be allotted to each service provider depending upon toll quality and non-toll quality network. However to take care of all possible future requirements, length of CIC may be reviewed and changed to 3-digit code in future.

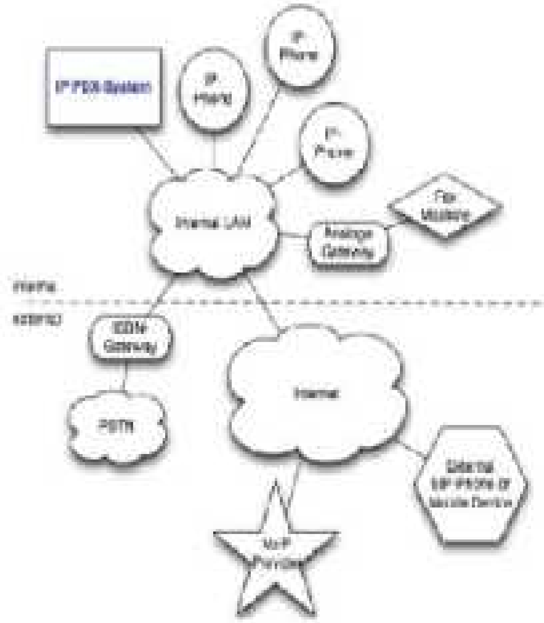
The allotment of CIC may start from '10' and codes '00' to '09' may be kept reserved. For intra circle long distance service, the carrier access code shall be the same as applicable for NLD service. The CIC from '10' to '79' shall be allotted to NLD service providers. For the NLD service providers, who are also Basic Service Operators (BSOs), same CIC shall be applicable for intra circle (service area) calls. CIC from '80' to '99' shall be allocated to the BSOs who are not licensed to provide NLD service.

4.5. Working Principle of PBX and Digital EPABX

PBX

What is a PBX Phone System?

PBX stands for Private Branch Exchange, which is a private telephone network used within a company or organization. The users of the PBX phone system can communicate within their company or organization and the outside world, using different communication channels like Voice over IP, ISDN or analog. A PBX also allows you to have more phones than physical phone lines (PTSN) and allows free calls between users. It also provides features like transfers, voicemail, call recording, interactive voice menus (IVRs) and ACD call queues.



PBX phone systems are available as Hosted or Virtual solutions (sometimes also called Centrex), and as inhouse solutions to be used on your own hardware.

PBX phone systems are usually much more flexible than proprietary systems, as they are using open standards and interfaces. Modern PBX phone systems are based on standard hardware, which is cheaper and can easier be replaced than a closed systems.

Switching to an IP PBX offers many benefits

With an IP phone system all your internal telephony is routed through the existing LAN (local computer network). This way a separate network for telephony is not required.

Even though the internal telephony is routed through the LAN, it is also possible to connect your IP-PBX via gateways to the PSTN. Of course, VoIP (Voice over IP, telephony via the internet) is also possible.

Since IP telephony is mostly using the open SIP standard, an IP phone system gives you a lot more freedom in your choice of phones.

Basically any SIP compatible phone (VoIP phone) will work with an IP PBX. Furthermore an IP PBX doesn't limit the growth of a company.

Since VoIP phones don't have to be connected physically to the phone system, it doesn't require a free port in the phone system like it used to be with traditional phone systems.

IP phones can not only be connected via the LAN but also via the internet, using for example a VPN connection. Because of this, multiple locations and offices can easily be connected.

There is a huge variety of VoIP providers on the internet which provide SIP trunking (telephony services) for cheaper call rates than traditional telephony providers. Internal calls via an IP phone system are free general.

Practical advantages of IP telephony

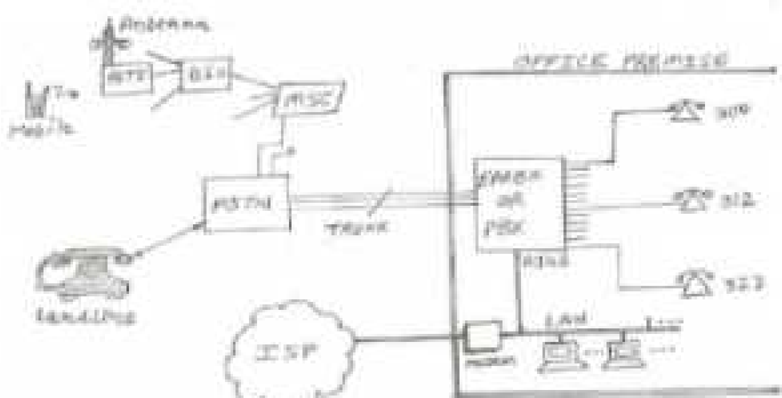
Interconnecting teams and mobile working is one of the huge advantages of IP phone systems. No matter if team members are on the road, are located in a different country or work from home, they can connect via IP desk phone, smart phone or laptop to the PBX in the office.

This way all calls within the company are free and clients will not realize if an employee is in the office or somewhere else around the world. The same also applies for conferences, these can be hosted directly on the own IP PBX with as many participants as required. This safes traveling time and money.

Digital EPABX

As shown in the figure EPABX/PBX facilitates use of one external telephone line by many internal users in the office premises. In the office each employee is provided one telephone set and all the telephones are connected with PBX.

All the employees within the office premises can communicate using 3-digit or 4-digit number programmed in EPABX/PBX without any charge.



EPABX/PBX is connected to PSTN (Public switched Telephone network) via trunk lines; hence all can use one external voice line in time shared basis.

PSTN is connected with MSC (Mobile switching centre) of cellular networks such as GSM/CDMA/UMTS. By this mobile cell phone user can connect to any telephone set in the office premises using extension number.

Similar to voice line EPABX/PBX can be used for Data applications. As shown in figure Data port of PBX is connected to LAN where so many PCs are connected and are using same external internet connection line from ISP via Modem/router. The same facility of PBX can extended for WLAN users too.

4.6. Units Of Power Measurements

The watt (symbol: W) is a derived unit of power in the International System of Units (SI), named after the Scottish engineer James Watt (1736–1819). The unit is defined as joule per second[1] and can be used to express the rate of energy conversion or transfer with respect to time. It has dimensions of

L2MT-3

When an object's velocity is held constant at one meter per second against constant opposing force of one newton the rate at which work is done is 1 watt.

$$W = \frac{J}{s} = \frac{N \cdot m}{s} = \frac{kg \cdot m^2}{s^3}$$

In terms of electromagnetism, one watt is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V).

$$W = V \cdot A$$

Two additional unit conversions for watt can be found using the above equation and Ohm's Law.

$$W = \frac{V^2}{\Omega} = A^2 \cdot \Omega$$

Where ohm (Ω) is the SI derived unit of electrical resistance.

Femtowatt

The femtowatt is equal to one quadrillionth (10−15) of a watt. Technologically important powers that are measured in femtowatts are typically found in reference(s) to radio and radar receivers. For example, meaningful FM tuner performance figures for sensitivity, quieting and signal-to-noise require that the RF energy applied to the antenna input be specified.

These input levels are often stated in dBf (decibels referenced to 1 femtowatt). This is 0.2739 microvolt across a 75-ohm load or 0.5477 microvolt across a 300 ohm load; the specification takes into account the RF input impedance of the tuner.

Picowatt

The picowatt is equal to one trillionth (10−12) of a watt. Technologically important powers that are measured in picowatts are typically used in reference to radio and radar receivers, acoustics and in the science of radio astronomy.

Nanowatt

The nanowatt is equal to one billionth (10^{-9}) of a watt. Important powers that are measured in nanowatts are also typically used in reference to radio and radar receivers.

Megawatt

The megawatt is equal to one million (106) watts. Many events or machines produce or sustain the conversion of energy on this scale, including lightning strikes; large electric motors; large warships such as aircraft carriers, cruisers, and submarines; large server farms or data centers; and some scientific research equipment, such as supercolliders, and the output pulses of very large lasers.

A large residential or commercial building may use several megawatts in electric power and heat. On railways, modern high-powered electric locomotives typically have a peak power output of 5 or 6 MW, although some produce much more.

The Eurostar, for example, uses more than 12 MW, while heavy diesel-electric locomotives typically produce/use 3 to 5 MW. U.S. nuclear power plants have net summer capacities between about 500 and 1300 MW.

The earliest citing of the megawatt in the Oxford English Dictionary (OED) is a reference in the 1900 Webster's International Dictionary of English Language. The OED also states that megawatt appeared in a 28 November 1947 article in the journal Science

Gigawatt

The gigawatt is equal to one billion (109) watts or 1 gigawatt = 1000 megawatts. This unit is often used for large power plants or power grids. For example, by the end of 2010 power shortages in China's Shanxi province were expected to increase to 5–6 GW and the installed capacity of wind power in Germany was 25.8 GW. The largest unit (out of four) of the Belgian Nuclear Plant Doel has a peak output of 1.04 GW. HVDC converters have been built with power ratings of up to 2 GW.[11] The London Array, the world's largest offshore wind farm, is designed to produce a gigawatt of power

Terawatt

The terawatt is equal to one trillion (1012) watts. The total power used by humans worldwide (about 16 TW in 2006) is commonly measured in this unit. The most powerful lasers from the mid-1960s to the mid-1990s produced power in terawatts, but only for nanosecond time frames. The average lightning strike peaks at 1 terawatt, but these strikes only last for 30 microseconds.

Petawatt

The petawatt is equal to one quadrillion (1015) watts and can be produced by the current generation of lasers for time-scales on the order of picoseconds (10−12 s). One such laser is the Lawrence Livermore's Nova laser, which achieved a power output of 1.25 PW (1.25 × 1015 W) by a process called chirped pulse amplification. The duration of the pulse was about 0.5 ps (5 × 10−13 s), giving a total energy of 600 J, or enough energy to power a 100 W light bulb for six seconds

4.7. Working principle of Internet Protocol Telephone

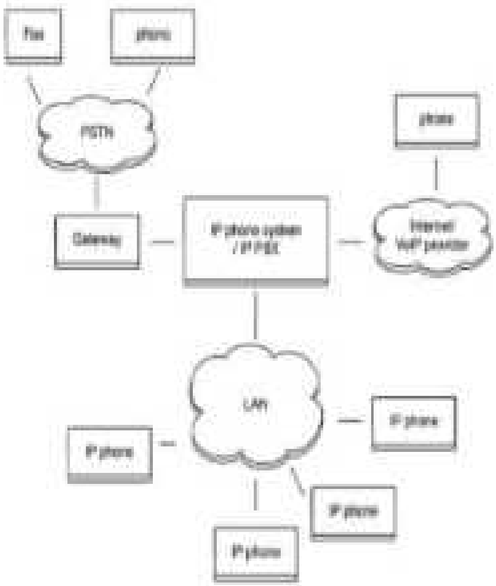
Internet Protocol Telephony (IP Telephony) is the use of IP-based networks to build, provide and access voice, data or other forms of telephonic communications. IP telephony provides traditional telephonic communication over an IP-based network, the Internet - via an Internet service provider (ISP) - or directly from a telecommunications service provider.

IP telephony is designed to replace the telecommunications' infrastructure of circuit switched public data networks (CSPDN) and public switched telephone networks (PSTN) with packet switched IP communication networks. In a consumer IP telephony solution, a soft IP phone application and backend Internet connection enable voice and data communication, such as calling and faxing.

A user may call other soft phone users, send or receive faxes and even communicate with circuit switched and cellular communication services. In an enterprise environment, IP telephony is implemented through physical IP phones that work on top of an IP network infrastructure. An IP phone's built-in firmware provides the complete functionality for initiating and managing telephonic communications.

How do IP phone systems work?

