Chapter-14

Introduction:

In astronomical terms, a satelite is a celestial body that orbits around a ~~gate~~ planet (moon). In aerospace terms, however, a satellite is a space vehicle launched by humans and orbits earth on another celestial body.

A communication satellite is a microwave repeater in the sky that consists of a diverse combination of one or more of the following: receiver, transmitter, amplifier, regenarator, filter, onboard computer, multiplexer, demultiplexer, antenna, waveguide, regenarator, and about any other electronic communications circuit even developed.

A satellite radio repeater is called a transponder.

A satellite system consists of one or more satellite space vehicles, a ground-based station to control the operation of the system and a user network of earth stations.

Kepler's Law:

" " may be simply stated as:

① The planets move in ellipses with the sun at one focus.

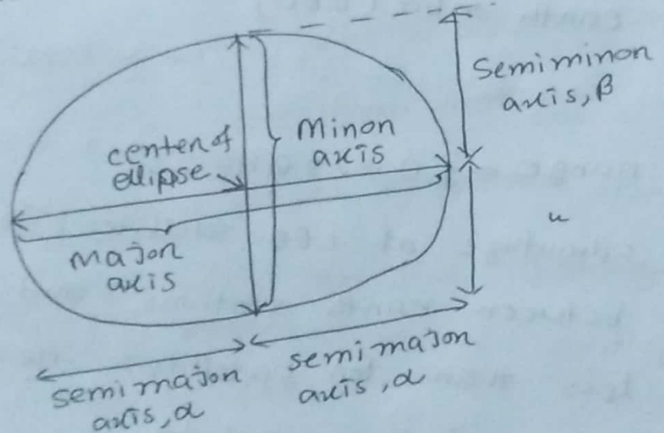
② The line joining the sun and a planet sweeps out equal areas in equal intervals of time.

③ The square of the time of revolution of a planet divided by the cube of its mean distance fnom the sun gives a numben that is same fon all planets.

⇒ Keplan's Law can be applied to any two bodies that in space intenact through gnavitation.

⇒ The langen body → pnimany
" smallen " → secondany / satellite.

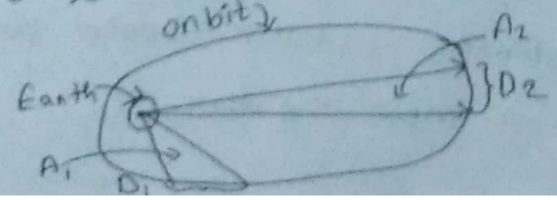
Keplan's first law states that a satellite will onbit a pnim-any body following an elliptical path. An ellipse has two focal point and the centen of the mass of a two-body system is always centened on one of the foci.



fon the semimajon axis α and the semimion axis, β shown in figune, the eccentnicity of the ellipse can be defined as,

$$e = \frac{\sqrt{\alpha^2 - \beta^2}}{\alpha}$$

Keplons 2nd law is also known as law of aneas



Keplar's Third law can be stated mathematically as,

$$\alpha = AP^{2/3}$$

A = constant (unitless)

P = mean solar earth days ~~orbit~~

α = semimajor axis (kilometers)

Satellite Elevation categories:

Satellites are generally classified as having a low earth orbit (LEO), medium earth orbit (MEO), or geosynchronous earth orbit (GEO)

LEO: frequency range = 1.0 − 2.5 GHz.

The main advantage of LEO satellites is that the path loss between earth stations and space veshicles is much less than for satellites revolving in medium- or, high-altitude orbits.

Less path loss equals to lower transmit powers, smaller antenna, and less weigth.

MEO

frequency range = 1.2 GHz − 1.66 GHz.

orbit between 6000−12000 miles above earth.

The department of defense's satellite based positioning system, NAVSTAR is a MEO system.

GEO:

frequency range = 2 GHz – 18 GHz.

orbit 22300 miles above earth's surface.

Most commercial communications satellites are in

G: geosynchronous orbit.

G. satellites have an orbital time of approximately 24 hours; same as Earth; thus G satellites appear to be stationary.

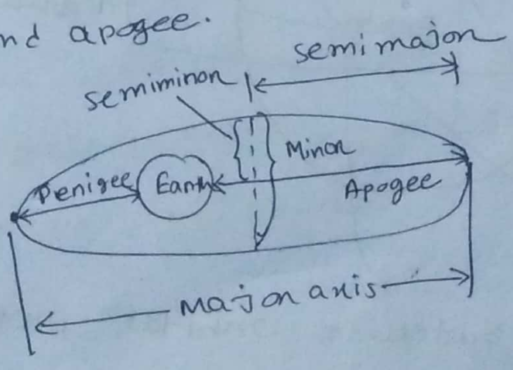
Satellite orbital patterns:

Terms: ① Apogee = The point in an orbit that is located farthest from earth.

② Perigee = closest to earth

③ Major axis / line of apsides = the line joining the perigee and apogee through the center of the earth.

