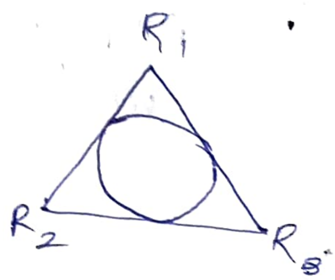
Unit - 2

Satellite communication principle.

Long distance (Terrestorial) communication we u. to use repeaters. for every 30-40 km [every radio Ho.. satellites replace them.

↳ Natural satellites
↳ Man made satellites
↳ Geosynchronous satellites can be enough for Global com.



R_1 → Europe, Africa, Russia, Mangolia
R_2 → North & south America, canada, Greenland.
R_3 → Asia, Australia, New zeland, south pacific

→ Frequency Bands: All μ-wave frequency bands additional : VHF (·1 to 0.3 GHz)
UHF (·3 to 1 GHz)
V (4-75 GHz) W (70-110 GHz)

wavelengths of 110-330 nm & μ m (300-3000 GHz)

→ Services :-
> Fixed satellite services: [FSS]
↳ Linking Global telephone n/w & tv
> Broadcasting satellite services - [BSS), DTH
> Mobile satellite service - (L Band) [MSS]
↳ Land mobile, Aeroplane, Maritime.

> Navigational satellite service : GPS [NSS]

> Weather Monitoriags:- Search & resume operation [WPS]

AOR – Atlantic ocean region

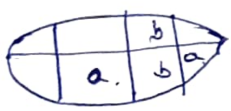
IOR – Indian –"–

POR – Pcefic –"–

→ Kepler's law [1571 – 1630]

Kepler law I :- A satellite which revolve around a planet will have elliptical orbit

satellite - lighter body , earth - heavier - body.



$$\text{eccentricity} = \frac{\sqrt{a^2 - b^2}}{a}$$

$$0 < e < 1$$

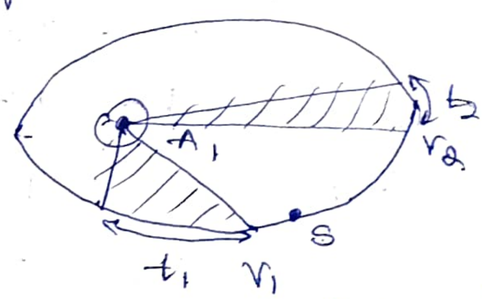
→ Kepler law II :- A satellite revolving around the plant will cover same area at two equal time periode in the orbital plane.

if $t_1 = t_2$

then $A_1 = A_2$

&

$V_2 < V_1$



→ Kepler's law III :- Square of the period time of orbit is proportional to cube of the mean distance b/w two bodies (Earth and satellite)

$$a^3 = \frac{\mu}{n^2}$$ under ideal condition.

$n \rightarrow$ mean motion of satellite rad/sec

$\mu \rightarrow$ earth's geocentric gravitational constant

$\mu = 3.986 \times 10^{14}$ m^3/sec^2

If P is orbital period then $n = \frac{2\pi}{P}$

Ex: Find a for geo synchronous satellite.

1 Day = 86400 sec

$$n = \frac{2\pi}{P} = \frac{2\pi}{86400} = 7.272 \times 10^{-5} \text{ rad/sec}$$

Now,
$$a^3 = \frac{\mu}{n^2} = \frac{3.986 \times 10^{14}}{7.272 \times 10^{-5 \cdot (2)}}$$

$$a = \sqrt[3]{0.548 \times 10^{29}}$$

$$= 42241 \text{ Km}$$

Here, $e = 0$ & Hence $b = a$

Hence, the path is circular

→ Satellite velocity is an orbit:-

$$V_s = \sqrt{\frac{\mu}{r_e + h}}$$

$\mu = GM$

$G = 6.672 \times 10^{-11}$ Nm / kg^2

M = Mass of earth = 5.97

r_e → Radius of earth

h → Height of the orbit

→ Satellite time period in an orbit:

$$T_s = \frac{2\pi}{\sqrt{\mu}} (r_e + h)^{3/2}$$

$T_s \propto r_e \propto h$

→ Gravitational force on Satellite:-

$$F = \frac{\mu m}{(r_e + h)^2}$$ m → mass of satellite

Here, $F \propto \frac{1}{h} \propto m$

All these are obtained from the IIIrd law.

