LECTURE NOTES

ON

SATELLITE COMMUNICATION

IV B. Tech II semester (JNTUH-R13)

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UNIT-1

Communication Satellite

Unit I

Satellite Communication :-

Introduction:-

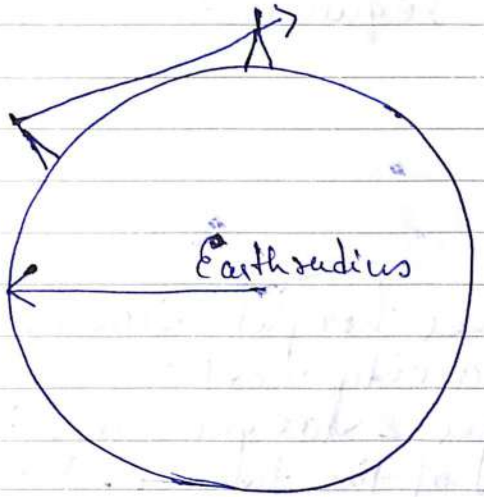
Need of Space Commⁿ.

It is a wireless form of communication.

Terrestrial wave links are not suitable to meet the demand of large geographical coverage for radio, television networking and even cellular telephony.

The basic requirement is earth is not flat & its surface is not flat and wave commⁿ it goes St. line just like light. So if there are 2 towers and unless if the other tower is in radio visibility it will not be able to receive from the transmitting tower. So, therefore only short distance can be covered. For ex:- mobile tower covers shorter distance, radio & TV towers they cover only the City.

Radio & TV ~~towers~~ repeaters towers are needed after every few Kilometres.



A Calculation.

How many cellular towers are required to cover Indian land mass?

Assume :-

Indian land area = 4×10^6 Km² (4 million Km²).

Mobile tower cover a radius of 1Km (for simplicity)

All towers are interconnected to provide all India coverage. (Any geographical location in Indian land mass is covered)

Calculate the no. of mobile towers required to fully cover India.

Mobile tower coverage with 1km radius $= \pi r^2$
$= \pi (1)^2$
$= 3.14 Km^2$

No. of towers required to cover India = $\frac{4\times10^6}{3{\cdot}14}$

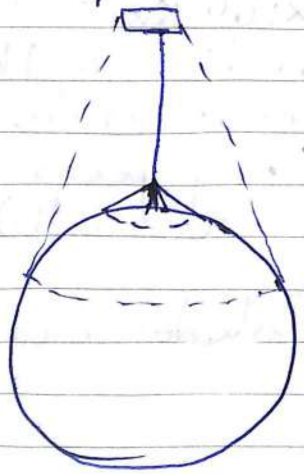
$= 1{\cdot}27$ million.

↓

which is Impossible

Typical tower height <100m covers small part of a city. If we really want to cover larger & larger area if have to increase the height of the tower. Very long height tower can cover 1/3rd of the earth & on top of the tower we can put up a repeater

Repeater is which rxs the microwave signals & transmits it back. So more earth coverage is possible at a higher altitude & that higher altitude is calculated as 36000 Km from the surface of the earth.



More earth coverage with higher altitude of repeater can reduce the no. of repeaters

Typical tower height <100m covers small part of a city.

Tower height of 36,000 kms can cover one third of earth.

Such an impossible height of a tower. Instead of building such impossible tower, it is easier to orbit the repeater around earth. This ht cannot be realised using todays technology So we should float the repeater by the name called commn satellite. That will be floating means it will be orbiting around the earth.

So we will learn about how it can orbit around the earth instead of simply floating & that will be at 36,000km above the surface of earth. So this repeater with its radio visibility will permit 2 or more users (any no. of users) which is available within its radio visibility to deliver & xchg information in various forms.

A commn satellite is a orbiting microwave repeater that permits 2 or more users to deliver or xchg information in various forms.

Repeater is an electronic device that receives a signal & retransmits it. Repeaters are used to extend transmission so that the sig can cover longer distances or be on the other side of an obstruction.

Early Idea.

- Arthur C Clarke wrote a seminal paper in 1945 in Wireless World.
- Use of 3 satellites in geosynchronous orbit to enable intercontinental communications.

