VikashPolytechnic,Bargarh

Vikash Polytechnic
Campus: VikashKnowledgeHub,BarahagudaCanalChowk,NH6 PO/DIST: Bargarh-768028, Odisha

Lecture Note on
ADVANCE COMMUNICATION ENGINEERING

Diploma 6th Semester
BRANCH-ECE

Submitted By:-*ADITEE SAHOO*

CONTENTS

CH-1 RADAR and Navigation Aids

➢ RADAR is an electronic equipment used for detecting distant targets and measure its parameters such as range, speed, etc using radio frequency signal.

➢ RADAR is an electromagnetic system for detection and location of reflected high frequency signals from 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.

➢ RADARs are used in Different Fields like: -

  ➢ Military

  ➢ Remote Sensing

  ➢ Air Traffic Control

  ➢ Law Enforcement

  ➢ Highway Safety

  ➢ Aircraft Safety and Navigation

  ➢ Ship Safety

  ➢ Space Vehicles Control etc.

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 TP 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.

➢ Hencetherangebeyondwhichthetargetappearsassecond-timearoundechois called Maximum Unambiguous Range. $R_{unamb} = CT_P/2 = C/2F_P$

Where, Tp = Pulse Repetition Period. & F_P = PulseRepetitionFrequency.

Fig.1.1BasicRADAROperation

RADARRange Equation:

ConsideringanOmni-directional antenna radiatingpower P_t:

ThefieldintensityreceivedatadistanceRfromtheantennaisgivenby: $E = P_t/4\pi R^2$

Now,consideringtheantennatobedirectionalhavingagainofG_t,thefieldintensityreceived at a distance R from the antenna is given by:

$E = P_t G_t/4\pi R^2$

If the effective crosssection area of the target is given by σ, the field intensity reflected backby the target measured at the surface of the target is given by:

$E = P_t G_t \sigma /4\pi R^2$

Nowifthereflectedsignalisreceivedbackbythesametransmittingantennaofeffective aperture A_e,the field intensity received at the receiving station is given by:

$E = P_t G_t \sigma A_e/(4\pi R^2)^2$

Considering the receiver antenna gain to be G_r, the signal strength received at the receivingend is given by:

$S = P_t G_t G_r \sigma A_e/(4\pi R^2)^2$

Consideringthelimitingcaseformaximumrange,thesignalstrengthatthereceiving terminal is the minimum detectable signal is given by:

$S_{min} = P_t G_t G_r \sigma A_e/(4\pi R_{max}^2)^2$

Hencethemaximumrangeof aRADARisgivenby:

$$R_{max}=(P_tG_tG_r\sigma A_e/16\pi^2 S_{min})^{1/4}$$

So in order toincrease the range of the RADAR by a factor of 2, the transmitter power to be increased by a factor of 16.

PulseRADAR:

The RADAR system which transmits the signal in form of short pulses to detect the range of the target is known as pulse radar. The following figure 1.2 shows the block level concept of the working of pulse radar.
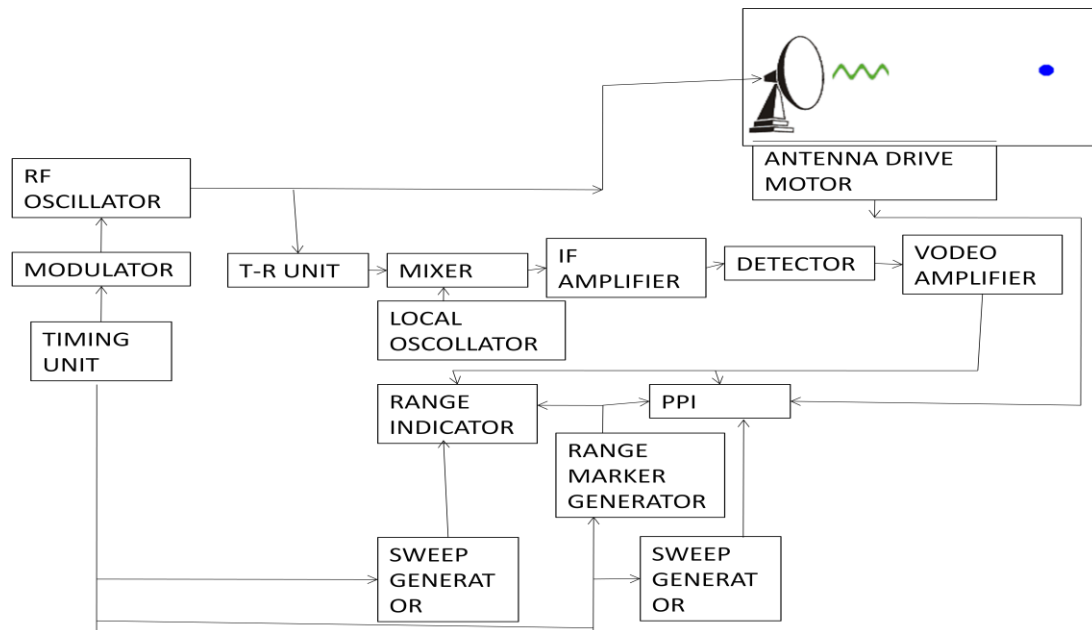

Fig.1.2Pulse RADARBlock Diagram

➤ Itconsistofthreemajorsection

(1) Transmitter.

(2) Receiver

(3) Display unit

(4) Transmissionsection

TRANSMITTER:-

➤ Inthetransmittersection,thehighpoweroscillatorthatgeneratestheRFenergyis usually a magnetron.

➤ Theenergyburstsareobtainedbyaperiodicallyapplicationofhighvoltagepulsesbetween the anode & cathode.

➤ Thevoltagepulsesareformedinamodulatorcircuit,whichdeterminetheamplitude, duration & shape of the pulse.

- The pulse repetition frequencyis commonlycontrolled bytiming unit, which mayconsist of multi-vibrator or a blocking oscillator.
- Trigger pulses from the timing unit are also applied to various circuit in the indictor forthe purpose of synchronization.

RECEIVER:-
- The radar receiver is of the super-heterodyne type with a mixer for frequency conversion as theI/P stage.
- A nonlinear device, consisting of a slab of crystalline material in contact with the tip of a wire is most effective at radar frequency for securing a favorable signal to noise ratio.
  - Generallyareflexklystronisusedasthelocal oscillator.
  - Typicalintermediate frequenciesare30MHz&60MHz.
  - Detectionisaccomplishedbya conventionaldiodecircuit.
- Video Amp. Following the detector raise the signal amplitude to an appropriate level for application to the indicator devices.

DISPLAYUNIT:-
- The display unit includes sweep generators for providing the beam deflection, that forms the time base for range measurement.
- Thesecircuits aretriggered bythepulsesgenerated bythe timing unit.
- To calibrate the distance along the time base accurately in terms of RADAR range, a range marker generator is often employed.
- This circuit produces a set of narrow pluses that forms a set of equally spaced vertical lines along the time base of range indicator and a set of dots along the time base of PPI. (Plan position Indicator).

TRANSMISSIONSECTION:-
- The RF energy transmission section generally consists of rectangular waveguide or coaxial cables connecting the transmitter section to the Antenna.
- In the transmission section, the TR switch is used in order to isolate the receiver from transmitter channel during high power transmission & direct the received signal towards the receiver during reception.
- The TR switch generally consists of a rectangular shaped waveguide piece in which inert gasses are filled. During the transmission phase, due to the high power pulses, the gas is ionized & cuts of the receiver section.
- PRT–Pulserepetitiontime (formula)

$$\text{Radar range } R = \frac{CT}{2}$$

Where C = Speed of EM wave   T = Pulse repetition time

Continuous Wave (CW) RADAR

➢ Continuous wave radar works on the principle of Doppler Effect in order to measure the relative target speed of the target with respect to the RADAR system.

➢ When the transmitted signal is reflected back from a moving target a small change in the transmitted signal frequency is observed at the receiver which may be processed in order to calculate the relative target speed.
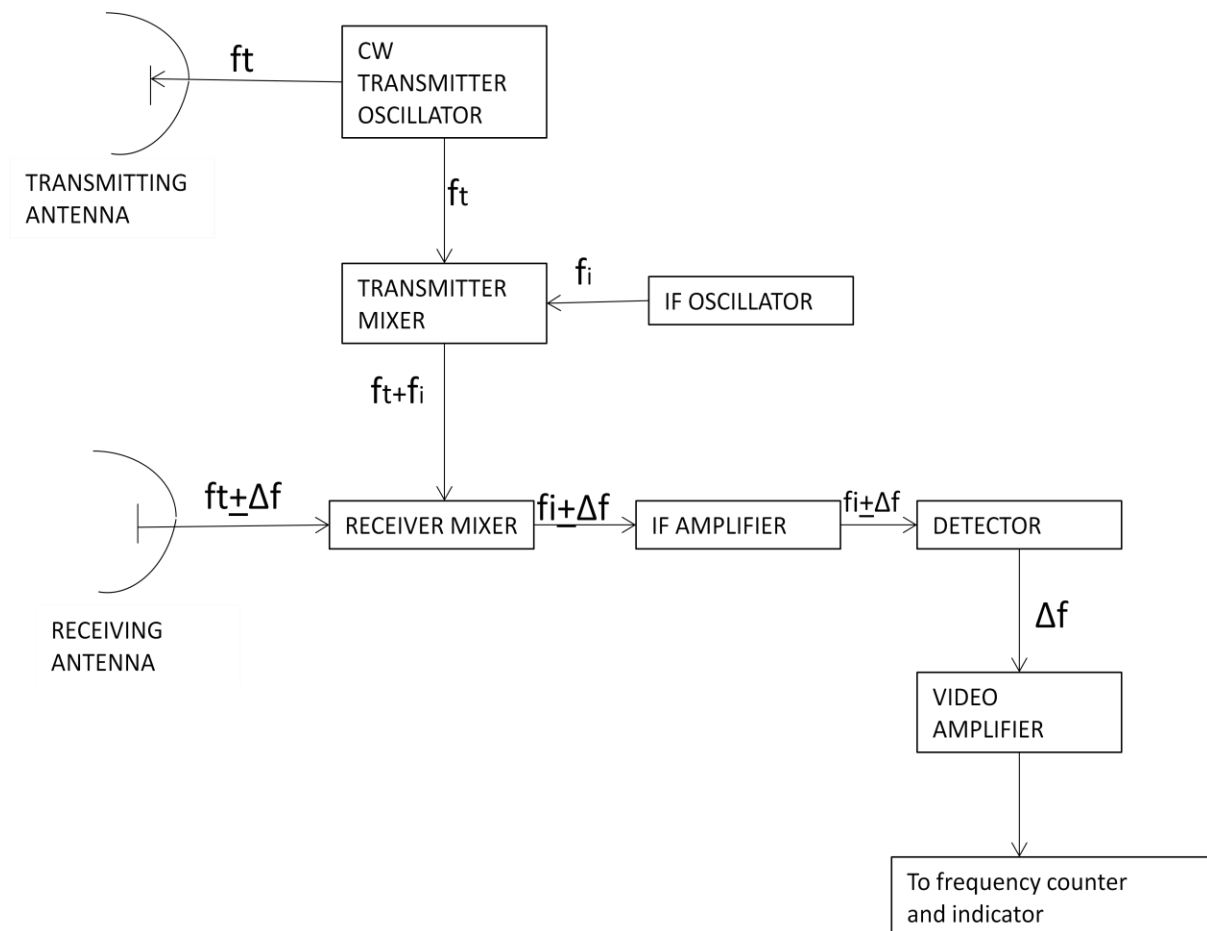

Fig.1.3 CW RADAR Block Diagram

➢ The fig 1.3 shows the block diagram of a CW radar.

➢ In this system continues wave signal of frequency 'ft' is transmitted through the transmitting antenna.

➢ A sample of the transmitter frequency mixed with the IF frequency is fed to the receiver channel.

➢ The Doppler shifted signal ($f_t \pm \Delta f$) is received by the receiver antenna & fed to the receiver mixer.

- The receiver mixer cancels out the transmitted signal component and gives an o/p signal with frequency fi ± Δf.
- Thisifsignalisamplifiedbythe IFampandsubsequentlytheintermediatefrequency signal is removed at the detector stage.
- Thedetector output is onlyhavingtheDoppler shift component ofthesignal
- This signal is non directional. Byusingthis Doppler shift the relative target speed maybe calculated as follows.

$$\Delta f = \frac{2V}{\lambda} \quad \text{-------- (1)}$$

Where Δf=Dopplershiftfrequency. V=

Target speed.

λ=Transmitted signalwavelength

- Weknowthat λ=c/f_t ----------------------------- (2)

Wherec= Velocityofelectro

Magneticwaveinfreespacei.e 3×10^8 sm/sec f_t =

Transmitted signal frequency

- Puttingthe value of &from eq-(2)in eq-(1)wehave Δ f=$\frac{2Vr}{c/f}$

- In case of CW radar two separate antennas are preferred for transmission & reception in order to get the isolation between the transmission reception channels.
- Ifasingleantennaisuseditmay,reducedthesensitivityofthereceiver.

  Advantages:-
- Itgivesanaccuratemeasurementofrelativetargetspeedusinglowtransmitterpower (nearly = 100w)
- Simple circuitry.
- Lowpowerconsumption.
- Smallequipmentsize.

  Disadvantage:-
- Smallmaximumpowertransmissionlimitsrange of operation.
- Uncertainoutputincaseofmultitargetscenario.
- Indoesnothavecapabilityofrangecalculation.

  Applications:-

  (1) SpeedmeasurementofAutomobile,Guidedmissilesetc.

  (2) Itcandetectpresenceofmovingobjectsinstationarybackgroundwhichmakesuitable to be employed for security purposes during the night & bad weather.

(3) Detectionofmovingaircraftin ECM(Electroniccountermeasure) systems.

MovingTargetIndicator(MTI)RADAR:-

➢ The moving target in dictator radar system is designed on Doppler Effect in which the phase correlation of the transmitted pulse and the received pulse is processed in order to track the moving targets.

➢ The phase of the received signal is compared with the transmitted signal to get the target parameters.

➢ In case of moving target the phase of the received signal continuously varies where as in case of steady target the phase remains unchanged. By comparing the phase of received signal, the steady target signals are eliminated from the display unit.
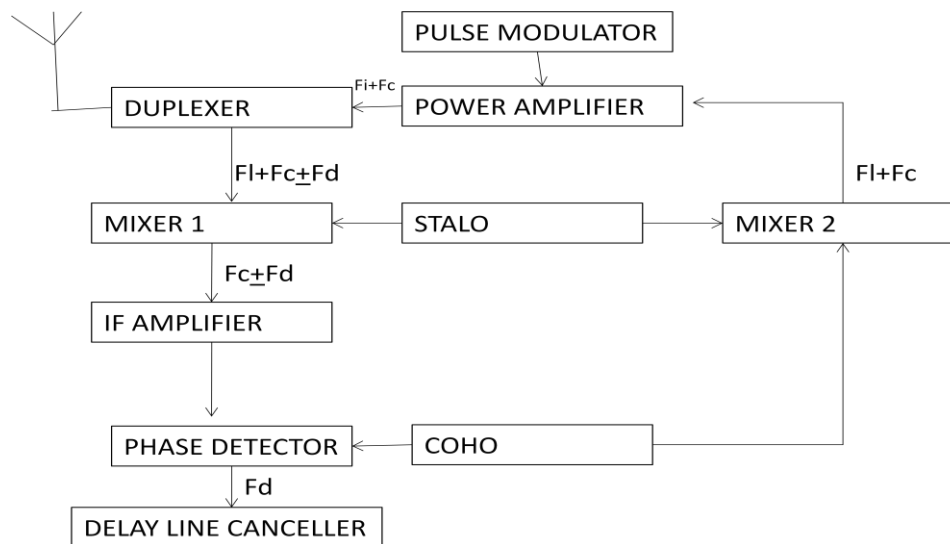

Fig.1.4MTIRADARBlock Diagram

➢ The fig, 1.4 shows the block level concept of a MTI system. The receiver channel is identicalto a standard radar system except the local oscillator which is having a veryhigh frequency stability & a limiter is included in the IF amplifier so that the echo signal applied to the phase detector which always have same amplitude.

➢ The oscillator providing the different phase is termed as coherent oscillator (COHO) operating at a frequency i.e closely the difference between the transmitter & the stable oscillator (STALO) frequency.

➢ When the magnetron in the transmitter section transmits the pulses whose phases are same, the received pulses phase is dependent on the target movement.

➢ It is necessary that the phase of coherent oscillator must be matched with the phase of transmitter for each transmitted pulse.

- This is achieved by rejecting power from each transmitted pulse into the COHO channel by the coupler.

- Thephasedetector o/p for successive pulses issubtracted from each otherbyadelayline.

- Thedelayoffered bythe delayline is exactlyequals to one pulse repetition time period of the signal transmission.

- Sotheo/pofthedelaylinedeliverechoofthesametargetcorrespondingtothephase detector output produced by the next transmitted pulse.

- The delayed& un-delayed echoes are then subtracted by the subtractor. Here the phasecomparison is carried out at the intermediate frequency.

Radar Indicator

- The output of the radar receiver is always displayed to the radar operator with the help of cathode ray tubes.

- Thedisplaysareeitherintensitymodulatedordeflectionmodulateddependingon whether the trace is deflected or brightened by the presence of echo.

- Therearedifferenttypesofindicatorusedintheradarsystemtodisplaythetargetare mainly.

  (i)   PlanpositionIndicator(PPI)

  (ii)   A– scopeIndicator.

  (iii) B– scopeIndicator.

(1) PlanpositionIndicatorPPI

Fig.1.5 PPIIndicatior

- PPIis a intensitymodulateddisplaysystem representingthe approximatetarget rangeand relative Bearing with respect to the central axis of the radar antenna.

- The saw tooth timing wave deflects to the cathode range pulse radials outwards from the center &synchronizedwiththetransmittedpulse.Thedistanceoutwardfromthecenteris proportional to the distance of the target from the radar.

- The angular direction in which the saw tooth timing wave deflects the cathode rayspot at anyinstantismadeto correspondto thedirection inwhichtheantennabeamisdirectedat the movement.

- Thesignals fromthereceiveroutput areapplied tothecontrolelectrodeoftheCRT.

- The signal of significant amplitude causes an intensity modulated spot on the CRT when the beam or sweep passes the target position.

- DependingonthepositionofthetargetfromthecentrepointoftheCRT,theradar operator can calculate the approximate range of the target by the range rings.

- TheBearinginformationofthetargetcanbedeterminedbycheckingthetargetposition w.r.to thebearingringwhich isplaced aroundthePPI.

- Longpersistencetimephosphorsarenormallyusedtoensurethatthefaceofthe PPI screen doesn't flicker.

- The resolution on the screen depends on the bandwidth of the antenna, pulse length & the transmitted frequency etc.
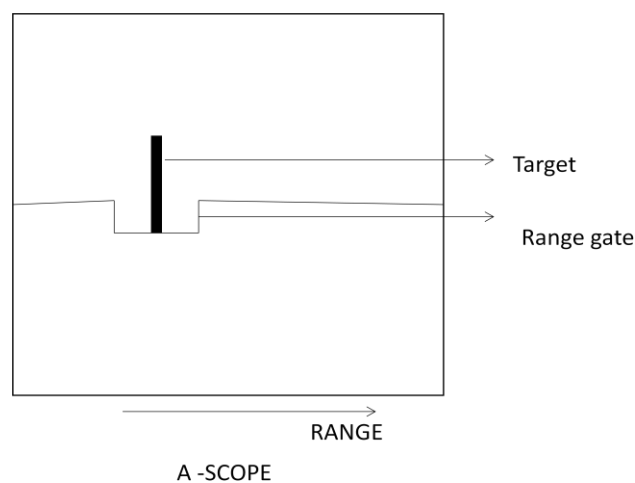
(2) A-SCOPE:-

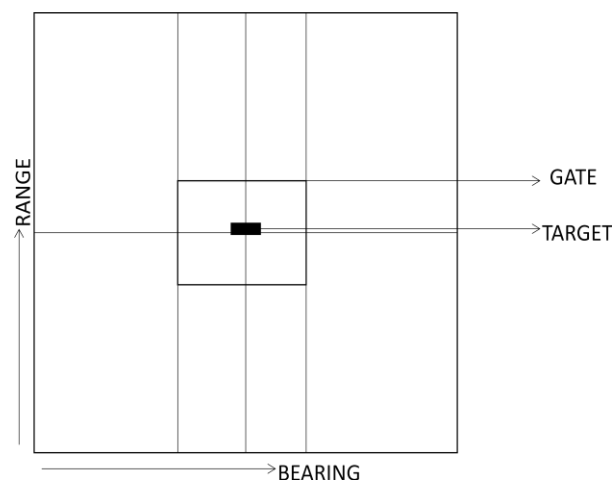Fig.1.6A-ScopeIndicator

- A-scopeisa rectangularindicatorwhichisdeflection modulated.

- A linear saw tooth voltage is applied to the horizontal deflecting plates which move thesweep from left to right.

- Theflybackperiodisverysmall.

- Inthe absenceofthetargetasimplehorizontallineisdisplayedonthescreen.

➢ When the target signal is present at output of the receiver section it is applied to the vertical deflecting plates which makes a vertical impression on the horizontal line showing the target position.

➢ Therangeof theA-scopecan becalibratedbyadjustingthe saw tooth waveduration.

➢ In case the A-scope to be used for the whole radar range, the duration of the saw tooth wave must be equal to the pulse repetition time period of the transmitter & the target range is the displacement measured from the left hand side of the screen.

(3) B– SCOPE:

Fig.1.7B-Scope Indicator

➢ Theabovefigureshows thescreenrepresentationoftheB– Scope.

➢ B– Scopeishavingarectangular displaywhich isintensitymodulated.

➢ In this case one axis represents the range coordinate & the second/other represent the angular coordinates. So these indicators may be use for accurate acquisition of target in bearing & elevation.

➢ Thisangularcoordinatesystemislimitedto thebeamwidthofthetransmitting antenna.

AircraftLandingSystem (ALS)

➢ During the poor visibility condition, It is not possible by the pilot to land the aircraft without any help of radio aids.

➢ Therearetwopossible waysto helpthepilotforproperlandingofthe aircraft.

  (i)   InstrumentLandingSystem.

  (ii)   GroundControlapproach.

i) INSTRUMENT LandingSystem:-

> The figure 1.8 shows the arrangement of radar beacons on the approach path to the runway which guides the pilot for easy and accurate landing point estimation of the aircraft.
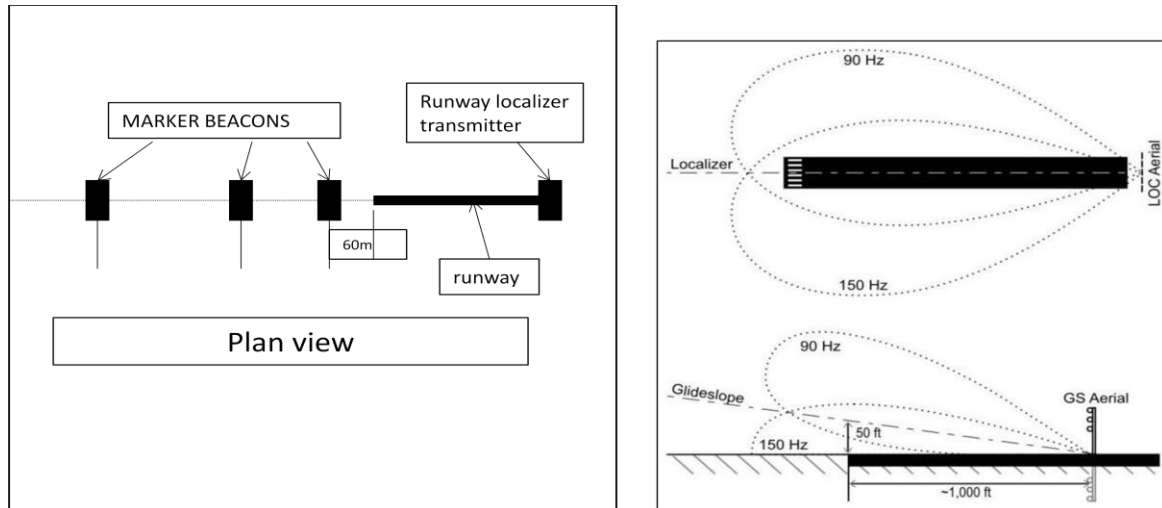

Fig.1.8Instrument LandingSystem

> Out of all these beacons the glide path equipment and runway localizer transmitter are horizontally polarized and the marker beacons are vertically polarized.

> Therunawaylocalizer enables the airplaneto approach the runwayfrom proper direction.

> It consists of two horizontally polarized very high frequency radar which are omni-directional in nature.

> The radiated wave is a single carrier wave associated with both the antennas is amplitude modulated.

> When both thetransmitterstransmit simultaneously, theyproducea null signal path along the runway, which is sense by the receiver at the aircraft through the indication system & the pilot align the aircraft to the null direction.

> Oncethe aircraftachievestheproperlandingdirectionthedescendingprocedure starts.

> The height of the aircraft from ground level is adjusted by the pilot by sensing the beams of marker beacons.

> The marker beacons are vertically polarized antenna with a fixed distance from the runway as shown in the figure.

> Thedifferent markerbeacons areidentified bydistinct tonemodulation and in general the 7km beacons generates 400 cycles of dashes & 1.5 km beacon produces 1300 cycle dots and the 60m beacon produces 3000 cycles un-modulated signal.

Main precaution:-

- The localizer and Glide path antenna system should be completely freeform spuriousequi-signal path, which may result from interaction of side lobes.

ii) Groundcontrolapproach:-

- This system employs two radars, one for long range target identification & 2nd for controlled approach of the aircraft towards the runway.
- Thelongrangeradarishaving arangeof about50kms.
- The 2nd radars has two displays, the 1st display represents the target elevation in 'y' co-coordinate target range in X- coordinate while the 2nd display represents the bearing & range of the target ona PPI.
- An approximate glide path is indicated on the 1st display & the direction of approach to the glide path is control by the 2nd display.
- The aircraft to be landed is 1st taken to the proper direction of approach with the help of1^{st} long range radar.
- A controller/operator at the indicator of the 2nd radar then takes over the aircraft for landing by establishing a voice link between the aircraft pilot & the control station depending on the distance from the runway and height of the aircraft from ground level, the controller guides the pilot for descending towards the runway.
- If the range & height of the aircraft are not in proportion theaircraft pilot is instructed to move upward & reproach the glide path again

  Advantages:-

  (i)   In the aircraft no equipment is required other than the radio receiver for
          landingsystem.

  (ii)   Thegroundinstallationcanbemobile.
          Disadvantages:-

  (i)   Due to a number of human links in the process, the responsibility of the pilot for
          making a successful landing is taken away from him.