Basic Definations :-

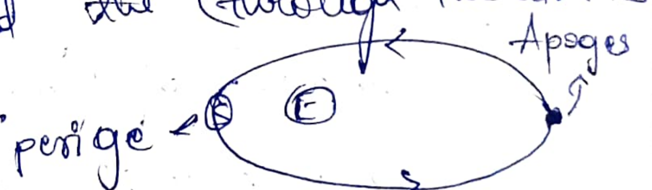
1. Satellite path / orbits : path traced out by satellite at some point above the earth.

↳ elliptical path

↳ circular path

orbits - height above the earths surface.
LEO, MEO, polar, Geosynchronous.

2. Primary and secondary bodies :-
point closest to earth from satellite path is perigee. Farthest point is apogee. Line joing perigee & Apogee is called ~~the~~ (through the earth's centre) line of apsides.



3. AN → Ascending node :
Point where orbit crosses the earth's equator where satellite is moving from south to North
DN → Descending Node.

4. Line connection AN and DN through centre of the earth surface is called line of Node

5. Angle b/w the equatorial plane and the orbital plane measured wrt ascending Node the moving from East to west is called the Angle of inclination (i)

6. Prograde orbit :- rotation of earth and satellite is same ($0 < i < 90$)

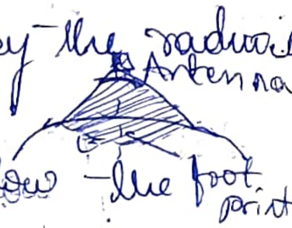
Advantages :- Energy req for maintenance is reduced and even the cost of launch is reduced.

7. Retrograde orbit :- Opposite direction of motion

Here ($90 < i < 180$)

8. Epoch :- position of the satellite in orbit at a given instant of time.

9. Satellite footprint :- Area covered by the radiation pattern on the earth's surface.



10. Subsatellite point :- point directly below the satellite on the surface of the earth.

11. Uplink :- link b/w the base station and satellite where base station transmits and satellite receives

The vice versa is Downlink.

12. Mean solar time : 24 Hours.

13. Orbital pertribations :- gravitational pull from Heavenly bodies like sun, Moon.

14. Earth surface is no flat (Non spherical Horizon).
Permittivity & permeability of (atmosphere). (drag) Air pressure
solar activity (fusion and tension). Earths magnetic field.

14) Antennae look. LS : Used to locate satellites. Earth station latitude, longitude satellite longitude / latitude from sub satellite point.

15. Escape velocity :- Velocity req to leave the atmosphere (9.2 Km/sec) = 33 times of sound speed.

16. Pay load :- Physical weight of the satellite (Actual weight).

17. Bus :- Interconnecting medium for signal tx to take place.

18. Transpondence :- Active tranceivers that receives the signal from earth through uplink and tx the same via downlink.

19. Planes :- Equitorial plane, Polar plane.

20. Sun synchronous orbit :-

21. Eclipse of satellite :-
To avoid eclipse of satellite multi point tracking is done.

22. 1° body - Earth - mass 'M'
2° body - satellite - mass 'm'

→ Why satellite communication? :-

> It is a broad band network.
> Economical compared to terrestrial comm;
> Accessible from any point (ocean, desert, in aeroplane)
> Backbone of internet.
> Various services - telephone linking, mobile, education, metrology, rescue works, defence system, TV broadcasting.

→ Orbits :-

Inclined . polar . LEO . MEO . geosynchronous

→ Advantages of Geosynchronous orbit.

1. No tracking required
2. Access of sattellite is possible over entire day.
3. Sattelite will be within line of sight.
4. Footprint of antenna is large so that it can cover no of base stations.
5. Good quality of signal is possible
6. Dopler effect can be avoided
7. Inclination angle is zero.

