SATELLITE COMMUNICATION

Saathi

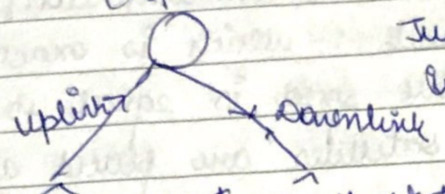
Date 1/12/18

✓ satellite :- Any body which revolves around an active body.

(Reflector station).

✓ Types :-

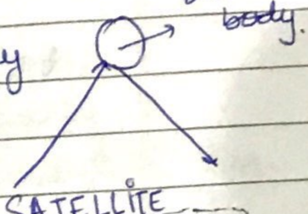
⇒ Passive satellite :-



Just reflect back the information.

(used earlier). large amount of power. (Earth station). (Earth station).

⇒ Active satellite :- It has active reflector ~~to~~ body ~~so~~ having transistors, amplifiers, transducers.



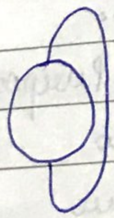
POWER SYSTEM OF ACTIVE SATELLITE

Antenna — Transducer — signal conditioner — Amplifier — Antenna

✓ Terms Associated

- Uplink :- Earth station ⟶ Satellite
- Downlink :- Satellite ⟶ Earth station.

POLAR ORBIT

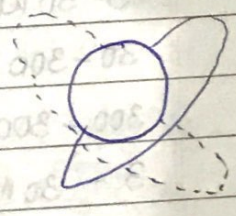


EQUILATERAL ORBIT

⇓

In this only 3 satellites are enough to cover whole world.

INCLINED



~~Earth~~ If the distance of orbit is less from earth then it is called LEO (Low Earth orbit). [50 - 8000 km]

↳ Google Mapping.

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MEO :- Medium Earth Orbit. (8000 - 20,000 km). [

GEO :- Geo synchronous Earth Orbit (36,400 & above).
[Communication].

* Geostationary Orbit :- which is exactly at 36,400 km
Here the satellite speed is equal to earth's speed.
[∵ Broadcasting satellites are placed at this orbit].

$$t = \frac{36400 \times 1000 \text{ m}}{3 \times 10^8 \text{ m/s}}$$

$$t = 12.1 \times 10^{-2} s$$

$\boxed{t = 0.121 \text{ sec}}$ ⇒ This is the transmission delay ~~from~~ during uplink.

→ During Downlink $t = 0.121$ sec.

⇒ Total Time delay = $0.121 + 0.121 = 0.242$ sec.

12/12/18.

Frequency Allocation :-

Frequency Bands		Applications
< 3kHz.	ELF	Landline
3-30 KHz	VLF	Mobile Comm.
30-300 KHz	LF	Navigational Purposes.
300-3000 kHz.	MF (Mid).	AM Radio
3 - 30 MHz	HF	Shortwave
30 - 300 MHz	VHF	FM Radio.
300M- 3GHz	UHF (Ultra)	Cell Phone (GSM).
3 - 30GHz	SHF (Super)	
30 - 300GHz	EHF (Extreme)	

μ-wave Freq.

~~1~~ - 40 GHz → basic band for satellite communications
Above these range, they are affected by rain.

1 to 40 GHz [mm] :- line of sight comm. possible.
Env. effect is less.

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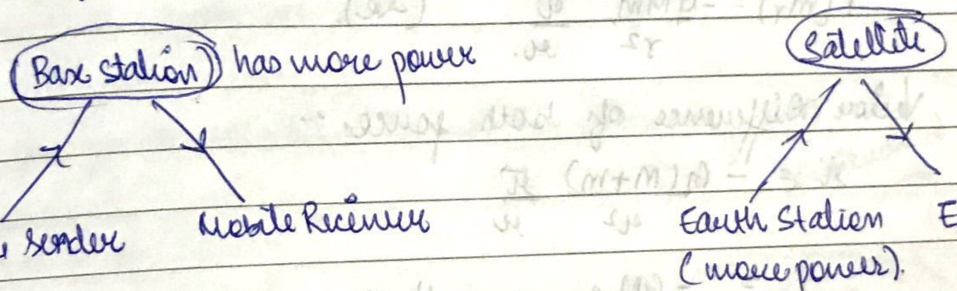
1 to 40 GHz

Range.	Uplink f.	Band	Downlink f.	Applications :-
1-2 GHz		L		GPS
2-4 GHz		S		Radar Communication.
4-8 GHz	6	C	4	satellite comm. (Effect of Rain is very less).
8-12 GHz	11	X	7/8	Military & Government.
12-18 GHz	16	Ku	14	Satellite comm. in Europe.
18-26 GHz	23-26	K	17/18.	satellite comm. (Investigatory).
26-40 GHz.		Ka.		Military Purpose.