The "IP" in IP phone system refers to Voice over IP, or having your phone calls routed over the internet or your local network (LAN). This is great for many reasons. First of all, you don't have to use the telephone network of your telephony service provider for making calls, which will reduce your costs for phone calls.



At the same time you are gaining many technical advantages by using IP technology for your telephony. Users of an VoIP phone system simply plug their IP phone into the nearest LAN port. Then, the IP phone registers automatically at the VoIP phone system.

The IP phone always keeps its number, and behaves exactly the same way, no matter where you plug it in – on your desk, in the office next door or on a tropical island. All of this works because of the SIP protocol.

It is a standard widely used by ISPs, VoIP phone systems and VoIP phones world-wide. It makes expensive proprietary phones obsolete, and helps that all devices can talk to each other.

IP phone systems are usually built on standard PC or embedded hardware which are more cost-effective and powerful than the hardware of the traditional phone manufacturers.

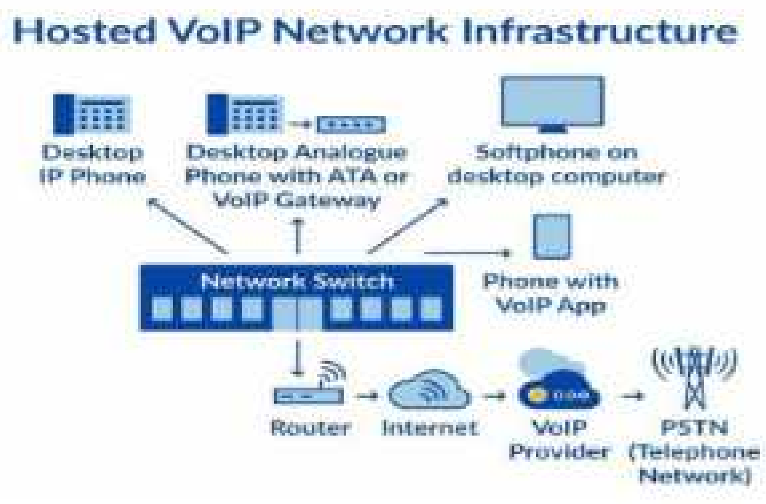
At the same time, ip phone systems are scalable, as they are not limited to a certain number of physical phone ports. That means you don't need to replace your phone system when your company grows.

4.8. Working principle of Internet Telephone

For a business application, VoIP is an ideal solution to provide employees reliable phone service, and it won't cost you all that much.

One of the top reasons VoIP has far outpaced traditional phone service is the flexibility and professional calling features for one low price.

Instead of having a server room with an on-premises PBX (Private Branch Exchange), all we need are configured VoIP desk phones.



This approach is known as a cloud phone system or a "cloud PBX." Administrators can manage the permissions and features for each employee along with more sophisticated VoIP features with an online interface.

When an employee calls a customer, they pick up the handset and dial them just as they normally would. The IP phone (or app) travels through the Local Area Network (LAN) switch and business router before reaching the VoIP service provider. From there, the VoIP provider establishes the call.

If the network path to the called party supports a digital voice signal, then the call quality is upgraded to high definition. Otherwise, a VoIP provider connects the call over the Public Switched Telephone Network (PSTN).

Using a hosted VoIP system in the business is that simple. However, for established businesses with a more sophisticated phone system, there are different needs.

If the office uses a PBX, they probably also pay for trunked telephone lines. These trunked lines handle voice calls from the PBX to the phone company—*and they're not cheap!*

Short Questions with answers

1. Define CDMA and TDMA.

Ans – **TDMA-** Time-division multiple access (**TDMA**) is a channel access method for shared-medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot.

FDMA- **FDMA** is the process of dividing one channel or bandwidth into multiple individual bands, each for use by a single user (Fig. 1). Each individual band or channel is wide enough to accommodate the signal spectra of the transmissions to be propagated.

2. What is a PBX phone system ?

Ans - A business telephone system is a multiline telephone system typically used in business environments, encompassing systems ranging in technology from the key telephone system to the private branch exchange.

3. What is Digital EPABX ?

Ans - MDX-50 **Digital EPABX**. BPL MDX-50 is used to form private networks or PLCC type of networks with similar type of exchanges. This **system** comes with a proven **digital** non-blocking technology. The MDX-50 is cost effective high performance communication **system**.

4. Define Internet Telephone .

Ans - **Internet Telephony** refers to all types of **telephony** services (including **phone calls**, fax, voicemail, video **calls** and other forms of communication) where **calls** and data are sent digitally over the **Internet** using the **Internet** Protocol (IP), rather than being transmitted over traditional analogue landlines.

5. What is Picowatt and NanoWatt ?

Ans -

Picowatt

The picowatt is equal to one trillionth (10−12) of a watt. Technologically important powers that are measured in picowatts are typically used in reference to radio and radar receivers, acoustics and in the science of radio astronomy.

Nanowatt

The nanowatt is equal to one billionth (10^{-9}) of a watt. Important powers that are measured in nanowatts are also typically used in reference to radio and radar receivers.

6. What is Internet Protocol Telephony ?

Ans –

Internet Protocol Telephony (IP Telephony) is the use of IP-based networks to build, provide and access voice, data or other forms of telephonic communications. IP telephony provides traditional telephonic communication over an IP-based network, the Internet - via an Internet service provider (ISP) - or directly from a telecommunications service provider.

Long Questions

1. Explain Te working of basic electronic Telephone system.

2. Explain basic call Procedure.

3. Write short note on CDMA and TDMA.

4. Explain the working principle of PBX system.

5. Explain working principle of Digital EPABX system.(S-24)

6. Explain i detail the working principle of Internet Telephone.

CHAPTER-05 : DATA COMMUICATION

5.1 Basic concept of Data Communication

In Data Communications, *data* generally are defined as information that is stored in digital form. *Data communications* is the process of transferring digital information between two or more points. *Information* is defined as the knowledge or intelligence. Data communications can be summarized as the transmission, reception, and processing of digital information. For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs). The effectiveness of a data communications system depends on four fundamental characteristics: delivery, accuracy, timeliness, and jitter.

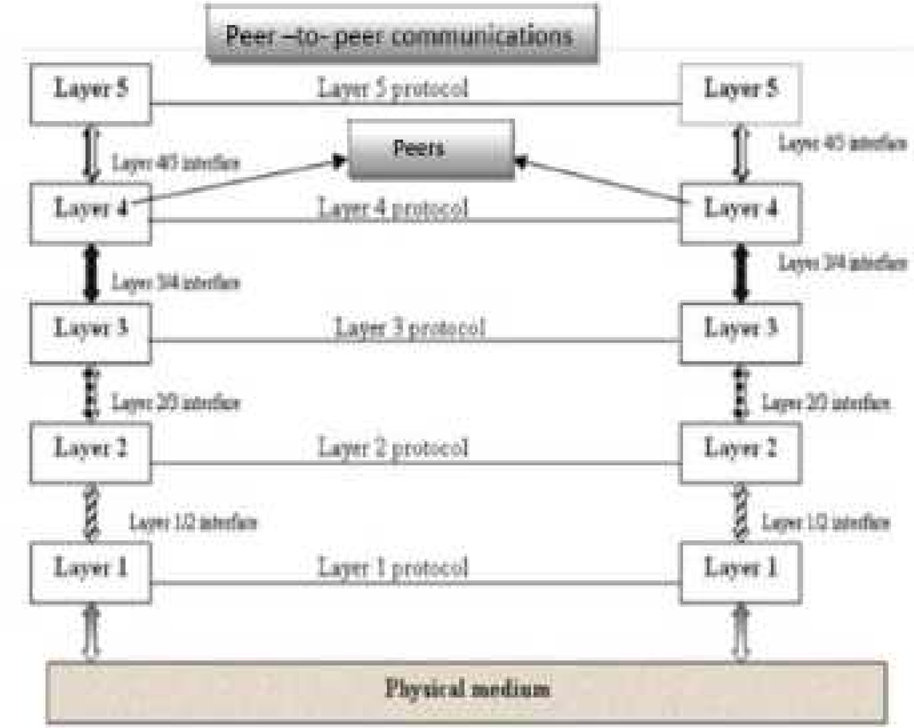
A data communications system has five components:

1. **Message:** The message is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.
2. **Sender:** The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.
3. **Receiver:** The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.
4. **Transmission medium:** The transmission medium is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.
5. **Protocol**: A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices.

5.2 Architecture, Protocols and Standards

Architecture :

To reduce the design complexity, most of the networks are organized as a series of **layers** or **levels**, each one build upon one below it. The basic idea of a layered architecture is *to divide the design into small pieces*. Each layer adds to the services provided by the lower layers in such a manner that the highest layer is provided a full set of services to manage communications and run the applications. The benefits of the layered models are modularity and clear interfaces, i.e. open architecture and comparability between the different providers' components. A basic principle is to ensure independence of layers by defining services provided by each layer to the next higher layer without defining how the services are to be performed. This permits changes in a layer without affecting other layers. The basic elements of a layered model are services, protocols and interfaces. A ***service*** is a set of actions that a layer offers to another (higher) layer. ***Protocol*** is a set of rules that a layer uses to exchange information with a peer entity. These rules concern both the contents and the order of the messages used. Between the layers service interfaces are defined. The messages from one layer to another are sent through those interfaces.



With layered architectures, communications between two corresponding layers requires a unit of data called a ***protocol data unit (PDU)***. A PDU can be a header added at the beginning of a message or a trailer appended to the end of a message. Data flows downward through the layers in the source system and upwards at the destination address. As data passes from one layer into another, headers and trailers are added and removed from the PDU. This process of adding or removing PDU information is called ***encapsulation/decapsulation***. Between each pair of adjacent layers there is an ***interface***. The *interface* defines which primitives operations and services the lower layer offers to the upper layer adjacent to it. A set of layers and protocols is known as **network architecture**. A list of protocols used by a certain system, one protocol per layer, is called **protocol stack**.

Protocols and Standards :

An association of organizations, governments, manufacturers and users form the standards organizations and are responsible for developing, coordinating and maintaining the standards. The intent is that all data communications equipment manufacturers and users comply with these standards. The primary standards organizations for data communication are:

1. **International Standard Organization (ISO)**

   ISO is the international organization for standardization on a wide range of subjects. It is comprised mainly of members from the standards committee of various governments throughout the world. It is even responsible for developing models which provides high level of system compatibility, quality enhancement, improved productivity and reduced costs. The ISO is also responsible for endorsing and coordinating the work of the other standards organizations.

2. **International Telecommunications Union-Telecommunication Sector (ITU-T)**

   ITU-T is one of the four permanent parts of the International Telecommunications Union based in Geneva, Switzerland. It has developed three sets of specifications: the V series for modem interfacing and data transmission over telephone lines, the X series for data transmission over public digital networks, email and directory services; the I and Q series

   for Integrated Services Digital Network (ISDN) and its extension Broadband ISDN. ITU-T membership consists of government authorities and representatives from many countries and it is the present standards organization for the United Nations.

3. **Institute of Electrical and Electronics Engineers (IEEE)**

   IEEE is an international professional organization founded in United States and is compromised of electronics, computer and communications engineers. It is currently the world's largest professional society with over 200,000 members. It develops communication and information processing standards with the underlying goal of advancing theory, creativity, and product quality in any field related to electrical engineering.

4. **American National Standards Institute (ANSI)**

   ANSI is the official standards agency for the United States and is the U.S voting representative for the ISO. ANSI is a completely private, non-profit organization comprised of equipment manufacturers and users of data processing equipment and services. ANSI membership is comprised of people form professional societies, industry associations, governmental and regulatory bodies, and consumer goods.