⇒ Disadvantages:

1. Earth station latitudes > 81.5° (i.e places in northern and southern hemisphere) are not able to access.
2. Strength of the received signal will be weak
3. Delay in uplink and downlink (> 270 m sec)
4. Powerful launching vehicles are required
5. Larger path loss.
6. Congestion of the orbit.

→ Lower earth orbit (LEO)

1. height is 1000km from earth.
2. Mobile commn
3. Elliptical orbit
4. Large no of sattellites is LEO
5. Low power is sufficient.

→ Disadvantages:
1. Satellite have limited life
2. Time of rotation Tr. 1hr 30min
3. Satellite is visible only for 15min

→ Medium earth orbit (MEO)
1. Height - 1000 to 2000 Km.
(van Allen belt, separate troposphere & ionosphere)
2. MEO is close to van Allen belt
3. Circular orbit.
4. Longer life
5. Telephone linking, FAX, email
6. Rotation time - 5 hr 12 min.
7. visibility period - 2hrs.

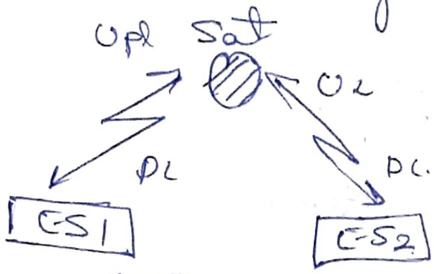
~~Disadvantages~~

→ Highly eccentric orbit (HEO)
1. Countries near polar region (Greenland Russia) use this satellite for app.
2. height - 20,000 km
3. Rotation period 12 hrs.
4. Visibility period - 8hrs.

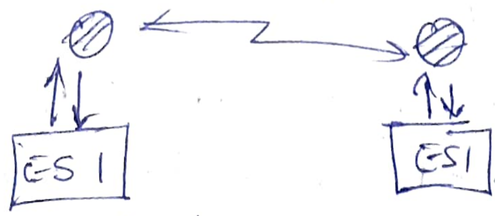
→ Satellite communication systems:-
* Space segment
* Earth/ground segment
* Link segment

* Space segment: GSO is highest orbit (36000km)
1. This segment consists of satellites
Satellite → passive - only receivers
→ Active - Transponders (receive process & transfer)

* Ground to ground commⁿ system.

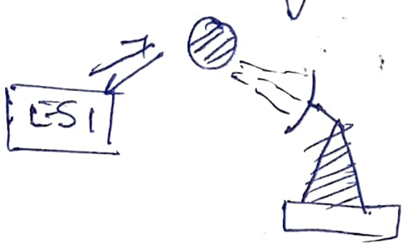


If it is LOS



If donot come in LOS.

* Ground to relay.



Relay platform.

Constituents of space segment.
1. power supply
2. Solar arrays/panels
3. Antenna
4. transponders
5. Sensor ckts [Altitude control.

1. Power supply:
> Constant solution of satellite
> Various force (drags (to overcome)
> House keeping operation (ie. if a sattelite is in one
> Active ckts of transponders
> Miscellaneous.

→ power consumed by different units.

Transponders 5%.
House keeping operation - 12%
Active devices excitation - 80%
Miscellaneous 3%
Total - 100%

→ Ambiguity / Mishappening :-

- Main power supply
- Manufactioning
- Interference (EMI, RFI)
- Interconnecting failure (bias stration)

In order to take care of all these ambiguity back up power supply will be present.

→ Batteries :- Ni-cd, Ni-Hydrozene, Ag Zn

- Ni-Hydroxide batteries are popular coz stable of temp. stability, long life, less charging time (<15 hrs)
- SMPS (switch mode power supply) is used nowa-day coz of ~~sol~~ stability.

2. solar panel / solar arrays.

- Temp range -190°c to 60°c
- Silicon is used in common
- Folded during the launch & defolds once it reach the orbit.

3. Satallite antennas

parameters to be considered

- Structure
- weight of the antena
- Beam width
- Radiation pattern
- Gain
- Directivity
- polarization.