Uplink & Downlink freq. should be at different freq.

→ In case of mobile Downlink freq. > Uplink frequency.

→ In case of satellite comm., Uplink freq. > Downlink freq.



⇒ International Telecommunication Union (ITU)

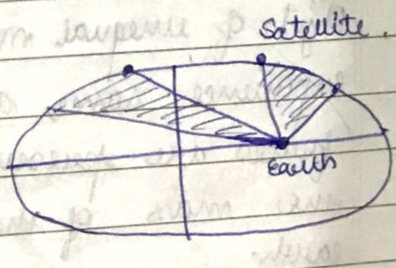
⇒ INTETSAT (International Telecommunication satellite

14/7/18

KEPLER'S LAW

1st Law :-

Planets move in the elliptical orbit with sun at one focus.



2nd law :-

Planets cover equal area in equal time.

3rd Law :-

$$T^2 \propto D^3$$

Square of Time period is directly prop. to cube of distance of satellite from earth or sun

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Newton's Law of Motion:-

$$f = ma = m\frac{dv}{dt}$$

Law of Gravitation

$$f = -\frac{GMm}{r^2}\frac{\vec{r}}{r}$$

where $M \rightarrow$ Mass of Earth.
$m \rightarrow$ mass of satellite
$r \rightarrow$ distance b/w Earth & satellite

$e_r \Rightarrow \frac{\vec{r}}{r}$ = unit vector to show direction of force of attraction

Force towards Earth is:-

$$F(M\ddot{r}) = \frac{GMm}{r^2}\frac{\vec{r}}{r} \quad (+ve)$$

Force towards satellite is:-

$$F(m\ddot{r}) = -\frac{GMm}{r^2}\frac{\vec{r}}{r} \quad (-ve).$$

Vector Difference of both force:-

$$\ddot{r} = -\frac{G(M+m)}{r^2}\frac{\vec{r}}{r}$$

$$= -\frac{GM}{r^2}e_r = -\frac{\mu}{r^2}e_r$$

Gallileo's Theory

Objects of unequal mass, when fall from same distance experience same acceleration provided no external forces are present (like air buoyance force etc) also the mass of the object should be negligible to the earth.

Orbital Parameters:-

1) semimajor axis (a)
2) Eccentricity (e)
3) Inclination / tilt (i)

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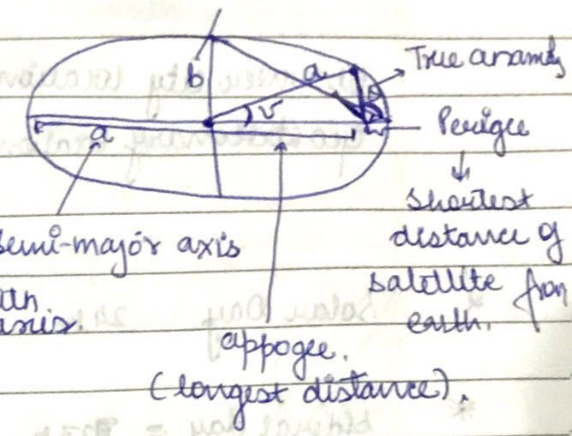
- Longitude of ascending node (Ω)
- Argument of perigee (ω')
- Mean anamoly of Epoch (M_0) :→ The position in which satellite is present snapshot of that time

Eccentricity (e) $= \sqrt{1 - (b/a)^2}$

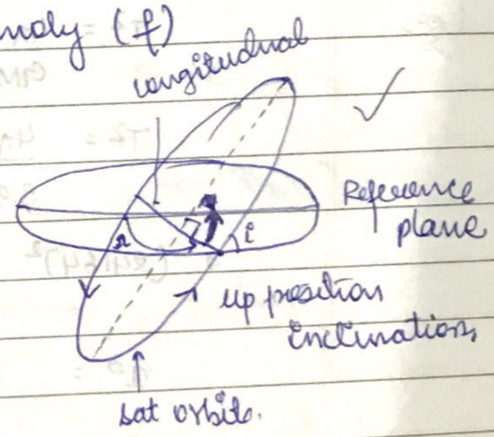


Mean Anamoly (f)
True Anamoly (θ) → Angle of focus to satellite with major axis.
Eccentric Anamoly. (v)

Angle of from centre to satellite is eccentric anomaly (v).