5. **Electronics Industry Association (EIA)**

   EIA is a non-profit U.S. trade association that establishes and recommends industrial standards. EIA activities include standards development, increasing public awareness, and lobbying and it is responsible for developing the RS (recommended standard) series of standards for data and communications.

6. **Telecommunications Industry Association (TIA)**

   TIA is the leading trade association in the communications and information technology industry. It facilitates business development opportunities through market development, trade promotion, trade shows, and standards development. It represents manufacturers of communications and information technology products and also facilitates the convergence of new communications networks.

7. Internet Architecture Board (IAB)

IAB earlier known as Internet Activities Board is a committee created by ARPA (Advanced Research Projects Agency) so as to analyze the activities of ARPANET whose purpose is to accelerate the advancement of technologies useful for U.S military. IAB is a technical advisory group of the Internet Society and its responsibilities are:

I. Oversees the architecture protocols and procedures used by the Internet.
II. Manages the processes used to create Internet Standards and also serves as an appeal board for complaints regarding improper execution of standardization process.
III. Responsible for administration of the various Internet assigned numbers
IV. Acts as a representative for Internet Society interest in liaison relationships with other organizations.
V. Acts as a source of advice and guidance to the board of trustees and officers of Internet Society concerning various aspects of internet and its technologies.

8. Internet Engineering Task Force (IETF)

The IETF is a large international community of network designers, operators, vendors and researchers concerned with the evolution of the Internet architecture and smooth operation of the Internet.

9. Internet Research Task Force (IRTF)

The IRTF promotes research of importance to the evolution of the future Internet by creating focused, long term and small research groups working on topics related to Internet protocols, applications, architecture and technology.

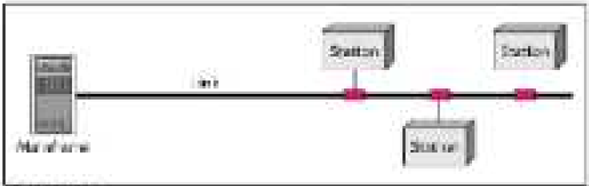
5.3. Data Communication Circuits

A data communications circuit can be described in terms of circuit configuration and transmission mode.

Circuit Configurations

Data communications networks can be generally categorized as either two point or multipoint. A *two point* configuration involves only two locations or stations, whereas a *multipoint* configuration involves three or more stations.

a. Point-to-point



b. Multipoint

A two-point circuit involves the transfer of digital information between a mainframe computer and a personal computer, two mainframe computers or two data communications networks. A multi-point network is generally used to interconnect a single mainframe computer (host) to many personal computers or to interconnect many personal computers and capacity of the channel is either *Spatially shared*: Devices can use the link simultaneously or *Timeshare*: Users take turns

Transmission Modes

There are four modes of transmission for data communications circuits:

a. Simplex

b. Half-duplex

c. Full-duplex

In ***simplex mode(SX)***, the communication is unidirectional, as on a one way street. Only one of the two devices on a link can transmit; the other can only receive. Commercial radio broadcasting is an example. Simplex lines are also called receive-only, transmit-only or one-way-only lines.

In ***half-duplex(HDX)*** mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa. The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction. Citizens band (CB) radio is an example where push to talk (PTT) is to be pressed or depressed while sending and transmitting.

In ***full-duplex mode(FDX)*** (called duplex), both stations can transmit and receive simultaneously. One common example of full-duplex communication is the telephone network. The full-duplex mode is used when communication in both directions is required all the time. The capacity of the channel must be divided between the two directions.

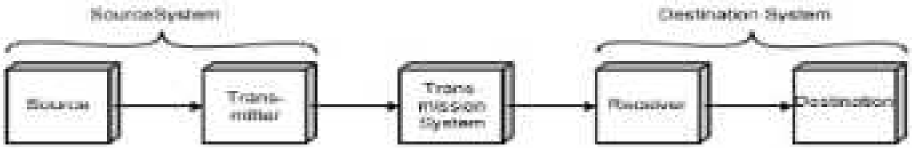
In ***full/full duplex (F/FDX)*** mode, transmission is possible in both directions at the same time but not between the same two stations (i.e. station 1 transmitting to station 2, while receiving from station 3). F/FDX is possible only on multipoint circuits. Postal system can be given as a person can be sending a letter to one address and receive a letter from another address at the same time.

5.4. Types of Transmission & Transmission Modes

The underlying purpose of a digital communications circuit is to provide a transmission path between locations and to transfer digital information from one station (node, where computers or other digital equipment are located) to another using electronic circuits. Data communications circuits utilize electronic communications equipment and facilities to interconnect digital computer equipment. Communication facilities are physical means of interconnecting stations and are provided to data communications users through public telephone networks (PTN), public data networks (PDN), and a multitude of private data communications systems.

The following figure shows a simple two station data communications circuit. The main components are:

Source: This device generates the data to be transmitted; examples are mainframe computer, personal computer, workstation etc. The source equipment provides a means for humans to enter data into system.



(a) General block diagram

(b) Example

Transmitter: - A transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system. For example, a modem takes a digital bit stream from an attached device such as a personal computer and transforms that bit stream into an analog signal that can be handled by the telephone network.

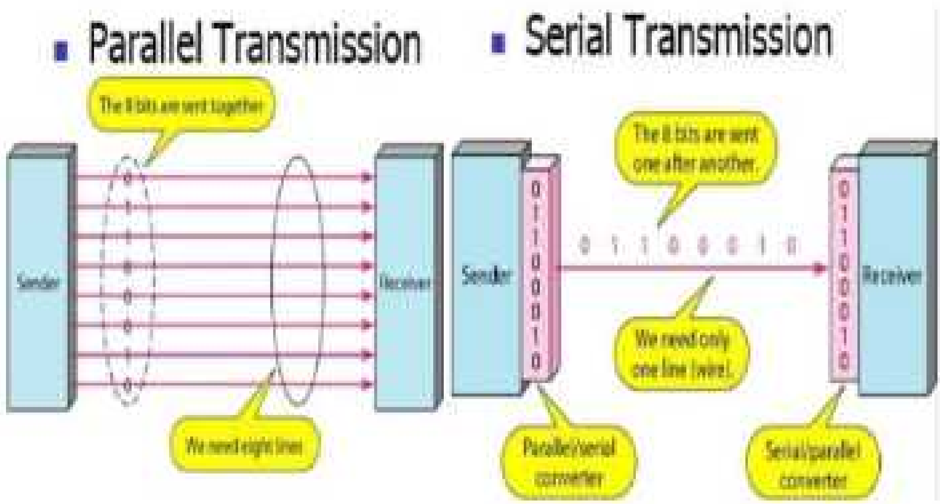
Transmission medium: - The transmission medium carries the encoded signals from the transmitter to the receiver. Different types of transmission media include free-space radio transmission (i.e. all forms of wireless transmission) and physical facilities such as metallic and optical fiber cables.

Receiver: - The receiver accepts the signal from the transmission medium and converts it into a form that can be handled by the destination device. For example, a modem will accept an analog signal coming from a network or transmission line and convert it into a digital bit stream.

Destination: - Takes the incoming data from the receiver and can be any kind of digital equipment like the source.

Serial and Parallel Data Transmission

There are two methods of transmitting digital data namely ***parallel and serial*** transmissions. In parallel data transmission, all bits of the binary data are transmitted simultaneously. For example, to transmit an 8 bit binary number in parallel from one unit to another, eight transmission lines are required. Each bit requires its own separate data path. All bits of a word are transmitted at the same time. This method of transmission can move a significant amount of data in a given period of time. Its disadvantage is the large number of interconnecting cables between the two units. For large binary words, cabling becomes complex and expensive. This is particularly true if the distance between the two units is great. Long multiwire cables are not only expensive, but also require special interfacing to minimize noise and distortion problems. Serial data transmission is the process of transmitting binary words a bit at a time. Since the bits time share the transmission medium, only one interconnecting lead is required.



While serial data transmission is much simpler and less expensive because of the use of a single interconnecting line, it is a very slow method of data transmission. Serial data transmission is useful in systems where high speed is not a requirement. Parallel communication is used for short-distance data communications and within a computer, and serial transmission is used for long-distance data communications.

5.5. Data Communication codes

DATA CODES

This refers to the way in which data is represented. The sender and receiver must use the same code in order to communicate properly. Here, we will briefly look at two common codes, one which was developed earlier on and was widely used in early telegraph systems, and the other, which is in widespread use today.

The Baudot Code

The Baudot code was used extensively in telegraph systems. It is a five bit code invented by the Frenchman Emile Baudot in 1870. Using five bits allowed 32 different characters. To accommodate all the letters of the alphabet and numerals, two of the 32 combinations were used to select alternate character sets.

Each character is preceded by a start bit, and followed by a stop bit. It is an asynchronous code, and thus suited for low speed data communication.

For instance, lets consider coding the phase "JAMES BOND 007 SAYS HI!" using the Baudot code. To switch between the LTRs and FIGs requires the use of a LetterShift or a FigureShift. Once switched, you stay in that mode till you want to switch back again. So, here is the phrase encoded in Baudot.

J	A	M	E	S	B	O	N	D		0	0	7	S	A	Y	S	H	I
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ASCII (American Standard Code for Information Interchange)

The ASCII code is the most popular code for serial data communications today. It is a seven bit code (128 combinations), and thus supports upper and lowercase characters, numeric digits, punctuation symbols, and special codes. The table below lists the values for each character in the ASCII set.

	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D
00	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	TAB	LF	VT	FF	CR
10	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS
20		!	"	#	$	%	&	'	(	)	*	+	,	-
30	0	1	2	3	4	5	6	7	8	9	[illegible]	[illegible]	[illegible]	
40	@	A	B	C	D	E	F	G	H	I	J	K	L	M
50	P	Q	R	S	T	U	V	W	X	Y	Z	[illegible]	[illegible]	]
60	`	a	b	c	d	e	f	g	h	i	j	k	l	m
70	p	q	r	s	t	u	v	w	x	y	z	[illegible]	|	}

To work out a particular value from the table, you first determine the row value, then add the column value. For example, the character **A** has a value of 41, being a row value of 40 and a column value of 1.

ASCII is also used as the data code for keyboards in computers. **Control Codes** have values between 00 and 1F (hexadecimal). Control codes are used in binary synchronous communication, and device control codes in communicating with devices such as printers or terminals.

A control code can be generated from a keyboard by holding down the Ctrl key and pressing another key. For instance, holding down the Ctrl key and pressing the A key generates the control code SOH.

5.6. Basic idea of Error control & Error Detection

There are many reasons such as noise, cross-talk etc., which may help data to get corrupted during transmission. The upper layers work on some generalized view of network architecture and are not aware of actual hardware data processing. Hence, the upper layers expect error-free transmission between the systems. Most of the applications would not function expectedly if they receive erroneous data. Applications such as voice and video may not be that affected and with some errors they may still function well.

Data-link layer uses some error control mechanism to ensure that frames (data bit streams) are transmitted with certain level of accuracy. But to understand how errors is controlled, it is essential to know what types of errors may occur.

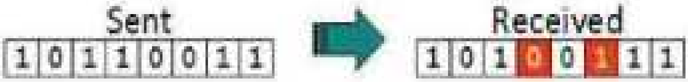
Types of Errors

There may be three types of errors:

- **Single bit error**

In a frame, there is only one bit, anywhere though, which is corrupt.

- **Multiple bits error**



Frame is received with more than one bits in corrupted state.

- **Burst error**

Frame contains more than1 consecutive bits corrupted.