RADARAidsto Navigation

- The position of air craft or a ship can be found by use of radio navigation aids. This is achievedbyinstallationofradiotransmitterandreceiveratknownlocationonthe earthsurfaceaswellasatair 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 andindirectmeasurementofdelayoccurringbetweentransmissionandreceptionofthese

waves.

- ➢ The measurement of direction, distanceand the difference between two transmitters give an indication of the position of an air craft or ship leading to correct navigation.
- ➢ Directionfindingthroughradioisoneoftheveryearliestmethodsofelectronic navigationalaids widely used in ship and air craft even today.

NAVSAT(NavigationSatellite System)

- ➢ Itisusedfor givingself positionofNavalships withthehelpofsatellite system.
- ➢ Thesatellitesareplaced at low earthorbits at an altitudeofabout 1100 kmwith an orbital period of 106 minutes.
- ➢ Thereare5satellites usedto provideglobalcoverage.
- ➢ Another5 satellites areplaced inthesameorbit for redundancy.
- ➢ Theorbitsofthesatellitewerechosentocovertheentireearthsurface&whichare crossed over at poles and spread out at the equator.
- ➢ Thesystemprovidesanaccuracyofroughly200 mtrsandalsothetimingsynchronization about 50 μ sec.

Operation:-

- ➢ The system satellite broadcast the UHF carriers, the satellite position & clock correction are uploaded twice every day to each satellite from the base stations.
- ➢ Thisbroadcastinformationallowsagroundreceivertocalculatethelocationofthe satellite at certain point f time.
- ➢ Useoftwocarrierspermitsthegroundreceivertoreducenavigationerrorcausedby ionosphere.
- ➢ ThesatelliteBroadcast on150MHz&400MHz frequencybands.
- ➢ The multiple frequencies are used to compensate the bending of the satellite radio beams by the ionosphere and cancelled out, thereby increasing the location accuracy.
- ➢ The critical information that allowed the receiver to compute location was a unique frequency curve caused by the Doppler Effect.
- ➢ The Doppler Effect causes an apparent compression of the carrier wave as the satellite approaches the receiver and stretching the wavelength as the satellite recedes /goes away from the target.
- ➢ Thereceivedcarriervariation can bemuchas 10 KH$_z$forasatellitespeed of17000 miles/ hour.
- ➢ ThisDopplercurveis unique foreach location, within the line ofsight of thesatellite.

Ex-Theearthrotationcausedbythegroundreceivertomovetowardsorawayfromthe

satellite orbit, creating a nonsymmetrical Doppler shift approach & allowing the receiver to determine whether it was east or west of the satellites north, south, ground track.

- The navigation software used the satellite motion to compute a trial Doppler curve based on the initial location of the receiver.

- Thesoftware then perform a least square curve fit for each 2 min section of Doppler curve & moving the trial position until the trial Doppler curve must closely matched with the actual doper received from the satellite for all two minute curve segment.

- The positional accuracy up to 100 meter can be achieved from slow moving ship through the system.

CH-2 SATELLITE COMMUNICATION

Satellite is an electronic repeater placed above the ground to enhance the data common.

➢ Depending on the shape of the orbit, the satellite orbit can be broadly classified into two categories.

(i)   Circular orbit satellite.

(ii)   Elliptical orbit satellite.

➢ Depending on the placing of the orbits with respect to the latitude of the earth, the satellite can be classified into the following three categories.

(i)   Equatorial satellite.

(ii)   Polar satellite.

(iii)   Inclined satellite.

➢ Depending on the height of the satellite above the ground level the orbit of the satellite divided into 3 categories.

(i)   Low earth orbit satellite.

(ii)   Medium earth orbit satellite.

(iii)   Geostationary orbit satellite.

(i) Low earth orbit (LEO) satellite:-

The LEO satellites typically at a light 760 km to 1800 km (less than 2000 km) have been launched to provide mobile common link.

➢ They follow an elliptical path.

Example of- LEO satellite is iridium satellite system.

➢ This system covers the whole world with 72 [66+6 standby] polar orbiting satellites.

➢ It provides up to 10 spot beams (the foot print of the satellite is divided into spot beams, which facilities the reuse of frequency)

➢ The orbital period for this satellite system is about 100 minutes.

➢ The modulation pattern used is QPSK (Quadrature phase shift keying)

➢ The frequency for data common used is given below. 23 GHz for satellite to satellite link.

29 GHz for uplink.

19 GHz for downlink.

➢ The satellite system can handle voice, data, fax etc.

(ii) MEO(Medium Earthorbit Satellite)

- The MEO satellite system generallyorbits at an altitude of 10,000 km, Generallyused for commercial satellite telephone service.

- Itoffers asignal propagationdelayof about70 msec.

- Italsoprovidesupto60spotbeams.AnexampleofMEOsatellitesystemisGlobstar which comprises of 48 satellites (44+4stand by) aimed at polar regions of earth.

- Theorbitalplainsareinclinedat50°toequator&concentrateon70°north&south latitudes.

(iii) GEO:-(Geo stationaryorbit satellite)

- TheGEOsatelliteorbitaroundthe earthatan altitudeofabout 36000km.

- Theyorbit aroundtheequator line&having circularshape.

- Therearethreesatellitesrequiredfortotalglobalcoverage.

- Thesignal propagation delayoffered bythis satellitesystem is about 250m sec.

- Itprovides upto 150spot beams.

- FewexamplesofGeosatellitesareAsia cellularsystem,Khuraya etc.

- Asiancellularsystemsatellitesprovidecoveragefrom Indiato Indonesia &Australia.

- TheKhurayasystemconnects50countriesfromwestAsiatoIndiaSubcontinentspositions at 44° east longitude on Indian Ocean.

- The Geo stationarysatellites are synchronous to the earth rotation. The orbital velocityof the satellite is equal to the velocity of a point on earth equator.

- LetM&m be the mass of earth andsatellite respectively.

- LetR&R_E be the radius of satellite orbit and earth respectively.

- If W be the angular velocity of the satellite in radians/ second, then the centrifugal force acting on the satellite is given by

$F_{cf}=mRW^2$------------------------(i)

- Thecentripetalforceequaltothegravitationalforceactingthesatellitegivenby Newton's gravitational law.

$F_{cp} =\dfrac{GMm}{R^2}$-------------------------(ii)

- Where,G is the gravitational constant=$6.672 \times 10^{-11} m^3/kg/sec^2$

M= mass of the earth = 5974×10^{-24}kg

R_E =6370 km

- Attheearthsurface,the gravitationalforceisgivenby

$f_g = mg$ ----- (iii)

Where, g = Acceleration due to gravity = 9.8 m/s^2

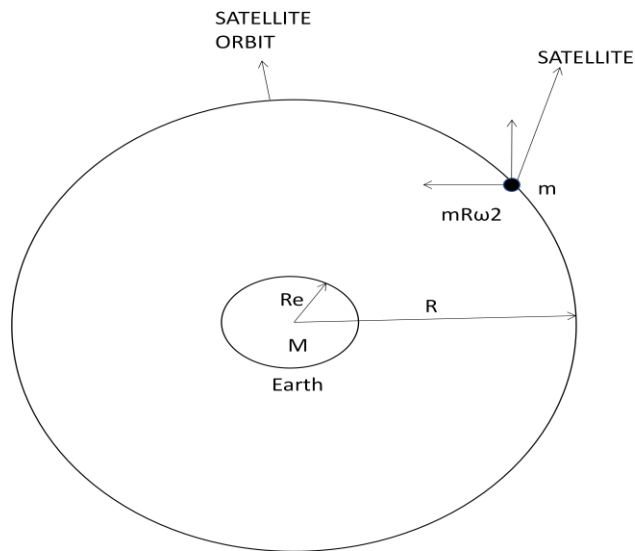Fig.2.1 Satellite Orbit

> Hence $\dfrac{GMm}{R_E^2}$ = mg -------- (iv)

Comparing eq^n(1) & eq^n(4) we have

$$mRW^2 = \dfrac{GMm}{R^2} = mg\dfrac{R_E^2}{R^2}$$

f = Rotation rate of the satellite in revolution/day. Value

f = 1

Hence e, R = $(g*R_e^2/w^2)^{1/3}$ = 42,208 km

> Hence the height of the satellite from the earth surface is given by R-R$_E$ = 42208 – 6370 = 358.38 = 36000

> From Keppler's law for circular orbit the time period of rotation is given by T=2π

$$(R^3/GM)^{1/2}$$

> Putting the values we have

T = 2.3 hour 56 minute 4sec = 24 hour.

> The satellite velocity for circular orbit is given by

V = $(GM/R)^{1/2}$

> The signal transmitted to the satellite is returned back o the receiver after travelling a distance.

$$d = 2(R-R_E)$$

> The EM wave travels at speed of light i.e 3 x10^{8}m/sec.

➤ Thetimedelayforthesignalreceptiongivenby

$T_d = C/D = 250$ msec

Kepler'sLawsforOrbits

➤ So far, we have assumed that satellites travel in circular orbits, but this is not necessarily trueinpractice.Newton's Lawscanbeusedtoderivetheexactformofasatellite'sorbit.

➤ However, a simpler approach is to look at Kepler'sLaws, 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) Allplanetstravelinellipticalorbitswiththe Sunatonefocus(definestheshapeof orbits).

(2) TheradiusfromtheSuntotheplanetsweepsoutequalareasinequaltimes (determines how orbital position varies in time).

(3) The squareofthe period ofaplanet's revolution is proportionalto the cubeof its semi major axis (suggests that there is some systematic factor at work).

SatelliteFrequencyBands:-

	Band	uplinkfreqBand(MHz)	DownlinkfreqBand(MHz)
1.	UHFMilitary	292-312MH$_2$	250 – 270 MH$_2$
2.	C–BandCommercial	5925 MH$_2$– 6425	3700 – 4200
3.	X–BandMilitary	7900 – 8400	7250 – 7750
4.	Ku–BandCommercial	14, 000 – 14, 500	11700 – 12200
5.	Ka– Band Commercial	27, 500 – 30, 000	17, 700 – 21, 200
6.	Ka– Band Military	43, 500 – 45, 500	20, 200 – 21, 200

Inadditiontoallthesebands,formetrologicalsatellitesthefollowingbandsareused

(i) 16.68.4to 16.70 MH$_2$.

(ii) 1670to 1690MH$_2$.

(iii) 1690to 1700MH$_2$.

(iv) 1700to 1710 MH$_2$.

(v) 7450to 7550 MH$_2$.

➤ The uplink & down link frequencies used is the satellite system are made different in order to avoid interference between the uplink & down link signal.

➤ The downlink signal frequency is made lesser than the uplink frequency in order to avoid bulky circuits, high power requirement, and high maintenance requirement at the satellite station in order to reduce the cost with high reliability of satellite operation.

General Structure of Satellite Link System

➢ The satellite communication system consists of a satellite in space that links many earth/base stations on the ground.
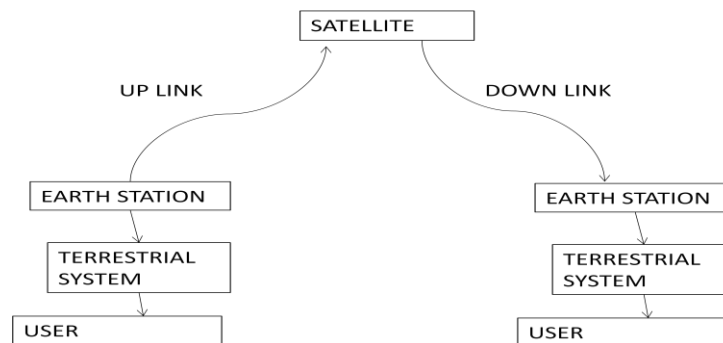

Fig.2.2GeneralStructureofSatellite Link

➢ The user is connected to the base stations through terrestrial network which may be telephone switch or dedicated link to the base station.

➢ The user generates the base band low freq signal that is processed & transmitted to the satellite at the base station. The block level representation of earth station functionalityis shown in the fig below.
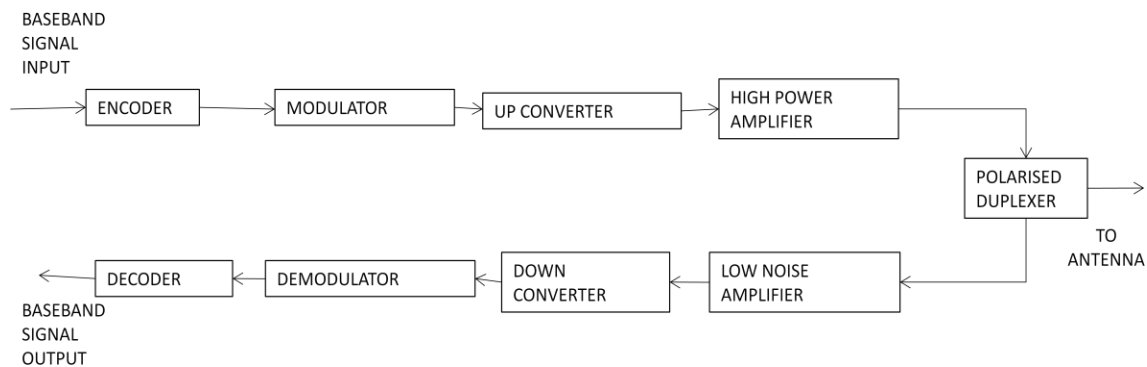

Fig.2.3Blockdiagram ofearth station

SatelliteEarthStation

➢ It is broadly a combination of a transmitter section & receiver section coupled to a common antenna through duplexer.

➢ The terrestrial networks which multiplex the base band signal received from the user & does the necessary formatting. Then it is fed to the transmitter section.

➢ The earth station or base station first encodes the signal followed by modulation. This modulatedencryptedsignalisfrequencytranslatedtotheuplinkfrequencybandbytheup converter.

- Thenthesignalisamplifiedbythehighpoweramplifier&directedtotheappropriate polarization port of the antenna feed.
- Thesatelliteantennareceivestheuplink signal&buffersbeforeanyprocess.
- Then signal is decoded in the transponder & checked for the recipient address & re-again encodes the signal.
- Thenthetranspondertranslatesthesignalfrequencytodownlinkfrequency&passit through a power amplifier before feeding the downlink antenna at the satellite station.
- Thesignal receivedfrom thesatelliteis amplified byalow noiseamplifier at thefrontend at the receiver.
- Then the signal is down converted (frequency) from the down link frequency at the base station.
- Furtherthesignalis demodulated &decoded toderivethe originalbaseband signal.
- Critical components must be installed with redundancy with automatic switch over in the event of failure. So that uninterrupted operation is maintained at the satellite.
- There may be interference caused by side lobes of adjacent satellites. Other sources of interference include ground microwave relay links, sun transit effect & inter modulated products generated in the transponder & on earth station.

SatelliteTransponder

- Thetranspondersarethe repeatersatthesatellitewhichperformsthebasic two functions.
1. The amplification of the signal from on I/P power of the range ($-$ 100db) in watt to an output power of 10db(w) so about 110db gain is provided by the transponder.
2. The frequency down conversion that avoids the interference between high amplitude transmitted signal and the weak incoming signal.
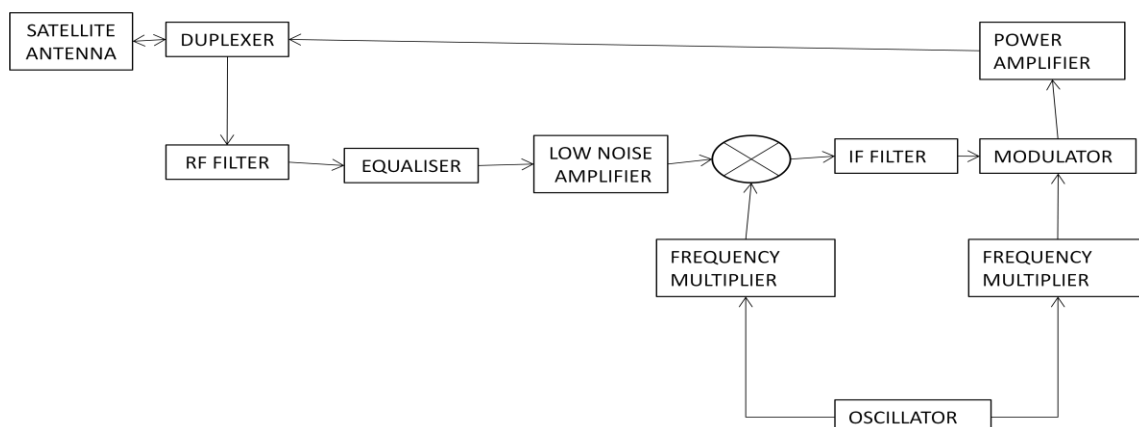

Fig.2.4SatelliteTransponder(RegenerativeType)

- The transponders having additional provision of detection & demodulation process are known as regenerative transponders.

- The satellite antenna receives the uplink signal & passes it to the front end of the transponder through the diplexer.

- The diplexer isolates the transmission & receiver signal in order to utilizing a signal antenna for both transmission & reception purpose.

- The front end of the transponder comprises of RF filter, equalizer & low noise amplifier stage.

- The RF filter are generally band pass/low pass waveguide ll wave filter used forachieving desired masking, noise rejection& equalization they alsocontribute towardsthe ckt noise.

- Theequalizer is used to cancel out the delayproduced bythe RF filter.

- The low noise amplifiers are having very high gain. Generally tunnel diodes are used at this stage for low frequency band ("C" band) & FETs are used for high frequency band ('K' band).

- The transponder shown in the figure above is a regenerative transponder. The frequency translation is carried out by first translating the uplink frequency to a low intermediate frequency band & then the entire IF band is modulated to the down link RF band.

- These allow for the uplink commands transmitted with the carrier modulation to be recovered during the demodulation & satellite telemetric to be inserted into the base band for down link modulation.

- After frequency translation the power amplifier usually consist of TWTs commonly used as high gain broad band amplifier. It provides a $\max^m$ gain of about 55db. Then the signal is passed to the antenna through the diplexer unit for retransmission.
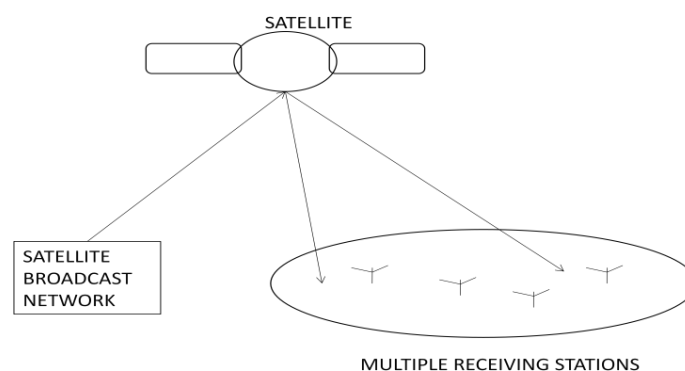
DirectBroadcastSystem(DBS)

Fig.2.5 DirectBroadcast system

➢ Thedirectbroadcastsystemisbasedononepointtomultipointconnectivityfeatureofthe satellite communication system.

➢ Theabovefigureshowsthebroad mechanismof a DBS.

➢ Thesystemtakesfulladvantageofinside areacoverageofsatellitefoot print.

➢ The satellite broadcasting consists of one transmitting system/Base station & many receive only stations as show in figure.

➢ The program is to telecast is beamed of to the satellite via uplink antenna from the studio having base station antenna system.

➢ In case of earth station or base station & uplink antenna is remotely located, the program to be telecast is 1stly collected by a mobile base station & transmitted to the nearly base station through the satellite link or terrestrial link.

➢ Thenthebasestationactivates thenormalbroadcast station.

➢ The downlink signal is received at each receiving station & distributed among the usersby terrestrial link.

➢ Incaseofwideareabroadcasting,multiplesatellitescanbeutilizedlinkingdifferentbase   station through the signal hopping process.
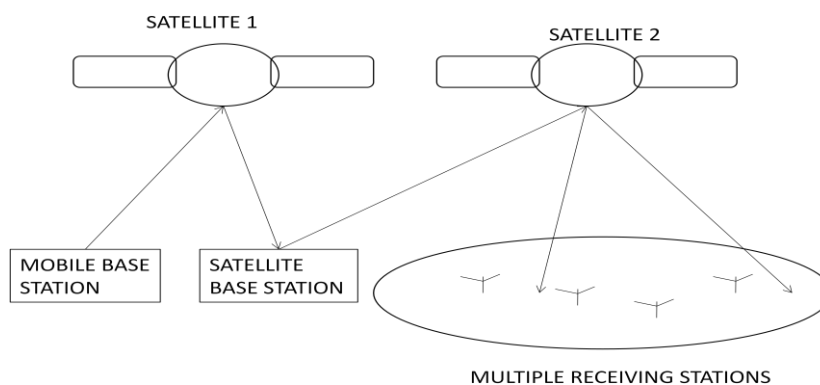
Fig.2.6DirectBroadcast System(Remote Location)

GlobalPositioningSystem (GPS):-

➢ TheGPSsystemsareusedasmeansofnavigationforships&aircraftsandalsofor surveying and many other applications.

➢ Themain features of GPS are.

(1) Itconsistof24satellitesatMEOorbitatanaltitudeof20,200kmwith55^{0}orbital inclination providing navigation & timing information.

(2) Thesatellites aregroupedinto four called constellation,each separated by60^{0}longitudes.

(3) Theorbitalperiodofeachsatelliteis 11hoursand58minutes.Atany instantatleast 4 satellites are visible from any base station.

➢ TheGPSprovides the following information

(i)   Extremelyaccuratethree dimensionalposition information.

(ii)   Extremelyaccuratevelocityinformation

(iii)   Precisetimingservice.

(iv)   Continuousrealtimeinformation

➢ The world wide GPS satellite control system consists of 5 monitoring stations & four ground antennas.

➢ Themonitoringstations useGPS receiverto passivelytrack thenavigational signals ofall the satellites.

➢ Information from the monitoring system is then processed at the master control system which sends updated navigation information to GPS satellites through ground antennas operating in 's' band.

➢ The GPS satellites broadcast signals on two different frequencies which can correct for distortion effect due to ionosphere.

➢ Thesignaltakes 35to 65sectoreach fromsatellite toearth station.

➢ Horizontalposition accuracycanbeachieved up to7 to 10meter.

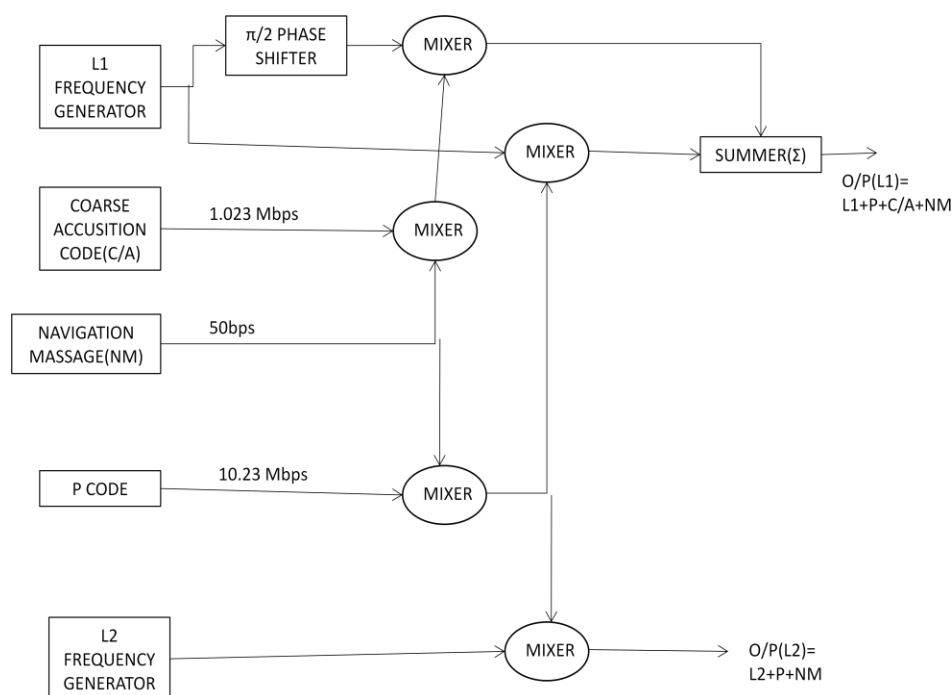➢ Thestabilityoftheclocksonboardisapproximately1sec/30,000yrs.

GPS TRANSMITTER

Fig.2.7GPS Transmitter

- The transmission by GPS satellite is based on the pseudo random sequence codes.
- The Generation of L_1 & L_2 signals is shown in the figure above.
- All the satellites in the GPS system transmits the coarse accusation (C/A)code & at frequency 1575.42 MHZ using BPSK modulation technique.
- It is 154 times more than the master clock frequency (10.23 MHz).
- The pseudo random sequence code lasts exactly 1mse c as 1023 bit sequence are transmitted at 1.023 MHz frequency.
- The transmission of positional code uses BPSK modulation technique at L_2 carrier frequency (1127.6 MHz at 4 carriers in phase quadrature with course accusation code.
- The course accusation code & positional code transmission from all GPS satellites are over laid in L_1 & L2 frequency bands, marking the GPS system (DSSS) direct sequence spread spectrum system.
- At the receiver the signals from individual GPS satellites are separated using knowledge of the unique coarse accusation code that is allocated to each satellite.

GPS RECEIVER:-
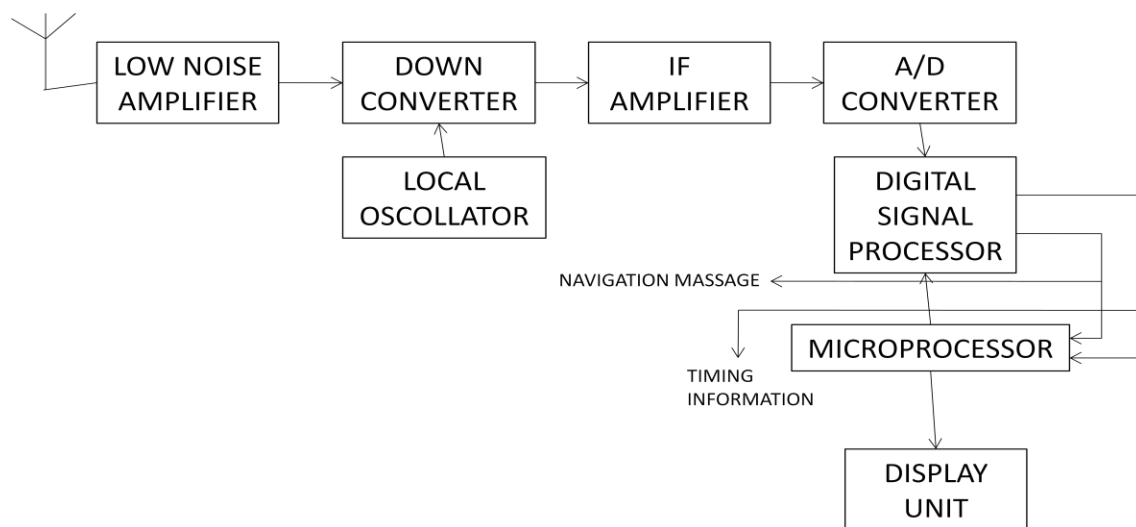
Fig.2.8 GPS Receiver

- The fig2.8 shows the schematic of a coarse accusation code GPS receiver.
- The antenna is circularly polarized which receive the downlink signal from the satellites.
- The low noise amplifier selects the desired frequency band and amplifies the signal.
- The super heterodyne receiver consisting of frequency down converter & local oscillator generates an intermediate frequency signal of a band with about 2 MHz.
- This analog signal is digitized by the A/D to converter which consists of a sampler & quantizer.