④ Minor axis: The line perpendicular to the major axis and halfway between the perigee and apogee.

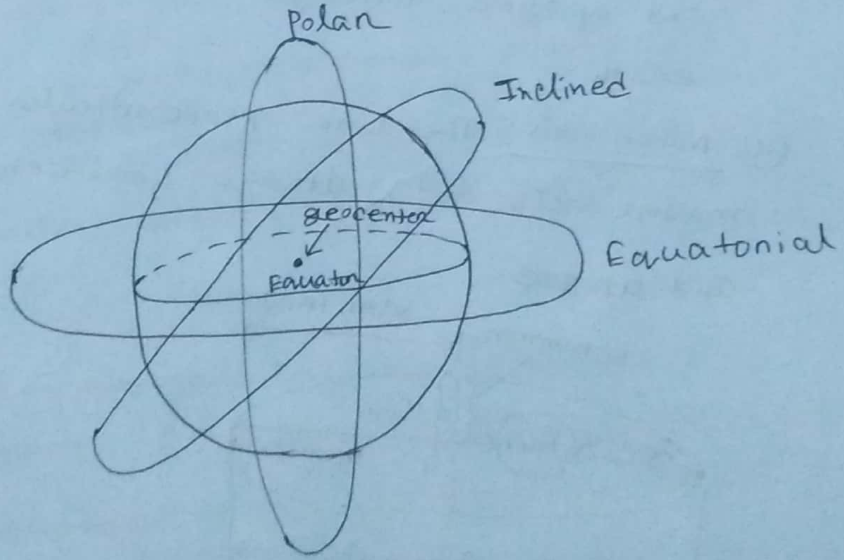


Three paths are useful for communications satellite: inclined, equatorial, or polar.

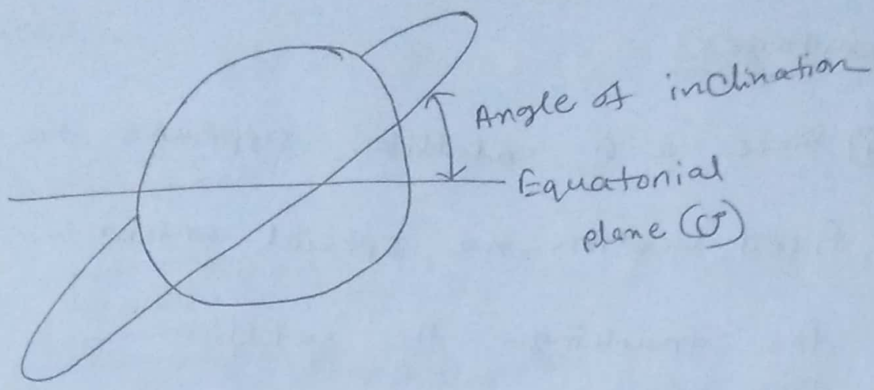
All satellites rotate around Earth in an orbit that forms a plane that passes through the center of gravity of Earth called the geocentre.

<u>Inclined orbit</u>: are virtually all orbits except those that travel directly above the equator or directly over the North and South poles.

The angle of inclination is the angle between the Earth's equatorial plane and the orbital plane of a satellite measured counterclockwise at the point in the orbit where it crosses the equatorial plane travelling from south to north.



Satellite orbital patterns.



Equatonial onbit : is when the satellite notates in a path ~~that~~ directly above the equaton, usually in a cinculan path.

~~th~~ With an equatonial onbit, the angle of inclination is zeno. All geosynchnonous satellites ane in this onbit

Polan onbit: A polan onbit is when the satellite notates in a path that takes it oven the Nonth and South poles in an onbit penpendiculan to the equatonial plane.

Geosynchnonous satellites

⇒ Sometimes nefenned to as stationany satellites - why?

G. satellites onbit Eanth above the equaton with the same angulan velocity as eanth. Hence G. satellites appean to nemain in a fixed location above one spot on Eanth's sunface.

Advantages:

① Since a G. satellites appears to remain in a fixed location, no special antenna is needed for tracking the satellite.

② Make repeated observations over a given area.

③ Get high temporal resolution data.

④ The orbit is quite high, so they do not experience as much atmospheric drag - their orbits may be a lot more stable.

⑤ Only three satellites are sufficient to cover the entire earth.

Disadvantages:

① Due to high orbit, the spatial resolution data is not as great as for the polar orbiting satellites.

② Due to longer transmission distance, the received signal is very weak.

③ It provides poor coverage at higher latitude places usually greater than

77 degrees.

Math $h = ?$ $a = ?$

$$\boxed{a = AP^{2/3}} \text{ km}$$

$$\boxed{h = a - 6378\text{km}} = \text{km}$$

The circumference of a G- orbit,

$$\boxed{C = 2\pi a} = \text{km}$$

velocity, $\boxed{V = \dfrac{C}{24hr}}$ km/hr

exam-A must

Satellite system link models:

A satellite system consists of three basic sections:

① Uplink model:

The primary component within the uplink section of a satellite system is the earth station transmitter.