Angle from pt of perigee to satellite is mean anamoly (f)

$\boxed{\Omega + \omega' = 180^\circ}$



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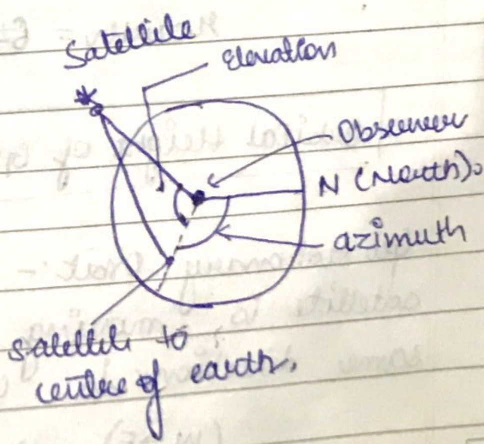
Look angles of satellite

Using elevation and azimuth angle, line of sight is maintained b/w antenna & satellite



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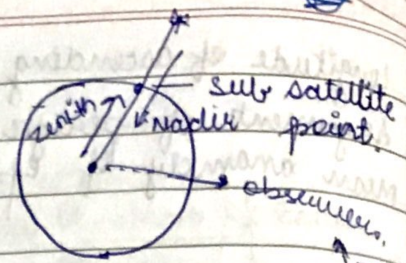
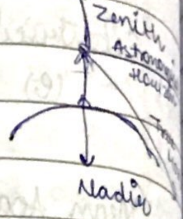
Sub satellite point.



highest pt. on celestial sphere.

Upward direction :- Zenith

Downward direction :- Nadir.



Observer city location :- 83E, 22N.

Geo stationary location :- 83E. (Longitude).

83E
22S

* Solar Day :- 24 h. = 84600 sec.

* Sidereal day = 23 h 56 m 4 sec. = 84164 sec.

"Zenith is an imaginary pt directly above a particular location on the imaginary celestial sphere.
Above :- opposite to grav. force.
The opp. direction (e) towards gravity pull, is Nadir".

Orbital Height :- Geo

$T^2 \propto a^3$

$T^2 = \frac{4\pi}{GM} a^3$

$T^2 = \frac{4\pi}{3.98 \times 10^5} a^3$

$\Rightarrow (84164)^2 = \frac{4\pi}{3.9 \times 10^5} a^3$

$a^3 = \frac{(84164)^2 \times 3.9 \times 10^5}{4\pi}$

$\boxed{a = 42164 \text{ km}}$ $\Rightarrow$ This distance is from earth's centre ~~from~~ to satellite

r_{earth} = ~~640~~ 6378 km.

~~42164~~

$\boxed{\text{Orbital Height of GSO from earth surface} = 35786 \text{ km.}}$

Geo stationary Orbit :- The orbit ~~which~~ on which the satellite is moving with same speed of earth with same direction is called geo stationary orbit

(W→E) → satellite & earth's moving directions

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$v = \left[\frac{\mu}{r}\right]^{1/2}$ Km/s.

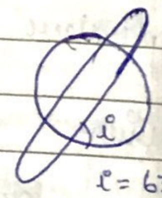
$v = \left[\frac{GM}{r}\right]^{1/2}$ Km/s.

where ~~r~~ = radius of that orbit (ie) semi-major axis of the orbit calculated from centre of ~~earth~~ earth.

Apeasis

Periasis.

Molniya orbit :- Highly Inclined elliptical Orbit.



$i = 63.2°$

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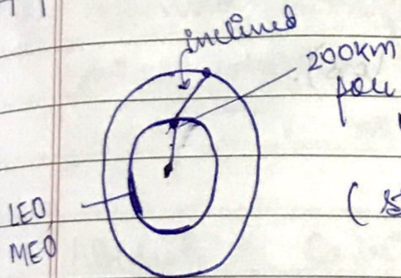
SATELLITE LAUNCHING

(less atmospheric pressure).



for minimum wastage of fuel.

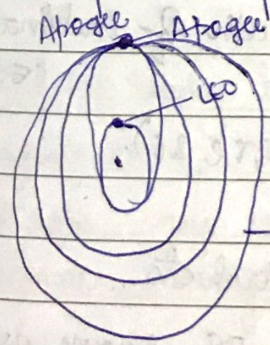
(straight launching).

If straightly the satellite is launched, fuel wastage takes place.

LEO :- Lower Earth Orbit (~~Hofman~~ Hohman Transfer).