- The digital signal processing unit processes the digital portion of received signal, which consist of a coarse accusation code generator and a correlator which select the code sequence.
- The microprocessor carries out the timing measurement & calculates the receiverposition.
- Theoutput datais displayed onthedisplaydevice.

VerysmallapertureTerminal(VSAT)

Themaincharacteristics ofaVSATsystem are.

- They operate in the 'Ku' band with earth/base station with antenna diameter of 1 to 2 meter & transmitter power 1 to 2 Watt.
- The earth stations are usually organized by star network topology in which the earth station connect to a central hub station through GEO satellites.
- Data rate on this link is from a few 1000 bits/sec to 256 kbps depending on the traffic requirement.
- The VSAT systems are used to link business and stores to a central computer system so that the sale traction can be completed more rapidly than by using telephone & modem. Hence the central offices can rapidly redistribute and collect information from a large no of location is a region or country.
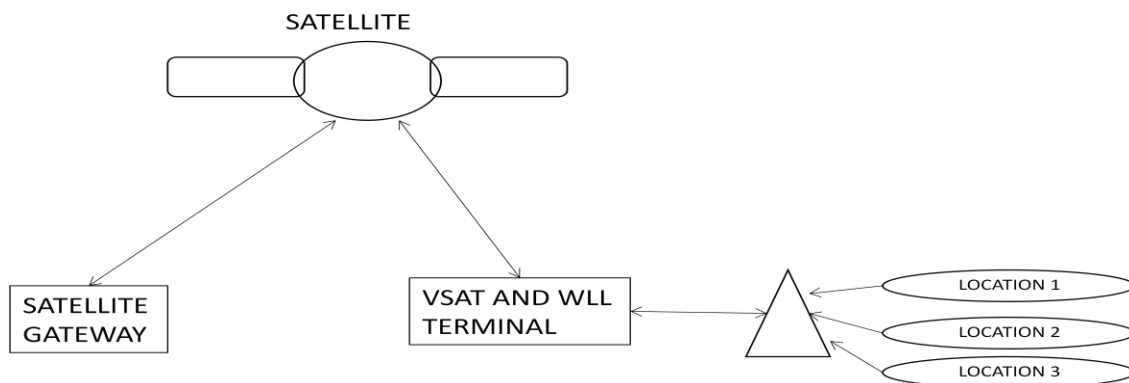
OPERATION:

Fig.2.9VSATArchitecture

- The wireless local loopis coupled with VSAT distribution architecture as shown in thefigure above.
- The Geo stationary satellite links a large no of VSATS with the main switching centre ina large city.

- It VSAT acts as a link to the local switching centre in the village or rural community with the final mile of telephone link being carried over with wireless local loop.
- The characteristic of a VSAT network are
  (i) It allows multimedia traffic to be broadcast directly to the end user but generally handles only small traffic.
  (ii) The user accesses the satellite in a demand assign multiple access (DAMA) mode. Wherever the data is send or received, a short massage above the transaction is replied in due course. For ex :- the credit card transaction
  (iii) The communication between satellite and earth station is completely automatic and transparent to the user.
  (iv) Due to the very less traffic, dedicated satellites are not used for this purpose instead leased or fractional leased transponder is used for medium to small network.

MultipleAccess:-
- The ability of satellites to carry many signals from multiple locations at the same time is known as multiple access.
- It allows the multiple earth stations to communicate simultaneously to a single satellite so that bandwidth of the satellite can be effectively used.
- The basic from of multiple access employed by all communication satellite is the use of multiple transponders.
- Though frequency reuse with multiple antenna beams & orthogonal polarization the spectrum can be reused several times.
- The frequency spectrum of the satellite is divided into smaller bandwidths which are allocated to the different transponders.
- This allows separate communication links to be established through the satellite on the basis of transmitter frequency.
- Depending on the method of allocation of the spectrum, access techniques are
  - (1) FDMA (Frequency division multiple access)
  - (2) TDMA (Time division multiple access)
  - (3) CDMA (Code division multiple access)
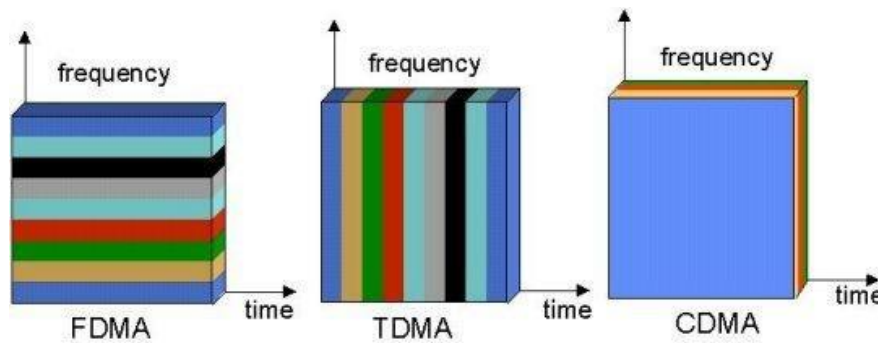 - (4) DAMA (Demand assign multiple access)

Fig.2.10MultipleAccessTechniques

FDMA:-

➢ Itisthefirstmultipleaccesstechniqueusedinsatellitecommunicationsystem.

➢ In this system, individual telephone channels can be shifted in frequency from basebandtoahigherfrequencyso thattheycanbestacked intoa group of channelsusingfrequency division multiplexing as shown as figure above.

➢ In this system all users use the satellite at the same time but with a unique allotted frequency band. It can be used both with analog & digital signals.

TDMA:-

➢ In this system a no. of earth station take their turn for transmitting burst of RF signal to a transponder.

➢ All the TDMA system are digital. This system allows a single transponder to be shared in time domain between RF carriers from different earth stations.

➢ Here the RF carrier from each earth station sharing a single transponder is sent as a burst at a specific allotted time.

➢ At the satellite, burst from different earth station arrived sequentially. So the transponder carries a near continuous signal sequence of short burst coming from different earth stations.

➢ The burst transmission is assembled at a transmitting earth station so that it will correctly fit with TDMA frame at satellite station.

➢ Theframe as a length varying from 125 μsecto manymilliseconds and theburst fromthe earth station must be transmitted at the correct time to arrive at the satellite at correct position within the TDMA frame.

➢ This requires synchronization of all earth stations in a TDMA network adding considerable complexity to the equipment at the transmitting station.

➢ Thetransmission time is to becloselymonitored to avoid anydataoverlapping.

- AtimeoverlapoftwoRFsignalsiscalledcollision&resultsislossofdataofboth carriers.
- HighspeedTDMAsystemsoperateataspeedof 120MBPS.

Advantages:-

    (1) Thedata can be easilyreconfigured for changingtraffic demands dueto the useof digital modulation techniques.

    (2) Lessnoise interference.

    (3) Itcan easilyhandle mixedvoice, video&data traffic.

    (4) Nonlinearityeffectofthetranspondercanbeovercomeasonesignaltakesthe whole band width of the transponder.

Disadvantages:-

    1) Alltheearthstationsneedtotransmitathighbitratetooccupythewhole bandwidth.

    2) Duetohighbitrate,hightransmittero/ppowerisrequired.

    3) Notwell suitedfornarrowband signalsfromearth station.

    4) Due to digital data, non-linearity characteristic of transponder may cause inter symbol interference. Hence equalizers are required at earth station to minimizethis effect.

CDMA:-

- Inthis system,ano.of userscan occupyallof thetransponder bandwidthat all time.
- CDMAsignalsareencodedsuchthatinformationfromindividualtranspondercanbe recovered by a receiving station that is having the code used at the transmitting end.
- So thereis averyless interferencebetween the encoded signals in thesameband width in the CDMA system.
- This provides a decentralized satellite network, as only the pair of earth stations that are communicating with each other need to coordinate their transition.
- Eachreceivingstation isallocatedaunique CDMAcode.
- Any transmitting station that wants to send data to the desired earth station must use the correct code.
- Thesecodeshavinglengthfromfewbitstomany1000ofbitsareknownaschips.To distinguish them from message bits of data transmitted a special sequence is used.
- The chip rate is always higher than the data rate which increases the speed of the digital transmission of the chip sequence.
- CDMAisalso knownasspread spectrum.

- Direct sequence spread spectrum (DSSS) is the only type of currently used technique in satellite communication.

Advantage:-

- Here the energy of the data is spread across a wide band width which makes the signal strength less than that of noise. Hence it can't be detected by anyunintended receiver. Hence providing high date security, the receiver having the codeofCDMAsignalcanonlyrecoverthedatathoughtheprocessofcorrelation.

- The base station is immune to jamming due to the use of a pseudo random noise sequence coding.

- An application like soft handoff is possible with this technology which is extensively used for mobile communication.

Disadvantage:-

Itislessefficient ishandlingthe bandwidthof satelliteascomparedtoTDMA&FDMA.

CommunicationSatellites:-

- Itisan artificialsatellite stationin spaceforthepurposeoftelecommunication.
- Moderncommunication satellitesuseLEO&GEO.
- For fixed point to point services they provide a microwave relay radio technology complementary to that of communication through cables. They are also used for mobile applicationsuchascommunicationtoships,vehicles,aircrafts.,handheldterminals&for TV & Radio broadcast for which application of other technologies such as cable TV is impractical or impossible.
- Thecommunication satellites areusuallycomposed of followingsubsystems.
  - (i) Communicationpay load, normally composed of transponders, antennas & switching system.
  - (ii) Propulsionsystemsusedtobringthesatellitestoitsdesiredorbit.
  - (iii) Station keeping tracking & stabilization subsystem used to keep the satellite in the right orbit with its antenna pointed in the right direction & its power system facing towards the sun.
  - (iv) Power subsystem use to power the satellite system normally composed of solar cells and batteries that maintain the power during solar eclipses.

(v) Command and control system which maintains communication with ground control stations. The ground control station monitors the satellite performance & controls their functionality during the entire life cycle of the satellite.

➢ Iridium system is the 1st communication satellite system launched by USA for long distance international telephone services.

➢ The fixed public switched telephone network (PSTN) relays telephone calls from landline telephone to the earth station, where they are transmitted to a GEO satellite.

➢ The downlink follows an analogous as path.

➢ The use of fiber optic cables reduce the importance of satellite telephoning but still it is extensively used for remote unreachable islands where land line or underwater cable system does not exist.

➢ The satellite phones directly connect to the LEO or GEO satellite. Calls are then forwarded to a satellite teleport connected to the PSTN.

➢ The TV broadcasting is also now uses of the advantages of satellite communication. The direct broadcast system provides a major TV services in North America.

Satellite Digital Radio:-

➢ The satellite radio signal that is relayed though one or more satellites and thus can be received in much wider geographical areas than FM radio station.

➢ Mobile services such as SARIUS, XM, and worldspace allow listeners to roam across the entire continent, listen to the same audio program any where they go. Other services such as MUZAK'S satellite deliver contained, required a fixed location receiver and dish antenna system.

➢ In all cases the antenna must have a clear view of the satellite i.e. line of light communication.

➢ In areas where tall building, bridges or even parking areas obscures the signal, repeaters can be placed to make the signal available to listeners.

➢ The satellite radio uses 2.3 GHz 'S' band in North America and generally shares the 1.4 GHz 'L' band with local digital audio broadcasting stations elsewhere.

➢ It is a type of direct broadcast system and is strong enough that it receives the signal.

➢ The curvature of the earth limits the reach of the signal but due to high orbits of the satellite, 2 or 3 satellites usually sufficient to provide the radio service.

➢ Local repeaters similar to broadcast translator booster enable signal to be available even if the view of the satellite is blocked. For Tunnels, Repeaters are used.

CH-3 OPTICAL COMMUNICATION

INTRODUCTION

➢ The common system utilizing the optical energy for data transfer from transmitter to receiver is known as optical communication.

➢ In order to carry the data through optical means, optical fiber cables are used.

➢ The experimental wavelengths of optical energy which are least attenuated in the channel is shown in the following graph.

➢ The optical window shows that the signal will be less attenuated at the wavelength 850nm, 1300 nm, 1550 nm.

➢ So the optical source & the optical detector are designed for the above mentioned wavelength.
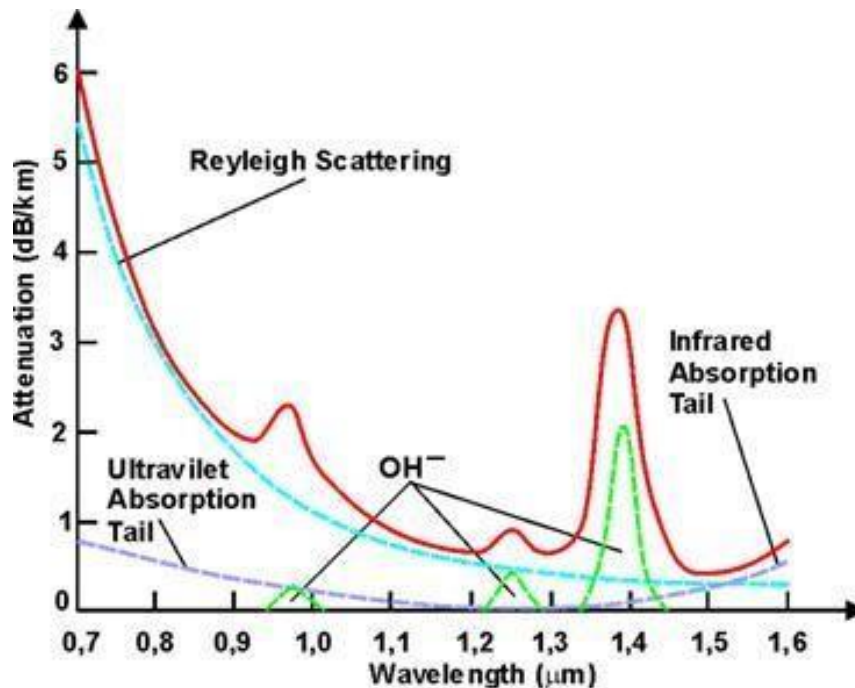
Fig.3.1 Optical Fiber operating wavelengths

The advantages of optical fiber common system over the copper cable lines

1)   For Long distance transmission:-

Optical fibers have lower transmission losses compared to copper wires. (Attenuation/1 km channel: copper is 25db and optical fiber is 0.2 db).

Consequently data can be sent over longer distance there by reducing the number of intermediate repeaters needed to boost and restore signals in long spans. This reduction in equipment and component decreases the system cost & complexity.

2)   Largeinformation capacity:-

Optical fibers have wider bandwidth than copper wires. So that more information can be send overa single physical line, (for Example thebandwidth of co-axial line is 400 MHz whereas foroptical fiberit is 1 to 10GHz).This propertydecreases theno. of physical lines required for sending given amount of information.

3)   Smallsize&low weight:-

The low weight small dimension of fibers offers a distinct advantages over heavy bulky wirecablesincrowdedundergroundCTductsorinceilingmountedcabletrays.This feature is of important in aircraft, satellite & ships where small, light weight cables are advantageous & tactical military application where large amount of cables must be laid & retrieve rapidly.

4)   Immunityto ElectromagneticInterfere:-

Asthecoreof thefiber opticcable ismadeof dielectric material, it doesn't carrycurrent.

Thismakestheopticalfiberimmunetoelectromagneticinterferenceeffect.

5)   Enhancesafety:-

Optical fiber offers a high degree of operational safety, since they don't have theproblem of ground loops, sparks and potentially high voltages inherent in the copper wires. However precautions from laser light emission need to be observed to prevent possible eye damage.

6)   Increasedsignalsecurity:-

An optical fiber offers a high degree of data security. Since the optical signal is well confined within the fiber and opaque coating around the fiber absorbs any signal emission. This feature is in contrast to the copper wire where electrical signal potentially could be tapped easily. The fibers are attractive in application where information security is important such as financial, legal, government & military systems.

7)   Crosstalkverylittle:-

Leaking of light from an optical fiber is extremely small and almost no external light enters the fiber. This leads to no crosstalk between optical fibers laid in the close vicinity or nearby.

8)   GoodEnvironmentalqualities:-

Fibersarechemicallyinert,electricallyinsulatorsandresistanttohightemperature.

Thereforetheycan beinstalled in hazardous environment conditions.

OpticalFiberCommunicationSpectrum:
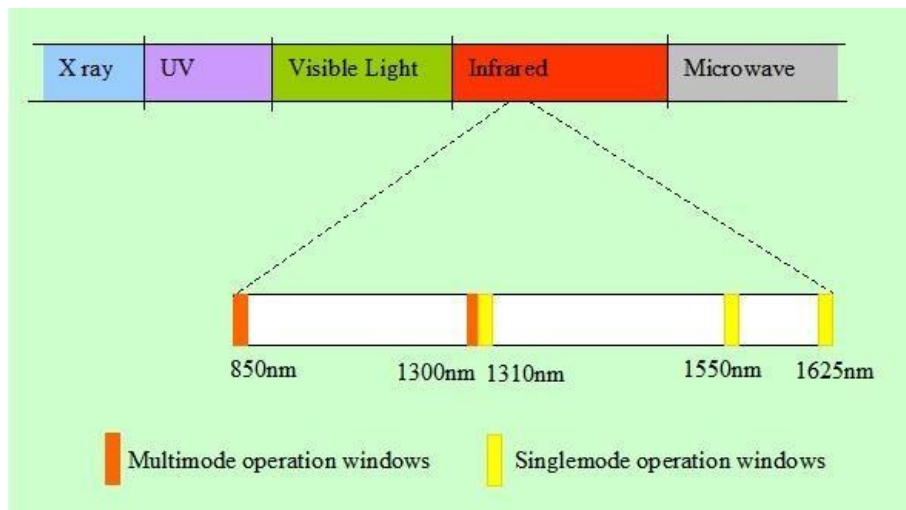
Fig.3.2OpticalSpectrum

OPTICALFIBERCOMMUNICATIONLINK:-

➢ Thekeyelement of an optical fiber communication link can bebroadlyinto foursections.

    (i)   OpticalTransmitter Section.

    (ii)   OpticalReceiverSection.

    (iii)   Optical Link.

    (iv)   IntermediateSignalRegenerationCKT/section

Fig3.3OpticalLink

(i) Optical Transmitter:-

➢ Theopticaltransmitterconvertstheelectricalsignalintointensitymodulatedoptical signal to be transmitted through the optical fiber.

➢ Thesourcesusedto converttheelectrical signaltoopticalarelaserdiodesorLEDs.

(ii) Optical Receiver:-

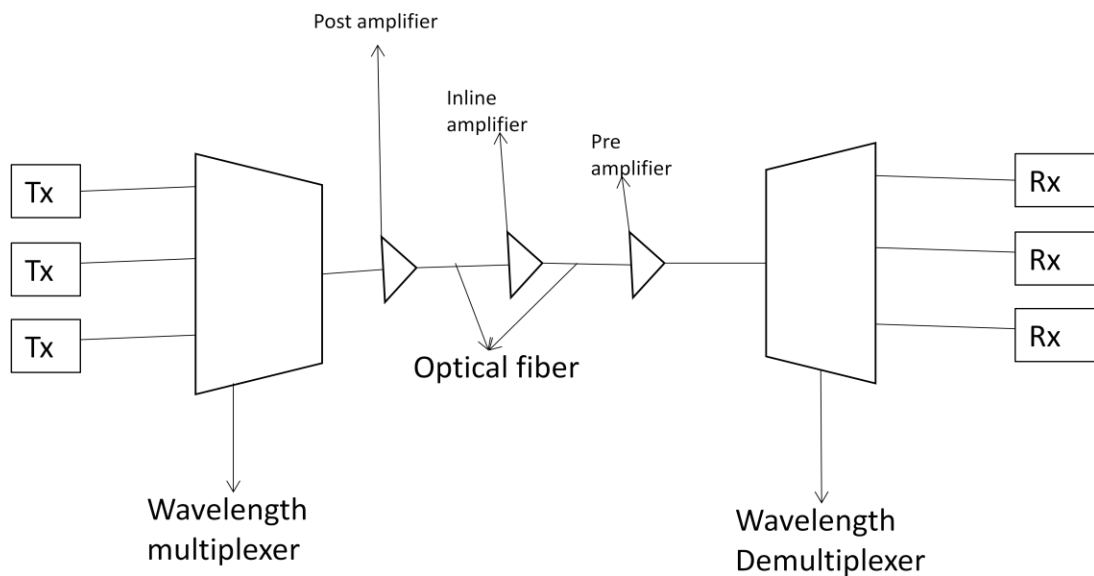➢ The optical receiver receives the optical signal from optical fiber cables & converts it to the electrical signal.

➢ ThecommonlyusedopticaldetectorsareP-I-Ndiode&Avalanchephotodiode(APD)

(iii)Optical fiber link:-

➢ The optical fiber link connects the transmitter and receiver and hence provides the pathfor data communication from transmitter to receiver.

➢ Dependingonthelengthofopticalfiberlink,thetypeofopticalfibersselectedasfollows.

Length   Opticalfibertype

Up to 20km-------------------------Multimode stepIndex

20 to 100km----------------------MultimodegradedIndex

Morethan 100km ----------------SinglemodestepIndex

(iv)IntermediateRegenerationSection:-

➢ When the optical signal passes through the optical fiber, It gets attenuated and the signal strength becomes weak.

➢ When the long distance link is designed, the signal is loss becomes dominant. Therefore intermediate Repeater sections are used to amplify the signal so that it can be detected at the receiver side.

➢ These Repeaters are electrical Circuits. Therefore the optical signal is 1st converted to electrical signal and then amplified & Re-again converted back to the optical form.

➢ Hencethecoastofthese Repeatersisquitehighascomparedtomicrowave Repeaters.

OpticalFiber Construction:-

Theoptical fibercable basicallyconsist of 3 dustinglayer namely,
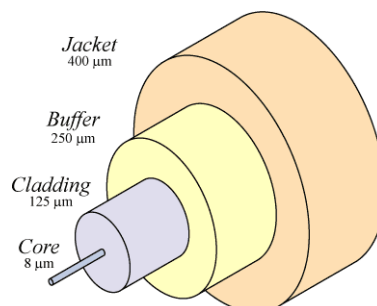
(1) Core.

(2) Cladding.

(3) Buffercoating.

Fig.3.4 OpticalFiberstructure

➢ Thecoreis modeof upsilicahavingmorerefractiveindexthen that of thecladdinglayer.

➢ Thecorecarriesthedata (optical) fromtransmitter tothereceiver.

➢ The core is surrounded by a solid dielectric cladding which reduces the scattering lossthat results from dielectric discontinuities at the core surface and also providesmechanical strength to the fiber core.

➢ Italsoprotects thecorefrom observingsurfacecontaminates.

➢ Generally the core is made of up pure silica gas (Sio_2) and surrounded by a glasscladding.

➢ Thebuffercoatingsaremadeupofelastic abrasionresistanceplasticmaterial.

➢ This material adds further strength to the fiber and mechanically isolates the fibers from small geometrical irregularities, distraction, and roughness of adjacent surfaces.

➢ Depending on the variation of the refractive index profile of the core, the fiber can be classified into two groups-

(i) Stepindexfiber.

(ii) Gradedindexfiber.

The optical fiber in which the refractive index of the core is uniform throughout and under goes an abrupt change (Step) at the core - cladding boundary is known as step index optical fiber.

➢ Variation in the material composition of the core the optical fibers can be classified into following 3 categories.

(i) Singlemodestep Indexfiber.

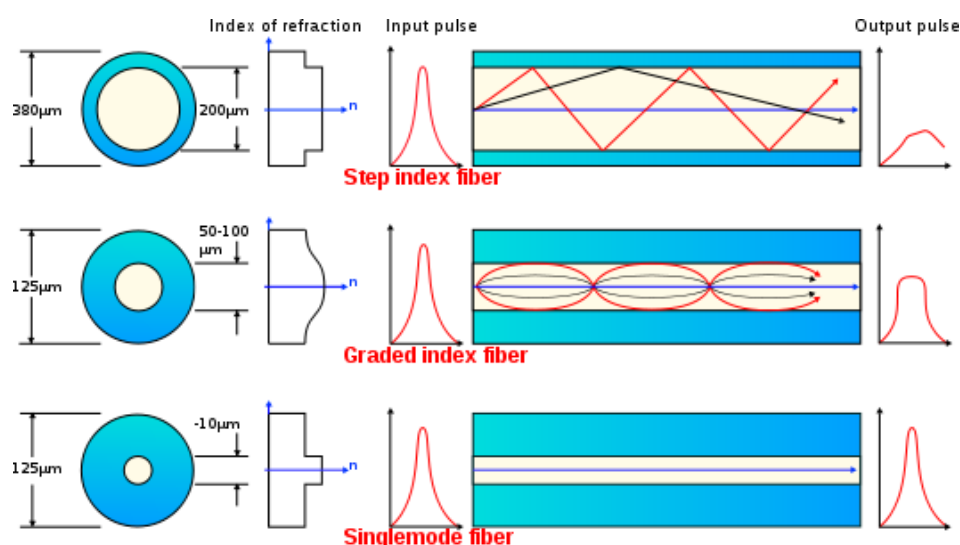(ii) MultimodestepIndexfiber.

(iii) MultimodeGraded Indexfiber.

Fig.3.5Opticalfibertypes

1) SINGLEMODESTEP INDEXFIBER:-

➤ Commerciallyavailablesingle modefibers arestep index.

➤ Theyarehighqualityfibersusedforwideband,longdistancetransmission&aregenerally fabricated from doped silicon.

➤ In step Index fiber the refractive Index of the core is uniform throughout & under goes an abrupt change at the core-cladding boundary.

➤ Thesinglemodestepindexfiberhasanattenuationof2to5dbperkmat850nm operating wavelength & 0.35 db/ km at 1300 nm and 0.21 db/ km at 1550 nm.

➤ These fibers are ideally suitable for high bandwidth, very long distance application such as telephone common.

➤ Thesefibersneedto be coupled withlaserdiodesources only.