Error control mechanism may involve two possible ways:

- Error detection
- Error correction

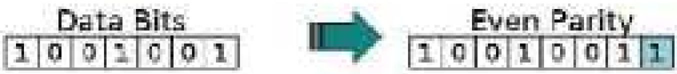
Error Detection

Errors in the received frames are detected by means of Parity Check and Cyclic Redundancy Check (CRC). In both cases, few extra bits are sent along with actual data to confirm that bits received at other end are same as they were sent. If the counter-check at receiver' end fails, the bits are considered corrupted.

Parity Check

One extra bit is sent along with the original bits to make number of 1s either even in case of even parity, or odd in case of odd parity.

The sender while creating a frame counts the number of 1s in it. For example, if even parity is used and number of 1s is even then one bit with value 0 is added. This way number of 1s remains even. If the number of 1s is odd, to make it even a bit with value 1 is added.

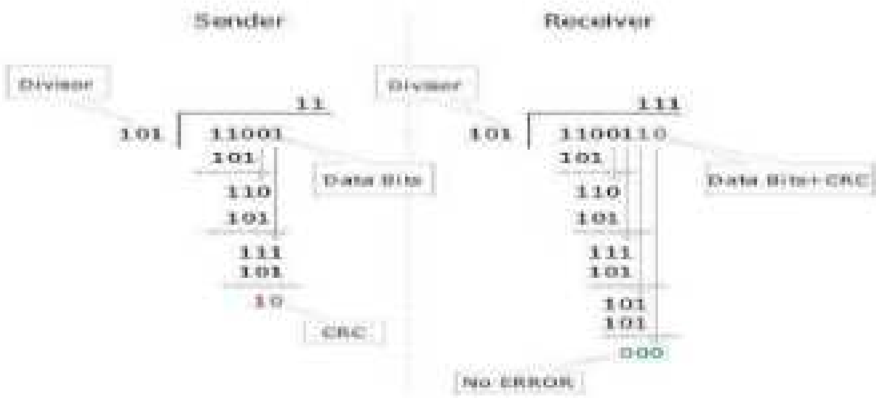


The receiver simply counts the number of 1s in a frame. If the count of 1s is even and even parity is used, the frame is considered to be not-corrupted and is accepted. If the count of 1s is odd and odd parity is used, the frame is still not corrupted.

If a single bit flips in transit, the receiver can detect it by counting the number of 1s. But when more than one bits are erroneous, then it is very hard for the receiver to detect the error.

Cyclic Redundancy Check (CRC)

CRC is a different approach to detect if the received frame contains valid data. This technique involves binary division of the data bits being sent. The divisor is generated using polynomials. The sender performs a division operation on the bits being sent and calculates the remainder. Before sending the actual bits, the sender adds the remainder at the end of the actual bits. Actual data bits plus the remainder is called a codeword. The sender transmits data bits as codewords.



At the other end, the receiver performs division operation on codewords using the same CRC divisor. If the remainder contains all zeros the data bits are accepted, otherwise it is considered as there some data corruption occurred in transit.

Error Correction

In the digital world, error correction can be done in two ways:

- **Backward Error Correction** When the receiver detects an error in the data received, it requests back the sender to retransmit the data unit.
- **Forward Error Correction** When the receiver detects some error in the data received, it executes error-correcting code, which helps it to auto-recover and to correct some kinds of errors.

The first one, Backward Error Correction, is simple and can only be efficiently used where retransmitting is not expensive. For example, fiber optics. But in case of wireless transmission retransmitting may cost too much. In the latter case, Forward Error Correction is used.

To correct the error in data frame, the receiver must know exactly which bit in the frame is corrupted. To locate the bit in error, redundant bits are used as parity bits for error detection. For example, we take ASCII words (7 bits data), then there could be 8 kind of information we need: first seven bits to tell us which bit is error and one more bit to tell that there is no error.

For m data bits, r redundant bits are used. r bits can provide 2r combinations of information. In m+r bit codeword, there is possibility that the r bits themselves may get corrupted. So the number of r bits used must inform about m+r bit locations plus no-error information, i.e. m+r+1.

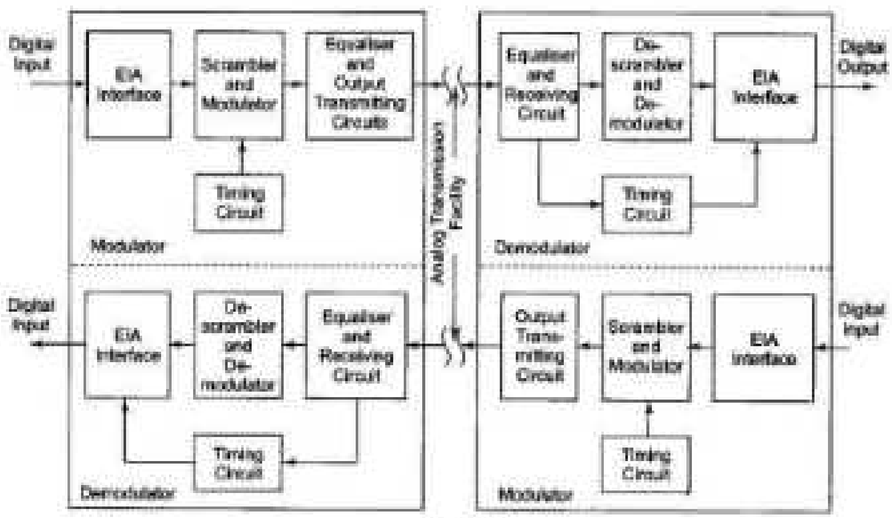
$$2^r >= m+r+1$$

5.7. MODEM & its basic block diagram& common features Voice Band Modem

The term Modem Definition is an acronym for modulator-demodulator. The primary modem function is to convert digital data into an analog form which is suitable for transmission on common carrier circuits (example telephone lines). Modulation is the D/A conversion in which the digital data is placed on the transmission line by modulation of a tone or carrier. Demodulation is the reverse process.

In a data communication system, transmitting and receiving modems are necessary at each end of the analog transmission line. The interfaces in the modulator and demodulator sections are usually EIA RS 232 C or current loop interfaces providing connections for standard external devices. The output transmitting circuits and receiving circuits are networks required for transmitting and receiving analog information to and from the transmission line.

Three modulation techniques in common use are amplitude, frequency and phase modulation. In a simple amplitude modulation system, the amplitude of the modulated carrier frequency corresponds to the value of the data bits. The spectrum of the modulated waveform includes the carrier frequency plus the upper and lower side bands. The side bands are displaced from the carrier by the frequency of the modulating input. The resulting band width is therefore twice that of the data rate.



Modem

Since the receiver clock is derived from the received data, those data must contain enough changes from 0 to 1 (and vice versa) to assure that the timing recovery circuit stays in synchronization. In principle, the data stream provided by the associated terminal or business machine can consist of any arbitrary bit pattern. If the pattern contains long strings of the same value, the data will not provide the receiver with enough transitions for synchronization. The transmitter must prevent this condition by changing the input bit stream in a controlled way. The part of the transmitter circuitry that does this is called the scrambler. Scrambler are usually implemented as feedback shift registers which may be cascaded or connected in series. They are designed to ensure that each possible value of phase angle is equally likely to occur, to provide the receiver demodulator with enough phase shifts to recover the clocking signal.

The modulator section of the transmitter converts the bit patterns produced by the scrambling process into an analog signal representing the desired phase and amplitude of the carrier signal. The carrier frequency, baud rate, and number of bits represented by each baud is different for modems of different rates.

Short Questions with Answers

Q(1) What do you mean by a computer network?

Ans:- Computer network is an interconnection of autonomous computers connected together using transmission media.

Q(2) What is the need for networking the computers?

Ans:-

1. Sharing of Information,
2. Reliability,
3. Reduces cost

Q(3) What is the full form of ARPANET?

Ans.- Advanced Research Projects Agency Network

Q(4) What are various data transmission modes?

Ans.- There are three modes of data transmission

Simplex

Half-duplex

Full-duplex

Q(5) What is the difference between Simplex and half duplex transmission?

Ans:- In simples transmission mode, the data can be transferred in only one direction where as in half

duplex transmission mode, the data can be transmitted in both directions but one at a time.

Q(6) What do you mean by MODEM?

Ans:- MODEM stands for MODulatorDEModuator. It is a device that can convert an analog signal into

digital signal and vice versa.

Q(7) Define the terms Bandwidth.

Ans:- Bandwidth is the range of frequencies that is available for the transmission of data. Wider the

bandwidth of a communication channel, the more data it can transmit in a given period of time.

Q(8) What are various types of transmission media?

Ans:- There are two broad categories of transmission media

Guided media

Unguided Media

Q(9) Explain in brief the advantages and disadvantages of Twisted pair Cable.

Ans:- **Advantages**

Inexpensive

Often available in existing phone system

Well tested and east to get

Disadvantages

Susceptible to noise (sound, energy etc.)

Not as durable as coaxial cable

Does not support high speed

Q(10) What do you mean by communication protocol?

Ans:- A protocol is a set of rules to enable computers to connect with one another and to exchange

information with minimum possible error.

Long Questions

1. Explain the Architecture of Data communication.
2. Describe about the different standards and protocols of Data Communication.
3. Write a short note on Types of Transmission modes.
4. Describe Data communication codes.
5. Describe in detail how error is detected and corrected.
6. Explain the basic working principle of MODEM with a neat block Diagram.

CHAPTER-06 : WIRELESS COMMUNICATION

6.1. Basic concept of Cell Phone, frequency reuse, channel assignment, strategic handoff, co-channel Interference and system capacity of a Cellular Radio systems.

Cellular network is an underlying technology for mobile phones, personal communication systems, wireless networking etc. The technology is developed for mobile radio telephone to replace high power transmitter/receiver systems. Cellular networks use lower power, shorter range and more transmitters for data transmission.

Features of Cellular Systems

Wireless Cellular Systems solves the problem of spectral congestion and increases user capacity. The features of cellular systems are as follows −

- Offer very high capacity in a limited spectrum.
- Reuse of radio channel in different cells.
- Enable a fixed number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.
- Communication is always between mobile and base station (not directly between mobiles).
- Each cellular base station is allocated a group of radio channels within a small geographic area called a cell.
- Neighbouring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning.
- Organization of Wireless Cellular Network.

Cellular network is organized into multiple low power transmitters each 100w or less.

Shape of Cells

The coverage area of cellular networks are divided into **cells**, each cell having its own antenna for transmitting the signals. Each cell has its own frequencies. Data communication in cellular networks is served by its base station transmitter, receiver and its control unit.

The shape of cells can be either square or hexagon −

Square

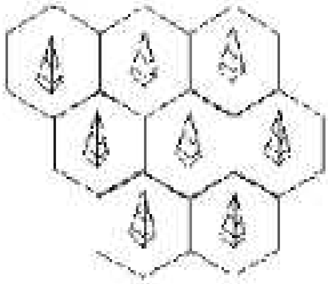
A square cell has four neighbors at distance **d** and four at distance Root **2 d**

- Better if all adjacent antennas equidistant
- Simplifies choosing and switching to new antenna

Hexagon

A hexagon cell shape is highly recommended for its easy coverage and calculations. It offers the following advantages −

- Provides equidistant antennas
- Distance from center to vertex equals length of side



Frequency Reuse

Frequency reusing is the concept of using the same radio frequencies within a given area, that are separated by considerable distance, with minimal interference, to establish communication.

Frequency reuse offers the following benefits −

- Allows communications within cell on a given frequency
- Limits escaping power to adjacent cells
- Allows re-use of frequencies in nearby cells
- Uses same frequency for multiple conversations
- 10 to 50 frequencies per cell

For example, when **N** cells are using the same number of frequencies and **K** be the total number of frequencies used in systems. Then each **cell frequency** is calculated by using the formulae K/N.