MEO :- Medium Earth Orbit.

for GEO Transfer



Apogee Kick Motor → then ~~through~~ providing multiple launching required inclination is provided and finally it becomes circular.

— To make orbit circular.

Orbital station keeping :- To fix the satellite on a particular orbit.

Affected by :- •) Gravitational force of earth, solar system

•) Silestrial Gravitational force. (N-S)

solar lunary.

Non Keplerian force

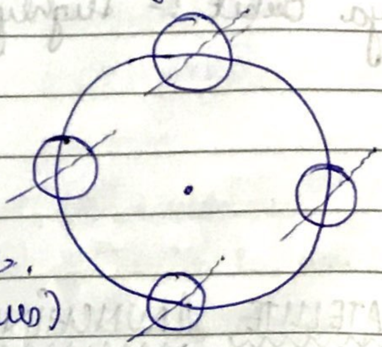
•) Solar Radiation Pattern.

North South Control :- (Longitude Control) :- 0.85°/year ⇒ Speed from the Earth station
⇓ Need more fuel

East- West Control :- (Lattitude Control):- 0.05°/ month.
→ Thruster.
⇓ Takes less fuel.

* Eclipse Season Effect :- (Power Pt. of view)

21st March
23rd September ⇒ (±23 days
1 min to 72 min)



Solar Batteries
⇓
doesn't get sunlight for this duration of time.

⇒ Fixed Batteries (non-changable batteries) are send.

(More Batteries ⇒ More weight ⇒ More loss).

Eclipse Period :

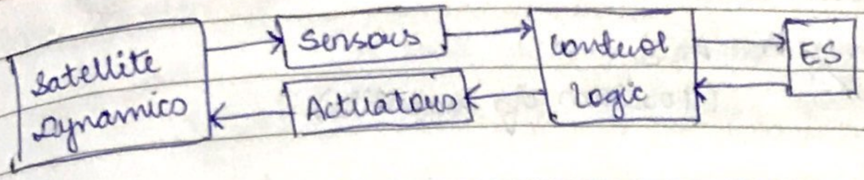
/01/19 Satellite Subsystem ~~(space segment)~~.

① Attitude of Orbit Control (AOCS).
Attitude Control → position control of satellite
Orbit Control → Angle of Elevation, azimuth & Inclination (ES).

② Telemetry, Tracking, Control & Command (T,TC &C).
→ sensors on satellite.
↳ to sense may be speed, alignation, control etc...

Then it sends the data to ES ⟶ Then ES track using required control logi
& send command to sa

Each antenna is fixed for a particular frequency.



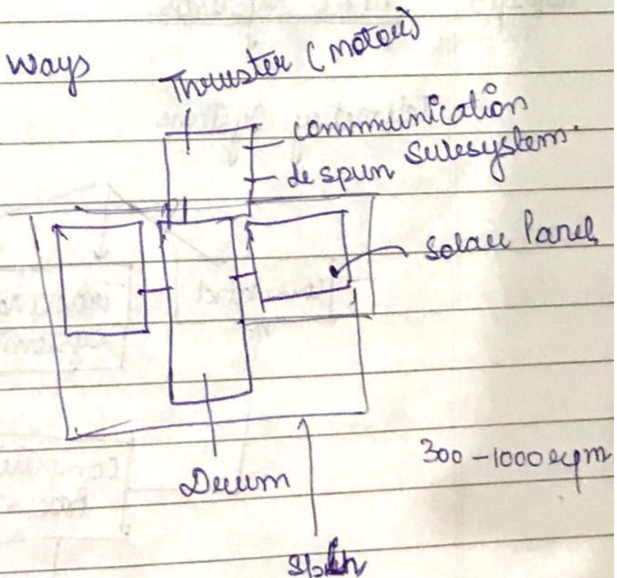
(3) Power systems :- Primary : Solar system.
Secondary : Battery.

(4) Thermal system :- To protect solar panels, machinery & systems from the solar radiations. It is a mechanical & structural body for protection.

(5) Communication subsystem :→ uplink / downlink antenna & Transmitter - Receiver / Transponder.

(6) Antenna subsystem :- ~~Ree~~ Used for sending position control data of satellite. Each antenna works on single frequency.
no - 4-6.

Attitude & Orbit Control :-
Attitude Control → GEO → ⇓ Two ways



•) Spin Axis Control :-

Communication system is fixed.

Since the body is moving continuously, maximum solar panels are used, thus become heavy.
But used for position control purpose.