2) MULITMODESTEPINDEXFIBER:-

➤ These fibers have reasonable large core diameter & large numerical apertureto facilities efficient coupling of non-coherent light sources such as LED.

➤ Themultimodefiberscansupportupto60,000modes.Thetypicalnumericalaperture ranges from 0.16 to 0.5.

➤ Itoffers aattenuation2.6to250 db/kmat850 nmwavelengthand 0.4db/km at1300 nm.

➤ Itoffers abandwidthof6to50 MHz.

➤ Itissuitableforshort distance,limited bandwidth &relativelylowcost application.

3) MULTIMODEGRADED INDEX FIBER:-

➤ In multimode graded index fibers, the core refractive index is mode to very as a function of the radial distance from the centre of the core of the fiber.

➤ Thetypicalvalueofnumericalapertureis 0.2to 0.3.

➤ Theproblemofintermodaldispersionobservedincaseofmultimodestep indexfibercan be reduced by using a graded index profile in the fiber core.

➤ Thisallowsmuchlarger bandwiththanstepindexfiber.

Advantagesof MMfibersoverSMfibers:-

(1) The larger core diameter of MM fiber make it easier to lunch optical power into the fiber and facilitate the inter connection of similar fibers.

(2) The light can be launched into a multimode fiber using a LED source where as the single mode fiber must be excited by Laser diodes.

(3) Although LEDs has less optical powers than laser diode, they are easier to make, Less expensive, Required Less complex driving CKT & having longer life time than laser diodes. So it makes them suitable for low cost short distance transmission system.

MODESOF PROPAGATION:-

➢ In optical fiber the core – cladding boundary condition leads to a coupling between the electric & magnetic field component. This gives rise to hybrid modes. The hybrid modes are designated as HE mode and EH mode.

➢ Theorder ofamode isequal to thenumber Efieldzeros existingacrossthe optical fiber.
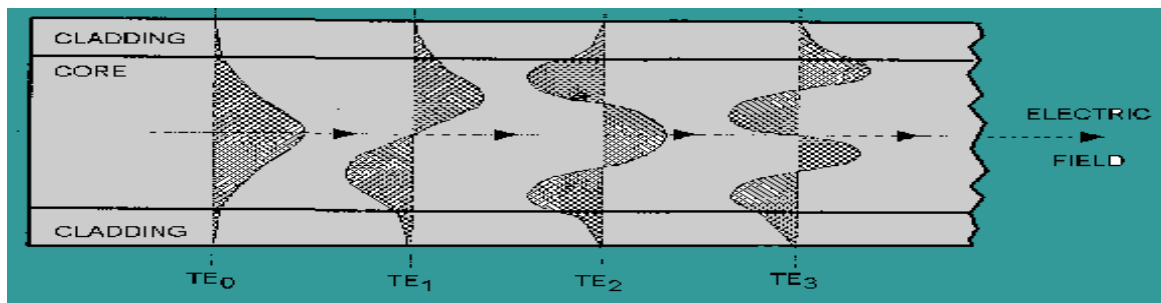
➢ Thefollowingfigureshows fewlower ordermodes inoptical fiber.

Fig.3.6Modesof operation

➢ Fromthe abovecharacteristic curvethe followingpointsmaybenoted.

(1) The electric fields of the guided modes are not completely confined to the core. They don't go to zero at the core cladding interface.

(2) The field varies harmonically in the core region of refractive index n_1 and decays exponentially in the cladding region with refractive index n_2.

(3) For lower order modes, the fields are concentrated near the axis of the optical fiber and a very small penetration towards the cladding region is observed (TE_O mode).

(4) For higher order modes, the fields are distributed more towards edges of the core and penetrate further into the cladding region.

➢ In addition to supporting a finite no of guided modes, the optical fiber has infinite no of radiation modes. These are not confined to the core region but guided through the cladding region.

➢ The radiation field basically results from the optical power which is outside the fiber acceptance angle being refracted out of the core.

➢ Because of the finite radius of the cladding some of these radiations gets trapped in the cladding, thereby causing cladding mode to appear.

➢ As the core & the cladding modes propagate along the fiber, mode coupling occurs between the cladding modes & higher order core modes or guided modes.

➢ This coupling occurs because the electric fields of the guided core modes are not completely confined to the core but extends partially into the cladding & vice versa.

➢ Thusdiffusionofpower back&forthbetweenthecore &claddingmodesoccurs.

- Generally this results in the loss of power from the core mode.
- In addition to the bounded & refracted mode, another category of modes called leaky modes is present in the optical fiber.
- These leaky modes are only partially confined to the core region & attenuated by the continuously radiating their power out of the core as they propagate along the fiber.
- A mode remains guided if the following condition is satisfied.

$n_2 K < \beta < n_1 K$

where n_1 = Refractive index of core.

n_2 = Refractive index of cladding

k = wavefactor = $\frac{2\pi}{\lambda}$

β = Propagation factor.

Optical Ray Theory:

SNELLS LAW:-

- The Snell's law state that when the light beam passes through different materials, some change in the velocity is observed.
- If the refractive index of incident medium be n_1 & the refractive index of the 2nd medium be n_2, the co-efficient of refraction is given by

$\frac{1}{\mu} = \frac{sin i}{sin r} = \frac{n2}{n1} = \frac{v1}{v2}$

Where μ = co-efficient of refraction.

i = Incident angle measured for the normal of surface.

r = Refracted ray angle measured for the normal to the surface. n_1 = refractive index of 1st medium.

n_2 = refractive index of 2nd medium.

v1 = velocity of light in 1st medium

v2 = velocity of light in 2nd medium

- The refractive index of any medium is given by n = velocity of light in vacuum divided by velocity of light in medium.

$n = \frac{velocity\ of\ light\ in\ vaccum}{velocity\ of\ light\ in\ medium}$

- Few example of refractive indies for

For   Air = 1   Glass   = 1.5

Water = 1.33   Diamond = 2.43

- If for the angle of incidence (i) is such that the refracted ray angle (r) is 90^0, then the incident angle is known as the critical angle.

- For any angle of incident higher than the critical angle, the total internal refraction (TIR) takes place.

- Hence the critical angle is given by
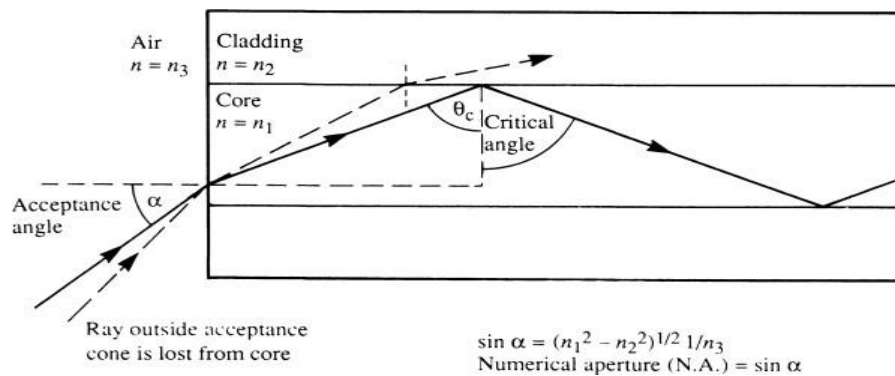
$$\theta_C = \sin^{-1}\frac{n2}{n_1}$$

Fig.3.7 Refraction

- In the figure 3.7 consider the ray i_2 at the critical angle θ_C in the fiber at the core cladding boundary.

- It is observed that these rays enters the fiber core at an angle θ_a (α) to the fiber axis and is refracted at the air-core interface before transmission to the core- cladding interface at an critical angle.

- So any ray which is incident into the fiber core at an angle greater than θ_a (ray dotted) will be transmitted to the core cladding interface at an angle less than θ_c and will not be totally internally reflected.

- So for light ray will be transmitted by the total refraction within the fiber core, they must be incident in the fiber core within an acceptance cone define by conical half angle θ_a.

- Hence θ_a is the maximum angle to the axis of the core at which light ray may enter the fiber core in order for propagation.

- It is also sometime referred as maximum or total acceptance angle for the fiber.

Numerical Aparature:-

- Considering the refraction at air–core interface according to Snell's law n_o sin

$\theta_i = n_1 \sin \theta_r$

$n_o \sin\theta_i = n_1 \sin(90 - \theta_c)$ (Limiting case)

- Limiting case for total internal refraction $\theta_i = \theta_a$ and as the incident medium is air $n_o = 1$ applying this factors we have $n_o \sin \theta_i = n_1 \sin (90-\theta_c)$

$n_o\sin\theta_a = n_1\cos\theta_c$

$\qquad = n_1(1-\sin^2\theta_c)^{1/2}$

$\qquad = n_1(1-\dfrac{n_2^2}{n_1^2})^{1/2}$

$\qquad = n_1(\dfrac{n_1^2-n_2^2}{n_1^2})^{1/2} = (n_1^2-n_2^2)^{1/2}$

- The numerical aperture is a dimension less quantity having value less than "1" and does not depends on the core dimensions.
- It establishes the relation between the acceptance angle and the refractive index of core &cladding.
- If the fractional change in the refractive index of core & cladding given by $\Delta = (n_1-n_2)/n_1$

Thenthenumericalaperture $N = n_1(2\Delta)^{1/2}$

- The typical; values of Δ are for single mode fiber $= 0.2$ to 1% and for multi mode fiber $= 1$ to 3%. Δ
- Ex:-forasiliconopticalfiber $n_1 = 1.5$ $n_2 = 1.47$ calculatethecriticalangle,numerical aperture & maximum acceptance angle.

$\qquad n_1 = 1.5$

$\qquad n_2 = 1.47$

$\qquad N_A = (n_1^2 - n_2^2)^{1/2} = 0.298$

$\qquad \theta_c = \sin^{-1}(n_2/n_1) = 78.5$

$\qquad \theta_a = \sin^{-1}(NA) = 17.33$

OpticalSource:-

- Theoptical sources musthavethe followingcharacteristics.
  - (i) Thelight output should be highlydirectional.
  - (ii) Thesourcesshouldbeliner(o/plightisproportionaltoelectricalI/pcurrent).
  - (iii) Itemitlightrayatdesiredwavelength(850nm,1300nm,1550nm)
  - (iv) Mustbecapableof signal modulation.
  - (v) Mustproducesufficientopticalpower.
  - (vi) Shouldhaveanarrowspectral bandwidth.
  - (vii) Mustproduceastableoptical output.
  - (viii) Economicallycost effective&longer life span.
  - (ix) Should haveveryfastresponse.
  - (x) ShouldhavesimpledrivingCKT.

- The semiconductor light sources used for optical fiber communication system are two types.
  - (i) LED
  - (ii) LASER
- A PN junction that consist of direct band gap semiconductor material act as an active or re-combination region.
- When the PN junction is forward biased electron & holes are recombined either radiatively (emitting light photons) or non-radiatively (emitting heat). This is the simple LED operation.
- In Laser the photon is further processed in a resonance cavity to achieve a coherent, highly directional optical beam with narrow beam width.

Basic LED operation:-

ABSORPTION:-

- Whenanelectronjumps fromahigherenergystate(CB)toalowerenergystate(VB),the difference in energy ($E_2 - E_1$) is radiated as a photon of energy; [EG = hv] either in form of light (radiating re combination) or as heat (non radiating recombination).
- If the photon energy hv of the incident light of frequency "v" is about the same as the energy difference [Eg = E_2- E_1], the photon is absorbed by the atom which ends up in a exited state.
- In the exited atoms, electrons eventually returns to their ground state & emit light in this process light emission can occur through two fundamental process.
  - (a) Spontaneous emission.
  - (b) Stimulatedemission.

(a)Spontaneousemission:-

E_2(CB)

hv

E_1(VB)

(INLED)
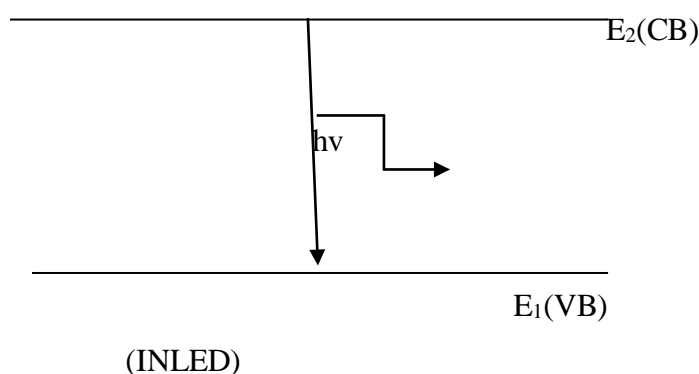
- Incaseofspontaneousemissionphotonsareemittedinrandomdirectionwithno phase relation among them.

(b)Stimulatedemission :-

E$_2$(CB)

hv

hv

hv

E$_4$(VB)

(IN LASER)
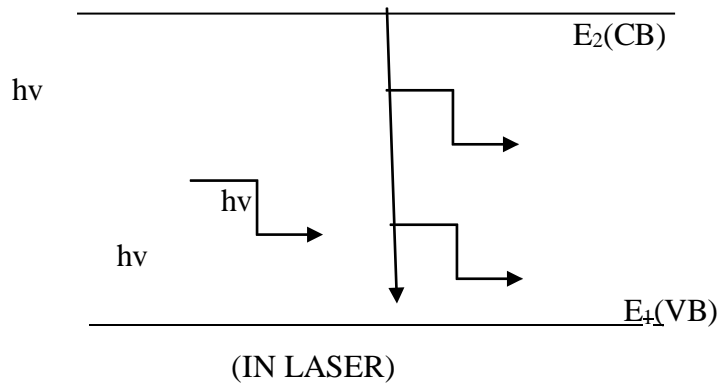
Fig.3.8 Electronemission

➢ Stimulatedemissionisinitiatedbyanexisting photon.

➢ The remarkable feature of stimulated emission is that the emitted photon matches with the original incident photon not only in energy (or frequency) but also in other characteristics such as phase & direction of propagation.

➢ The radiation emitted from ordinary optical sources (LED) occurs in a random manner and hence the sources are called non-coherent sources.

➢ In orderto producecoherent optical source(Laser) &amplifythelight beam, therateof stimulated emission must be increased above the level of spontaneous emission.

➢ The stimulated emissionmust dominate over the absorption and the spontaneous emission. In a two energy level system in which the spectral density of the radiation energy at the transition frequency and the density of atoms in the upper energy level should be more or increase w.r.to. the density at lower energy level. This phenomenon is known as population inversion.

➢ For stimulated emission to occur the no of electrons in the conduction band must exceed the number of electrons in valence band.

➢ Thisincreaseto beaccomplishedthrough theprocessof pumping.

➢ Pumping means to elevate the electron from VB to CB by passing some amount of current to the active region of the laser device.

➢ Stimulated emission of radiation will start to take place at a minimum current level at the active region of the laser structure, called the threshold current. Below this threshold current, stimulatedemissiondoesn'ttakeplacebecauseradiation &absorptionlossesoccurringinside the active region offset the additional photon generation below the threshold current.

DoubleHeteroStructureEdgeEmittingLED:-

➤ In normal PN junction in which both p- type & n- type semiconducting material are made up of same base material (Ge or Si), the recombination length of charge carriers is increased. Hence they are not confined to the vicinity of the PN junction.

➤ The result in carrier confinement problem to overcome this problem a thin layer is inserted between the p- type and n – type layer such that the band gap at the sandwich layer is smaller than the surrounding layer its role is to confine the carrier injected into it under forwardbias.

➤ The carrier confinement results discontinuity of band gap at the junction between two semiconductors which have the same crystalline structure but different band gap such junctions are called hetero junction. This phenomenon is used in LEDS for carrier confinement as shown in the figure.
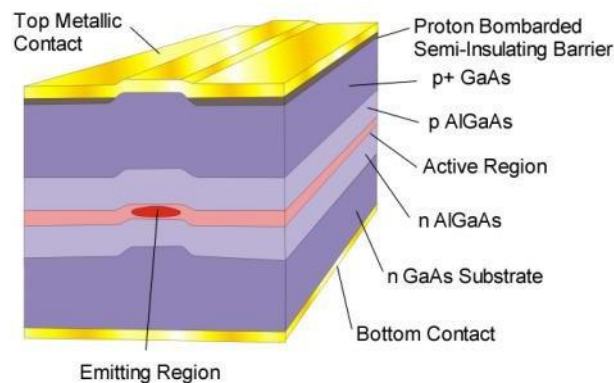
Fig.3.9EdgeEmittingLED Structure

➤ Most of the propagating light emits at one end face only due to the reflector on the other end face and an anti reflection coating on the emitting end face.

➤ Thetwoguidinglayershavingrefractiveindexmorethanactiveregionformsawave guide channel that guides the optical radiation towards the fiber core.

➤ Theemissionpattern oftheedge emitteris highlydirectional .

OpticalLaser:-

   FEBRYPAROT RESONATOR:-

➤ The light amplification in the laser, when a photon colliding with an atom in the excited energy state causes the stimulated emission of a second photon & they both the photons release two more & the process goes on cumulatively.

➤ Continuation of this process creates avalanche multiplication, when the electromagnetic waveassociatedwiththesephotonsareinphase&amplified,coherentemissionis

obtainedtoachievethislaseraction,itisnecessary tocontainphotonswithinthelaser medium &
maintain the condition for coherence.

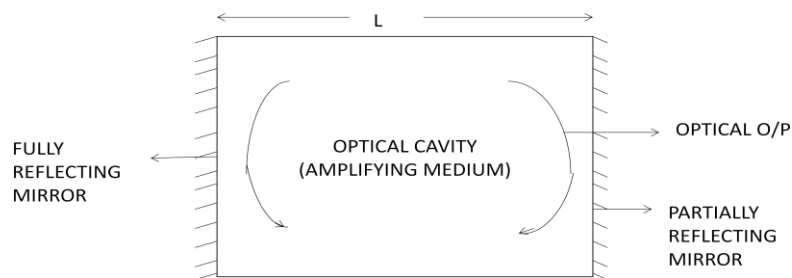➢ Itis perform byplacingmirrorat eitherside of theamplifyingmedium.

Fig.3.10LASERWorkingPrinciple

➢ The optical cavity so formed is more analogous to one oscillator than an amplifier and it
provides the positive feedback of the photons by reflection at the mirror at either end of
the cavity. Hence the optical signal is feedback manytimes while receiving amplification
as it passes through the medium.

➢ A stable o/p is obtained when the optical gain is equal to the total losses occurred in the
amplifying medium.

PhotoDetector

➢ The photo detector senses the luminance power (optical radiation) falling on it & convert
the variation of this optical power into a corresponding variable electric current.

➢ IngeneralP-I-NdiodesorAPD(Avalanchephotodiode)areusedinphotodetector.

P-I-NDiode:

➢ A simple way to inverse the depletion region width is to insert a pure semiconductor
material (Intrinsic semiconductor) between the PN junctions.

➢ Since the middle layer consists of intrinsic material, such structure is known as P-I-N
diode. Because of the intrinsic nature the middle layer, it offers a high resistance & most
of the voltage drop occurs across it. As a result, a large electric field exists across the "I"
layer.

➢ So the depletion region extends throughout the "I" region & its width "W" can be
controlled by changing the middle layer thickness.

➢ The optimum value of "W" depend a compromise between speed & sensitivity of the
photo detector.

ELECTRIC FIELD DISTRIBUTION UNDER REVERSE BIAS
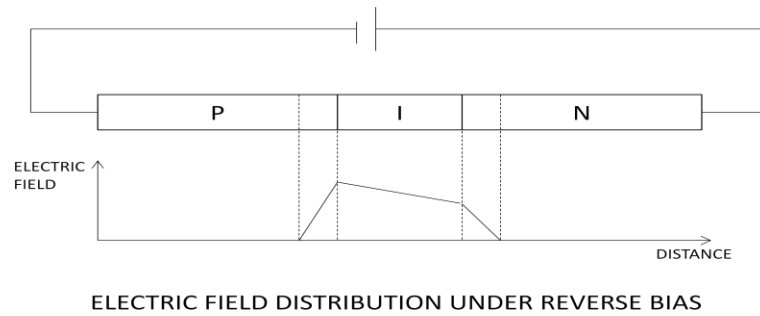
Fig.3.11P-I-NDiodefield distribution

Avalanchephoto diode (APD)

Incident photon
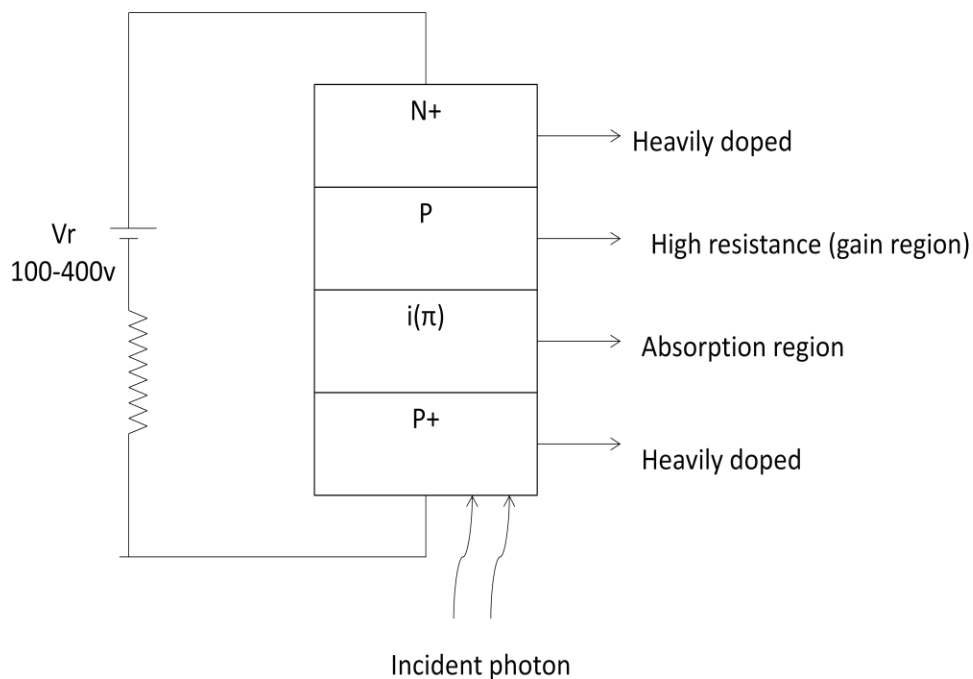
Fig.3.12 AvalanchePhotoDiode

➢ In APD we require high reverse bias voltage (100 to 400v) which creates an extremely high electric field region approximately 3×10^5 V/cm. in the depletion region here mostof the photons are absorbed & the primary carrier pairs are generated.

➢ Dueto thehigh electricfield region, thechargecarriers acquiresufficient energyto excite new carrier pairs. This process is known as Impact Ionization & this leads to avalanche break down in ordinary diodes.

➢ The high potential is required in order to create new carries by impact ionization. The carrier multiplication factor achieved by this process is of the order of10^4.

➢ Although the APD is moresensitive than the P-I-N diodes but it is verycostly& complex driving ckt limits its use for high end applications.

Wavelength Division Multiplexing(WDM):-

➢ The optical fiber cable is capable of carrying the data over a very wide spectral band width.

➢ To utilize the entire band width efficiently, multiple signals of lesser bandwidth are send simultaneouslyover the optical link. Since the light sources used can emit a narrow wave length band, many such sources can be coupled a single fiber simultaneously in different segments of this wavelength range.

➢ The technology of combining a no of such independent information carrying wavelength on to a single fiber is known as wave length division multiplexing.

➢ For practical purposes a verity of wavelength tunable components are used to produce different wave length for signal transmission over a single channel.

➢ The application of wavelength division multiplication technique includes long distance terrestrial communication, under Sea transmission system & metro networks etc.

➢ The use of "WDM" allows different signals in different coding to be sent simultaneously & independently over a fiber without the need for a common signal structure at higher data rates.

OPERATION

➢ In WDM, the discrete wavelengths forms an orthogonal set of carriers which can be separated, routed & switched without interfering with each other.

➢ This isolation between the channels holds as long as the total optical power intensity is kept low to prevent scattering & wave mixing.

➢ The implementation of "WDM" network requires both passive and active devices to combine, distribute, isolate & amplify optical power at different wave length.

➢ The passive devices require no external control for their operation where as the active devices can be control electrically & optically, thereby providing a large degree of network flexibility.

➢ The active WDM components include tunable optical filters, tunable sources &optical amplifiers.

➢ Thefollowingfigureshowstheimplementation ofatypical WDM link.
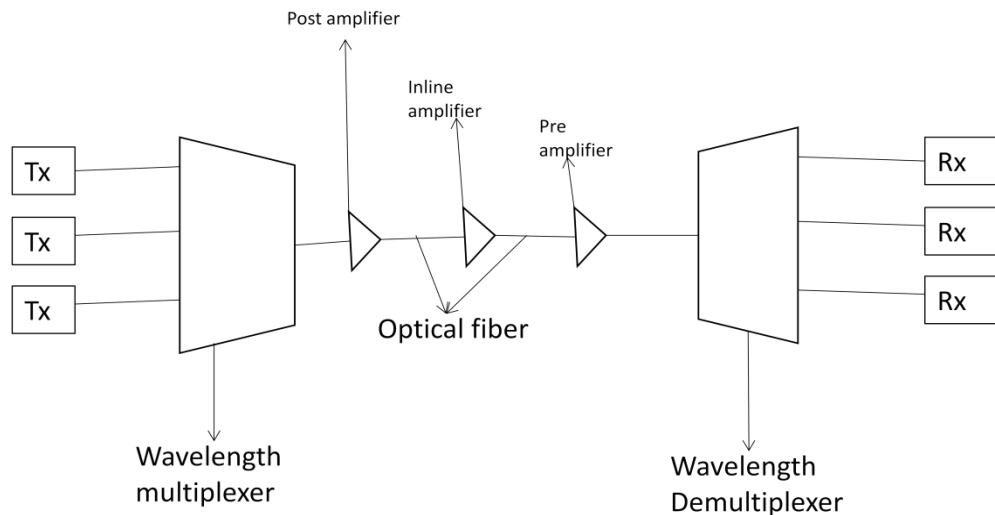
Fig.3.13WavelengthDivision Multiplexing

➢ At the transmitting end there are several independently modulated light sources each emitting signal at a unique wavelength. Here a multiplexer is required to combining these optical outputs into a continuous spectrum of signal which is further coupled to a single fiber.

➢ Theoptical signal isamplified intermittentlybytherepeaters in thechannel.

➢ At the receiving end a de-multiplexer is required to separate the optical signals into appropriate detection channels for signal processing.

➢ The operational frequency band allocated to a particular light source ranges from 25 to 100 GHz (0.25 to 0.8 nm).

CH-4 TELEPHONE SWITCHING SYSTEM

Introduction:-

The telephone system provides the means to pass the information from one terminal (calling subscriber) to other terminal (Called Subscriber).