In Advanced Mobile Phone Services (AMPS) when K = 395 and N = 7, then frequencies per cell on an average will be 395/7 = 56. Here, **cell frequency** is 56.

Channel Assignment Techniques :

1. Fixed Channel Allocation (FCA)

Fixed Channel Allocation (FCA), is a strategy of fixed channels or voice channels allocations to be allocated to cells. Once channels are allocated, they are not changed. This type of allocation is used to maximize frequency usage. If a user makes a call and cell is occupied then call is blocked. Borrowing channels from other cell solves this problem.

2. Dynamic Channel Allocations (DCA)

Dynamic Channel Allocations (DCA), is a strategy of allocation of channels or voice channels on request basis. Whenever a user makes a call requst then Base Station makes a request to Mobile Station Center to allocate the channel. Allcation increases when traffic increases.

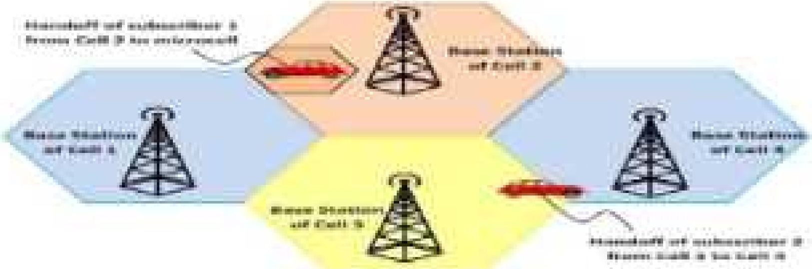
Following are the important difference between FCA and DCA.

Sr. No.	Key	Fixed Channel Allocation (FCA)	Dynamic Channel Allocations (DCA)
1	Channel Allocation	Fixed number of channels or voice channels are alloted.	Channels to be alloted are not fixed initially.
2	Blockage	If all channels are occupied, then user call is blocked.	If all channels are blocked, then Base Station(BS) requests more channels from Mobile Station Center(MSC).
3	Frequency Usage	Frequency usage is very high being call channels are separated using minimum reuse distance.	Frequency reuse is not maximum because of random channel allocation.
4	Tangible	A hardware can be touched being a physical electronic device.	Software being digital can be seen but cannot be touched.
5	Algorithm	No need to complex algorithm.	Algorithm to determine efficient channel availability is quite complex in DCA.
6	Cost	FCA is cheaper than DCA.	DCA is costly as real time computation needed.
7	Call Allocation	Once call is complete, channel remains with the cell.	Once call is complete, channel is returned back to Mobile Station Center.
8	MSC	Mobile Station Center has less burden.	Mobile Station Center has high signal load, and has more responsibilities.

Strategic Hand-Off Technique :

Definition

In cellular communications, the handoff is the process of transferring an active call or data session from one cell in a cellular network or from one channel to another. In satellite communications, it is the process of transferring control from one earth station to another. Handoff is necessary for preventing loss of interruption of service to a caller or a data session user. Handoff is also called handover.



Situations for triggering Handoff

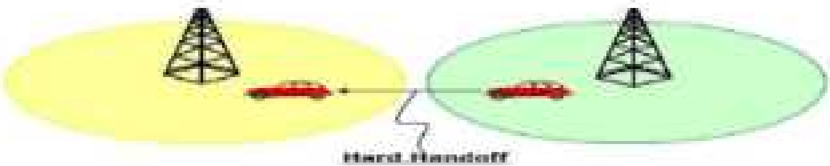
Handoffs are triggered in any of the following situations −

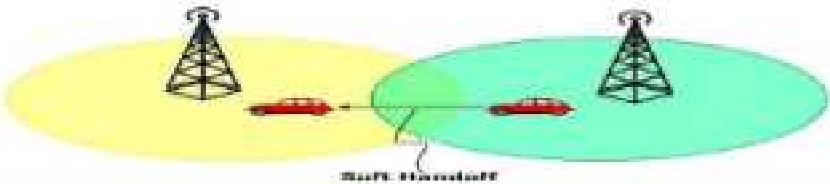
- If a subscriber who is in a call or a data session moves out of coverage of one cell and enters coverage area of another cell, a handoff is triggered for a continuum of service. The tasks that were being performed by the first cell are delineating to the latter cell.
- Each cell has a pre-defined capacity, i.e. it can handle only a specific number of subscribers. If the number of users using a particular cell reaches its maximum capacity, then a handoff occurs. Some of the calls are transferred to adjoining cells, provided that the subscriber is in the overlapping coverage area of both the cells.
- Cells are often sub-divided into microcells. A handoff may occur when there is a transfer of duties from the large cell to the smaller cell and vice versa. For example, there is a traveling user moving within the jurisdiction of a large cell. If the traveler stops, then the jurisdiction is transferred to a microcell to relieve the load on the large cell.
- Handoffs may also occur when there is an interference of calls using the same frequency for communication.

Types of Handoffs

There are two types of handoffs −

- **Hard Handoff** − In a hard handoff, an actual break in the connection occurs while switching from one cell to another. The radio links from the mobile station to the existing cell is broken before establishing a link with the next cell. It is generally an inter-frequency handoff. It is a "break before make" policy.
- **Soft Handoff** − In soft handoff, at least one of the links is kept when radio links are added and removed to the mobile station. This ensures that during the handoff, no break occurs. This is generally adopted in co-located sites. It is a "make before break" policy.





Mobile Assisted Handoff

Mobile Assisted Handoff (MAHO) is a technique in which the mobile devices assist the Base Station Controller (BSC) to transfer a call to another BSC. It is used in GSM cellular networks. In other systems, like AMPS, a handoff is solely the job of the BSC and the Mobile Switching Centre (MSC), without any participation of the mobile device. However, in GSM, when a mobile station is not using its time slots for communicating, it measures signal quality to nearby BSC and sends this information to the BSC. The BSC performs handoff according to this information.

Co-Channel Interference and Cell Separation

We assume a cellular system having a cell radius "R" and Co-channel distance "D" and the cluster size "N". Since the cell size is fixed, co-channel interference will be independent of power.

Co-chl interference is a function of "q" = D/R.

Q = Co-chl interference reduction factor.

Higher value of "q" means less interference.

Lower value of "q" means high interference.

"q" is also related to cluster size (N) as q = 3N

q = 3N = D/R

For different values of N, q is −

```
N = 1 3 4 7 9 12
Q = 1.73 3 3.46 4.58 5.20 6.00
```

Higher values of "q"

- Reduces co-channel interference,
- Leads to higher value of "N" more cells/cluster,
- Less number of channels/cells,
- Less traffic handling capacity.

Lower values of "q"

- Increases co-channel interference,
- Leads to lower value of "n" fewer cells / cluster,
- More number of channels / cells,
- More traffic handling capacity.

Generally, N = 4, 7, 12.

System Capacity :

Channel Capacity

Wireless communications deal with at least two main concerns: coverage and capacity.

One fundamental concept of information theory is one of channel capacity, or how much information can be transmitted in a communication channel. In the 1940's Claude Shannon invented formal characterization of information theory and derived the well-known Shanon's capacity theorem. That theorem applies to wireless communications. It presents a concise derivation of the equation, and includes a good introduction to important information theory concepts such as information and entropy.

The Shannon capacity equation gives an upper bound for the capacity in a non-faded channel with added white Gaussian noise:

$$C = W\log_2(1 + S/N) \quad (2.4)$$

where C= capacity (bits/s), W=bandwidth (Hz), S/N= signal to noise (and interference) ratio.

That capacity equation assumes one transmitter and one receiver, though multiple antennas can be used in diversity scheme on the receiving side. The formula will be revisited for multi-antenna systems in. The equation singles out two fundamentally important aspects: bandwidth and SNR. Bandwidth reflects how much spectrum a wireless system uses, and explains why the spectrum considerations are so important: they have a direct impact on system capacity. SNR of course reflects the quality of the propagation channel, and will be dealt with in numerous ways: modulation, coding, error correction, and important design choices such as cell sizes and reuse patterns.

Cellular Capacity

Practical capacity of many wireless systems are far from the Shannon's limit (although recent standards are coming close to it); and practical capacity is heavily dependent on implementation and standard choices.

Digital standards deal in their own way with how to deploy and optimize capacity. Most systems are limited by channel width, time slots, and voice coding characteristics. CDMA systems are interference limited, and have tradeoffs between capacity, coverage, and other performance metrics (such as dropped call rates or voice quality).

Cellular analog capacity:

> Fairly straight forward, every voice channel uses a 30 kHz frequency channel, these frequencies may be reused according to a reuse pattern, the system is FDMA. The overall capacity simply comes from the total amount of spectrum, the channel width and the reuse pattern.

TDMA/FDMA capacity:

> In digital FDMA systems, capacity improvements mainly come from the voice coding and elaborate schemes (such as frequency hopping) to decrease reuse factor. The frequency reuse factor hides a lot of complexity; its value depends greatly on the signal to interference levels acceptable to a given cellular system. TDMA systems combine multiple time slots per channels.

CDMA capacity:

a usual capacity equation for CDMA systems may be fairly easily derived as follows (for the reverse link): first examine a base station with N mobiles, its noise and interference power spectral density dues to all mobiles in that same cell is $I_{SC} = (N - 1)S\alpha$, where S is the received power density for each mobile, and α is the voice activity factor. Other cell interferences I_{OC} are estimated by a reuse fraction β of the same cell interference level, such that $I_{OC} = \beta I_{SC}$; (usual values of β are around 1/2). The total noise and interference at the base is therefore $N_t = I_{SC}(1 + \beta)$. Next assume the mobile signal power density received at the base station is $S = RE_b/W$. Eliminating I_{SC}, we derive:

$$N = 1 + \frac{W}{R} \cdot \frac{1}{E_b/N_t} \cdot \frac{1}{\alpha} \cdot \frac{1}{1+\beta} \cdot)$$

where

- W is the channel bandwidth (in Hz),
- R is the user data bit rate (symbol rate in symbol per second),
- E_b/N_t is the ratio of energy per bit by total noise (usually given in dB $E_b/N_t \approx$ 7dB),
- α is the voice activity factor (for the reverse link), typically 0.5,
- and β is the interference reuse fraction, typically around 0.5, and represents the ratio of interference level from the cell in consideration by interferences due to other cells. (The number 1 + β is sometimes called reuse factor, and 1/(1 + β) reuse efficiency)

This simple equation gives us a number of voice channels in a CDMA frequency channel [2].

We can already see some hints of CDMA optimization and investigate certain possible improvement for a 3G system. In particular: improving α can be achieved with dim and burst capabilities, β with interference mitigation and antenna downtilt considerations, R with vocoder rate, W with wider band CDMA, E_b/N_t with better coding and interference mitigation techniques.

Some aspects however are omitted in this equation and are required to quantify other capacity improvements mainly those due to power control, and softer/soft handoff algorithms.

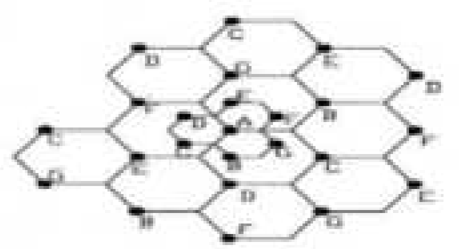
Of course other limitations come into play for wireless systems, such as base station (and mobile) sensitivity, which may be incorporated into similar formulas; and further considerations come into play such as: forward power limitations, channel element blocking, backhaul capacity, mobility, and handoff.

6.2. Concept of improving coverage and capacity in cellular system (Cell Splitting, Sectoring)

Methods for improving coverage area in cellular systems

Cell Splitting:

- It is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power.
- Cell splitting increase the capacity of the cellular system since it increases the number of times that channels are reused. By defining new cells which have a smaller radius than the original cells and by installing these smaller cells (microcells) between the existing cell, capacity increases due to additional channels/ unit area.
- An example of cell splitting is shown below the base station are placed in corners of the cells, and area served by base station A is assumed to be saturated with traffic.
- New base stations are therefore needed in the region to increases the number of channels in the area and to reduce the area served by the single base station.