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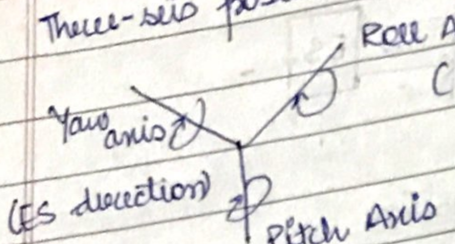
Three-axis position control.

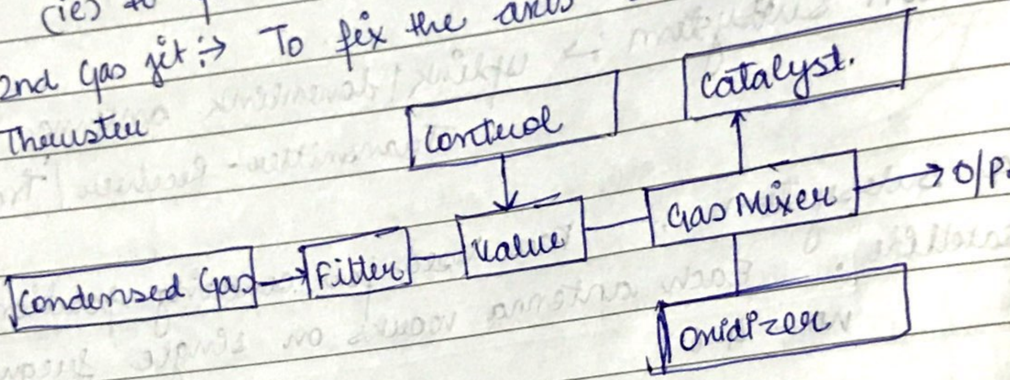


Each axis :- 2 Motors / Thruster / gas jet.

•) 1st gas jet :→ If the satellite is displaced, then roll axis is moved to fix the satellite.
(ie) to fix the direction from drifting

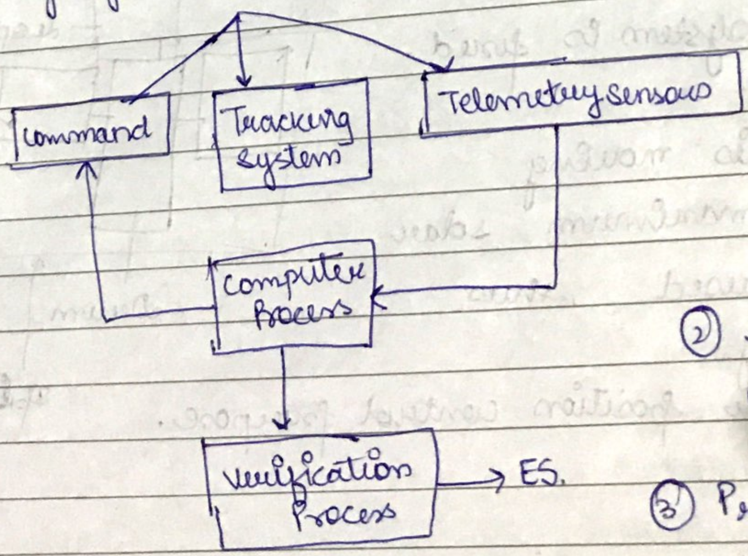
•) 2nd Gas jet :→ To fix the axis direction.

Thruster



18/01/19 TT&C systems

Telemetry Systems



Kind of Telemetry Data :-

① Voltage, current and Temp. of ~~switch~~ diff. parts of satellite

② switch status of comm. transponder

③ Pressure of propulsion tanks

④ output of altitude sensors

⑤ Reaction wheel speed.

Date __/__/__

⑥ Env. Information :-

* These sensors may be digital or analog but data communication b/w them is digital.

IR sensors.

Sat

E.S } Earth sensor (face to face)

This sensor

TRACKING SYSTEM :-

- To track azimuthal, elevation and inclination angle.
- Tracking is done from Earth station.
- It is nothing but how to move 1st antenna for proper work.
- Tracking is independent of telemetry data.