* Usually CFRPC (carbon fiber rainforce plastic) is used for fabricating antena. It has large tolerence (-125 to 125°c light weight, immune to EMI, RFI longlife

4. Transponder (Rejcer) is ?-

Consists of Rx & TX connected back-to back and contains antennae.

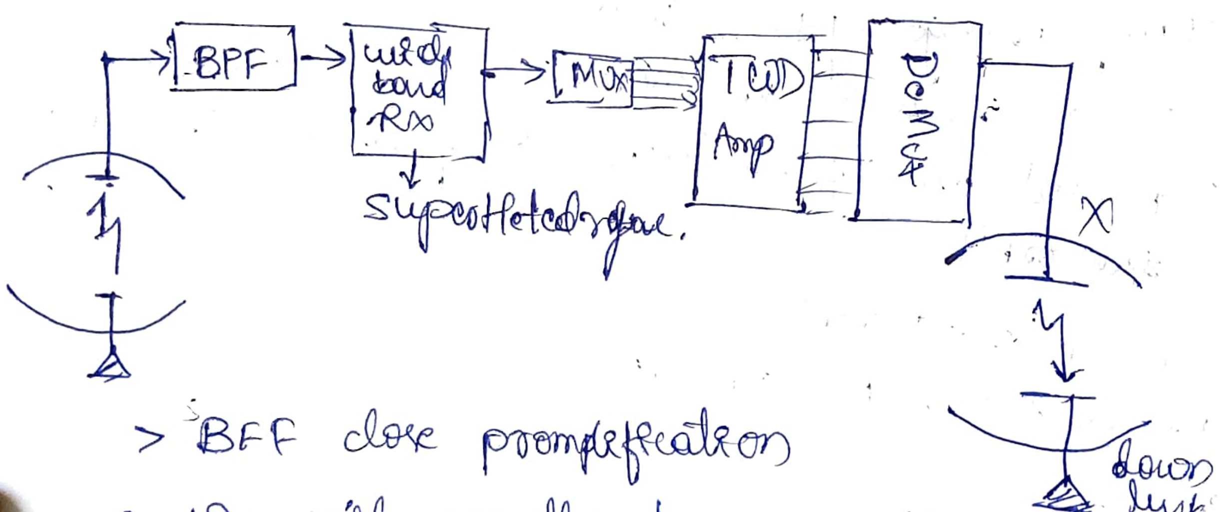
No of channels $\frac{B}{V_c}$ → Band of channels

suppose c-band 36 MHz, guard band, 4 MHz

BW of channel 500 KHz.

$$N = \frac{(36-4)M}{500K} = \frac{32 \times 10^9}{5 \times 10^5} = 6.4 \times 10^4$$

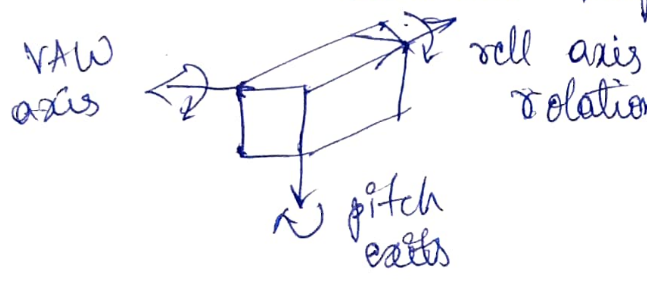
Spectral efficiency (ms) should be maximized by using frequency reuse system. use spot beam multiple access. for TDMA, CDMA, ODMA.



> BFF close preamplification

> We will usually have an alternative wideband Rx in case of malfunctioning.

> Attitude control: We control few parametres to make sure satellite steps in its orbits



why is it necessary?
* Salar panels must focus Towards the sun always.
* Cancel the effects of drags or torque
* Thermal effect.
* Antenna must always focus must always focus towards earth surface. can be done by using sensors anboard.
passive method : Here we use the powersupply of satellite
Active method : Here we use fuel in the satellite.
. Hydrazine (firing produce Torque).
→ ~~Stating~~ Station keeping / How keeping operation)
High degree of Accuracy is required
± 0.05° or ± 0.1°

→ Earth segment :-
1. Source processing : Signal can be analog / digital

Source processing → Signal conditions Fitching Amplification compound MUX → Modulator up convertor → o/p pow amp feed back ckt coupler → TXr

2. The signal should be fit into channel properly. remove harmonic components (trimming), compondor (compressor expandor). Adjcent channel interference. Compondor overcomm high frequency noise.
3. AM, FM, PCM, PM ⇒ ASK, FSK, QPSK.