A typical earth station transmitter consists of a IF modulator, an IF-to-RF microwave up-converter, a high power amplifier (HPA) and some means of bandlimiting the final output spectrum.

(a) The IF modular converts the input baseband signals to either an FM-, a PSK-, or a QAMmodulated intermidiate frequency.

(b) The up-converter converts the IF to an appropriate RF-carrier frequency.

(c) The HPA provides adequate gain and output power to propagate the signal to the satellite transponder.

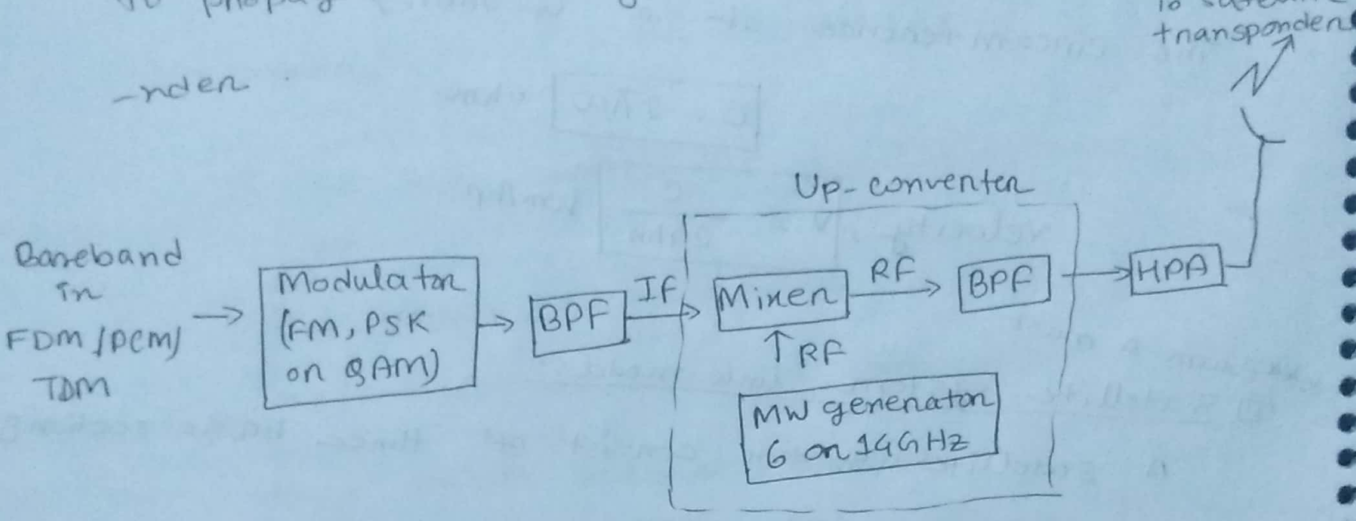


Fig: satellite Uplink Model.

② Transponder:

A typical satellite transponder consists of an input bandlimiting device (BPF), an input low noise amplifier (LNA), a frequency translator, a low level power amplifier, and an output bandpass filter.

(a) the input BPF limits the total noise applied to the input of the LNA (b) The output of the LNA is fed to a frequency translator, which converts the high-band uplink frequency to the low band downlink frequency.

(c) The low level power amplifier ~~which is~~ ~~commonly~~ amplifies the RF signal for trans-mission through the downlink to earth station receivers.

Each RF satellite channel requires a separate transponder.