Command system :→

Antenna Control

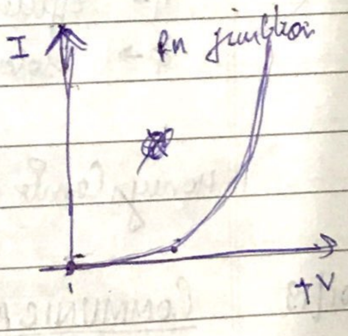
Solar cell Direction & Speech

Battery Life Reconfiguration

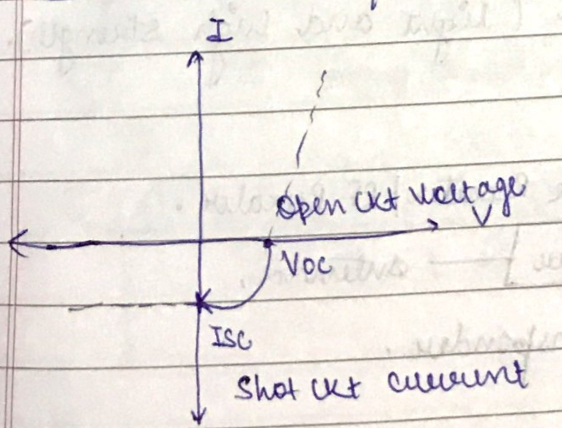
Propulsion Problems.

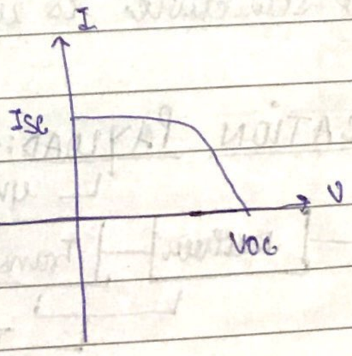
* Telemetry data are modified and then send.

These data are always encrypted



I-V Characteristics of solar cell / Photovoltaic cell.





Without any biasing there is some voltage.

Semiconductor used :-

Si → 15%

GaAs → 20%

* Mostly Si is used ∵ cost of GaAs is high and also its thickness as well as mass is more

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Si solar cell is always coated with quartz.

Date ___/___/______

Solar flux:-

$\phi = W \cdot d \cdot \cos\theta$

- d → distance from Earth.
- θ → Inclination of solar cell.
- W → solar flux density at earth.

Solar Cell efficiency :- $\eta_{EOL} = \eta_{BOL}\, e^{-0.043T}$

$\downarrow 27°C$

T - no. of years

- Quartz coating.

EOL : end of Life.

BOL :- Beggenning of Life.

Thermal and structural system:-

Antenna and solar cell → -150°C to 55°C. [huge variation].

(∵ these are generally opp. to sun).

Communication system :- -25°C to 50°C. [Power management]

$\boxed{\text{Power generated by solar cell} \rightarrow \phi\eta(1-l)\,n\,a}$

- n → no. of solar system
- l → loss due to shielding & blockage

a → total area of solar system

η → Efficiency at any time of life

φ → solar flux.

Honey Comb structure is used (light and high strength).

01/19 **COMMUNICATION PAYLOAD:-**

└ μwave Repeater / RF Repeater.

antenna — [Receiver] — [Transmitter] — antenna.

└ Transponder.

i) used for comm. system

ii) navigation purpose.

Regenerative Repeater :-

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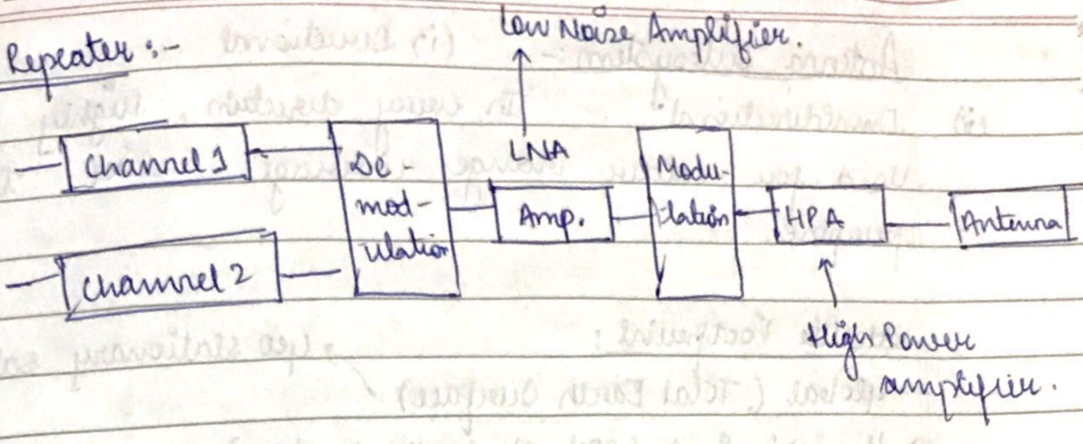
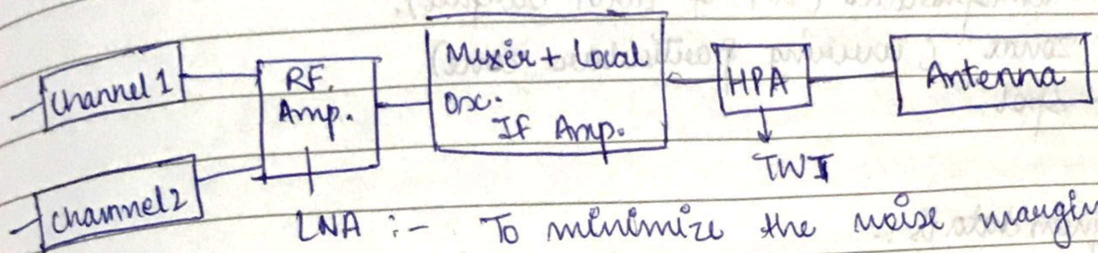
Regenerative Repeater :-