4. Modulated signal will be weak, we amplify them to particular level.

TWT, klystron, magnetron, CFA, for power ac
Balanced and unbalanced ckt (BALUNS)

Effective isotrophically radiate power (EIRP) must be high as possible dB watts.

Rcever unit

Signal recovery unit, D to A converter, transductors ← down conversion filter & Compound demux (RF to IF range) ← demodulator coherent, Non coherent dectors (SHR) ← coupling LNA

demodulator → envelop det, discriminator
→ Coherent, non-coherent

* TT and C signals (Health monitoring of satellite)

→ Telecommand, telemetry, Tracking : Onboard, sensors gather data regarding.

- battery life - Power consumption per units
- altitude - torque on satellite
- environmental info - Predictors meterite impact
- space craft temp - power supply availability
- stored fuel.

Each of them will be modulated by diff carrier and transmitted to ES trough down link.

Tracking :- Position of satellite in orbit

command and control : C band is used for TT & C

Start bit	bit address	Decoder address	Mode of operation	Address	command signal

- Faraday cage :-

$n_S \rightarrow$

General specifications of earth station

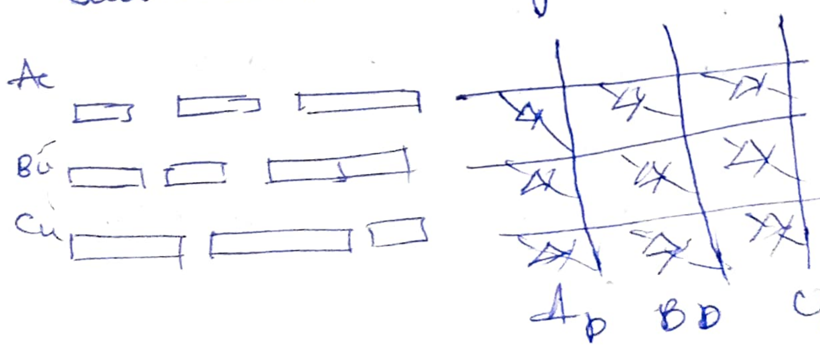
- Intermediate freq. used is 70MHz for earth station
- general earth station.
- For wide band sys - If is in the range 140-400MHz
- Mobile users - 3.4GHz to 4.2GHz.
- Local oscillator will be the crystal oscillator
- Solid state and vaccum - pulse & continuous mode ranging from 50W upto 150MW
- Single carrier per channel (SCPC) is used to minize interference b/w various channel

→ Satellite switched TDMA (SSTDMA)

Time division multiple axes

SSTDMA switches b/w the receiving stations ie which packet of info should go to which base station.

switch are arranged in 3x3 form.



> Link segment:

EM wave or μ-wave link connection b/w satellite & earth station. There are 2 links - uplinks & downlinks

Loss during linking

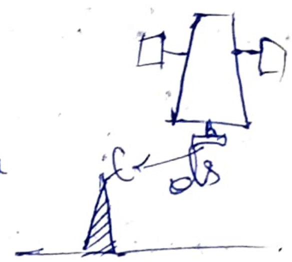
1. Path loss : (α_p) - Due to large distance
2. Loss in troposphere - scattering of signal absorption (due to rain, snow fig).
3. Loss in ionosphere - Faraday rotation which affect the polarization (α_i)
4. Loss in antenna - orientation prob. not properly focus, internal reflections in dish antenna (α_a)
5. Additional losses - Doppler shift occurs wrt mobile phones & stationary sat, tracking errors.

* α_p is predominantly as compared the other losses.