The telecommunication system broadly comprises of following basic elements.

      (1) End instrument or Telephone set.

      (2) Transmission system or connecting cables.

      (3) Switching system or Exchange.

      (4) Signaling.

The end instruments are responsible for transmitting and receiving the audio signal or data. The end instrument may be telephone handset or computer system.

Telephone Handset:-

The telephone is basically a trans-receiver. The transmitter of telephone converts the audio signal to an equivalent electrical signal and the receiver converts the electrical signal into audio signal.

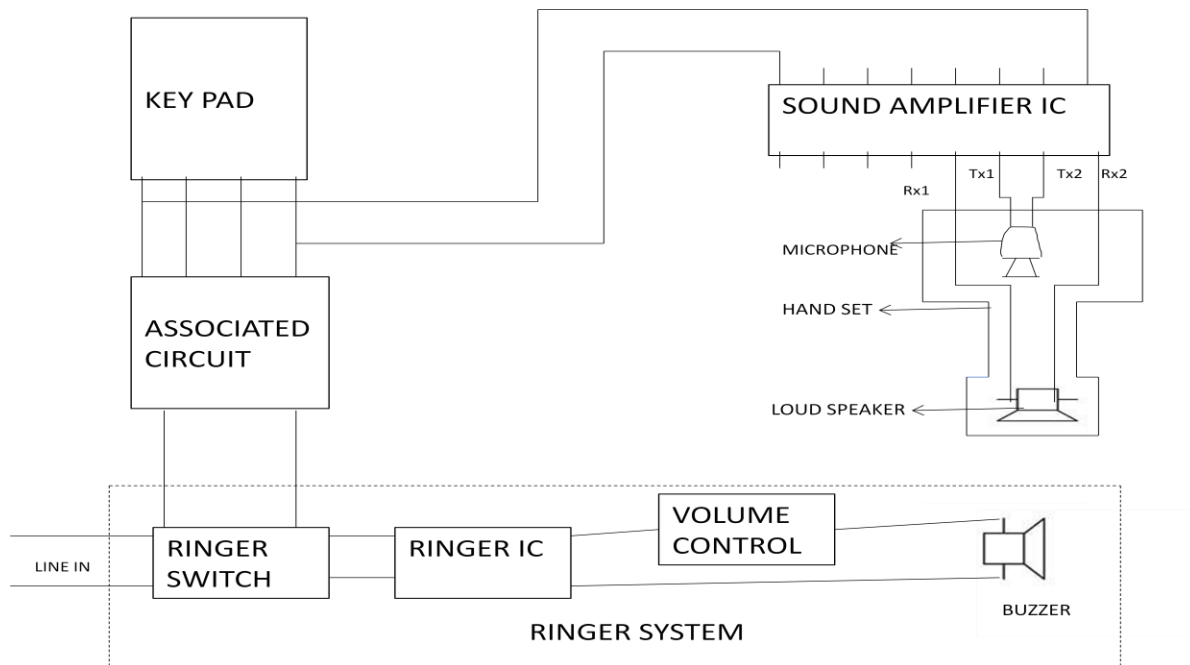The Circuit of a telephone base unit is shown in the fig. 4.1 below.

Fig.4.1 Telephone Base Unit

Themodern telephoneset consist of

(i) KeypadalongwithdialerIC.

(ii) SoundAmplifier IC.

(iii) Associatedckt.

(iv) RingerIC.

(v) Buzzervolume control.

(vi) Buzzer.

(vii) Ringerswitch.

Ringer:-

➢ Ringerisadevicethatalertsthecalledsubscriber. Theoriginal equipmentincludesan electromagnet and a ringer to generate AC signal.

➢ Thissignalproducesthe ringingalarm.

➢ Nowadays theringingsignals aresent bytheexchange.

➢ When a calling subscriber calls another subscriber, the exchange relays are activated and the ringing signal having frequencies 20KHz are passed to the called subscriber.

➢ Modernringersystemwhichincludesringerswitch,ringerIC,andringervolume control with Buzzer.

➢ PopularringerICSareKA2418-B,LS1240,HA31002P.

Hand Set:-

Thehandset connected tothe sound amplifierIC can bebroadlydivided into two parts.

(I) Transmittersection

(II) Receiversection.

Transmitter:-

➢ Thetransmittersectionconsistsofacarbon microphone.

➢ Oneside oftheenclosure is flexibleandconnectedtoa mechanical diaphragm.

➢ Whenthesoundwaveimpingesthisdiaphragm,it oscillatesorvibratesresultinginan uneven distribution of the carbon granules. This in turn changes the resistance of the carbon microphone.

➢ If a voltage is applied to the microphone, this variation in resistance will vary the current throughthe CKT proportionality.

➢ Hence the variation in current is proportional to the resistance of carbon Micro Phone which is further proportional to the vibration of the diaphragm in turn proportional to the audio signal.

➢ The voltage required to charge the carbon granules is provided from the exchange which comes from the central battery system.

➢ Theminimumcurrentisrequiredfortheproperoperationofcarbonmicrophoneis 23 mAmp and a voltage level maintain is 42 to 60 volts(48 volt practically)

➢ Thecentral batteryprovides thefollowing

      (i)   ACringingvoltagefor buzzer.

      (ii)   Metallicpathtoprovidechargeto carbon granules.

      (iii)   GeneratesthepulsatingDCcurrent duringdialing.

Receiver:-

➢ Thevaryingsignalfromthecallingsubscriberiscoupledtothereceiverofcalled subscriber.

➢ Thereceiveris anelectromagnetwithattachedmagnetic diaphragm.

➢ The diaphragm is made of cobalt iron & slightly conical in shape in order to providera uniform pressure distribution on the ear drum.

Thedialing unit:-

  Therearetwo dialingmethodused in telephone system.

     (I) Pulse dialing.

     (II) Multifrequencydialing.

➢ Inpulsesdialingarotarydialisusedinthissystematrainofpulsesisusedto represent a single digit of the called subscriber no.

➢ Inmultifrequencydialing,pairoftonesisattachedtoeachdigitbeingdialed.Itis also called as touch tone dialing or dual tone multi frequency dialing (DTMF)

Sound Amplifier:-

➢ The two wires of transmitter and receiver are connected to the sound and speech ICfor effective transmission and receiving of audio signal.

➢ This ICperformsthefollowingfunction.

     (a) Automaticgaincontrol.

     (b) Dialtone.

     (c) Biasing.

Theswitchingofficeperforms thefollowingfunctions.

     (i)   Identificationofthe callingsubscriber.

    (ii)   Addressing.

    (iii)   Findingand settingofthepathbetweencallingsubscriber &called subscriber.

    (iv)   BusyTesting.

    (v)   Interconnection.

    (vi)   Alerting

    (vii) Supervision

(viii)   Cleardown

(ix)   Billing

(I)   Identificationofcallingsubscriber:-

➢ The local switching centre must react to a calling signal from calling subscriber and must be able to receive information to identify the destination terminal.

➢ Thecallingsignalissometimescalledasseize.

(II)   Addressing:-

➢ Theswitchingsystemmustbeabletoidentifythecalledsubscriberfromthe information from calling subscriber.

➢ Theaddress maybeof same local exchangeor some other exchange.

➢ If the terminal (called subscriber) or the trunk is busy, then a suitable signal must be returned to the calling subscriber.

(III)   Finding&settingof the path

➢ Oncethecallingsubscriberdestinationisidentifiedandthecalledsubscriberisavailable, an accept signal is passed to the switching system & calling subscriber.

(IV)   Busytesting :-

➢ If the no dialed by the calling subscriber is wrong or the called subscriber is busy or the terminal may be free but no response is received then a switching system has to pass a corresponding voice massage or a busy tone after waiting for a certain interval of time.

(V)   Interconnection :-

➢ Fora call betweentwosubscribers,threeconnectionsaretobe made.

(i)   Fromlocalexchange&called subscriber.

(ii)   Fromlocalexchangetoother Exchange.

(iii)   Fromcallingsubscribertolocalexchange.

(VI)   Alerting:-

➢ Oncetheconnectionwas made,thesystemsendsasignaltoalertthecalledsubscriber to pick up the hand set.

(VII)   Supervision:-

➢ Once the path between calling subscriber & called subscriber is established, it should be supervised in order to detect the communication and clear down conditions for recoding the billing information.

(VIII)   Cleardown:-

➢ Whenthecallestablishediscompleted,thepathbetweenthecallingsubscribershould be disconnected.

➢ If the calling subscriber keeps down the handset 1st, the signal called clear backward signal is passed to the switching system.

➢ Byreceivingthiscleardownsignal,theswitchingsystemdisconnectsthepath between the calling subscriber and the called subscriber.

(IX)   Billing:

➢ Aswitchingsystemshouldhaveamechanismtomonitorandcountthenoofunits made during the conversation.

➢ The cumulative no of units made for a particular direction by the calling subscriber is calculated.

➢ Thisinformationissend forbillingpurpose tothe calling subscriber.

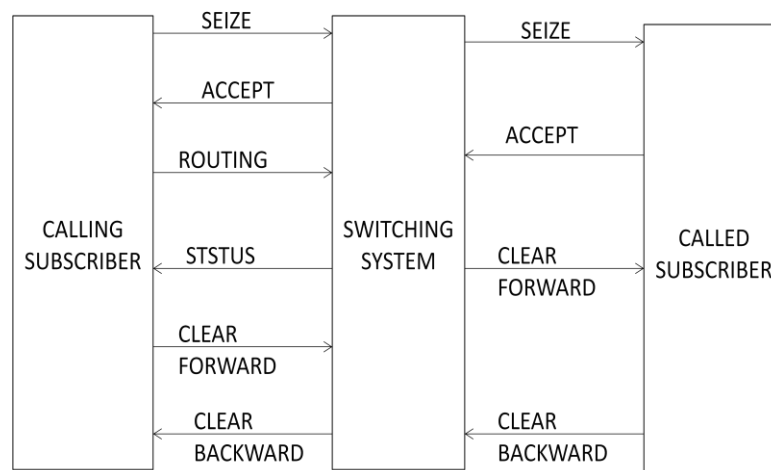**Thefunctionof anexchangeforprovidingacallbetweentwo subscribers**

Fig.4.2Call Procedure

Types ofSwitching:-

➢ Therearethree classes of switchingsystem based on the division of information in space, time, & frequency domain.

➢ Accordinglytherecalledas

   (i)   Spacedivisionswitching.

   (ii)   Time division switching.

   (iii)   Freqdivision switching.

(I)   Space division switching:-

➢ The space division switching method provides a fixed path for the entire duration of a call.

➢ The advantages of space division switching are

(i)   Simple configuration.

(ii)   Unlimited bandwidth.

(iii)   Limited crosstalk probability.

➢ But this switching method is very slow to operate, bulky and involves large amount of wiring.

(II) Time Division Switching:-

➢ In time division switching all the I/P and O/P of the switching canter are connected to a common switching mechanism.

➢ The switch connects certain pair of I/P & o/p for a short duration.

➢ Each I/p is sampled to change the connecting pattern hence the switching is first and compact is used the circuit becomes simple to operate.

➢ The various switching elements used for time division switching are

| (i) | Conventional relays. | iii) | Reed relays. |
| (ii) | Uni-selectors | | iv)Two motion selectors etc. |

➢ The conventional relays are simple electrical or electromechanical relays used for switching.

➢ To perform switching, the relays act as a crosspoint.

➢ The reed relays are electro mechanical switches used in modern switching equipments. They are faster than conventional relays but they required a large current to operate.

➢ Mercury wetted reed relays & dry reed relays are mostly used in the modern common system.

(III)   Frequency Division Switching:-

➢ In this switching system, the incoming signal is modulated with different carrier frequencies.

➢ The switching is achieved by using the demodulators operating at different frequency bands at receiver side.

➢ Other than radio communication, this switching system does not have any practical applications.

➢ This switching system is also used in certain application of satellite common system.

UnitOfPowerMeasurement

➢ In the telephone common system normally the logarithmic scale is the measure of power consumed & the units expressed in 'dB' or 'dBm'

$$P_{dB} = 10\log\frac{(p_2)_{watts}}{(p_1)_{watts}}$$

$$P_{dBm} = 10\log\frac{(p_2)_{watts}}{(p_1)_{mwatts}}$$

➢ ThereisalsoanotherunitcalledNeperforpowermeasurement. 1ne

per = 8.69 db

➢ Forany switchingsystemiftheinputpoweris16µwattando/pis30mwatt.Findthe power in decibel db & neper.

I/P p_1= 16µw = 16 x 10^{-6}watt

o/pp_2=30mwatt=30x10^{-3}watt

$$p_{db} = 10\log\frac{30\times10^{-3}}{16\times10^{-6}}$$

=32.73 db.

1nep =8.69

=3.76

$$P_{dbm} = 10\log\frac{(p_2)_{watts}}{(p_1)_{mwatts}}$$

=62.7 dbm

Q.Anamplifierhas an I/P resistanceof 600 Ω & aresistiveloadof75 Ω. When it has an I/P voltage 100 mv rms. The o/p current is 20MA rms find the gain of the amplifier in db.

Ans: I/P voltage = 100m v = 100 x 10^{-3}v

I/Pcurrent=20MA=20x10^{-3}A I/P

Resistance = 600Ω

o/pResistance=75Ω

I/PPower=$\frac{vin^2}{R}=\frac{(100\times10^{-3})^2}{600}$

=0.016 ×10^{-3}

O/ppower=I^2R

=$(20\times10^{-3})^2\times75$

=0.03 watt

Pdb   =10 log$\frac{P2}{P_1}$ watt

$$=10 \log \frac{0.03}{0.016 \times 10^{-3}}$$

$$=32.72 \text{ db}$$

$$\text{Dbm}=10\log\frac{P_2 watt}{P_1 mwatt}$$

$$=62.73 \text{ dbm}$$

OperationPBX&DigitalEPABX.

PBX stands for Private Branch Exchange, which is a private telephone network used within a companyororganization. Theusers ofthe PBX phonesystem can communicate within their company or organization and the outside world, using different communicationchannelslikeVoiceoverIP,ISDNoranalog.APBXalsoallows you to have more phones than physical phone lines (PTSN) and allows free callsbetween users. It also provides features like transfers, voicemail, call recording, interactive voice menus (IVRs) and ACD call queues.
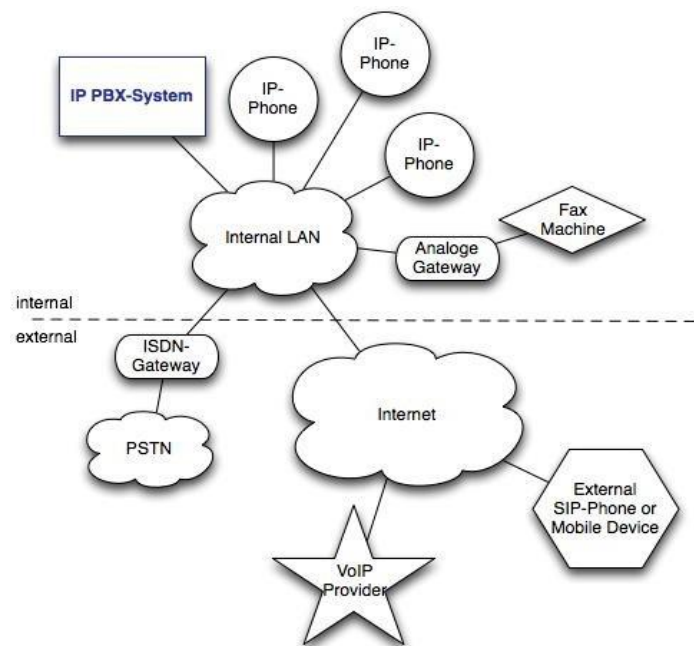
Fig.4.3PBXSystem

PBX phone systems are available as Hosted or Virtual solutions (sometimes also called Centrix),andas inhouse solutions to be used onyour own hardware. PBXphonesystems 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 telephonyis routed through the existing LAN (local computer network). This waya separate networkfortelephonyisnotrequired.Eventhoughtheinternaltelephonyisroutedthrough

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.

SinceIPtelephonyismostlyusingtheopenSIPstandard,anIPphonesystemgives youalotmore freedom in your choice of phones. Basically any SIPcompatiblephone (VoIPphone)willworkwithanIPPBX.FurthermoreanIPPBXdoesn'tlimit thegrowth 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 phonescannotonlybeconnectedviatheLANbutalsoviatheinternet,usingfor 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 trucking (telephony services) for cheaper call rates than traditional telephony providers. Internal calls via an IP phone system are free general.

PracticaladvantagesofIPtelephony:

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 en 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 saves traveling time and money.

DigitalEPABX

AsshowninthefigureEPABX/PBXfacilitatesuseofoneexternaltelephonelineby 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.
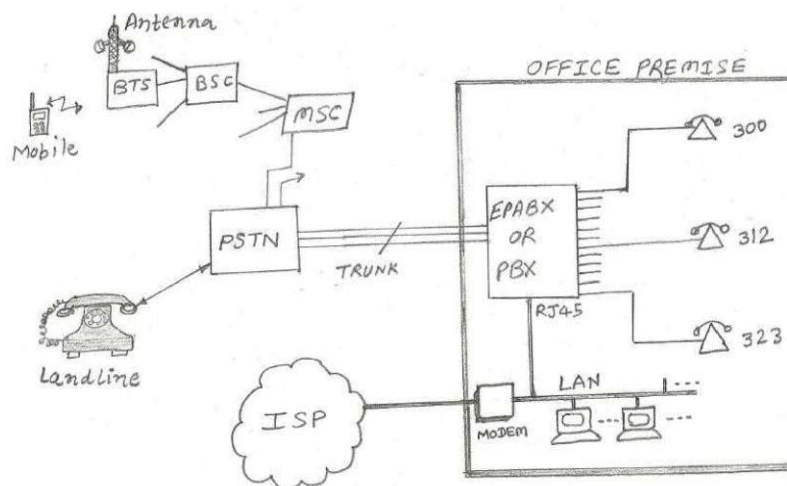
Fig.4.4SystemInterface

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

PSTNisconnectedwithMSC(Mobileswitchingcentre)ofcellularnetworks   suchas GSM/CDMA/UMTS. By this mobile cell phone user can connect to anytelephone 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 usingsameexternalinternetconnectionlinefromISP   viaModem/router.ThesamefacilityofPBX can extended for WLAN users too.

TelephoneNumbering System:-

➢ It is a type of numbering scheme used in telecommunication to allocate a specific number to each subscriber so that the telephone calls can be routed from calling subscriber to called subscriber through the telephone network.

➢ There arebasicallytwo types of numberingplans.

      (1)   Closednumbering plan.

      (2)   Opennumberingplan.

➢ The closed numbering plan is used for the telephone system normally deployed for house hold applications.

➢ Theyarehavingafreelengthnumberallocatedtoeach user.

➢ The open numbering plan is a variable length numbering system generally used for large office or organization using the PBX or EPBX system.

➢ Adial plan establishes theexpected number andpattern ofdigits foratelephonenumber.

    (a)   Countrycode.   b)Areacode.   c)Localportcode.

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- The public switch telephone network (PSTN) system uses a 10 digit dial plan including 3 digit area code and 7 digit telephone number.

- The PSTN system follows E:164 standards which include
  (a) Country calling code (ISD Code)   (b) Area code (STD Code)   (c) Local no.

(b) COUNTRY CALLING CODE:-

- It is necessary only when dialing to phone in other countries.

- In international use, the telephone numbers are prefixed with the country code along with a '+' sign with spaces in place of hyphen.

- Ex–Tey+[$\overline{XX}\overline{FFF}\overline{ZZZZZZ}$] _____

- This format allows the user to choose the exchange code need to dial from its location.

- For GSM network '+' is an actual character that may be used internally as the international access code.

AREA CODE:-

- These are known as numbering plan areas (NPA) and formally known as STD codes.

- These are necessary only when the dialled number is from outside the area code.

- These usually indicate geographical areas within one country that covers 100's of in the dial string by the national access code (04 India & 1 for USA) or the international access code and local number.

- The local number or subscriber number must always be dialled entirely.

- The 1st few digits indicate the local telephone exchange no followed by the subscriber no.

- For short range calling, the subscriber need not include the area code or country code in the dialed no. string which enables shorter digital string.

Internet Telephony:

- Internet telephony, also known as voice-over-IP, replaces and complements the existing circuit- switched public telephone network with a packet-based infrastructure.

- Internet telephony supports communications services such as voice, facsimile, and/or Voice-messaging applications – that are transported via the Internet, rather than the public switched telephone network (PSTN).

- The basic steps involved in originating an Internet telephone call are conversion of the analog voice signal to digital format and compression/translation of the signal into Internet protocol (IP) packets for transmission over the Internet; the process is reversed at the receiving end.

- More technically, Internet telephony is the real-time delivery of voice and possibly other

multimedia data types between two or more parties, across networks using the Internet protocols, and the exchange of information required to control this delivery.

➢ One of the strengths of Internet telephony is the ability to be *media-neutral*, thatis,almost theentire infrastructure does not need to change if a conversation includes video, shared applications or text chat.

➢ In this system the call goes over the local PSTN network to the nearest gateway server, which digitizes the analog voice signal, compresses it into IP packets and moves it through the internet gateway for transporting to the receiving end.

➢ It supports computer to telephone calls, telephone to computer calls and telephone to telephone calls.

➢ Itofferstremendouscostsavingascomparedtothe PSTNsystemforlongdistant calls.

➢ It finds the problem of less reliable data communication and lower sound quality due tolimited bandwidth operation and current data compression techniques used.

➢ Thefirstwidelyused standardizedsignalingprotocolwas providedbythe ITUin 1996, as the H.323 family of protocols.

InternetProtocol(IP)Telephony:

➢ IP telephony is the superset of Internet telephony, as it refers to all telephony servicesover IP, rather than just those carried across the Internet.

➢ In IP telephony,streamingmediarequiressynchronousdatadeliverywheretheshort-term average delivery rate is equal to the native media rate, but streaming media can often be buffered for significant amounts of time, up to several seconds, without interfering with the service.

➢ In IP telephony, the source is generally a human being and, more importantly, there is bidirectional real-time media interaction between the parties.

➢ In the area of IP telephony, 3GPP, the 3rd Generation Partnership Project, has been driving the standardization for third generation wireless networks using "based onevolved GSM core net- works and the radio access technologies that they support." It consists of a number of organizational partners, including ETSI. A similar organization, 3GPP2, deals with radio access technologies de- rived from the North American CDMA (ANSI/TIA/EIA-41) system; it inherits most higher-layer technologies, such as those relevant for IP telephony, from 3GPP.

CH-5 DATA COMMUNICATION

Introduction to Data Communications:

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 communications 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.
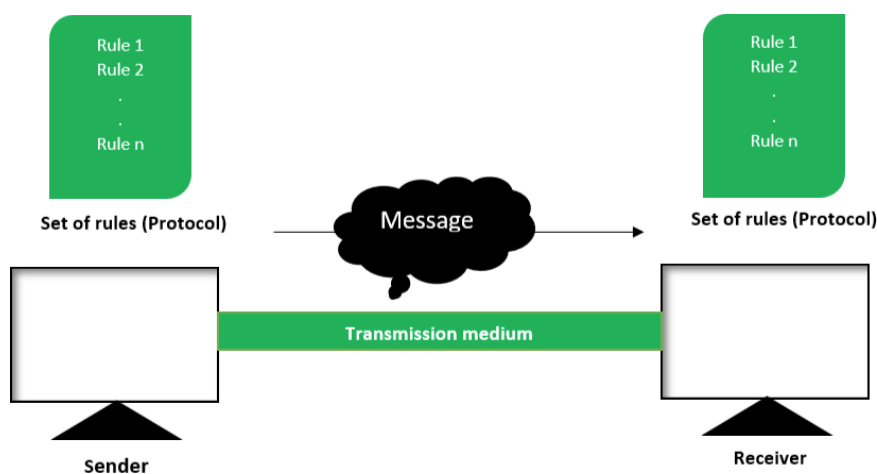

Fig.5.1 Datacommunication System

StandardsOrganizationsforData Communications

An association of organizations, governments, manufacturers and users form the standardsorganizationsandareresponsiblefordeveloping,coordinatingand 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. InternationalStandardOrganization(ISO)

   ISO is the international organization for standardization on a wide range of subjects. It is comprised mainlyof members from the standards committee of various governments throughout theworld. It is even responsible fordeveloping modelswhich 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. InternationalTelecommunicationsUnion-TelecommunicationSector(ITU-T)

   ITU-T is one of the four permanent parts of the International Telecommunications Union basedinGeneva,Switzerland.It has developed three sets of specifications: the Vseries formodeminterfacinganddatatransmissionovertelephonelines,theX 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 ofgovernmentauthorities and representativesfrommanycountries andit isthepresentstandardsorganizationforthe United Nations.

3. InstituteofElectricalandElectronicsEngineers(IEEE)

   IEEE is an international professional organization founded in United States and is compromised of electronics, computer and communications engineers. It is currentlythe 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. AmericanNationalStandardsInstitute(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 comprisedofequipmentmanufacturersandusersofdataprocessingequipmentand

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. InternetResearchTaskForce(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.
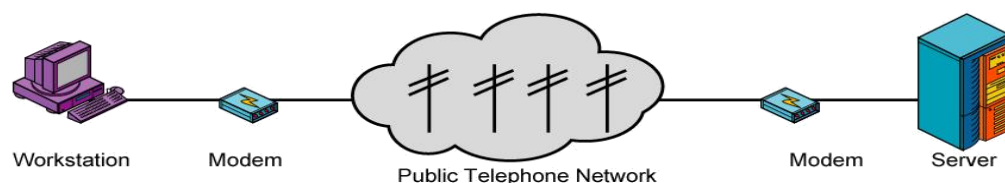
DataCommunicationCircuits

➢ 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.

➢ Datacommunicationscircuitsutilizeelectroniccommunicationsequipment and facilities to interconnect digital computer equipment.

➢ Communication facilities are physical means of interconnecting stations and areprovided todatacommunicationsusers through publictelephonenetworks (PTN),public data networks (PDN), and a multitude of private data communications systems.

Thefollowingfigureshowsasimpletwo-stationdatacommunicationscircuit.The main components are:
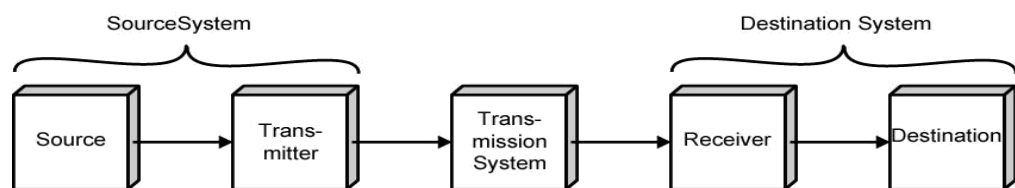
(a) General block diagram

(b) Example

Fig.5.2 DataCommunicationCircuit

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.