LNA :- To minimize the noise margin.

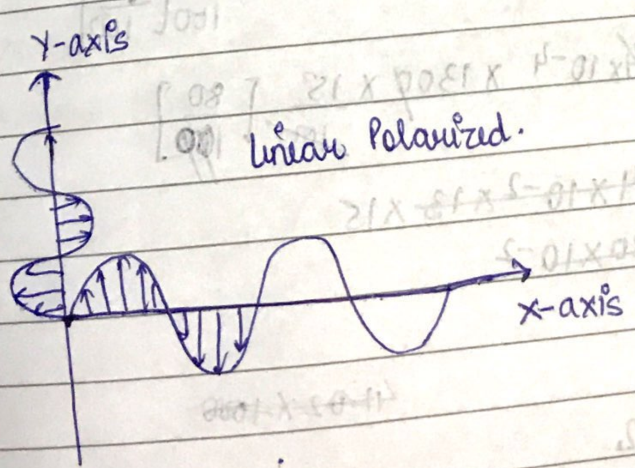
TWTA:- Travelling Wave Tube amplifier.

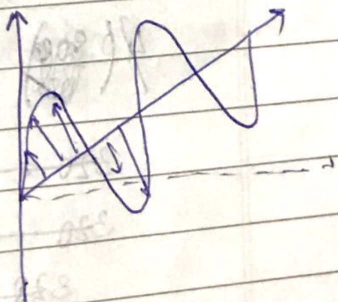
3.75 – 4.25 GHz = 0.5 GHz :- Bandwidth

The channel is sent in this bandwidth. ∴ Channels are minimised.

To maximize the channel, polarization of channels are done either linear or circular.

vertical   Right Hand | Left Hand.





Bandwidth = 2 GHz.

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Antenna Subsystem:- (i) Directional

(ii) Omnidirectional :- In every direction. Highly directional. Used for wider range coverage. like Telemetry purpose.

Satellite Footprint:

→ Global (Total Earth Surface) → Geo stationary satellite.

→ Hemispherical (20% of Earth surface).

→ Zonal (covering particular zone)

→ spot

Q:- Given data is:-

Solar flux: 1300 W/m^2

Solar Efficiency : 15%

Power loss due to extra coverage of cell = 20%.

Cell area = $4 cm^2$.

If satellite is equipped 4KW, what will be the no. of cell.

Sol:- Total Power = no. of cell × Cell Area × Solar flux. × η.

$$4\left(1-\frac{20}{100}\right) = n \times 4cm^2 \times 1300\, W/m^2 \times \frac{15}{100}\left[\frac{80}{100}\right]$$

$$4\left(\frac{80}{100}\right) = n \times 4 \times 10^{-4} \times 1300 \times \frac{15}{100}\left[\frac{80}{100}\right]$$

$$\cancel{320 = n \times 4 \times 10^{-2} \times 13} \times 15$$

$$\cancel{320 = n \times 780 \times 10^{-2}}$$

$$\cancel{\frac{320}{780 \times 10^{-2}} = n}$$

$\cancel{41.02 \times 1000}$

$$\cancel{n = 41.02}$$

$$\cancel{1000} = \cancel{41020}$$

$$4000 = n \times 4 \times 10^{-4} \times 1300 \times \frac{15}{100} \times \frac{80}{100}$$

$$400000 = n \times 4 \times 10^{-4} \times 13 \times 15 \times 80.$$

$$n = 4 \times 10^5 \times 10^9$$

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Q:- If satellite has to sustain for 15 years, what is the power req. at the beginning of life.

Sol:- Power $= \eta \times a \times n \times \phi (1-L)$.