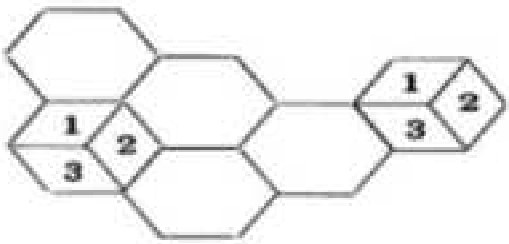


Cell Sectoring:

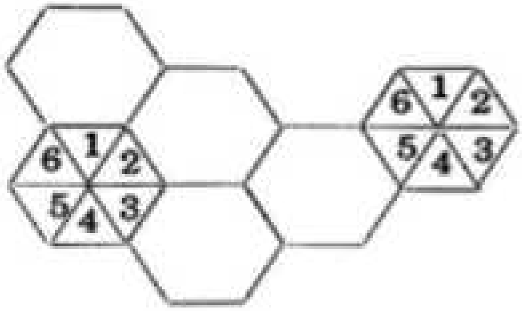
- It is a method to increase capacity is to keep the cell radius unchanged and seek methods to decrease D/R ratio.
- Sectoring increases SIR, so that the cluster size may be reduced. First the SIR is improved using directional antennas, then capacity improvement is achieved by reducing the number of cell in the cluster; thus increasing the frequency reuse.
- To achieve this, it is necessary to reduce the relative interference without decreasing the transmit power.

There are two types of sectoring in a cell

1. 3 Sectors 120o each



2) 2. 6 Sectors 60^0 each



6.3. Wireless Systems and its Standards.

Wireless connection to internet is very common these days. Often an external modem is connected to the Internet and other devices connect to it wirelessly. This eliminated the need for last mile or first mile wiring. There are two ways of connecting to the Internet wirelessly − Wi-Fi and WiMAx.

Wi-Fi

Wi-Fi is the acronym for **wireless fidelity**. **Wi-Fi technology** is used to achieve connection to the Internet without a direct cable between device and Internet Service Provider. Wi-Fi enabled device and wireless router are required for setting up a Wi-Fi connection. These are some characteristics of wireless Internet connection −

- Range of 100 yards
- Insecure connection
- Throughput of 10-12 Mbps

If a PC or laptop does not have Wi-Fi capacity, it can be added using a Wi-Fi card.

The physical area of the network which provides Internet access through Wi-Fi is called **Wi-Fi hotspot**. **Hotspots** can be set up at home, office or any public space like airport, railway stations, etc. Hotspots themselves are connected to the network through wires.

WiMax

To overcome the drawback of **Wi-Fi** connections, **WiMax (Worldwide Interoperability for Microwave Access)** was developed. WiMax is a collection of wireless communication standards based on **IEEE 802.16**. WiMax provides multiple **physical layer** and **media access control** (MAC) options.

WiMax Forum, established in 2001, is the principal body responsible to ensure conformity and interoperability among various commercial vendors. These are some of the characteristics of WiMax −

- Broadband wireless access

- Range of 6 miles
- Multilevel encryption available
- Throughput of 72 Mbps

The main components of a WiMax unit are −

- **WiMax Base Station** − It is a tower similar to mobile towers and connected to Internet through high speed wired connection.
- **WiMax Subscriber Unit (SU)** − It is a WiMax version of wireless modem. The only difference is that modem is connected to the Internet through cable connection whereas WiMax SU receives Internet connection wirelessly through microwaves.

6.4. Discuss the GSM (Global System for Mobile) service and features.

GSM is a globally accepted standard for digital cellular communications.

GSM uses narrowband Time Division Multiple Access (TDMA) for providing voice and text based services over mobile phone networks.

What is GSM?

GSM stands for **G**lobal **S**ystem for **M**obile Communication. It is a digital cellular technology used for transmitting mobile voice and data services. Important facts about the GSM are given below −

- The concept of GSM emerged from a cell-based mobile radio system at Bell Laboratories in the early 1970s.
- GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard.
- GSM is the most widely accepted standard in telecommunications and it is implemented globally.
- GSM is a circuit-switched system that divides each 200 kHz channel into eight 25 kHz time-slots. GSM operates on the mobile communication bands 900 MHz and 1800 MHz in most parts of the world. In the US, GSM operates in the bands 850 MHz and 1900 MHz.
- GSM owns a market share of more than 70 percent of the world's digital cellular subscribers.
- GSM makes use of narrowband Time Division Multiple Access (TDMA) technique for transmitting signals.
- GSM was developed using digital technology. It has an ability to carry 64 kbps to 120 Mbps of data rates.
- Presently GSM supports more than one billion mobile subscribers in more than 210 countries throughout the world.
- GSM provides basic to advanced voice and data services including roaming service. Roaming is the ability to use your GSM phone number in another GSM network.

GSM digitizes and compresses data, then sends it down through a channel with two other streams of user data, each in its own timeslot.

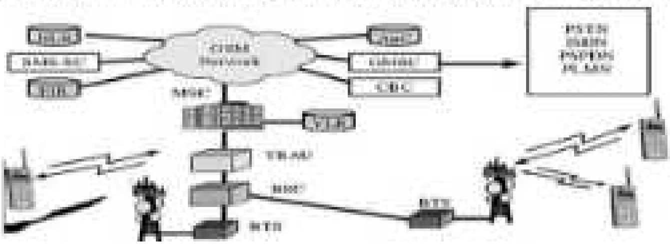
Why GSM?

Listed below are the features of GSM that account for its popularity and wide acceptance.

- Improved spectrum efficiency
- International roaming
- Low-cost mobile sets and base stations (BSs)
- High-quality speech
- Compatibility with Integrated Services Digital Network (ISDN) and other telephone company services
- Support for new services

6.5. Architecture of GSM system & GSM mobile station & channel types of GSM system

The following diagram shows the GSM network along with the added elements −



The MS and the BSS communicate across the Um interface. It is also known as the *air interface* or the *radio link*. The BSS communicates with the Network Service Switching (NSS) center across the *A* interface.

GSM network areas

In a GSM network, the following areas are defined −

- **Cell** − Cell is the basic service area; one BTS covers one cell. Each cell is given a Cell Global Identity (CGI), a number that uniquely identifies the cell.
- **Location Area** − A group of cells form a Location Area (LA). This is the area that is paged when a subscriber gets an incoming call. Each LA is assigned a Location Area Identity (LAI). Each LA is served by one or more BSCs.
- **MSC/VLR Service Area** − The area covered by one MSC is called the MSC/VLR service area.
- **PLMN** − The area covered by one network operator is called the Public Land Mobile Network (PLMN). A PLMN can contain one or more MSCs.

The BSS is composed of two parts −

- The Base Transceiver Station (BTS)
- The Base Station Controller (BSC)

The BTS and the BSC communicate across the specified Abis interface, enabling operations between components that are made by different suppliers. The radio components of a BSS may consist of four to seven or nine cells. A BSS may have one or more base stations. The BSS uses the Abis interface between the BTS and the BSC. A separate high-speed line (T1 or E1) is then connected from the BSS to the Mobile MSC

The Base Transceiver Station (BTS)

The BTS houses the radio transceivers that define a cell and handles the radio link protocols with the MS. In a large urban area, a large number of BTSs may be deployed.

The Base Station Controller (BSC)

The BSC manages the radio resources for one or more BTSs. It handles radio channel setup, frequency hopping, and handovers. The BSC is the connection between the mobile and the MSC. The BSC also translates the 13 Kbps voice channel used over the radio link to the standard 64 Kbps channel used by the Public Switched Telephone Network (PSDN) or ISDN.

The Network Switching Subsystem (NSS)

The Network switching system (NSS), the main part of which is the Mobile Switching Center (MSC), performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as authentication.

Home Location Register (HLR)

The HLR is a database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. When an individual buys a subscription in the form of SIM, then all the information about this subscription is registered in the HLR of that operator.

Mobile Services Switching Center (MSC)

The central component of the Network Subsystem is the MSC. The MSC performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others. Every MSC is identified by a unique ID.

Visitor Location Register (VLR)

The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time.

Authentication Center (AUC)

The Authentication Center is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and ciphering of the radio channel. The AUC protects network operators from different types of fraud found in today's cellular world.

Equipment Identity Register (EIR)

The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where its International Mobile Equipment Identity (IMEI) identifies each MS. An IMEI is marked as invalid if it has been reported stolen or is not type approved.

GSM - The Operation Support Subsystem (OSS)

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS).

6.6. working of forward and reveres CDMA channel,the frequency and channel specifications

What is CDMA?

Code Division Multiple Access (CDMA) is a digital cellular technology used for mobile communication. CDMA is the base on which access methods such as cdmaOne, CDMA2000, and WCDMA are built. CDMA cellular systems are deemed superior to FDMA and TDMA, which is why CDMA plays a critical role in building efficient, robust, and secure radio communication systems.

CDMA channel

CDMA channels can be broadly categorized as Forward channel and Reverse channel. This chapter explains the functionalities of these channels.

Forward Channel

The Forward channel is the direction of the communication or mobile-to-cell downlink path. It includes the following channels −

- **Pilot Channel** − Pilot channel is a reference channel. It uses the mobile station to acquire the time and as a phase reference for coherent demodulation. It is continuously transmitted by each base station on each active CDMA frequency. And, each mobile station tracks this signal continuously.
- **Sync Channel** − Synchronization channel carries a single, repeating message, which gives the information about the time and system configuration to the mobile station. Likewise, the mobile station can have the exact system time by the means of synchronizing to the short code.

- **Paging Channel** − Paging Channel's main objective is to send out pages, that is, notifications of incoming calls, to the mobile stations. The base station uses these pages to transmit system overhead information and mobile station specific messages.
- **Forward Traffic Channel** − Forward Traffic Channels are code channels. It is used to assign calls, usually voice and signaling traffic to the individual users.

Reverse Channel

The Reverse channel is the mobile-to-cell direction of communication or the uplink path. It consists of the following channels −

- **Access Channel** − Access channel is used by mobile stations to establish a communication with the base station or to answer Paging Channel messages. The access channel is used for short signaling message exchanges such as call-ups, responses to pages and registrations.
- **Reverse Traffic Channel** − Reverse traffic channel is used by the individual users in their actual calls to transmit traffic from a single mobile station to one or more base stations.

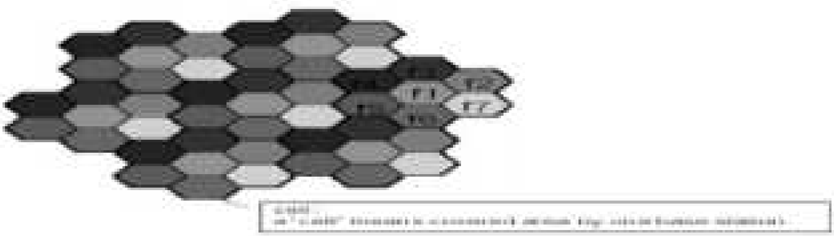
frequency and channel specifications

The major capacity advantage of CDMA is that it reuses the same allocated frequency in every sector of every cell. In IS-136 and analog cellular systems, there is a seven cell repeat factor, with three sectors. This means that only one out of every 21 channels is available to each sector. CDMA is designed to share the same frequency in each sector of each cell. For each user that uses cdma2000 coding rather than IS-95, the system is more efficient.