→ He used µwave repeater.
Around World War II time 1945 wireless ~~Arthur~~ World Arthur Clarke a scientist later he became a novelist he wrote a seminar paper did some calculations & didn't use the word satellite. He said it as a µwave repeater, if it can be floated then 3 such satellites can cover all the earth & this particular ht. he calculated and called as geosynchronous orbit. We will learn about it later.

Let us see India has some satellites. It is called INSAT-Indian National Satellite. The satellite is placed above equator. The full earth view. So anybody or anyplace from this visibility can see the satellite (radio visibility). If this field of visibility is reduced to Indian land mass then within that land mass the radio visibility is there from the satellite. So any users txd signal with the radio visibility of satellite & within that radio visibility others can receive it.

A satellite is a repeater with a smaller field of view. Why is it necessary. Because for a larger field of view u can see that most of the part is oceaned so if there is no requirement of the comm^n with some person in ocean

- Any station that can see INSAT I can communicate with other station that also see the same satellite.
- Comm^n is possible only bet^n the stations under the same satellite radio visibility.

Advantages of Satellite Communications.

- Broadcast to very large area.
  - Cost effective as it can reach large no. of Customers
  - Communication to/from unreachable area.
- Reliable sol^n to last mile problem.
  - No need to get govt. permission to dig the roads.

Last mile problem is from the last xchg to your place where ur comp there or cellular telephony is there that is the function problm is a serious problem. With satellite directly. Since local transmission is not used where multipath or other effects are coming & if satellite is vertically above u then this last mile problem is much less.

SUNDAY 28

- Quick set up time with bandwidth on demand.
  - Used for disaster & defence.
(when all commⁿ fails then it prevails)
- Provide fairness of service as demanded.
  - Diverse user network.
    (TV, video Conferencing, Gmail)
- Long life.
  As its much ht above in air so it is very cost effective.

Early Experiments :-

use of the moon for reflection radio waves was tried out by USA. (Not visible during day long distance)

Use of copper needles in orbit around the earth was tried out.

Large passive ballon type satellite name Echo 1 & 2 was tried out.

Disadvantages of Passive Satellites.

- Earth Stations require high power (10KW) to transmit signals strong enough to produce an adequate return echo.
- Large earth stations with tracking facilities were expensive.
- Communication via the Moon is limited by simultaneous visibility of the Moon by both transmit & receive stations along with the larger distance required to be covered compared to that of closer to earth satellite.
- A global system would have required a large no. of passive satellites accessed randomly by diffⁿ users.
- Control of satellites not possible from ground.

If u put a hydrogen balloon which has a metallic coating over it, up in the air it technically becomes a passive satellite. Such a balloon can reflect wave signals from one place to another. The passive satellites in space are similar. These satellites just reflect the signal back towards the earth without amplification. Since the satellites orbit height can range from 2000 to 35786km, attenuation due to atmosphere also comes into play & due to this the received signal is often very weak.

2015
01 JULY
WEDNESDAY

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Active Satellites

9

Advantages.

10

- Require lower power earth station
- 11 Less expensive than passive system.
- Not open to random use.
- 12 Directly controlled by operators from gnd.

Disadvantages.

- Need hi-reliable design to avoid disruption 2 of service due to failure of electronic components on-board satellites.
- 3 It is a single pt failure.
- Requirement of on-board power supply.
- 4 Requirements of larger & power rockets launch heavier satellites in orbit.

5

Active Satellites unlike passive satellites 6 amplify the transmitted signals before retransmitting it back to earth. This 7 ensure excellent s/g strength. Your home TV set have a set top box now. This is a direct to home (DTH) satellite Comm^n. Although illegal in India, there are satellite phones too. Imagine never being lost. You can go anywhere but u always have a guardian angel who knows exactly where u are. Passive satellites were the earliest comm^n satellite but now almost all new ones are active satellites.

Reduce Reuse Recycle

Recycling is excellent way to save energy and conserve environment. Reuse of simple things like electrical devices and boxes or containers saves lot of resources and uncalled wastage.

because the repeater is there.
It has an amplifier on board.

Applications of Satellite Comm^n are enormous.