$= \frac{94.9}{100} \times 4\times10^{-4} \times 6410 \times 1300 \left(\frac{80}{100}\right)$

Power $=$ 316.32 Watt

$\eta_{eoL} = \eta_{BoL}\, e^{-0.043T}$.

$\eta_{eoL} = \eta_{BoL}\, e^{-0.43\times15}$

$\eta_{eoL} = \eta_{BoL} (0.00158)$.

$\frac{15}{100}\times = \eta_{BoL} (0.0158)$

$\eta_{BoL} = 0.949$

$\boxed{\eta_{BoL} = 94.9\%}$

01/02/19:- Q:- Calculate the geo satellite distance from centre of earth?

Sol:- ~~36000 km~~

$T^2 \propto a^3$

$T^2 = \frac{4\pi^2}{\mu} a^3$

1 sidereal day (23h, 56 min 4 sec)

$\mu \rightarrow GM$ → Mass of earth. → Gravitational force.

Q:- Calculate the period and velocity of satellite whose altitude is 500 km from earth surface and orbit is circular.

$v = \left[\frac{\mu}{r}\right]^{1/2}$

$v = \sqrt{\frac{GM}{r}}$

$v = \left(\frac{3.198\times10^5 \text{ km}^3/\text{s}^2}{500+6378}\right)^{1/2} = \sqrt{\frac{3.198\times10^5}{6878}}$

$v = \sqrt{46.49}$

$\boxed{v = 6.81 \text{ km/sec}}$

$$T^2 = \frac{4\pi^2}{GM} a^3$$

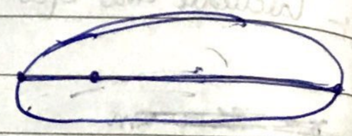
$$T^2 = \frac{4\times(3.14)^2}{3.198\times 10^5} \times (6378+500)^3$$

$$T^2 = \frac{12.33 \times 3253767.48 \times \cancel{10^8}}{10^5}$$

$$\boxed{T = 6333 \text{ sec.}}$$

Q:- A satellite at an elliptical orbit with Apogee of 4000 km and Perigee of 1000 km. Find the period of satellite?

Sol:-> $\boxed{T^2 = \frac{4\pi^2}{GM} a^3}$

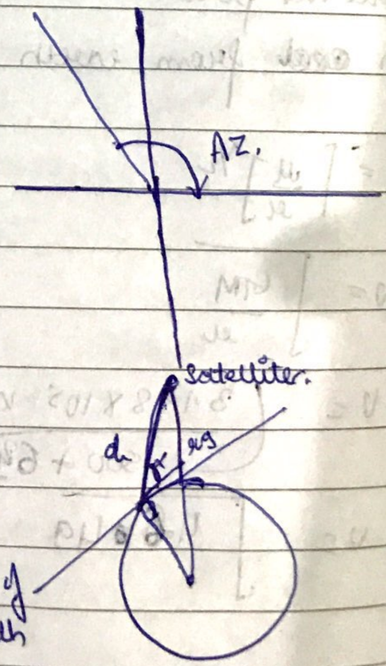


$2a = 2r_e + r_p + r_a.$

$2a = [2\times(6378) + 1000 + 4000]$

$a = ?$

Q:-> look angle calculation :-



$$\frac{\sin\gamma}{d} = \sin(El + 90^\circ)$$

$$\cos El = \frac{r_s \sin\gamma}{d}$$

γ :- central angle

r_e → radius of earth

r_s → distance from satellite to centre of Earth

d → distance from Earth station to satellite.

CS

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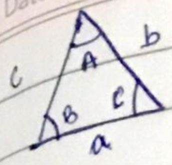


$$\frac{\sin A}{a} = \frac{\sin B}{B} = \frac{\sin C}{C}$$

$$c^2 = a^2 + b^2 - 2ab\cos c.$$

$$d^2 = r_s^2 + r_e^2 - 2 r_s r_e \cos r.$$

$$\boxed{d = r_s \left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos\gamma \right]^{1/2}.}$$

In case of geo satellite only $L_e \to 0$

Calculating always from the North, West

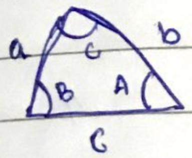
Latitude of earth station = L_e (from North)

Longitude of earth station = l_e (from West).

Latitude of subsatellite point = L_s.

Longitude of subsatellite point = l_s

$$\boxed{\cos\gamma = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(l_e)}$$



$$\cos A = \cos B \cos C + \sin B \sin C \cos A.$$

$$\cos\gamma = \cos(L_e)\cos(l_s - l_e)$$

Earth station is a north hemisphere