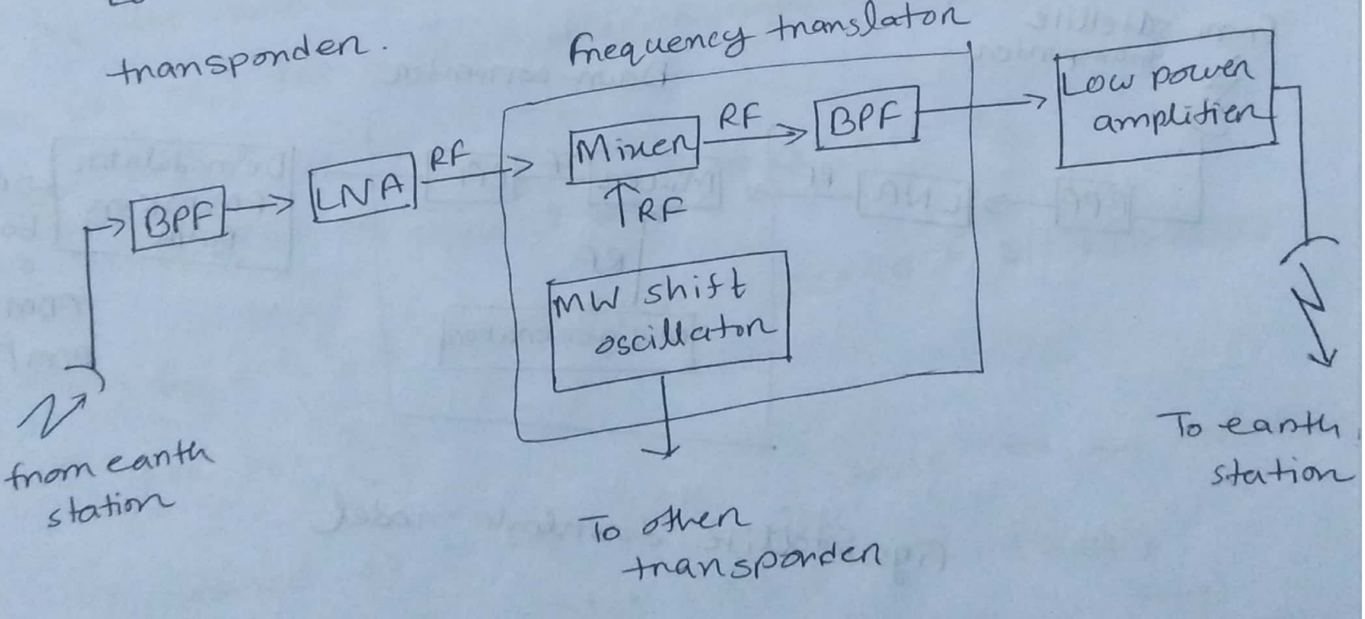


fig: satellite transponder.

③ Downlink Model:

An earth station receiver includes an input BPF, an LNA, and an RF-to-IF down converter.

ⓐ The BPF Limits the inputs noise power to the LNA.

ⓑ The LNA is a highly sensitive, low-noise device such as a tunnel diode amplifier or a parametric amplifier.

ⓒ The RF-to-IF down converter converts the received RF signal to IF frequency.

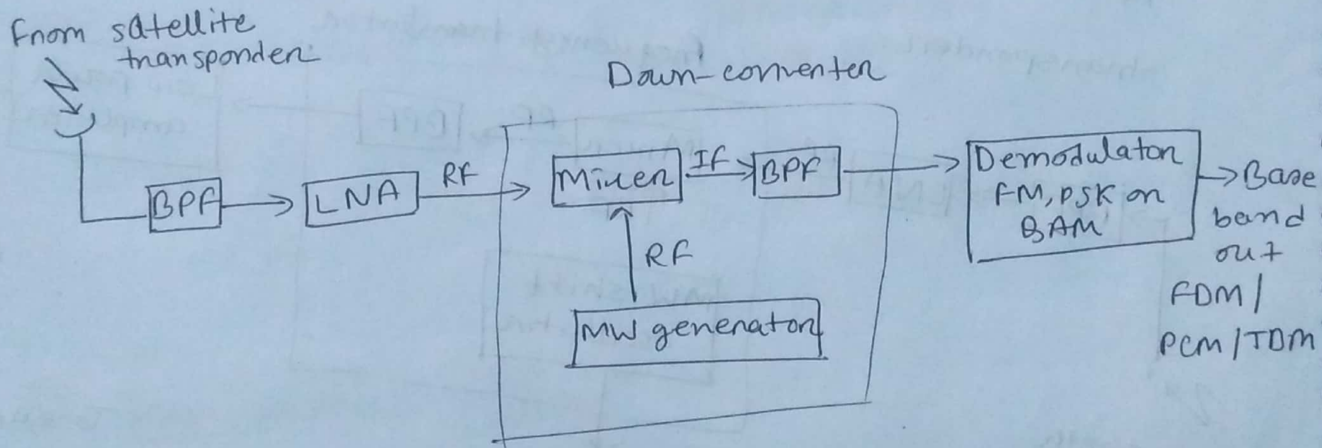


Fig: Satellite downlink model

② Cross link :

Occasionally, there is an application where it is necessary to communicate between satellites. This is done using satellite cross link / intersatellite link.

A disadvantage of using ISL is that both the transmitter and the receiver are space bound. Consequently both the transmitter's output power and the receiver input sensitivity are limited.

Example-2

For the total transmit power (P_t) of 1000W, determine the energy per bit (E_b) for a transmission rate of 50Mbps

Sol^{n}:

$$T_b = \frac{1}{f_b} = \frac{1}{50\times10^6 \text{ bps}} = 0.02\times10^{-6}\text{s}$$

$$E_b = P_t T_b = 1000 \text{ J/s} \times (0.02\times10^{-6} \text{ s/bit}) = 20\mu J$$

$$\left[\text{or, } E_b = \frac{P_t}{f_b}\right]$$

Expressed as a log with 1 Joule as the reference

$$E_b = 10\log(20\times10^{-6}) = -47\text{dBJ}$$ (Ans)

It is common to express P_t in dBW and E_b in dBW/bps.

or, $P_t = 10\log 1000 = 30\text{dBW}$

$$E_b = P_t - 10\log f_b = P_t - 10\log(50\times10^6)$$
$$= 30\text{dBW} - 77\text{dB}$$
$$= -47\text{ dBW/bps}$$

WDM

WDM (Wavelength - Division multiplexing)

It is a technology that enables many optical signals to be transmitted simultaneously by a single fiber cable.