If P_t - transmitted power

d_s - distance of separation (slant range)

G_t - Gain of transmitting antenna



power density at sat antenna $= \frac{P_t G_t}{4\pi d_s^2}$ W/m² --- (1)

where $P_t \times G_t$ called effective isotropically radiated power (EIRP)

* $G_t = \frac{A_{eff}}{A_{iso}} = \frac{\text{Effective aperture of antenna under consider}}{\text{effective aperture of isotropic antenna (reference)}}$

* G_t is represented in terms of dBi or dBd

* for isotropic antenna $G_t = 1$

Isotropic aperture = $\frac{\lambda^2}{4\pi}$

$$G_t = \frac{A_{eff} \cdot 4\pi}{\lambda^2} \quad \text{--} \rightarrow (2) \quad \Rightarrow A_{eff} = \frac{G_t \lambda^2}{4\pi}$$

using (2) in (1)

$$P_{received} = \frac{(\lambda^2/4\pi)\, P_t}{4\pi d_s^2}$$

$$\text{path loss} = \frac{P_t}{P_r} = \left(\frac{4\pi d_s}{\lambda}\right)^2 \quad \text{where } \lambda = \frac{c}{f}$$

→ This eqn is written for isotropic antenna where $G_t = 1$

also path loss $\alpha_p = \left(\frac{4\pi f d_s}{c}\right)^2$ → in nepers.

taking 10 log on b.s,

$$10\log(\alpha_p) = 20\log\left(\frac{4\pi}{c}\right) + 20\log(f) + 20\log(d_s)$$

↳ in dB

Simplifying above eqn path loss is given by

$$(\alpha_p)_{dB} = 92.4 + 20\log(f) + 20\log(d_s)$$

↳ for isotropic antenna

usually directional antenna are used

(where $G_t \neq 1$)

⇒ For directional antenna.

Let G_t be the gain of antenna.

Power received at the i/p of antenna

$$P_r' = \left(\frac{P_t A_{eff}}{4\pi d_s^2}\right) G_t$$

Here, $P_t \times G_t \Rightarrow EIRP$

$$\therefore P_r' = \frac{EIRP \times \lambda^2/4\pi}{4\pi d_s^2} = EIRP\left(\frac{\lambda}{4\pi d_s}\right)^2$$

If G_s is the gain of satellite antenna then power received $P_r = P_r' \cdot G_R$

$$P_r = EIRP\left(\frac{\lambda}{4\pi d_s}\right)^2 G_r$$

∴ Path loss for directional antennas at earth stations & satellite.

$$\alpha_p = \frac{P_t G_t}{P_r} \text{ or } EIRP$$

$$\alpha_p = \left(\frac{4\pi d_s f}{c}\right)^2 \frac{1}{G_r} \rightarrow \text{in nepers}$$

$$\therefore (\alpha_p)_{dB} = 20\log\left(\frac{4\pi}{c}\right) + 20\log(d_s) + 20\log(f) - 20\log G_s.$$

$$\therefore (\alpha_p)_{dB} = 20.4 + 20\log(d_s) + 20\log(f) - 20\log(G_r)$$

// problem..

1. $f = 5.62\,GHz$ dia of dish $= 6m$ transmitted power $P_t = 8kW$. $d_s = 39{,}920\,km$ $\eta = 0.7$ find EIRP. P_r, α_p, G_{dB}

- path loss $\alpha_p = 92.4 + 20\log(5.62) + 20\log(39{,}920)$

$$\alpha_p = 199.26\ dB$$

- $G_{dB} = 10\log(0.7) + 20.4 + 20\log(6m) + 20\log(5.62)$

$$= 49.4\ dB$$

- $(P_t)_{dB} = 10\log\left(\frac{8000}{W}\right) = 39.03\ dBW$

- $EIRP = P_t G_t = (P_t)_{dB} + (G_t)_{dB}$

$$= 88.43\ dB$$

- $(\alpha_p)_{dB} = (EIRP)_{dB} - (P_r)_{dB}$

$$= 88.43 - 199.26$$

$$= -110.83\ dBW$$

$$= 8.26\ pW$$