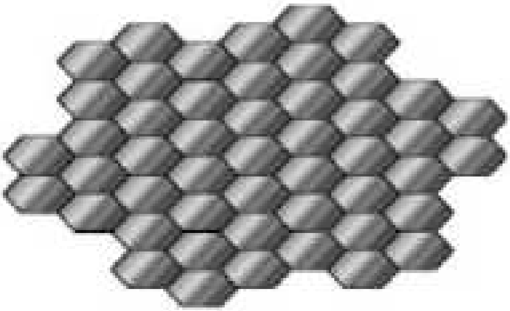
In FDMA or TDMA, radio resource is allocated not to interfere among neighbour cells −

- Neighbour cells cannot use the same (identical) frequency band (or timeslot).
- The left figure shows the simple cell allocation with seven bands of frequency.

In actual situation, because of complicated radio propagation and irregular cell allocation, it is not easy to allocate frequency (or timeslot) appropriately.



In a CDMA system against this, since all users share the same frequency, the arrangement of the frequency is not an issue. This is the biggest advantage of CDMA technology.



In CDMA, identical radio resource can be used among all cells, because CDMA channels use same frequency simultaneously.

- Frequency allocation in CDMA is not necessary.
- In this sense, CDMA cellular system is easy to design.

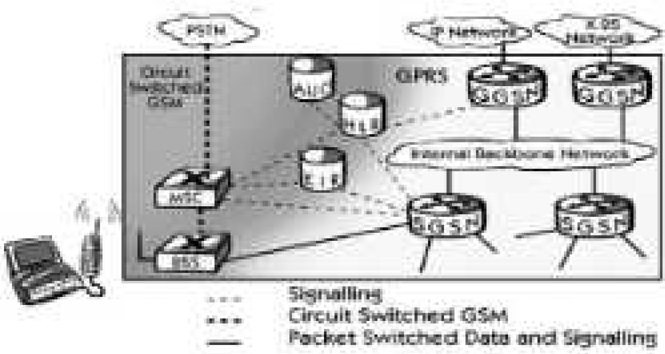
6.7. Architecture and features of GPRS.

General Packet Radio System is also known as **GPRS** is a third-generation step toward internet access. GPRS is also known as GSM-IP that is a Global-System Mobile Communications Internet Protocol as it keeps the users of this system online, allows to make voice calls, and access internet on-the-go. Even Time-Division Multiple Access (TDMA) users benefit from this system as it provides packet radio access.

GPRS Architecture :

GPRS architecture works on the same procedure like GSM network, but, has additional entities that allow packet data transmission. This data network overlaps a second-generation GSM network providing packet data transport at the rates from 9.6 to 171 kbps. Along with the packet data transport the GSM network accommodates multiple users to share the same air interface resources concurrently.

Following is the GPRS Architecture diagram:



GPRS attempts to reuse the existing GSM network elements as much as possible, but to effectively build a packet-based mobile cellular network, some new network elements, interfaces, and protocols for handling packet traffic are required.

Therefore, GPRS requires modifications to numerous GSM network elements as summarized below:

GSM Network Element	Modification or Upgrade Required for GPRS.
Mobile Station (MS)	New Mobile Station is required to access GPRS services. These new terminals will be backward compatible with GSM for voice calls.
BTS	A software upgrade is required in the existing Base Transceiver Station(BTS).
BSC	The Base Station Controller (BSC) requires a software upgrade and the installation of new hardware called the packet control unit (PCU). The PCU directs the data traffic to the GPRS network and can be a separate hardware element associated with the BSC.
GPRS Support Nodes (GSNs)	The deployment of GPRS requires the installation of new core network elements called the serving GPRS support node (SGSN) and gateway GPRS support node (GGSN).
Databases (HLR, VLR, etc.)	All the databases involved in the network will require software upgrades to handle the new call models and functions introduced by GPRS.

GPRS Mobile Stations

New Mobile Stations (MS) are required to use GPRS services because existing GSM phones do not handle the enhanced air interface or packet data. A variety of MS can exist, including a high-speed version of current phones to support high-speed data access, a new PDA device with an embedded GSM phone, and PC cards for laptop computers. These mobile stations are backward compatible for making voice calls using GSM.

GPRS Base Station Subsystem

Each BSC requires the installation of one or more Packet Control Units (PCUs) and a software upgrade. The PCU provides a physical and logical data interface to the Base Station Subsystem (BSS) for packet data traffic. The BTS can also require a software upgrade but typically does not require hardware enhancements.

When either voice or data traffic is originated at the subscriber mobile, it is transported over the air interface to the BTS, and from the BTS to the BSC in the same way as a standard GSM call. However, at the output of the BSC, the traffic is separated; voice is sent to the Mobile Switching Center (MSC) per standard GSM, and data is sent to a new device called the SGSN via the PCU over a Frame Relay interface.

GPRS Support Nodes

Following two new components, called Gateway GPRS Support Nodes (GSNs) and, Serving GPRS Support Node (SGSN) are added:

Gateway GPRS Support Node (GGSN)

The Gateway GPRS Support Node acts as an interface and a router to external networks. It contains routing information for GPRS mobiles, which is used to tunnel packets through the IP based internal backbone to the correct Serving GPRS Support Node. The GGSN also collects charging information connected to the use of the external data networks and can act as a packet filter for incoming traffic.

Serving GPRS Support Node (SGSN)

The Serving GPRS Support Node is responsible for authentication of GPRS mobiles, registration of mobiles in the network, mobility management, and collecting information on charging for the use of the air interface.

Internal Backbone

The internal backbone is an IP based network used to carry packets between different GSNs. Tunnelling is used between SGSNs and GGSNs, so the internal backbone does not need any information about domains outside the GPRS network. Signalling from a GSN to a MSC, HLR or EIR is done using SS7.

Routing Area

GPRS introduces the concept of a Routing Area. This concept is similar to Location Area in GSM, except that it generally contains fewer cells. Because routing areas are smaller than location areas, less radio resources are used While broadcasting a page message.

6.8. Discuss the mobile TCP, IP protocol.

Transmission Control Protocol (TCP)

TCP is a connection oriented protocol and offers end-to-end packet delivery. It acts as back bone for connection.It exhibits the following key features:

- Transmission Control Protocol (TCP) corresponds to the Transport Layer of OSI Model.
- TCP is a reliable and connection oriented protocol.
- TCP offers:
  - Stream Data Transfer.
  - Reliability.
  - Efficient Flow Control
  - Full-duplex operation.
  - Multiplexing.
- TCP offers connection oriented end-to-end packet delivery.
- TCP ensures reliability by sequencing bytes with a forwarding acknowledgement number that indicates to the destination the next byte the source expect to receive.
- It retransmits the bytes not acknowledged with in specified time period.

TCP Services

TCP offers following services to the processes at the application layer:

- Stream Delivery Service
- Sending and Receiving Buffers
- Bytes and Segments
- Full Duplex Service
- Connection Oriented Service
- Reliable Service

Stream Deliver Service

TCP protocol is stream oriented because it allows the sending process to send data as stream of bytes and the receiving process to obtain data as stream of bytes.

Sending and Receiving Buffers

It may not be possible for sending and receiving process to produce and obtain data at same speed, therefore, TCP needs buffers for storage at sending and receiving ends.

Bytes and Segments

The Transmission Control Protocol (TCP), at transport layer groups the bytes into a packet. This packet is called segment. Before transmission of these packets, these segments are encapsulated into an IP datagram.

Full Duplex Service

Transmitting the data in duplex mode means flow of data in both the directions at the same time.

Connection Oriented Service

TCP offers connection oriented service in the following manner:

1. TCP of process-1 informs TCP of process – 2 and gets its approval.
2. TCP of process – 1 and TCP of process – 2 and exchange data in both the two directions.
3. After completing the data exchange, when buffers on both sides are empty, the two TCP's destroy their buffers.

Reliable Service

For sake of reliability, TCP uses acknowledgement mechanism.

Internet Protocol (IP)

Internet Protocol is **connectionless** and **unreliable** protocol. It ensures no guarantee of successfully transmission of data.

In order to make it reliable, it must be paired with reliable protocol such as TCP at the transport layer.

Internet protocol transmits the data in form of a datagram as shown in the following diagram:

<table>
<tr><td>4</td><td>8</td><td>16</td><td colspan="2">32 bits</td></tr>
<tr><td>VER</td><td>HLEN</td><td>D.S. type of service</td><td colspan="2">Total length of 16 bits</td></tr>
<tr><td colspan="3">Identification of 16 bits</td><td>Flags 3 bits</td><td>Fragmentation Offset (13 bits)</td></tr>
<tr><td>Time to live</td><td colspan="2">Protocol</td><td colspan="2">Header checksum (16 bits)</td></tr>
<tr><td colspan="5">Source IP address</td></tr>
<tr><td colspan="5">Destination IP address</td></tr>
<tr><td colspan="5">Option + Padding</td></tr>
</table>

Points to remember:

- The length of datagram is variable.
- The Datagram is divided into two parts: **header** and **data.**
- The length of header is 20 to 60 bytes.
- The header contains information for routing and delivery of the packet.

6.9. Working of Wireless Application Protocol (WAP).

WAP is the set of rules governing the transmission and reception of data by computer applications on or via wireless devices like mobile phones. WAP allows wireless devices to view specifically designed pages from the Internet using only plain text and very simple black-and-white pictures.

WAP is designed in a layered fashion, so that it can be extensible, flexible, and scalable. As a result, the WAP protocol stack is divided into five layers −

Layers of WAP Protocol

Application Layer

Wireless Application Environment (WAE). This layer is of most interest to content developers because it contains among other things, device specifications, and the content development programming languages, WML, and WMLScript.

Session Layer

Wireless Session Protocol (WSP). Unlike HTTP, WSP has been designed by the WAP Forum to provide fast connection suspension and reconnection.

Transaction Layer

Wireless Transaction Protocol (WTP). The WTP runs on top of a datagram service, such as User Datagram Protocol (UDP) and is part of the standard suite of TCP/IP protocols used to provide a simplified protocol suitable for low bandwidth wireless stations.

Security Layer

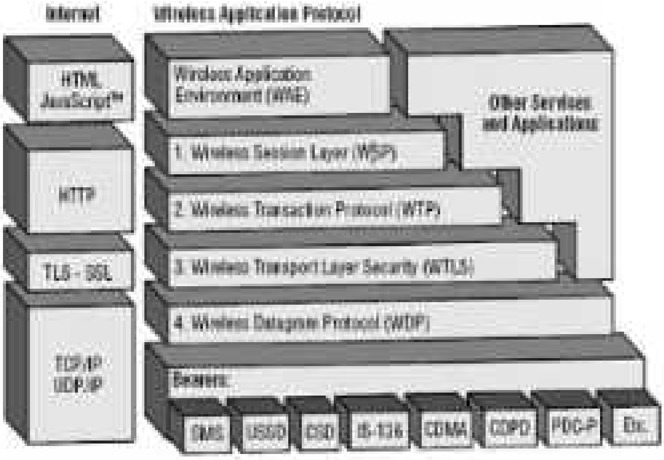
Wireless Transport Layer Security (WTLS). WTLS incorporates security features that are based upon the established Transport Layer Security (TLS) protocol standard. It includes data integrity checks, privacy, service denial, and authentication services.

Transport Layer

Wireless Datagram Protocol (WDP). The WDP allows WAP to be bearer-independent by adapting the transport layer of the underlying bearer. The WDP presents a consistent data format to the higher layers of the WAP protocol stack, thereby offering the advantage of bearer independence to application developers.

Each of these layers provides a well-defined interface to the layer above it. This means that the internal workings of any layer are transparent or invisible to the layers above it. The layered architecture allows other applications and services to utilise the features provided by the WAP-stack as well. This makes it possible to use the WAP-stack for services and applications that currently are not specified by WAP.