WDM is coupling light at two or more discrete wavelengths into and out of an optical fiber. Each wavelength is capable of carrying vast amounts of information in either analog or digital form, and the information can already be time or frequency division multiplexed.

Similarity with FDM

WDM is sometimes referred to as simply wave division multiplexing. Since wave and frequency are closely related, WDM is similar to FDM, in that the idea is to send information signals that originally occupied the same band of frequency through the same fiber at the same time without their interfering with each other.

WDM vs FDM

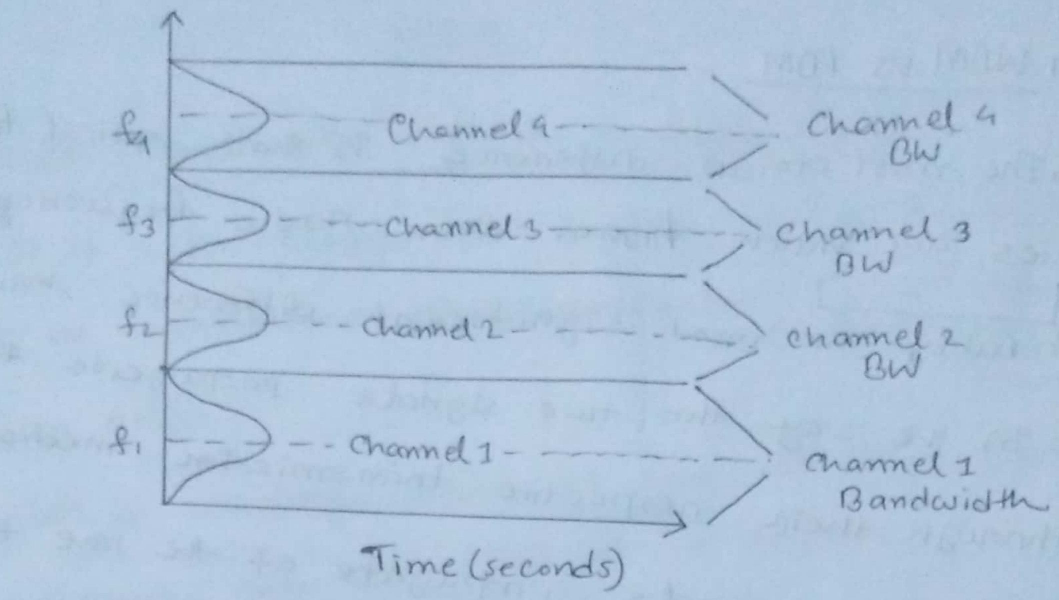
⇒ The most obvious difference is that optical frequencies are much higher than radio frequencies.

⇒ Probably the most significant difference, however, is in the way the two signals propagate ~~at the~~ through their respective transmission media.

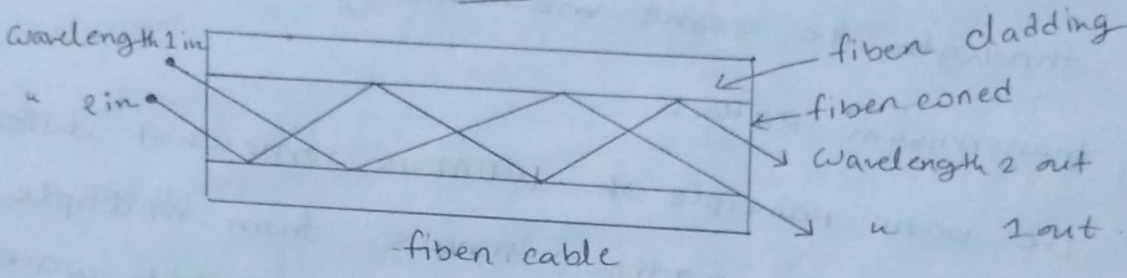
⇒ With FDM, signals propagate at the save time and through the same medium and follow the same transmission path.

The basic principle of WDM is somewhat different. With WDM, information signals from multiple sources modulate lasers operating at different wavelengths. Hence the signals enter the fiber at the same time and travel through the same medium. However, they do not take the same path down the fiber. Since each wavelength takes a different path, they each arrive at the receive end at slightly different time.

⇒ [WDM multiplexing is performed at extremely high frequencies, whereas FDM " " " relatively low radio and baseband frequency] first line এর পর হবে



(a)



(b)

Fig: (a) FDM, (b) WDM

Dense-Wave Division multiplexing (DWDM):

WDM is generally accomplished at approximate wavelengths of 1550nm, 100 GHz frequency separation and 0.8nm wavelength separation. Using a multiplexing technique called DWDM, the spacing between adjacent frequencies is considerably less.