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 acceptananalogsignalcomingfromanetworkortransmissionlineandconvertitinto a digital bit stream.

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

Typesof 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. Allbits of a word are transmitted at the same time. This method of transmission can move a significant amount ofdatain a given period of time. Its disadvantage isthe largenumber of interconnecting cables between the two units. For large binary words, cablingbecomes complex and expensive. This is particularly true if the distance between thetwo units is great. Long multi wire cables are not only expensive, butalso requirespecial interfacing to minimize noise and distortion problems.

➢ Serial data transmission is the process oftransmittingbinarywordsa 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 ofa 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.
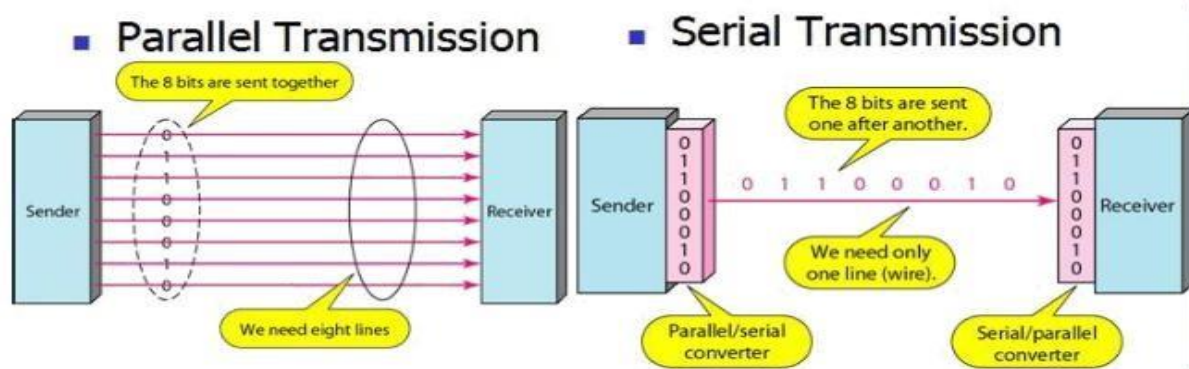
Fig.5.3TypesofDataTransmission

TransmissionModes

Therearefourmodesoftransmissionfordata communicationscircuits:

a. Simplex

b. Half-duplex

c. Full-duplex
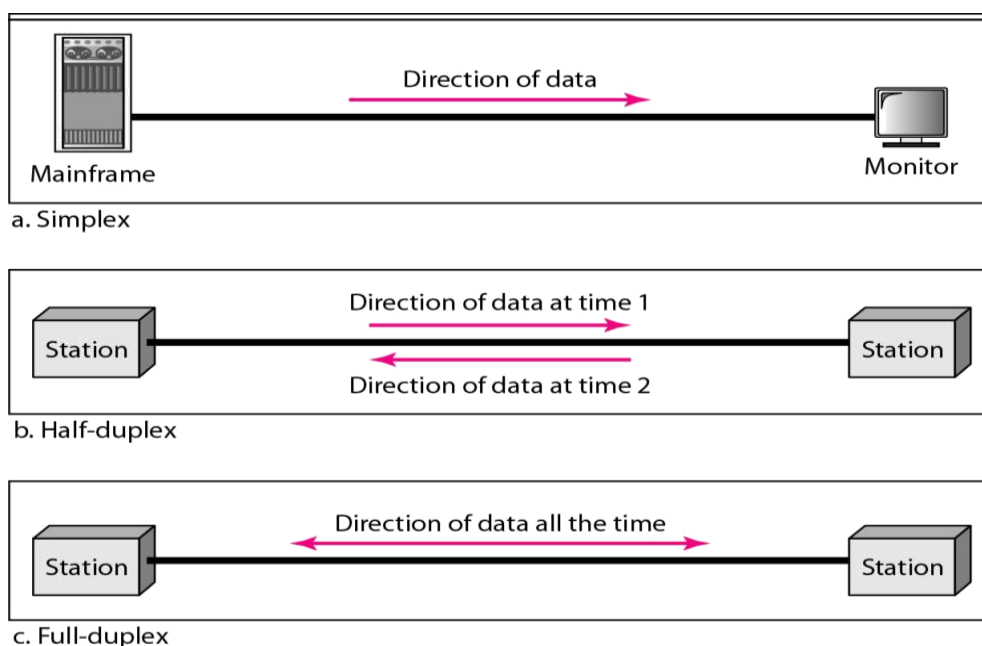
Fig.5.4Modes ofData Transmission

➢ In simplexmode (SX)**,**thecommunicationis unidirectional,ason aone-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.

➢ Inhalf-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-duplexmodeisusedincaseswheretherereisnoneedforcommunicationinboth 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.

DataCommunications Codes

- Datacommunicationscodesareusedtorepresentcharactersandsymbolssuchas letters, digits and punctuation marks.

- Datacommunicationscodesarecalledcharactercodes,charactersets,symbol codesor character languages.

- Therelationshipofbytestocharactersisdeterminedbyacharacter code.

- Eachtimeauserpressesakeyonaterminal/PC,a binarycodeisgeneratedfor the corresponding character.

- Variouscharactercodeshavebeenusedindata communicationincluding:Morse, Baudot code, EBCDIC code, ASCII code, etc.

BaudotCode

- TheBaudotcode(sometimescalledtheTelexcode)wasthefirstfixed-lengthcharacter code. One of first codes developed for machine to machine communication.

- Ituses1'sand0'sinsteadofdotsanddashes.Itwasusedfortransmittingtelex messages (punch tape). Few important characteristics of these codes are:
  - Fixedcharacterlength(5-bits)
  - 32different codes
  - increased capacitybyusingtwo codes for shifting
  - 11111(32)   ShifttoLower(letters)
  - 11011(27)   ShifttoUpper(digits,punctuation)
  - 4specialcodesforSP,CR,LF&blank
  - Total=26+26+4=56differentcharacters

Limitations:

- Requiredshiftcodetoswitchbetweencharacter sets
- Nolowercase, fewspecialcharacters
- Noerrordetectionmechanism
- Charactersnotordered bybinary value
- Designedfortransmittingdata,notfordataprocessing

International Baudot

- Addeda6thbit for parity
- Usedtodetect errors withinasingle character

ASCIICode

- AmericanStandardCodeforInformationInterchange.
- 7-bitcodedevelopedbytheAmericanNationalStandards Institute (ANSI).
- mostpopulardatacommunicationcharacter codetoday.
- Allowsfor128differentcharacterrepresentations (2^7).
- includesupperandlowercase.
- lots ofspecialcharacters(non-printable).
- generallyusedwithanadded paritybit.
- betterbinaryorderingofcharactersthan EBCDIC.
- ExtendedASCIIuses8databits andno parity
- Usedforprocessingandstorage ofdata.
- Allowsforinternational characters.
- 8thbitstripped offortransmissionofstandard characterset.

EBCDICCode

- ExtendedBinaryCodedDecimalInterchangeCode.
- 8-bitcharacter codedevelopedbyIBM.
- Usedfordatacommunication,processingandstorage.
- Extendedearlierproprietary6-bitBCDcode.
- Designed forbackwardcompatibilityor marketing?
- Stillin usetodayon somemainframesand legacysystems.
- Allowsfor256different characterrepresentations(28).
- Includesupperandlowercase.
- Lotsofspecialcharacters(non-printable).
- Lotsofblank (non-usedcodes).

SUMMARYOFCHARACTERCODES

Morse	=	Dot(.)andDash (-)
Baudot	=	5 bit (no parity)
InternationalBaudot	=	6bit (5data+1 parity)
ASCII	=	8bit (7 data+1 parity)
EBCDIC	=	9bit (8 data+1 parity)

ErrorControl

Networks must be able to transfer data from one device to another with complete accuracy. Data can be corrupted during transmission. For reliable communication, errors must be detected and corrected. Error control can be divided into two general categories:

[1].ErrorDetection

[2]. Error Correction

Error detection and Error correction are implemented either at thedata link layer or the transport layer of the OSI model.
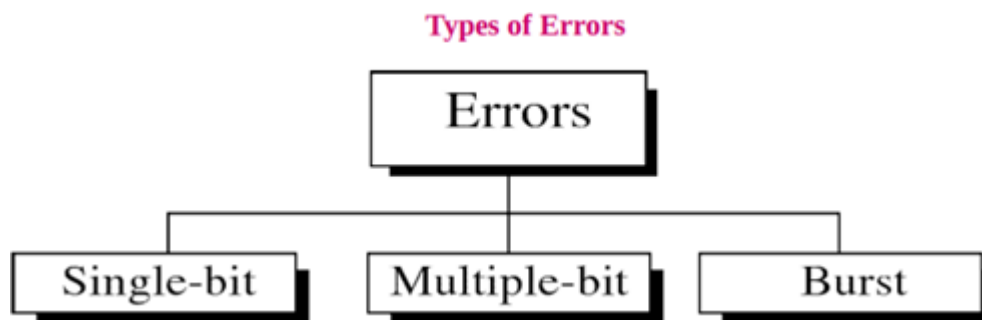
Fig.5.5TypesofdataError

[1].SingleBitError
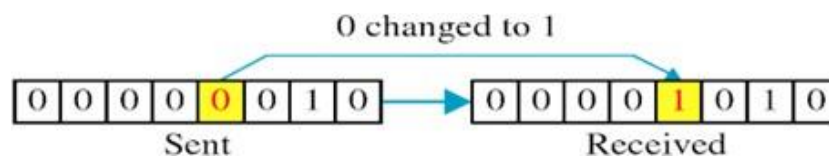
Fig.5.6SinglebitdataError

Singlebiterrors arethe leastlikelytypeoferrorsinserialdatatransmissionbecausethenoise must have a very short duration which is very rare.However this kind of errors can happenin parallel transmission.

[2].MultipleBit Error
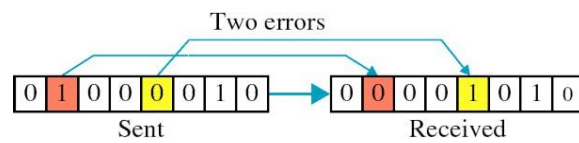
Fig.5.7MultiBitDataError

[3].bursterror
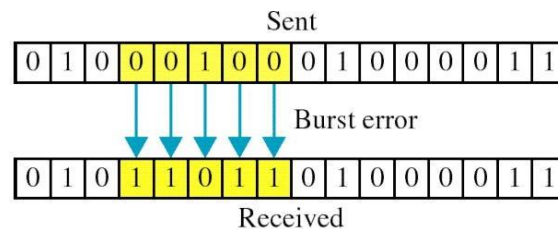
Fig.5.8 BurstDataError

- The term burst error means that two or more bits in the data unit have changed from 1 to0 or from 0 to 1.

- Burst error does not necessarily mean that the errors occur in consecutive bits, the length of the burst is measured from the first corrupted bit to the last corrupted bit. Some bits in between may not have been corrupted.

- Bursterrorismostlikelytohappen in serialtransmission sincethedurationofnoiseis normally longer than the duration of a bit. The number of bits affected depends on the data rate and duration of noise.

Errordetection

Error detection means to decide whether the received data is correct or not without having a copy of the original message.Error detection uses the concept of redundancy, which means adding extra bits for detecting errors at the destination.
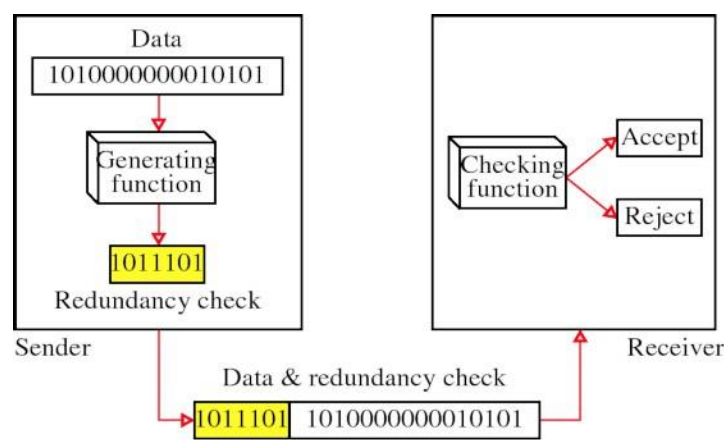
Fig. Redundancy

Fig.5.9 ErrorCheck

RedundancyCheck Types:
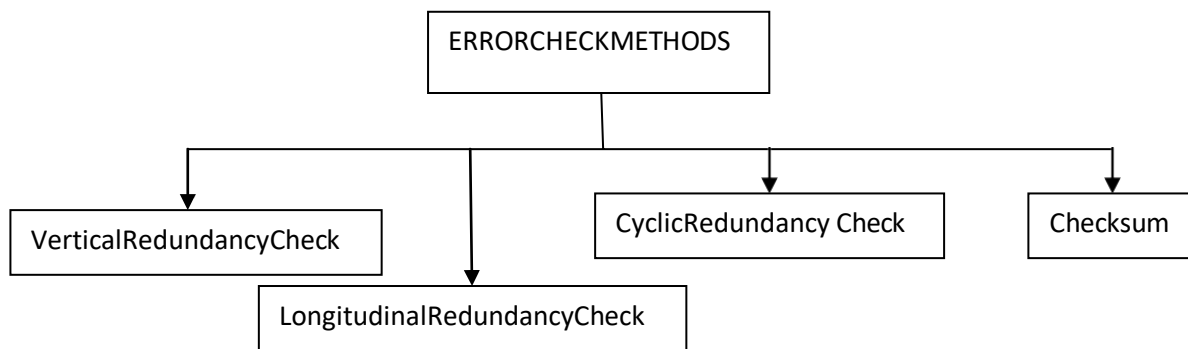
Fig.5.10ErrorCheckMethods

VerticalRedundancyCheck(VRC)

VRC isalso referred to ascharacterparity.With characterparity,each characterhasitsown error-detectionbitcalledtheparity bit.Theparitybitisconsideredasa redundantbit.An n-character message would have 'n' redundant parity bits.

• Itcandetectsinglebiterror.

• Itcandetectbursterrorsonlyif thetotalnumber oferrorsisodd.

LongitudinalRedundancyCheck(LRC)

LRC is also referred to as message parity since it is used to check error occurred within a message. With LRC each bit position has a parity bit. LRC is the result of XORing the bits present in all the characters present in a message whereas VRC is the result of XORing the bits within a single character.

• InLRC evenparityisgenerallyused,whereaswith VRCodd parityisgenerallyused.

• LCRincreasesthelikelihoodofdetectingbursterrors.

• Iftwobitsinonedataunitsaredamagedandtwobitsinexactlythesamepositionsin another data unit are also damaged, the LRC checker will not detect an error.

Checksum

Thecharacterswithinamessagearecombinedtogethertoproduceanerror-   checking character called as checksum, which can be as simple as the arithmetic sum of the numerical values of all the characters in the message. The checksum is appended to the endof the message.

The receiver replicates the combining operation and determines its own checksum. The receiver's checksum is compared with transmitter checksum appended with the message, and if they are the same, it is assumed that no transmission errors have occurred.

CyclicRedundancyCheck(CRC)

It's a most reliable redundancychecking technique for error detection is a convolution coding scheme called Cyclic Redundancy Check(CRC). Given a k-bit frame or message, the transmittergenerates an (n-k) bit sequence, knownas a frame check sequence(FCS)(or) Block Check Code(BCS),sothattheresultingframe,consistingof'n' bits,isexactly divisiblebysome predetermined number. The receiver then divides the incoming frame by the same number and, if there is no remainder, assumes that there was no error.

Modulator-Demodulator(MODEM)

Modems are used for data transfer from one computer network to another computer network through telephone lines. The computer network works in digital mode, while analog technologyisusedforcarryingmessagesacrossphonelines. The device which performs modulation is called a modulator and the device which recovers the information signal from the modulated carrier is called a demodulator. In data transmission, we usually come across devices which perform both modulation as well as demodulation functions and these devices are called modems.

When data is to be transmitted over long distances, modems are needed. In a modem, the input signal modulates a carrier which is transmitted to the distant end. At the distant end, another modem demodulates the received carrier to obtain the digital signal. Thus, a pair of modems is always required. The term 'modem' is derived from the words, Modulator and Demodulator.

Modulator converts information from digital mode to analog mode at the transmitting endand demodulator converts the same from analog to digital at receiving end. The process of converting analog signals of one computer network into digital signals of another computer networksotheycanbeprocessedbyareceivingcomputerisreferredtoasdigitizing.A modem contains a modulator as well as a demodulator.

Nearly all the modems are designed for utilizing the analog voice band service provided by the telecommunication network. Thus, the modulated carrier produced by a modem fits into the 300-400 Hz bandwidth of the speech channel. The figure shows a typical data connection set up using modems. The digital terminal devices exchange digital signals and are known as Data Terminal Equipment (DTE). Two modems are always needed, one at each end. At the transmitting end, the modem converts the digital signal from the DTE intoan analog signal by modulating a carrier. At the receiving end, the modem demodulates the carrierandhandsoverthedemodulateddigitalsignaltotheDTE.

A dedicated leased circuit or a switched telephone circuit can be used as transmissionmedium between the two modems. In the latter case, moderns are connected to the local telephone exchanges. Whenever data transmission is needed, connection between themodems is established through the telephone exchanges. Modems are also needed within a building to connect terminals which are located at distances, more than 15 metres from the host.

Building blocks of a Modem
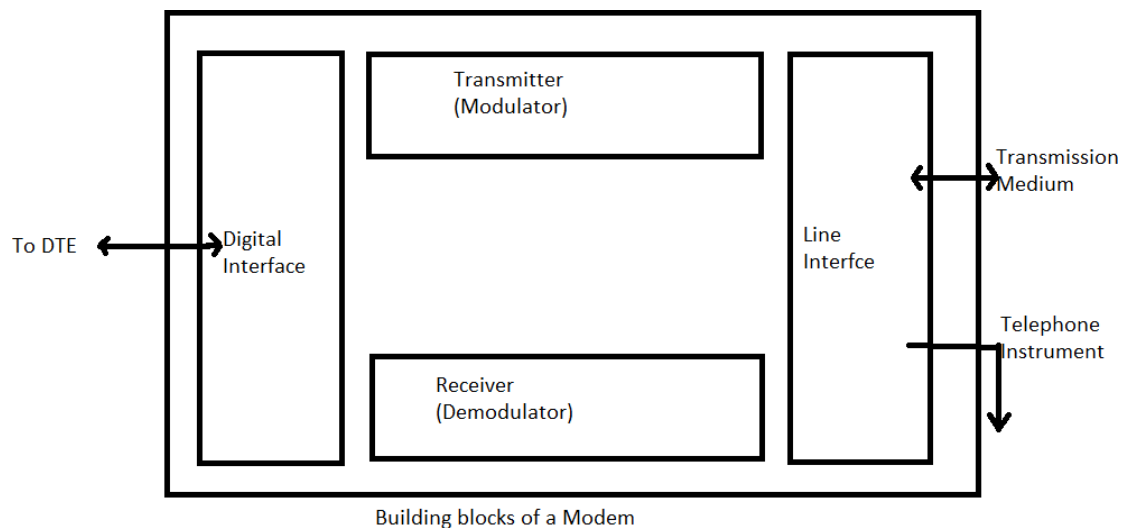
Fig.5.11MODEMBlockDiagram

A block diagram of a modem is shown in the above figure, which comprises a transmitter, a receiver and two interfaces. The digital signal to be sent is given to the transmitter. The modulated carrier that is received from the distant end is given to the receiver. TI1e digital interface connects the modem to the DTE which produces and receives the digital signals. In order to transmit it and receive the modulated signals, the line interface connects the modem to the transmission channel. Modems connected to telephone exchanges have additional provision for connecting a telephone instrument, which enables establishment of the telephone connection.

The transmission medium between the two modems can be a dedicated circuit or a switched telephone circuit. If a switched telephone circuit is used, then the modems are connected to the local telephone exchanges. Whenever data transmission is required connection between the modems is established through telephone exchanges.

CH-6 WIRELESS COMMUNICATION

Introduction

In the older mobile radio systems, single high power transmitter was used to provide coverage in the entire area. Although this technique provided a good coverage, but it was virtually impossible in this technique to re-use the same radio channels in the system, and any effort to re-use the radio channels would result in interference. Therefore, in order to improve the performance of a wireless system with the rise in the demand for the services, a cellular concept was later proposed. This chapter will examine several parameters related with the cellular concept.

The Cellular Concept

The design aim of early mobile wireless communication systems was to get a huge coverage area with a single, high-power transmitter and an antenna installed on a giant tower, transmitting a data on a single frequency. Although this method accomplished a good coverage, but it also means that it was practically not possible to reuse the same frequency all over the system, because any effort to reuse the same frequency would result in interference. The cellular concept was a major breakthrough in order to solve the problems of limited user capacity and spectral congestion. Cellular system provides high capacity with a limited frequency spectrum without making any major technological changes. It is a system-level idea in which a single high-power transmitter is replaced with multiple low- power transmitters, and small segment of the service area is being covered by each transmitter, which is referred to as a cell. Each base station (transmitter) is allocated a part of the total number of channels present in the whole system, and different groups of radio channels are allocated to the neighbouring base stations so that all the channels present in the system are allocated to a moderately small number of neighbouring base stations.

The mobile transceivers (also called mobile phones, handsets, mobile terminals or mobile stations) exchange radio signals with any number of base stations. Mobile phones are not linked to a specific base station, but can utilize any one of the base stations put up by the company. Multiple base stations covers the entire region in such a way that the user can move around and phone call can be carried on without interruption, possibly using more than one base station. The procedure of changing a base station at cell boundaries is called **handover**. Communication from the Mobile Station (MS) or mobile phones to the Base Station (BS) happens on an **uplink channel** also called **reverse link**, and **downlink channel** or **forward link** is used for communication from BS to MS. To maintain a bidirectional communication

between a MS and BS, transmission resources must be offered in both the uplink and downlink directions. This can take place either using Frequency-Division Duplex (FDD), in which separatefrequenciesareused forboth uplink and downlink channels, orthrough Time-Division Duplex (TDD), where uplink and downlink communications take place on the same frequency, but vary in time.

FDD is the most efficient technique if traffic is symmetric, and FDD has also madethe task of radio planning more efficient and easier, because no interference takes place between base stations as theytransmit and receive data on different frequencies. In case of an asymmetry in the uplink and downlink data speed, the TDD performs better than FDD. Asthe uplink data rate increases, extra bandwidth is dynamically allocated to that, and as thedata rate decreases, the allotted bandwidth is taken away.

Someofthe importantcellularconceptsare:

- Frequency reuse
- Channel Allocation
- Handoff
- Interference and system capacity
- Trunking and grade of service
- Improving coverage and capacity

Frequencyreuse

Cells using the same set of Radio channels
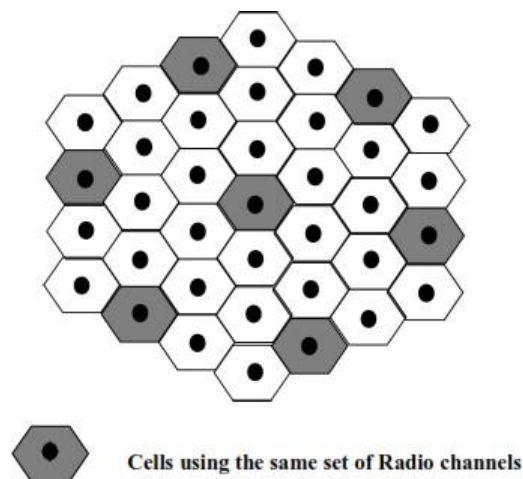
Fig6.1.CellularNetworkwith FrequencyReuse

Conventional communication systems faced the problems of limited service area capability and ineffective radio spectrum utilization. This is because these systems are generally designed to provide service in an autonomous geographic region and by selecting radiochannelsfromaparticularfrequencyband.Ontheotherhand,thepresentmobile

communication systems aredesigned to offer a wide coverage area and high grade of service. These systems are also expected to provide a continuous communication through an efficient utilization of available radio spectrum. Therefore, the design of mobile radio network must satisfy the following objectives i.e., providing continuous service, and wide service area, while efficiently using the radio spectrum.

In order to achieve these objectives, the present mobile systems use cellular networks which dependmoreonanintelligentchannelallocationandreuseofchannelsthroughouttheregion. Each base station is allocated a set of radio channels, which are to be used in a geographic area called a *cell.* Base stations in the neighboring cells are allocated radio channel sets,which are entirely different. The antennas of base station antennas are designed to get the required coveragewithin thespecificcell. Byrestrictingthecoveragearea ofabasestation to within the cell boundaries, the same set of radio channels can be used in the different cells that are separated from each other by distances which are large enough in order to maintain interferencelevelswithinlimits.Theprocedureofradiosetsselectionandallocationtoall the base stations present within a network is called **frequency reuse**.

Fig. 6.1 shows the frequency reuse concept in a cell in a cellular network, in which cells utilize the same set of radio channels. The frequency reuse plan indicates where different radio channels are used. The hexagonal shape of cell is purely theoretical and is a simple model of radio coverage for each base station, although it has been globally adopted as the hexagon permits the easy analysis of a cellular system. As hexagon covers the largest area from the center of a polygon to its fart hest point, therefore, hexagon geometry can cover the entire geographic region to the fullest with minimum number of cells. When hexagon geometryis used to cover the entire geographic area, the base stations are either put up at the center of the cell, these cells are also called center excited cells or at the three of the six vertices (edge excited cells).

Generally, center excited cells use omni-directional antennas and corner excited cells use directional antennas, but practically considerations for placing base stations are not exactly the same as they are shown in the hexagonal layouts.

ChannelReuseSchemes

The radio channel reuse model can be used in the time and space domain. Channel reuse in the time domain turns out to be occupation of same frequency in different time slots and is also called Time Division Multiplexing.