The WAP protocol architecture is shown below alongside a typical Internet Protocol stack.



Note that the mobile network bearers in the lower part of the figure above are not part of the WAP protocol stack.

6.10. Features of SMS, MMS, 1G,2G, 3G, 4G& 5G Wireless network.

Since the introduction of first commercial mobile phone in 1983 by Motorola, mobile technology has come a long way. Be it technology, protocols, services offered or speed, the changes in mobile telephony have been recorded as generation of mobile communication. Here we will discuss the basic features of these generations that differentiate it from the previous generations.

SMS And MMS

GPRS has opened a wide range of unique services to the mobile wireless subscriber. Some of the characteristics that have opened a market full of enhanced value services to the users. Below are some of the characteristics:

- **Mobility** - The ability to maintain constant voice and data communications while on the move.
- **Immediacy** - Allows subscribers to obtain connectivity when needed, regardless of location and without a lengthy login session.
- **Localization** - Allows subscribers to obtain information relevant to their current location.

Non-voice services like SMS, MMS and voice calls are also possible with GPRS.

1G Technology

1G refers to the first generation of wireless mobile communication where analog signals were used to transmit data. It was introduced in the US in early 1980s and designed exclusively for voice communication. Some characteristics of 1G communication are −

- Speeds up to 2.4 kbps
- Poor voice quality
- Large phones with limited battery life
- No data security

2G Technology

2G refers to the second generation of mobile telephony which used digital signals for the first time. It was launched in Finland in 1991 and used GSM technology. Some prominent characteristics of 2G communication are −

- Data speeds up to 64 kbps
- Text and multimedia messaging possible
- Better quality than 1G

When GPRS technology was introduced, it enabled web browsing, e-mail services and fast upload/download speeds. 2G with GPRS is also referred as 2.5G, a step short of next mobile generation.

3G Technology

Third generation (3G) of mobile telephony began with the start of the new millennium and offered major advancement over previous generations. Some of the characteristics of this generation are −

- Data speeds of 144 kbps to 2 Mbps
- High speed web browsing
- Running web based applications like video conferencing, multimedia e-mails, etc.
- Fast and easy transfer of audio and video files
- 3D gaming

Every coin has two sides. Here are some downsides of 3G technology −

- Expensive mobile phones
- High infrastructure costs like licensing fees and mobile towers
- Trained personnel required for infrastructure set up

The intermediate generation, 3.5G grouped together dissimilar mobile telephony and data technologies and paved way for the next generation of mobile communication.

4G Technology

Keeping up the trend of a new mobile generation every decade, fourth generation (4G) of mobile communication was introduced in 2011. Its major characteristics are −

- Speeds of 100 Mbps to 1 Gbps
- Mobile web access
- High definition mobile TV
- Cloud computing
- IP telephony

5G Technology

5th Generation Mobile Network or simply 5G is the forthcoming revolution of mobile technology. The features and its usability are much beyond the expectation of a normal human being. With its ultra-high speed, it is potential enough to change the meaning of a cell phone usability.

Some of the significant applications are −

- It will make unified global standard for all.
- Network availability will be everywhere and will facilitate people to use their computer and such kind of mobile devices anywhere anytime.
- Because of the IPv6 technology, visiting care of mobile IP address will be assigned as per the connected network and geographical position.
- Its application will make world real Wi Fi zone.

6.11. Smart Phone and discuss its features indicate through Block diagram.

Definition :

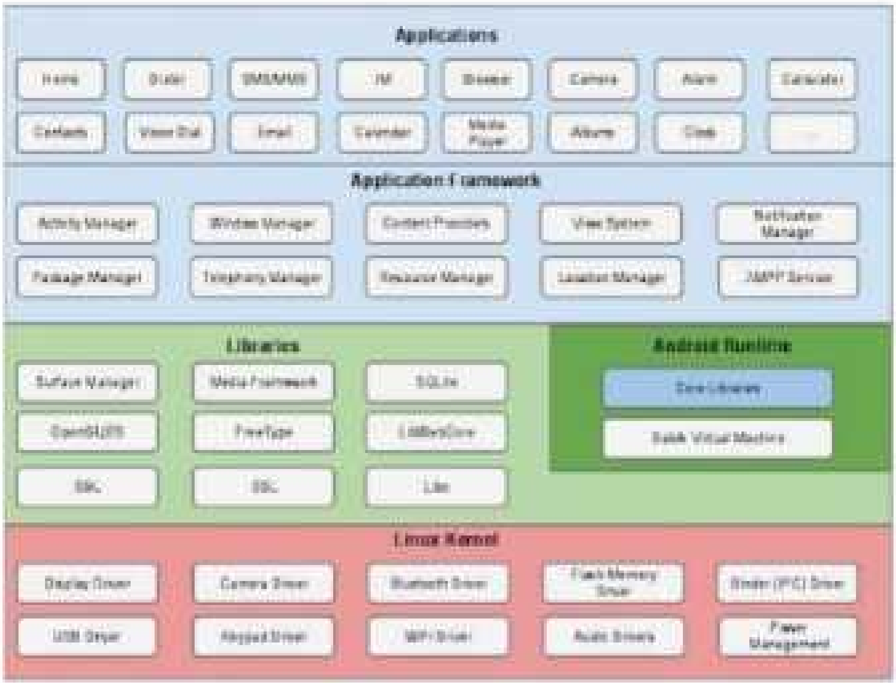
A **smartphone** is a portable device that combines mobile telephone and computing functions into one unit.

Features :

- Instant Communication. **Smartphones** evolved from the earliest communication devices. ...
- Web Surfing. The **smartphones** also make it convenient for people to surf the web. ...
- Camera. In this "selfie" generation, the camera is so important. ...
- Entertainment. ...
- Education. ...
- Productivity Apps. ...
- GPS. ...
- Privacy.

Block Diagrm Explanation :

Android operating system is a stack of software components which is roughly divided into five sections and four main layers as shown below in the architecture diagram



Linux kernel

At the bottom of the layers is Linux - Linux 3.6 with approximately 115 patches. This provides a level of abstraction between the device hardware and it contains all the essential hardware drivers like camera, keypad, display etc. Also, the kernel handles all the things that Linux is really good at such as networking and a vast array of device drivers, which take the pain out of interfacing to peripheral hardware.

Libraries

On top of Linux kernel there is a set of libraries including open-source Web browser engine WebKit, well known library libc, SQLite database which is a useful repository for storage and sharing of application data, libraries to play and record audio and video, SSL libraries responsible for Internet security etc.

Android Libraries

This category encompasses those Java-based libraries that are specific to Android development. Examples of libraries in this category include the application framework libraries in addition to those that facilitate user interface building, graphics drawing and database access. A summary of some key core Android libraries available to the Android developer is as follows −

- **android.app** − Provides access to the application model and is the cornerstone of all Android applications.
- **android.content** − Facilitates content access, publishing and messaging between applications and application components.
- **android.database** − Used to access data published by content providers and includes SQLite database management classes.
- **android.opengl** − A Java interface to the OpenGL ES 3D graphics rendering API.
- **android.os** − Provides applications with access to standard operating system services including messages, system services and inter-process communication.
- **android.text** − Used to render and manipulate text on a device display.
- **android.view** − The fundamental building blocks of application user interfaces.
- **android.widget** − A rich collection of pre-built user interface components such as buttons, labels, list views, layout managers, radio buttons etc.
- **android.webkit** − A set of classes intended to allow web-browsing capabilities to be built into applications.

Having covered the Java-based core libraries in the Android runtime, it is now time to turn our attention to the C/C++ based libraries contained in this layer of the Android software stack.

Android Runtime

This is the third section of the architecture and available on the second layer from the bottom. This section provides a key component called **Dalvik Virtual Machine** which is a kind of Java Virtual Machine specially designed and optimized for Android.

The Dalvik VM makes use of Linux core features like memory management and multi-threading, which is intrinsic in the Java language. The Dalvik VM enables every Android application to run in its own process, with its own instance of the Dalvik virtual machine.

The Android runtime also provides a set of core libraries which enable Android application developers to write Android applications using standard Java programming language.

Application Framework

The Application Framework layer provides many higher-level services to applications in the form of Java classes. Application developers are allowed to make use of these services in their applications.

The Android framework includes the following key services −

- **Activity Manager** − Controls all aspects of the application lifecycle and activity stack.
- **Content Providers** − Allows applications to publish and share data with other applications.
- **Resource Manager** − Provides access to non-code embedded resources such as strings, color settings and user interface layouts.
- **Notifications Manager** − Allows applications to display alerts and notifications to the user.
- **View System** − An extensible set of views used to create application user interfaces.

Applications

We will find all the Android application at the top layer.We will write your application to be installed on this layer only. Examples of such applications are Contacts Books, Browser, Games etc.

Short Questions With Answers

1. Why are wireless standards so important in today's world?

Ans- **Wireless communications** have enabled the connection of billions of people to the Internet so that they can reap the benefits of today's digital economy. Similarly, agreed standards for mobile phones allow people to use their devices everywhere in the world.

2. What are the steps involved in transmission in the wireless communication link?

Ans- Propagation Losses. Antenna and Wave propagation plays a vital role in **wireless communication** networks. An antenna is an electrical conductor or a **system** of conductors that radiates/collects (transmits or receives) electromagnetic energy into/from space.

3. What are the main characteristics and challenges of wireless communication?

Ans- Since **wireless** devices need to be small and bandwidth constrained, some of the **key challenges** in **wireless networks** are Signal fading, mobility, data rate enhancements, minimizing size and cost, user security and (Quality of service) QoS.

4. What are the types of wireless communication?

Ans- The Different Types of Wireless Communication

- Satellite **Communication**. Satellite **communication** is a crucial form of **wireless communication**. ...
- Infrared **Communication**. Infrared **communication** is present in most homes in the form of a television remote control. ...
- Broadcast Radio. ...
- Microwave **Communication**. ...
- Wi-Fi. ...
- Mobile **Communication** Systems. ...
- Bluetooth Technology.

5. What are two advantages of wireless communication?

Ans- **Advantages of Wireless Communication**

- **Wireless** networks are cheaper to install and maintain.
- Data is transmitted faster and at a high speed.

6. What are 3 types of wireless connections?

Ans- There are basically **three different types of wireless networks** – WAN, LAN and PAN: **Wireless** Wide Area **Networks** (WWAN): WWANs are created through the use of mobile phone signals typically provided and maintained by specific mobile phone (cellular) service providers.

7. Define Cell Splitting.

Ans- **Cell splitting** is a **means** of increasing the capacity of a **cellular** system by subdividing or **splitting cells** into two or more smaller **cells.**

8. Define Cell Sectoring .

Ans- In **cell sectoring** a single omni-directional antenna at base station is replaced by several directional antennas, each radiating within a specified sector ..... The technique for decreasing co-channel interference and thus increasing system performance by using directional antennas is called **sectoring**.

9. What is frequency Reuse ?

Ans- Technique for using a specified range of **frequencies** more than once in the same radio system so that the total capacity of the system is increased without increasing its allocated bandwidth.

10. What is frequency reuse factor of CDMA?

Ans- The amount of out-of-cell interference determines the **frequency reuse factor**, f, of a **CDMA** cellular system. Ideally, each cell shares the same **frequency** and the maximum possible value of f (f=1) is achieved.

Long Questions

1. Explain the basic concept of Cell Phone.

2. Discuss the techniques used for improving the coverage and capacity in cellular system.

3. Explain the GSM service and its features.

4. Discuss the architecture of GSM system in detail.(S-22)

5. Explai the working of CDMA system.

6. Discuss the architecture of GPRS.(S-22)