Generally, optical systems carrying multiple optical signals spaced more than 200GHz or 1.6 nm apart in the vincity of 1550nm are considered standard WDM.

WDM systems carrying multiple optical signals in the vincity of 1550nm with less than 200GHz separation are considered D-WDM.

The more wavelengths used in a WDM system, the closer they are to each other and the denser the wavelength spectrum.

DWDM transmitter can simultaneously carry 206 digitally modulated wavelengths of colors over a single optical fiber cable.

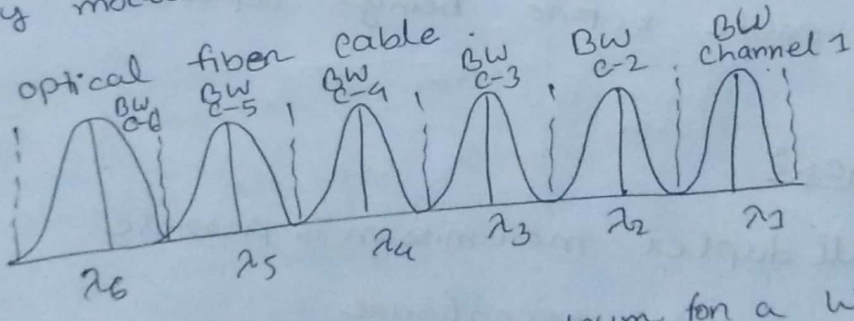


fig: Wavelength spectrum for a WDM system using six wavelengths.

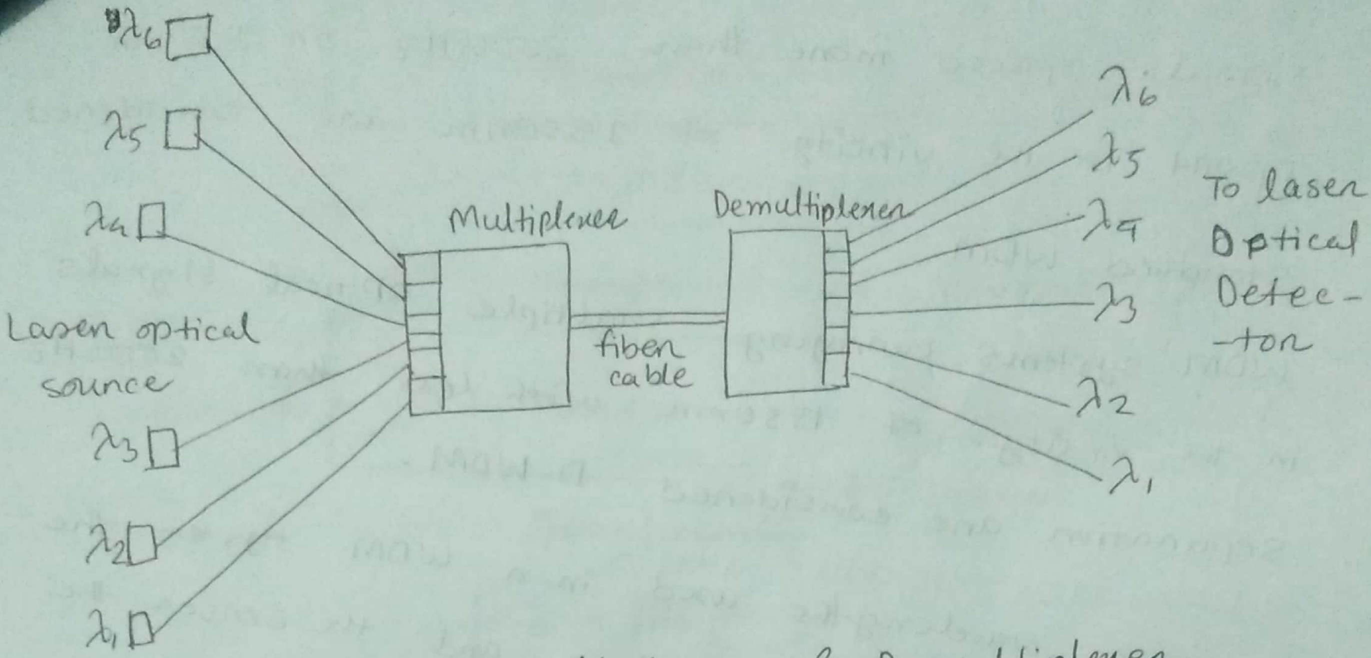


Fig: Multiplexer & Demultiplexer

Shows how the output wavelengths from six lasers are combined (multiplexed) and then propagated over a single optical cable before being separated (demultiplexed).