Channel reuse in the space domain is categorized into:

a) Same channel is allocated in two different areas, e.g. AM and FM radio stations using same channels in two different cities.

b) Same channel is frequently used in same area and in one system the scheme used is cellular systems. The entire spectrum is then divided into K reuse sets.
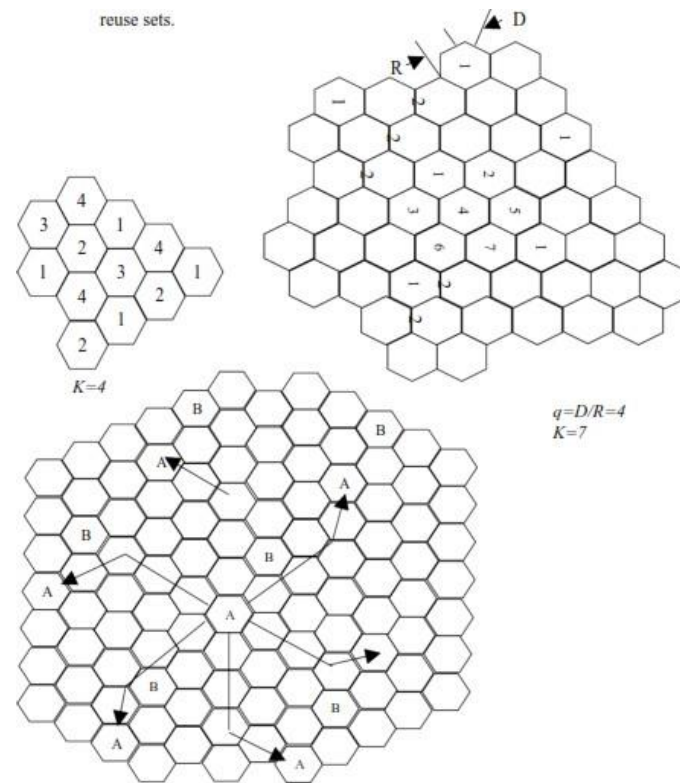
K-CELL REUSE PATTERN

Fig.6.2 Channel Reuse

Channel Allocation Schemes

For effective utilization of the radio spectrum, a channel reuse scheme is required which must be able to increase the capacity and reduce interference. Several channel allocation schemes have been proposed to address these objectives. Channel allocation schemes are classified into **fixed, dynamic, and hybrid.** The selection of a particular channel allocation scheme influences the performance of the system, mainly how to manage the calls when a call is handed-over from one cell to another.

In a fixed channel allocation scheme, a set of nominal channels are permanently allocated to each cell. Any call generated from within the cell can only be served by the idle radio Channels present in that cell. If all the radio channels present in that cell are occupied, then the call is *blocked*. However, there exist a several variations of the fixed allocation. In one of the variation, a cell can borrow channels from neighbouring cells if its own channels

are already busy, and this scheme is called channel borrowing strategy. Such a borrowing procedure is being managed by mobile switching center (MSC) and it try to make sure that the borrowing of a radio channel form neighbouring cells does not interfere with any of the existing calls present in the donor cell.

In a dynamic channel allocation scheme, cells are not allocated radio channels permanently. Instead, every time when a call is received, the serving base station (BS) enquires a channel from the MSC. The MSC allocates a channel to the cell after taking into consideration the possibility of future blocking rate of the candidate cell, the re-use distance of the channel, and several other parameters.

Therefore, the MSC then allocates a particular channel if that radio channel is currently not in use in the candidate cell as well in any other neighbouring cell which falls inside the minimum channel reuse distance in order to avoid co-channel interference. The Dynamic channel allocation minimizes the possibility of blocking, thereby increasing the trunking capacity of the system, as all the available channels are accessible to all the cells. In Dynamic channel allocation schemes MSC gather information on traffic distribution, channel occupancyofallchannelsonaregularbasis.This resultsinincreasedchannelutilizationwith decreased probability of dropped and blocked calls, but at the same time the computational load on the system also increases.

Handoff Strategies

When a mobile moves from one cell to another cell when a call is in progress, the MSC automatically shifts the call to a new channel present in the new cell. This handoff operation requires the identification of a new base station, and channels that are associated with the new base station.

In any cellular network, managing handoff is very important job. Many handoff schemes give high priority to handover requests over new call requests while allocating free channels, and it must be performed successfully and as infrequently as possible.

Therefore, in order to satisfy these requirements, optimum signal at which to begin a handoff level must be specified by system designers. When an optimal signal level for acceptable voice quality is specified, a somewhat stronger signal level is used as a thresholdat which a handoff is made. This margin is given by A = *Pr handoff - Pr minimum_usable*and it should not be too large or too small. If A is very large, needless handoffs which can burden the MSC may take place, and if A is very small, there may not be a sufficient time to completeahandoff process, before a call is vanished dueto weak signal. Therefore, Ashould be carefully selected to meet these contradictory requirements.
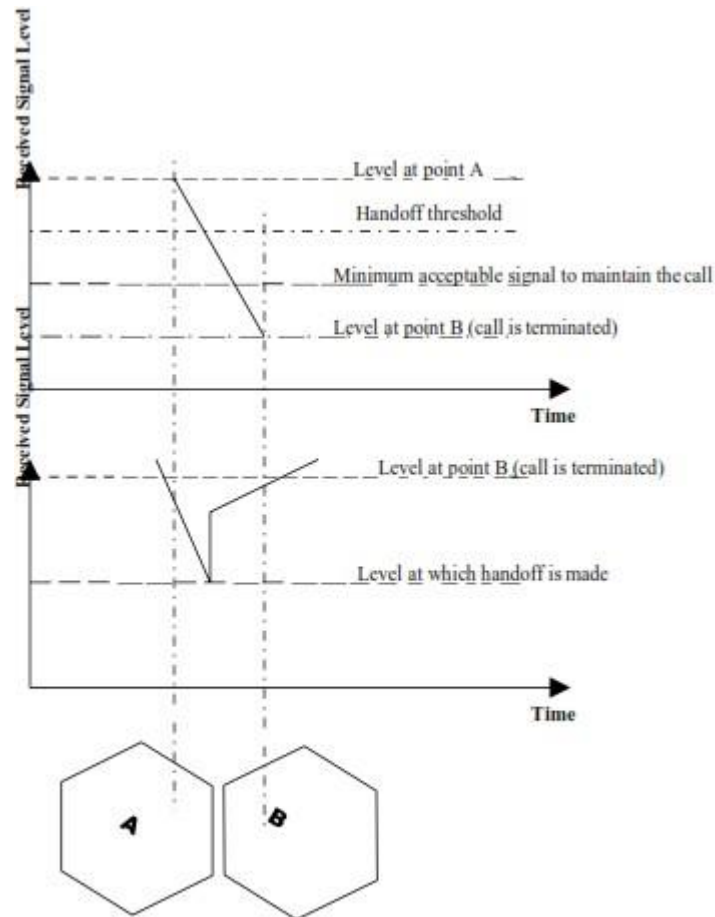
Fig. 1.11: Handoff Situation

Fig.6.3HandoffStrategy

Fig. 6.3 above shows a handoff situation. It presents a case in which a handoff does not take place and the signal strength falls below the minimum acceptable level in order to keep the channel active. This call dropping occurs when there is tremendous delay by the MSC in allocating a handoff, or when the threshold A is too small. During high traffic loads unnecessary delays may take place and this happens either due to computational overloading at the MSC or no free channels are available in any of the neighbouring cells and thereby MSC has to wait until a free channel is found in a neighbouring cell.

While deciding about handoff initiation time, it is important to make sure that thedrop in the signal level is not due to temporary fading but the mobile is in fact moving away from its base station. Therefore, base station observes the signal strength for a definite period oftimebeforeahandoffbegins.Thissignalstrengthmeasurement mustbeoptimizedinorder to avoid unwanted handoffs, while ensuring that unwanted handoffs are completed before a callgetsdropped.Thetimerequiredtocometoadecisionifahandoffisneeded,dependson

thespeedofthevehicleatwhichitismoving.Informationaboutthespeedofvehiclecanalso   be calculated from the fading signal received at the base station.

The time during which a caller remains within a cell, without any handoff to the neighbouring cells, is called the **dwell time.** The dwell time of a call depends upon a number of factors i.e. propagation, interference, distance between the caller and the base station, and several other time varying factors. It has been analyzed that variation of dwell time depends on the speed of the caller and the radio coverage type. e.g., a cell in which radio coverage is provided to highway callers (using vehicles), a large number of callers have a moderately steady speed and they follow fixed paths with good radio coverage. For such instances, the dwell time for random caller is a random variable having distribution that is highly concentrated on the mean dwell time. Whereas, for callers present in dense, micro-cellular environments, there is normallya huge deviation of dwell time about the mean, and the dwell times in general are shorter than the cell geometry. It is clear that the information of dwell time is very important while designing handoff algorithms.

In first generation cellular systems, signal strength computations are done by the base stations and monitored by the MSC. All the base stations regularly observe the signal strengths of its reverse channels to find out the relative location of each mobile user with respect to the base station. In addition to calculating the radio signal strength indication (RSSI) of ongoing calls in the cell, an extra receiver in each base station, is used to find out signal strengths of mobile users present in the neighbouring cells. The extra receiver is controlled by the MSC and is used to examine the signal strength of callers in the neighbouring cells, and informs RSSI to the MSC. Based on the RSSI values received from each extra receiver, the MSC determines whether handoff is required or not.

In second generation cellular systems using digital TDMA technology, handoff decisions are *mobile assisted.* In *mobile assisted handoff (MAHO),* each mobile station measures the received power from the neighbouringbase stations and informs these results to the serving base station. A handoff starts when the power received from the base station of a neighbouring cell go above the power received from the present base station. In MAHO scheme, the call to be handed off between different base stations at a lot faster speed than in first generation systems because the handoff computations are done by each mobile and by keeping the MSC out of these computations. MAHO is suitable for micro-cellular network architectures where handoffs are more frequent.

When a call is in progress, if a mobile shifts from one cellular system to an another cellularsystemmanagedbyadifferentMSC,an*intersystemhandoff*isrequired.AnMSC

performs an intersystem handoff when a signal goes weak in a particular cell and the MSC fails to find another cell inside its system to which it can move the ongoing call, and several issues should be addressed while intersystem handoff is implemented. e.g. a local call might automaticallyturn into a long-distance call when the caller shifts out of its home network and enters into a neighbouring system.

Various systems have different methods for dealing with hand-off requests. Several systems manage handoff requests in the same way as they manage new call requests. In such systems, the possibility that a handoff call will not be served by a new base station is equivalent to the blocking probability of new calls. However, if a call is terminated unexpectedly while in progress is more frustrating than being blocked occasionally on a new call. Therefore, to improve the quality of service, various methods have been created to give priority to handoff call requests over new call requests while allocating channels.

PrioritizingHandoffs

One scheme for prioritizing handoffs call requests is called the *guard channelconcept,* in which a part of the existing channels in a cell is reserved entirely for handoff call requests. The major drawback of this scheme is that it reduces the total carried traffic, as smaller number of channels is allocated to new calls. However, guard channels scheme present efficient spectrum utilization when dynamic channel allocation strategies are used.

Queuing of handoff calls is another way to minimize the forced call terminations due to unavailability of channels in the cell. There is actually a trade off between theminimization in the possibility of forced call termination of handoff calls and total carried traffic. Handoff call queuing is possible as there is a fixed time interval between the time the received signal strength falls below the handoff threshold and the time the call is terminated due to unavailability of signal strength. The queue size and delay time is calculated from the traffic pattern of the service area. It should be noted that queuing of handoff calls does not promise a zero forced call terminations, because large delays will force the received signal strength to fall below the minimum level required to maintain communication and therefore, lead to forced handoff call termination.

Co-channelInterferenceandSystemCapacity

The channel reuse approach is very useful for increasing the efficiency of radio spectrum utilization but it results in co-channel interference because the same radio channelis repeatedly used in different co-channel cells in a network. In this case, the quality of a received signal is very much affected both by the amount of radio coverage area and the co-channel interference.

Co-channel interference takes place when two or more transmitters located within a wireless system, or even a neighbouring wireless system, which are transmitting on the same radio channel. Co-channel interference happens when the same carrier frequency (base station) reaches the same receiver (mobile phone) from two different transmitters.

This type of interference is generally generated because channel sets have been allocated to two different cells that are not far enough geographically, and their signals are strong enough to cause interference to each other. Thus, co-channel interference can either modifythe receiver or mask the particular signal. It mayalso merge with the particular signal to cause severe distortions in the output signal.

The performance of interference-limited cellular mobile system can be calculated from thefollowing results.

a) If the signal-to-interference ratio (S/I) is greater than 18 dB, then the system is said to becorrectly designed.

b) IfS/Iislessthan18dBandsignal-to-noiseratio(S/N)isgreaterthan18dB,thenthe system is said to be experiencing with a co-channel interference problem.

c) If both S/Iand S/N are less than 18 dB and S/Iis approximatelysame as S/N in a cell, then the system has a radio coverage problem.

d) IfbothS/I andS/Narelessthan18dBandS/I islessthanS/N,thesystemhasbothco- channel interference and radio coverage problem.

Theco-channel interferencecan bereduced bythefollowingmethods:

a. Increasingthedistance(D)betweentwoco-channelcells.

As D increases, the strength of interfering signal from co-channel interfering cells decreasessignificantly. ButitisnotwisetoincreaseDbecauseas Disincreased, Kmustalso be increased. High values of K means fewer number of radio channels are available per cell for a given spectrum. This results into decrease of the system capacity in terms of channels that are available per cell.

b. Reducingtheantenna heights

Reducing antenna height is a good method to minimize the co-channel interference in some environment, e.g., on a high hill. In the cellular system design effective antenna height is considered rather than the actual antenna height.

Therefore, the effective antenna height changes according to the present location of the mobile unit in such a difficult terrain.

When the antenna is put up on top of the hill, the effective antenna height gets more than the actualantennaheight.So,inordertominimizetheco-channelinterference,antennawith

lower height should be used without decreasing the received signal strength either at the cell-site or at the mobile device. Similarly, lower antenna height in a valley is very useful in minimizing the radiated power in a far-off high-elevation area where the mobile user is believed to be present.

However, reducing the antenna height does not always minimize the co-channel interference, e.g., in forests, the larger antenna height clears the tops of the longest trees inthe surrounding area, particularly when they are located very close to the antenna. But reducing the antenna height would not be appropriate for minimizing co-channel interference because unnecessary attenuation of the signal would occur in the vicinity of the antenna as well as in the cell boundary if the height of the antenna is below the treetop level.

c. Usingdirectionalantennas.

Theuseofdirectional antennas in everycell can minimizetheco-channel interference if the co-channel interference cannot be avoided by a fixed division of co-channel cells. This will also improve the system capacity even if the traffic increases. The co-channel interference can be further minimized by smartly setting up the directional antenna.

d. Useofdiversityschemesatthe receiver.

Thediversityschemeused at thereceivingend of theantennais an efficient technique for minimizing the co-channel interference because any unwanted action performed at the receiving end to increase the signal interference would not cause further interference. For example,thedivisionoftworeceivingantennasinstalledatthecell-sitemeetingthecondition of h/s=11, (where h is the antenna height and s is the division between two antennas), would produce the correlation coefficient of 0.7 for a two-branch diversity system. The two correlated signals can be combined with the use of selective combiner. The mobiletransmitter could suffer up to 7 dB minimization in power and the same performance at the cell-site can be achieved as a non-diversity receiver. Therefore, interference from the mobile transmitters to the receivers can be significantly reduced.

AdjacentChannelInterference

Signals from neighbouring radio channels, also called adjacent channel, leak into the particular channel, thus causing adjacent channel interference. Adjacent channel interference takes place due to the inability of a mobile phone to separate out the signals of adjacent channels allocated to neighbouring cell sites (e.g., channel 101 in cell A, and channel 102 in cell B), where both A and D cells are present in the same reuse cluster.

The problem of adjacent channel interference can become more serious if a user transmittingonachannel,whichisextremelyclosetoasubscriber'sreceiverchannel,while

the receiver tries to receive a signal from base station on the desired channel. This is called the *near and far* effect, where a neighbouring transmitter catches the receiver of the user. Otherwise, the near-far effect occurs when a mobile near to a base station transmits on a channel which is close to the one being used by a weak mobile. The base station may find some trouble in separating out a particular user from the one using adjacent channel.

Adjacent channel interference can be reduced through careful and thorough filtering andefficientchannel allocations.Aseach cellisallocatedonlyaportionof thetotalchannels, acellmust notbeallocatedchannelswhicharelocatedadjacentinfrequency. Bymaintaining the channel separation as large as possible in a given cell, the adjacent channel interference may well be minimized significantly. Hence, instead of allocating contiguous band of channels to each cell, channels are allocated such a way that the frequency separationbetween channels in a given cell should be maximized. With sequentially allocating consecutive channels to various cells, several channel allocation schemes are capable enough tokeep apartadjacent channelspresentin acellwithbandwidthof *N* channels,where*N*isthe sizeofacluster.However,somechannel allocation schemesalso avoid asecondarysourceof adjacent channel interference by not using the adjacent channels in neighbouring cells.

 TrunkingandGradeof Service

 In cellular mobile communication, the two major aspects that have to be considered with extra care are: trunking, and grade of service. These aspects are to be planned very well in order to get a better system performance. The grade of service is a standard which is used to define the performance of a cellular mobile communication system by specifying a desired probability of a mobile user acquiring channel access, when a definite number of radio channels are present in the system. The cellular communication network depends on a trunking system to fit large number of mobile users in a limited radio band. The statistical behavior of mobile users is being exploited by trunking so that a fixed number of channels can be allocated to large mobile users. In trunking, large number of mobile users is being accommodated to share the limited radio channels available in a cell.

In trunked cellular communication systems, each mobile user present in network is allocateda channel on the basis of a request. After the call is terminated, the occupied channels immediately go back to the pool of available channels. When a mobile user made a requestfor channels and if all of the radio channels are occupied, then the incoming call is blocked.In few communication systems, aqueueis generallyused to keep the requestingmobile users untilachannelbecomesfree.Thegradeofservice(GOS)isusedtodeterminethecapability

of a userto get access to trunked radio systems duringbusyhours. The busyhour is generally based on customer's request for channels during peak load.

It is, therefore, necessaryto approximate the maximum required capacityin terms of number of available channels and to allocate the appropriate number of channels in order to meet the GOS. GOS is generally defined as the probability that a call is blocked. A call which cannot get completed after the call request is made by a user is called a blocked or lost call, and it may happen either due to channel congestion or due to the non availability of a free channel. Therefore, GOS can be computed from channel congestion which is defined as the call blocking probability, or being delayed beyond a certain time.

ImprovingCapacityInCellularSystems

With the rise in the demand for wireless services, the number of radio channels allocated to each cell could become inadequate in order to satisfy this increase in the demand. Therefore, to increase the capacity (i.e. a cellular system can take up more calls) of a cellular system, itis very important to allocate more number of radio channels to each cell in order to meet the requirements of mobile traffic. Various techniques that are proposed for increasing the capacity of a cellular system is as follows:

        i. Cellsplitting
       ii. Cell sectoring
      iii. Microzonemethod

Cell Splitting

Cell splitting is a method in which congested (heavy traffic) cell is subdivided into smaller cells, and each smaller cell is having its own base station with reduction in antenna heightand transmitter power. The original congested bigger cell is called macrocell and the smaller cells are called microcells. Capacity of cellular network can be increased by creating micro- cells within the original cells which are having smaller radius than macro-cells, therefore, the capacity of a system increases because more channels per unit area are now available in a network.
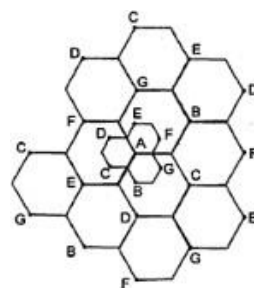

Fig.6.4CellSplitting

Fig. shows a cell splitting in which a congested cell, divided into smaller micro cells, and the base stations are put up at corners of the cells. The micro-cells are to be added in such a way in order to the frequency reuse plan of the system should be preserved. For micro-cells, the transmit poweroftransmittershould bereduced, and each micro-cell is havinghalftheradius to that of macro-cell. Therefore, transmit power of the new cells can be calculated by analyzing the received power at the cell boundaries. This is required in order to make surethat frequency reuse plan for the micro-cells is also working the same way as it was working for the macro-cells. In cell splitting, following factors should be carefully monitored;

1. In cell splitting, allocation of channels to the new cells (micro-cells) must be done very cautiously. So, in order to avoid co-channel interference, cells must follow the minimum reuse distance principle.

2. Powerlevels ofthetransmittersfornewand old cells must beredesigned. Ifthetransmitter of the old cell has the same power as that of new cells, then the channels in old cell interfere with the channels of new cell. But, if the power level of transmitter is too low then it may result into in sufficient area coverage.

3. In order to overcome the problem of point (2); the channels of macro cell is divided into two parts. The channels in the first part are for the new cell and other part consists of channel forthe oldcell.Splittingofcellsisdone accordingto thenumberofsubscriberspresentinthe areas, and the power levels of the transmitters must be redesigned according to the allocated channels to old and new cells.

4. Antennas of different heights and power levels are used for smooth and easy handoff, and this technique is called Umbrella cell approach. Using this approach large coverage area is provided for high speed users and small coverage area to low speed users. Therefore, the number of call handoffs is maximized for high speed users and provides more channels for slow speed users.

5. The main idea behind cell splitting is the rescaling of entire system. In cell splitting, reuse factor (D/R) is kept constant because by decreasing the radius of cell (R) and, at the same time, the separation between co-channel (D) is also decreased. So, high capacity can be achieved without changing the (D/R) ratio of system.

Sectoring

Another wayof improving the channel capacity of a cellular system is to decrease the D/R ratio while keeping the same cell radius. Improvement in the capacity can be accomplishedbyreducingthenumberofcellsinacluster,henceincreasingthefrequency

reuse. To achieve this, the relative interference must be minimized without decreasing the transmit power.

For minimizing co-channel interference in a cellular network, a single omni-directional antenna is replaced with multiple directional antennas, with each transmitting within a smaller region. These smaller regions are called sectors and minimizing co-channel interference while improving the capacity of a system by using multiple directional antennas is called sectoring. The amount up to which co-channel interference is minimized depends on theamountofsectoringused.Acellis generallydividedeitherintothree120degreeorsix 60 degree sectors. In the three-sector arrangement, three antennas are generally located in each sector with one transmit and two receive antennas.

The placement of two receive antennas provide antenna diversity, which is alsoknown as space diversity. Space diversity greatly improves the reception of a signal by efficiently providing a big target for signals transmitted from mobile units. The division between the two receive antenna depends on the height of the antennas above ground.

When sectoringtechniqueis usedin cellularsystems, thechannels usedin aparticular sector are actually broken down into sectored groups, which are only used inside a particular sector. With 7-cell reuse pattern and 120 degree sectors, the number of interfering cells in the neighboring tier is brought down from six to two. Cell sectoring also improves the signal-to-interference ratio, thereby increasing the capacity of a cellular system. This method of cell sectoring is very efficient, because it utilized the existing system structures. Cell sectoring also minimized the co-channel interference, with the use of directional antennas, a particular cell will get interference and transmit only a fraction of the available co-channel cells.

MicrocellZoneConcept

The micro-cell zone concept is associated with sharing the same radio equipment by different micro-cells. It results in decreasing of cluster size and, therefore, increase in system capacity. The micro-cell zone concept is used in practice to improve the capacity of cellular systems.

To improve both capacity and signal quality of a cellular system, cell sectoring depends upon correct setting up of directional antennas at the cell-site. But it also gives riseto increase in the number of handoffs and trunking inefficiencies. In a 3-sector or 6-sector cellular system, each sector acts like a new cell with a different shape and cell. Channels allocated to the un-sectored cell are divided between the different sectors present in a cell, thereby decreasing number of channels available in each sector. Furthermore, handoff takes place everytimeamobileusermovesfromonesectortoanothersectorofthesamecell.This

results in significant increase of network load on BSC and MSC of the cellular system. The problem of channel partitioning and increase in network load become very hard if all the 3 or 6-sectored directional antennas are placed at the centre of the cell.
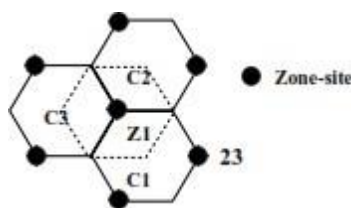

Fig.6.5MicroCell

As shown in the Fig. 6.5 three directional antennas are put at a point, Z1, also called zone-site, where three adjacent cells C1, C2, and C3 meet with each other. Z1, Z2 and Z3 are three zone-sites of the cell C1, and each zone-site is using three 135 degree directional antennas. All the three zone-sites also behave as receivers, which also receive signals transmitted by a mobile user present anywhere in the cell.

In order to avoid delay, these zone-sites are connected through a high-speed fiber link to the base station. The base station first finds out, which of the three zone-sites has the better received signal strength from the mobile user and then that particular zone-site is used to transmit the signal to the mobile user. Therefore, only one zone-site is active at a time for communicating with the user and it also minimizes the co-channel interference experienced by the mobile user.

IEEEWirelessStandards

☐ Wireless networks are standardized by IEEE.

☐ Under 802 LAN MAN standards committee.

The 802.11 standard is defined through several specifications of WLANs. It defines an over-the-air interface between a wireless client and a base station or between two wireless clients.

There are several specifications in the 802.11 family -

☐ **802.11** - This pertains to wireless LANs and provides 1 - or 2-Mbps transmission in the 2.4-GHz band using either frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS).

☐ **802.11a**-Thisisanextensionto802.11thatpertainstowirelessLANsandgoesasfastas

54 Mbps in the 5-GHz band. 802.11a employs the orthogonal frequency divisionmultiplexing (OFDM) encoding scheme as opposed to either FHSS or DSSS.

☐ **802.11b** - The 802.11 high rate WiFi is an extension to 802.11 that pertains to wireless LANsandyieldsaconnectionasfastas11Mbpstransmission(withafallbackto5.5,2,and

1Mbpsdependingonstrengthofsignal)inthe2.4-GHz band.The802.11bspecificationuses only DSSS. Note that 802.11b was actually an amendment to the original 802.11 standard added in 1999 to permit wireless functionality to be analogous to hardwired Ethernet connections.

☐ **802.11g**-Thispertains to wirelessLANs andprovides20+Mbps inthe2.4-GHzband.

☐ **802.11n** — 802.11n builds upon previous 802.11 standards by adding *multiple input multiple-output* (MIMO). The additional transmitter and receiver antennas allow forincreased data throughput through spatial multiplexing and increased range by exploiting the spatial diversity through coding schemes like Alamouti coding. The real speed would be 100 Mbit/s (even 250 Mbit/s in PHY level), and so up to 4-5 times faster than 802.11g.

☐ **802.11ac** — 802.11ac builds upon previous 802.11 standards, particularly the 802.11n standard, to deliver data rates of 433Mbps per spatial stream, or 1.3Gbps in a three antenna (three stream) design. The 802.11ac specification operates onlyin the 5 GHz frequencyrange and features support for wider channels (80MHz and 160MHz) and beam formingcapabilities by default to help achieve its higher wireless speeds.

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 aregiven 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.

➢ GSMownsamarketshareof morethan70%oftheworld's digitalcellular subscribers.

➢ GSM makes use of narrowband Time Division Multiple Access (TDMA) technique fortransmitting signals.

➢ GSMwasdevelopedusingdigitaltechnology.Ithasanabilitytocarry64kbpsto120 Mbps of data rates.

- Presently GSM supports more than one billion mobile subscribers in more than 190 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 twoother streams of user data, each in its own timeslot.