Advantages:

1. Full duplex transmission is possible
2. Easier to reconfigure.
3. Optical components are similar and more reliable
4. It provides higher bandwidth
5. High security

⑥ simple to implement.

Disadvantages:

① Signals can not be very close.

② Cost of system increases with addition of optical components.

③ Light wave carrying WDM are limited to 2-point circuit

④ Inefficiency in BW utilization, difficulty in wavelength tuning.

GSM

GSM: Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication.

GSM → 1991

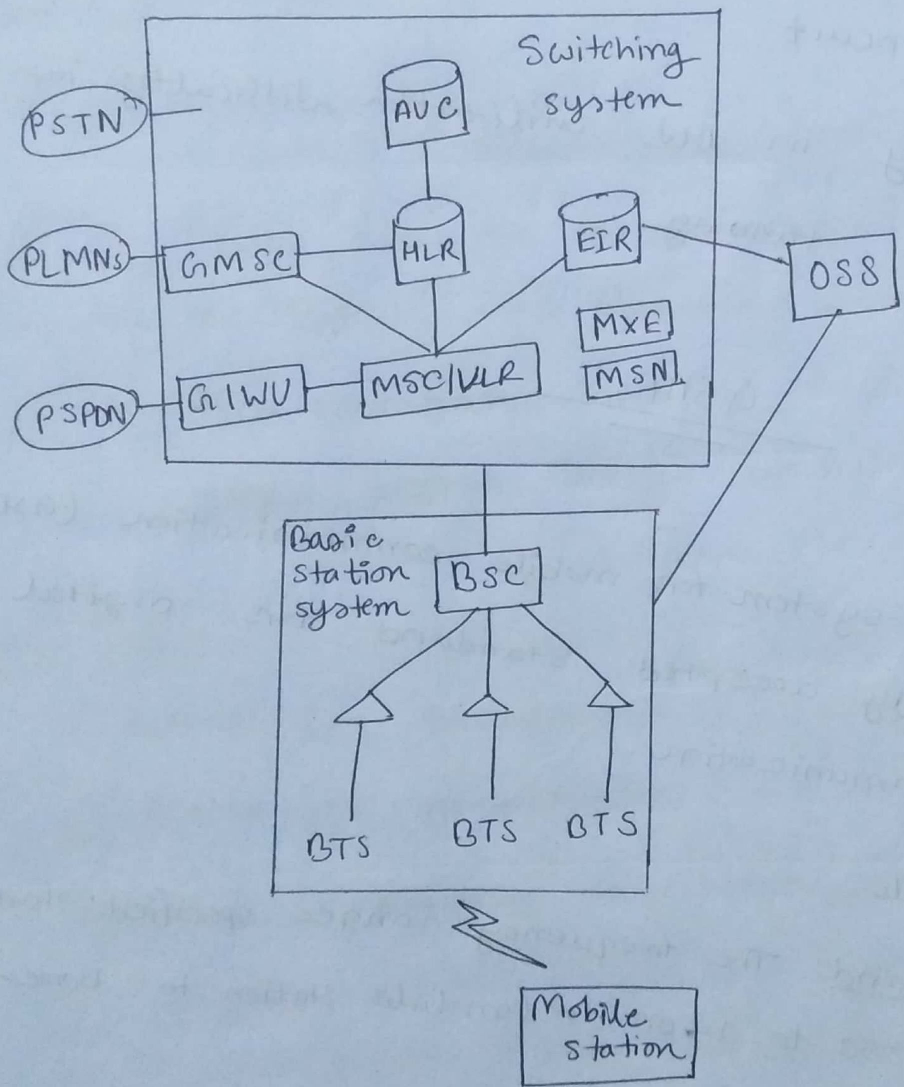
frequency band: The frequency range specified for GSM is 1850 to 1900 Hz (mobile station to base station).

Digital system was adopted for GSM.

☐ Narrowband time division multiple access solution (TDMA) was choosen for GSM.

☐ The GSM Network:

The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS) and the operation and support system (OSS).



(1) The switching system:

" " " is responsible for call processing and subscriber-related functions. The SS includs the following functional units:

(1) home location register (HLR): The HLR is a database used for storage and management of subscriptons. It stores permanent data about subscribers, including subscriber's service profile, location information, and activity status.

(2) mobile services switching center (MSC): The MSC performs the telephony ~~telephony~~ switching functions of the system. It controls calls to and from other telephone and data systems.

(3) Visitor location register (VLR): it is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.

(4) Authentication center (AUC): A unit called the AUC provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects the network operators from different types of fraud

found in today's cellular world.

(5) equipment identity register (EIR) : The EIR is a database that contains information about the identity of mobile equipment that prevents calls from stollen, unauthorized or defective mobile stations.

(ii) Base station system (BSS)

All radio-related functions are performed in the BSS, which consists of:

(1) BSC (Base station controllers):

The BSC provides all the control functions and physical links between the MSC and BTS. A number of BSCs are served by an MSC.