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
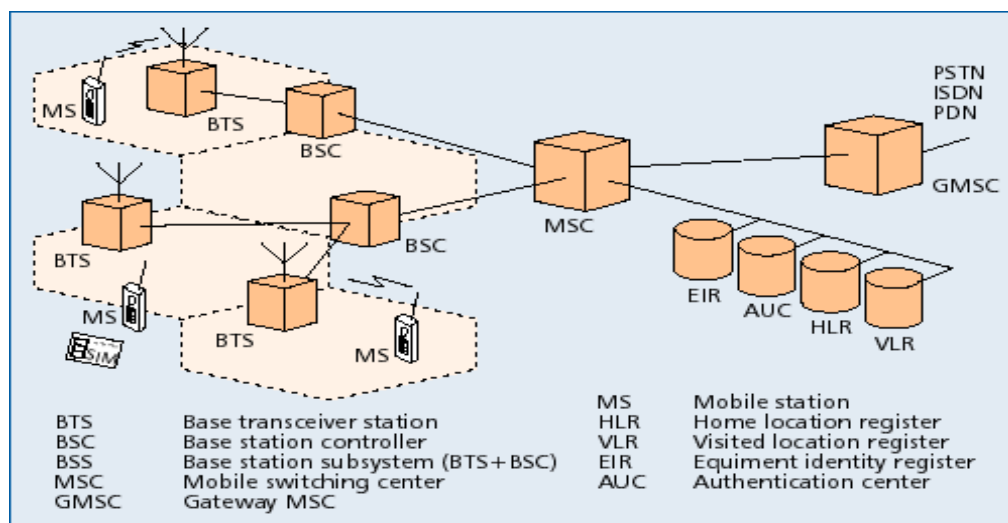- Support for new services

GSM:System Architecture

Fig.6.6GSMArchitecture

A GSM network comprises of many functional units. These functions and interfaces are explained in this chapter. The GSM network can be broadly divided into:

- The Mobile Station (MS)
- The Base Station Subsystem (BSS)
- The Network Switching Subsystem (NSS)
- The Operation Support Subsystem (OSS)

MobileStation (MS)

MSconsistsof followingtwo components

- • MobileEquipment(ME)
- • *Mobile*SubscriberIdentityModule(SIM)

Itallows separationofusermobilityfrom equipment mobility.

BaseTransceiverStation(BTS)

It isplaced onepercell.Itconsistsof high speed transmitter and receiver. TheFunction of BTS are:

- ➢ Providestwochannels
    - • SignallingandData Channel
- ➢ Performserrorprotectioncodingfortheradio channel.

BaseStationController (BSC)

ItcontrolsmultipleBTS.Themainfunctionsof BSC are:

- ➢ Itperformsradioresource management.
    - o Assignsandreleases frequenciesandtime slotsfor alltheMSs inits area.
    - o Reallocationoffrequenciesamongcells.
    - o Handoffprotocolisexecutedhere.
- ➢ Timeandfrequencysynchronizationsignalsto BTSs.
- ➢ TimeDelayMeasurement and notificationofanMS to BTS.
- ➢ PowerManagementof BTSand MS.

MobileSwitchingCenter(MSC)

- • ItistheswitchingnodeofaPLMN(PublicLandMobileNetwork).Therecanbe several MSCs in a PLMN. Its main functions are:
    - – Allocationofradioresource(RR)andHandoff.
    - – Mobilityof subscribers through maintain a location registration ofsubscriber.

GatewayMSC (GMSC)

It connects mobile network to a fixed network i.e. it is the entry point to a PLMN. Usually one GMSC per PLMN is used to Request routing information from the HLR and routes the connection to the local MSC.

HLR-HomeLocationRegister

It contains semi-permanent subscriber information of all users registered with the network, HLR keeps user profile. The MSCs exchange information is also held with HLR. When MS registers with a new GMSC, the HLR sends the user profile to the new MSC.

VLR-VisitorLocationRegister

It contains temporary info about mobile subscribers that are currently located in the MSC service area but whose HLR are elsewhere. It copies relevant information for new users (of this HLR or of foreign HLR) from the HLR. The VLR is responsible for a group of location areas, typically associated with an MSC.

AuC: Authentication Center is accessed by HLR to authenticate a user for service which contains authentication and encryption keys for subscribers.

EIR: Equipment Identity Register allows stolen or fraudulent mobile stations to be identified

Operationsubsystem(OSS):

The Operations and maintenance center (OMC), network management center (NMC), and administration center (ADC) work together to monitor, control, maintain, and manage the network.

Mobile Station:

The MS consists of the physical equipment, such as the radio transceiver, display and digital signal processors, and the SIM card. It provides the air interface to the user in GSMnetworks. As such, other services are also provided, which include:

➢ Voiceteleservices
➢ Databearerservices
➢ Thefeatures'supplementaryservices

The MS also provides the receptor for SMS messages, enabling the user to toggle betweenthe voice and data use. Moreover, the mobile facilitates access to voice messaging systems. The MS also provides access to the various data services available in a GSM network. These data services include:

➢ X.25 packet switching through a synchronous or asynchronous dial-up connection to the PAD at speeds typically at 9.6 Kbps.
➢ GeneralPacketRadioServices(GPRSs)usingeitheranX.25or IPbased datatransfer method at the speed up to 115 Kbps.
➢ Highspeed,circuitswitcheddataatspeedsupto64 Kbps.

The SIM provides personal mobility so that the user can have access to all subscribedservices irrespective of both the location of the terminal and the use of a specific terminal. You need to insert the SIM card into another GSM cellular phone to receive calls at that phone, make calls from that phone, or receive other subscribed services.

GSMChannels:

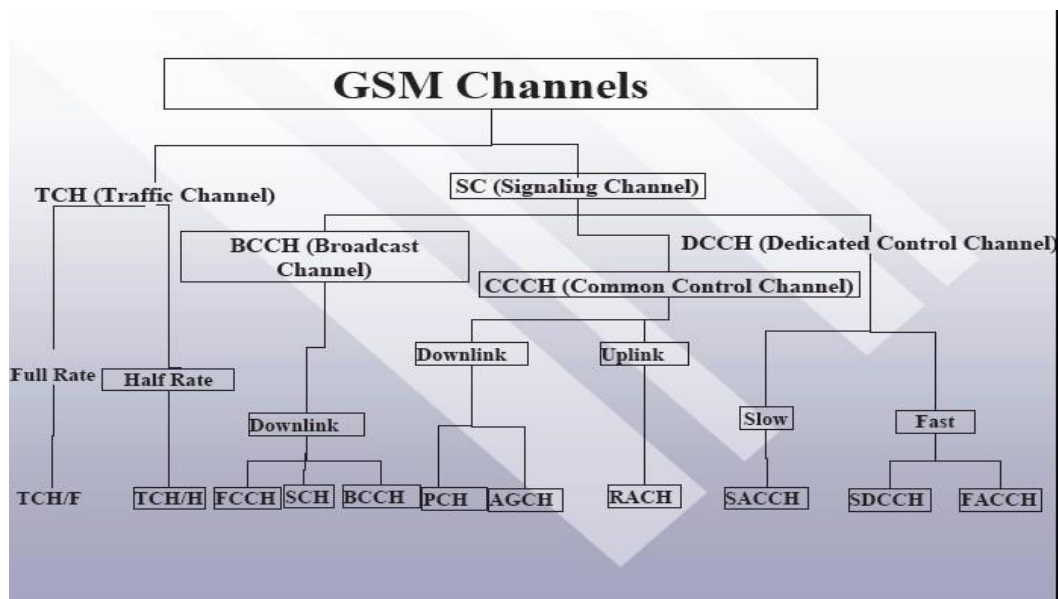Fig.6.7GSMChannel

Traffic Channel (TCH) Carries user voice traffic. Traffic Channel Transfer either encoded speech or user data. It is a bidirectional data channel. When operated in Full Rate TCH it can carry data rate of 22.4kbps and during Half Rate TCH the data rate is 11.2 kbps.

SignallingChannelcomprises of:

– BroadcastChannel(BCH)whichisunidirectional.

– CommonControlChannel(CCH)whichisunidirectional.

– Dedicated/Associated Control Channel (DCCH/ACCH) is bidirectional.

Broadcast Control Channel (BCCH)connects BTS to MS. It send cell identities, organization infoaboutcommoncontrolchannels,cellserviceavailable,etc.Itcarries   Radiochannel configurationinformationaboutCurrentcell&Neighbouringcells,Synchronizing informationincludes Frequencies &frame numberingandRegistration Identifierscontaining LA, Cell Identification (CI). Base Station Identity Code (BSIC), etc.

Frequency Correction Channel send a frequency correction data burst containing all zeros to effect a constant frequency shift of RF carrier by which the mobile station knows which frequency to use through repeated broadcast of Frequency Bursts.

Synchronization Channel send TDMA frame number and base station identity code to synchronize MSs. The MS knows which timeslot to use by Repeated broadcast of Synchronization Bursts.

AccessGrantChannel(AGCH)connectsBTStoMSusedtoassignanSDCCH/TCHtoMS.   Paging Channel (PCH) connects BTS to MS by Page MS.

RandomAccessChannel(RACH) connectsMStoBTSthroughSlottedAloha protocol.It carries request for dedicated SDCCH.

StandaloneDedicatedControlChannel(SDCCH)connectsMStoBTSforallocationof Standalone/Independent of Traffic Channel. It is used before MS is assigned to a TCH. DCCH(dedicatedcontrolchannel)isabidirectionalpoint-to-pointmain95ignalling channels. It Uses timeslots which are otherwise used by the TCH. It consists of:

> SDCCH(stand-alonededicatedcontrolchannel):forservicerequest,subscriberauthentication, equipment validation, assignment to a traffic channel.

> SACCH(slowassociatedcontrolchannel):forout-of-bandsignalingassociatedwitha traffic channel, eg, signal strength measurements.

> FACCH(fastassociatedcontrolchannel):forpreemptivesignalingonatraffic channel, eg, for handoff messages.

CDMA FORWARDANDREVERSE CHANNELS

A code channel is a stream of data designated for a specific use or person. This channel may be voice data or overhead control data. In a CDMA system Channels are separated by codes, these channels are broadly categorized as forward and reverse channels.

ForwardChannels

The Forward CDMA channel is the cell-to-mobile direction of communication or the downlink path.It consists of:

Pilot Channel is a reference channel which the mobile station uses for acquisition, timingandasaphasereferenceforcoherentdemodulation.Itistransmittedatall timesbyeachbase stationoneachactiveCDMAfrequency.Each mobilestationtracksthissignalcontinuously. **Sync Channel** carries a single, repeating message that conveys the timing and system configuration information to the mobile station in the CDMA system.

Paging Channels' primary purpose is to send out pages, that is, notifications of incoming calls, to the mobile stations.The base station uses them to transmit system overhead information and mobile station- specific messages.

Forward Traffic Channels are code channels used to assign call (usually voice) and 95ignalling traffic to individual users.

ReverseChannels

The Reverse CDMA channel is the mobile-to-cell direction of communication or the uplink path. **Access Channels** are used by mobile stations to initiate communication with the base station or to respond to Paging Channel messages.The Access Channel is used for short

registrations.**Reverse Traffic Channels** are used by individual users during their actualcalls to transmit traffic from a single mobile station to one or more base stations.

A CDMA channel is a pair of 1.25MHz frequency bands separated by guard-band. Theguard-band maybe 45 or 80MHz wide. Thepair of 1.25MHz band is located either in the 82- 893 MHz range in case of cellular CDMA or in the 1850-1989 MHz range in case of PCS CDMA.Theguard band usedincellularis45MHz forPCSforPCSitis80MHZ. In boththe cellular and PCS frequency ranges, CDMA channels have been identified by assigning CDMA channel numbers to the associated center frequencies for the two 1.25 MHz bands used by the channel. The channel numbers lie in the range 0-1023. Out of the two 1.25MHz bands associated with a CDMA channel, the higher frequency one is called the forward CDMA and the lower frequency one the reverse CDMA channel.

In general, each cell is assigned a specific CDMA channel which must be used by its base station and the mobiles within the cell. If the base station uses a sectorized antenna, each sector may be assigned a different CDMA channel. Thus sectorized cells may have 3 or 6 channels, instead of just one.

GPRSARCHITECTURE

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 sameair interface resources concurrently.

The GPRS specifications are written bythe European Telecommunications Standard Institute (ETSI), the European counterpart of the American National Standard Institute (ANSI). Following three key features describe wireless packet data:

• Always online feature – Removes the dial-up process, making applications only one click away.

• Upgradetoexistingsystems–Operatorsdonotneedtoreplacetheirequipment;rather, GPRS is added on top of the existing infrastructure.

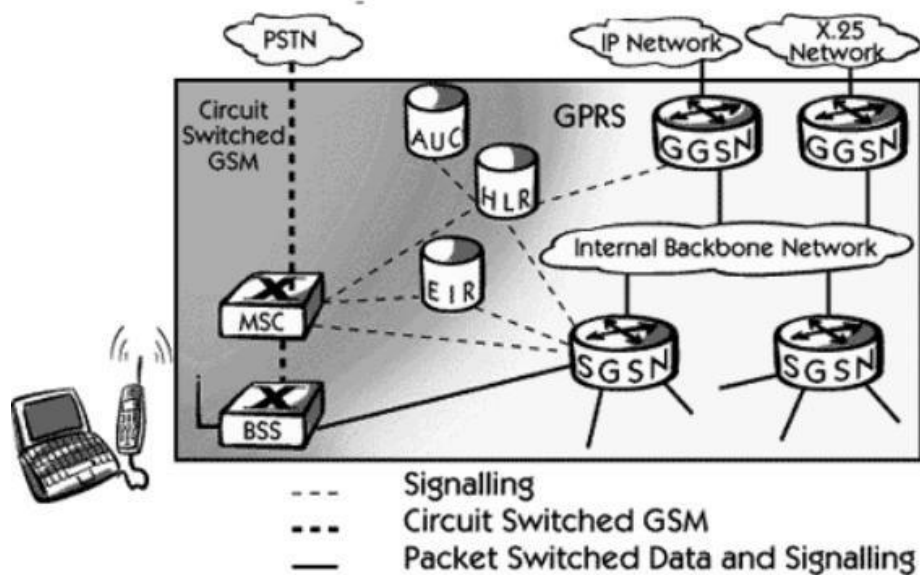• Anintegralpartoffuture3Gsystems–GPRSisthepacketdatacorenetworkfor3G systems EDGE and WCDMA.

Fig.6.8GPS Architecture

Themainnewnetworkarchitectureentitiesthatwereneededare:

- ➢ SGSN, Serving GPRS Support Node: The SGSN forms a gateway to the services within the network.

- ➢ GGSN Gateway GPRS Support Node: The GGSN, forms the gatewayto the outside world.

- ➢ PCU,PacketControlUnit: ThePCUdetectswhetherdataistoberoutedtothe packet switched or circuit switched networks.

Fromthe diagram given aboveit canbeseen that theGPRSnetwork architecture added some extra elements to the GSM network to enable it to carry the packet data. The PCU added to the base station network routed the data according to whether it was packet or circuit switched.

SGSN

The SGSN or Serving GPRS Support Node element of the GPRS network provides a number of takes focussed on the IP elements of the overall system. It provides a varietyof services to the mobiles:

- ➢ Packetroutingandtransfer
- ➢ Mobilitymanagement
- ➢ Attach/detach
- ➢ Logicallink management
- ➢ Authentication
- ➢ Chargingdata

There is a location register within the SGSN and this stores location information (e.g. current cell, current VLR). It also stores the user profiles (e.g., IMSI, packet addresses used) for all the GPRS users registered with the particular SGSN.

GGSN

The GGSN, Gateway GPRS Support Node is one of the most important entities within the GPRS network architecture.

The GGSN organises the interworking between the GPRS network and external packet switched networks to which the mobiles may be connected. These may include both Internet and X.25 networks.

The GGSN can be considered to be a combination of a gateway, router and firewall as ithides the internal network to the outside. In operation, when the GGSN receives data addressed to a specific user, it checks if the user is active, then forwarding the data. In the opposite direction, packet data from the mobile is routed to the right destination network by the GGSN.

PCU

The PCU or Packet Control Unit is a hardware router that is added to the BSC. It differentiates data destined for the standard GSM network (circuit switched data) and data destined for the GPRS network (Packet Switched Data). The PCU itself may be a separate physical entity, or more often these days it is incorporated into the base station controller, BSC, thereby saving additional hardware costs.

Wirelessnetwork generations:

First Generation, 1G These phones were the first mobile phones to be used, which was introducedin1982andcompletedinearly1990. Itwasusedforvoiceservicesandwasbased on technology called as Advanced Mobile Phone System (AMPS). The AMPS system was frequency modulated and used frequency division multiple access (FDMA) with a channel capacity of 30 KHz and frequency band of 824- 894MHz. Its basic features are:

- Speed-2.4kbps
- Allowsvoicecalls in1country
- Useanalogsignal.
- Poorvoice quality
- Poor batterylife
- Largephonesize
- Limitedcapacity

- Poorhandoff reliability

- Poor security

- Offeredverylow levelofspectrum efficiency

Second Generation (2G) 2G refers to the second generation based on GSM and wasemerged in late 1980s. It uses digital signals for voice transmission. Main focus of this technology was on digital signals and provides services to deliver text and picture message at low speed (in kbps). It use the bandwidth of 30 to 200 KHz. Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps. e.g.GPRS, CDMA and EDGE. The main features of 2G and 2.5G are : Second generation, 2G:

- Dataspeed wasupto64kbps

- Usedigitalsignals

- Enablesservicessuchastextmessages, picturemessagesandMMS(Multimediamessage)

- Providesbetterqualityand capacity

- Unabletohandle complex datasuchasvideos.

- Required strongdigital signals to help mobile phones work. If there is no network coverage in any specific area, digital signals would weak.

Third Generation (3G) 3G is based on GSM and was launched in 2000. The aim of this technologywas to offer high speed data. The original technologywas improved to allow data up to 14 Mbps and more using packet switching. It uses Wide Band Wireless Network with which clarityis increased. It also offersdataservices, access to television/video, newservices like Global Roaming. It operates at a range of 2100MHz and has a bandwidth of 15-20MHz used for High-speed internet service, video chatting. The main features of 3G are:

- Speed2Mbps

- Typicallycalledsmart phones

- Increased bandwidth and data transfer rates toaccommodate web-based applications andaudio and video files.

- Providesfastercommunication

- Send/receivelargeemailmessages

- High speed web/moresecurity/videoconferencing/3Dgaming

- Largecapacitiesandbroadband capabilities

- TVstreaming/mobileTV/Phone calls

- To downloada3minute MP3songonly11sec-1.5 minstime required.

- Expensivefeesfor3Glicenses services

- Itwaschallengetobuildtheinfrastructurefor3G

- Highbandwidthrequirement

- Expensive 3Gphones

- Large cell phones

Fourth Generation (4G) 4G offers a downloading speed of 100Mbps. 4G provides same feature as 3G and additional services like Multi-Media Newspapers, to watch T.V programs with more clarity and send Data much faster than previous generations. LTE (Long Term Evolution) is considered as 4G technology. 4G is being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, DigitalVideo Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth. The main features of 4G are:

- Capableofprovide10Mbps-1Gbps speed

- High qualitystreaming video

- CombinationofWi-Fiand Wi-Max

- Highsecurity

- Provideanykind of serviceatanytime as per user requirementsanywhere

- Expandedmultimediaservices

- Lowcostper-bit

- Batteryuses is more

- Hardtoimplement

- Needcomplicated hardware

- Expensiveequipmentrequiredtoimplementnextgenerationnetwork

Fifth Generation (5G) 5G refer to Fifth Generation which was started from late 2010s. Facilities that might be seen with 5G technologyincludes far better levels of connectivityand coverage. The main focus of 5G will be on world-Wireless World Wide Web (WWWW). Itis a complete wireless communication with no limitations. The main features of 5G are:

- Itishighlysupportable toWWWW (wirelessWorldWide Web)

- Highspeed,highcapacity

- ProvideslargebroadcastingofdatainGbps.

- Multi-medianewspapers,watchTVprogramswiththeclarity(HD Clarity)

- Fasterdatatransmissionthat ofthepreviousgeneration

- Largephonememory, dialingspeed,clarityinaudio/video

- Supportinteractivemultimedia,voice,streamingvideo,internetandother
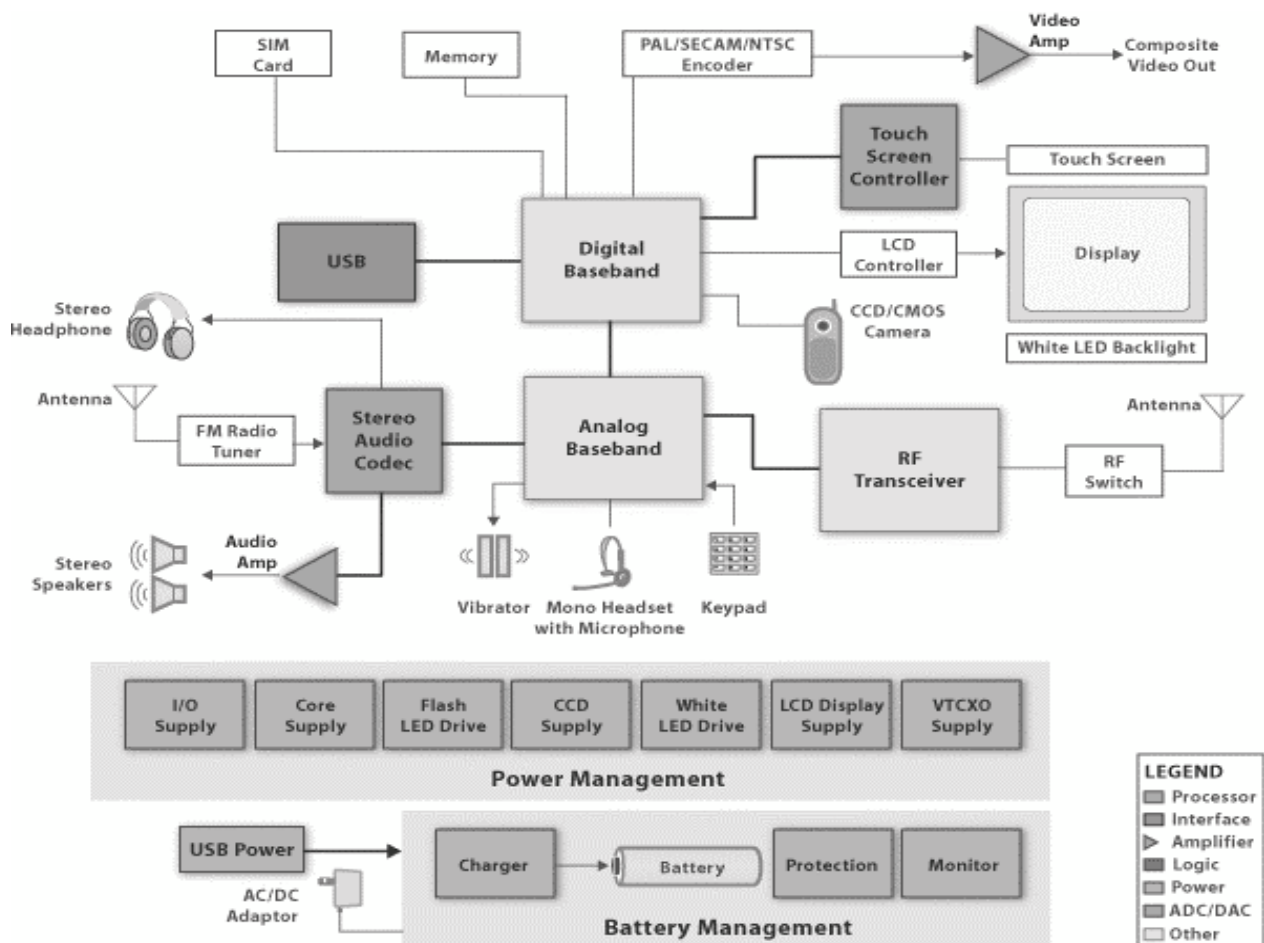
- Moreeffective andattractive

BlockDiagramofSmart Phone

Fig.6.9SmartPhoneBlock Diagram

The above figurerepresentsthe various blocksused inthe typicalcellphone system.The blocks
are described as follows:

➤ Microphone:Capturesvoicefor conversionfromanalogtodigitalmode.

➤ Speaker:Allowsmonitoringofremotephone.

➤ LCDDisplay:Shows Call,Phone,Signal &NetworkInformation.

➤ Keypad:Allowsaccess tospecificremotelocationsofthephone.

➤ Battery and Meter: While battery housings on cell phones are standard input designs.
Some cell phones also have some "battery processing" intelligence built in. Forexample,
they will check the charge level to start or stop the charge when the phone is
connectedtoadesktop,carorquickchargerandevenautomaticallydischargethe

battery for you when necessary. This is usually linked to the LCD display and to an audible beep to warn you of the battery charge status.

- LED Lights:Statusinformation,UsuallyGreen,white&Red.

- Digital Signal Processor: The DSP chipset is a critical component which is used to co-ordinates the voice, SMS and data/fax features of a cell phone. It processes speech, handles voice activity detection, as well as discontinuous GSM transmission and reception. One section amplifies the input signal received from the microphone, while another converts this.

- CODEC:Microphone voice signal from "analogue" to "digital".The digital conversion is necessary because the GSM cellular standard is a completely digital system. This DSP's voice processing is done with highly sophisticated compression technique mediated by the "CODEC" portion of the cell phone.

- RF Unit: The CODEC chipset instantly transfers this "compressed" information to the cell phone's Radio Frequency(RF) unit. RF Unit is essentiallyto perform thetransmitter and receiver section of the cell phone. It sends out the voice or data information via the cell phone antenna, over the air and on to the nearest cellular base station and ultimately to your call destination. The incoming voice also travels much the same route, althoughit is first in uncompressed digital form and translated into an audible analogue form, which is then piped out as sound through the cell phone's speaker. This analogue-to- digital and digital-to-analogue voice conversion via the CODEC is done at very high speeds, so that you never really experience any delay between talking and the other person hearing you and vice versa.

- SIM Card Reader: When you switch on your phone with a "live" SIM card inside, the subscriber information on the chip inside the SIM card is read by the SIM card readerand then transmitted digitallyto the network via the RF unit. The same route is followed when it hit the call button on the cell phone. The number you have inputted is instantly and digitally transferred to the network for processing.

- External Connectors: At the bottom of most cell phones there is an external connector system. You can usuallyplugin adata/fax adapter ora batterycharger, or a personal hands free device, or car-kit with external antenna connections. You will also find many with separate "speaker" and LED lights that are activated when the phone rings and/or when the batteryis low. Manyphones also have tiny LED lights under the keypad that light up when u presses a key and/or when the phone rings.