(2) BTS (Base transceiver stations):

The BTS handles the radio interface to the mobile station. A group of BTSs are controlled by a BSC.

(B.ii) The operating and support system (OSS):

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

The OSS is the functional unit from which the network operator monitors and controls the system. An important function of OSS is to provide a network overview and support the maintenance and maintenance activities of different operation organizations.

Intenface

DTE: Data tenminal Equipment can be virtually any binany digital senvice that generates, transmittes, neceives on inter-pnets data messages.

DCE: Data Communication Equipment is a genenal term used to descnibe equipments that intenfaces ~~dte~~ DTE to a trans-mission channel.

LCU: Line control unit is a DTE.

It pnocesses infonmation and senes as an intenface betwee-n the host computer ~~because it pase~~ and all the data communication cincuits it served. That's why it is often called a front-end-pnocesson on FEP.

FEP is a small sized computer that intenfaces to the host computer a number of netwonks on a number of peniphenal devices.

Within the FEP and LCUs, a single special-punpose integnated cincuit penfonms many of the fundame-tal data communications functions. This integnated cincuit is called

1. UART
2. USRT
3. USART

All three types of cincuits specify genenal purpose intnegaated cincuit chips located in a LCU on FEP that allow DTEs to intenface with DCEs.

UART: (Universal asynchronous receiven on transmitten)

A UART is used for asynchronous transmission of data between a DTE and a DCE. Asynchronous data transmission means that an asynchronous data format is used, and there is no clocking information transfe-rred between the DTE and DCE.

It can be divided into two functional section: ① Transmitten ② Receiven

The primany functions penformed by a UART are the following:

① Panallel-to-senial data convension in the transmi-tter and senial-to-panallel data convension in the neceiven.

② Ennon detection by insenting panity bits in the transmitten and checking panity bits in the neceiven.

③ Insent stant and stop bits in the T and detect and nemove stant and stop bits in the R.

④ Fonmating data in the T and R.

⑤ Provide transmit and receive status information to the CPU.

⑥ Voltage level conversion between DTE and the serial interface and vice versa.

Transmit and receive function can be performed by a UART simultaneously because the transmitter and receiver have separate control signals and clock signals and share a bidirectional data bus, which allows them to operate virtually independently of one another.

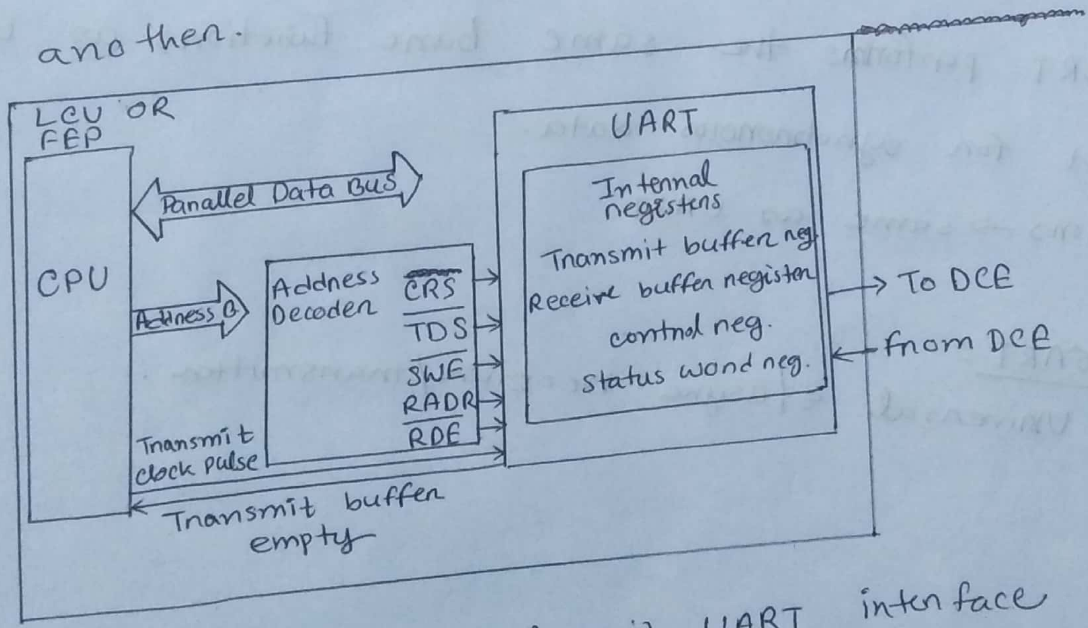


fig: Line control unit UART interface

(2) USRT:

Universal synchronous Receiver and transmitter.

A USRT is used for synchronous transmission of data between a DTE and a DCE.

Synchronous data transmission means that a synchronous data format is used, and clock information is generally transferred between the DTE and DCE.

A USRT performs the same basic functions as UART except for synchronous data.

functions → same as UART.

(3) USART:

Universal s/async receiver/transmitter.

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