-> Telephone
-> Television
-> Digital Cinema.
-> Radio Broadcasting
-> Amateur radio
-> Internet Access
-> Military.
-> Disaster Management

Active Satellites	Passive Satellites
Amplify the si/g before retransmitting no possi	Retransmit without amplification Simply reflect.

JULY 2015

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JUL
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First Commercial Satellite
-> Intelsat 1
- Launched in 1965
- Mass of 39Kg
- Life 18 months.
- Broadcast 1 TV Channel.
- 7dBW RF Power. (50 power).

- Indian Intelsat earth station set up at Arvi near pune in 1971.

- Antenna 28 m
- Power 3KW
- LNA 50°K. -> Noise had to be red^n by controlling the temp^r so it is 50°K
- Designed by ISRO.

-> INTELSAT 10 - 02.
- C- Band Transponder : up to 70 (present
- Ku- Band transponder : 36 (present)
- 3 steerable spot beams
- 5,575Kg,
- Launched 16. 6. 2004.

-> INMARSAT- 4 (Over the Sea).
- For mobile communication.
- Launched 11.3.2005.
- 6 Ton, 12KW.
- Solar array span 48 m.
- Spot beam EIRP 67dBW.
- Coverage : Global C-band - Global & Spot L-band

Thaicom - 4 (IPSTAR).

- For broadband comm^n using hybrid Ka/Ku band,
- Launched on 11 august 2005.
- Launch mass approx. 6491 kg.
- Lifetime more than 12 years.
- 84 Spot beams (2-way), 3 Shaped beams (2-way) & 7 broadcast beams (one way)

Thuraiya
- For mobile phones.

ETS- VIII
Engineering Test Satellite.

Developed by Japan.

Mass	5.8 ton at launch 3.0 ton at the beginning of life
Payload mass	1.2 ton.
Design life	10 years (Satellite Bus) 3 years (Payload)
Power	More than 7,500W. (at summer solstice after 3 years)
Launch Vehicle	H-II A 204.

Launch Date December 16, 2006.

Orbit GEO 146 degrees east longitude

Frequency 2,500.5 to 2,503 MHz (Transmission)
2,655.5 to 2,658 MHz (Reception.

For Smaller Delay, Lower Orbit, Larger Constellation.

IRIDIUM - A LEO Mobile System.

- 66 Satellites
- Orbit :- 780Km
- 48 Spot beams per satellite.

India : Evaluation Phase
Broadcas :- 1975-76.

- ATS 6 NASA
  - RF Power Max 51dBW

05 SUNDAY

All India Coverage with 30ft parabolic reflector

- Simple receivers.
  - 12 ft parabolic dish.
  - Rs 10,000.

- 2400 under-developed villages in Rajasthan, Madhya Pradesh, Orissa, Andhra Pradesh, Bihar, Karnataka
- Hub Stations at ~~Ahmebad~~ Ahmedabad & Delhi

Concept of DTH in 1970's

India :- Evaluation Phase
Telecommunication :- 1977-1978.

- Symphonie.
  - RF power max 34.7 dBW
  - 1977-79.

- P&T Collaboration.
- Transportable earth stations.
- Technologies Tested.
  - DCMA
  - TV with multiple ~~sad~~ audio.
  - SCPC
  - Comp networking
  - Radio networking.

Concept of SNG & SAT. based Internet in 1970s.

India Evaluation Phase :- APPLE 1981.

- First Indian Comsat.
  - Max^m RF Power 31·5dBW
  - All India beam.
- Applications
  - Random access packet switching
  - TDMA
  - SSMA
  - ISRONET
  - Continue STEP experiments.

Indian Operational Comm^n. Satellites.

GSAT-2 48

INSAT-3E.
METSAT
EDUSAT
INSAT-3C
INSAT-4CR
INSAT-2E
INSAT-3B
INSAT-4A
INSAT-3A
INSAT-4B.

INAT:- Indian National Satellite

Total 211 transponders as on July 2008

India is increasingly using space technology for its development of which satellite comm^n is a major component.

Use of Satellite Communication:

- Direct to home broadcasting for television & radio.
- Satellite news gathering
- Very small aperture terminals for commercial data trans.
- ISP & mobile network backbone.
- Television & radio networking.
- Disaster communications.
- Mobile Communications
- Remote Area telecom.
- Many more

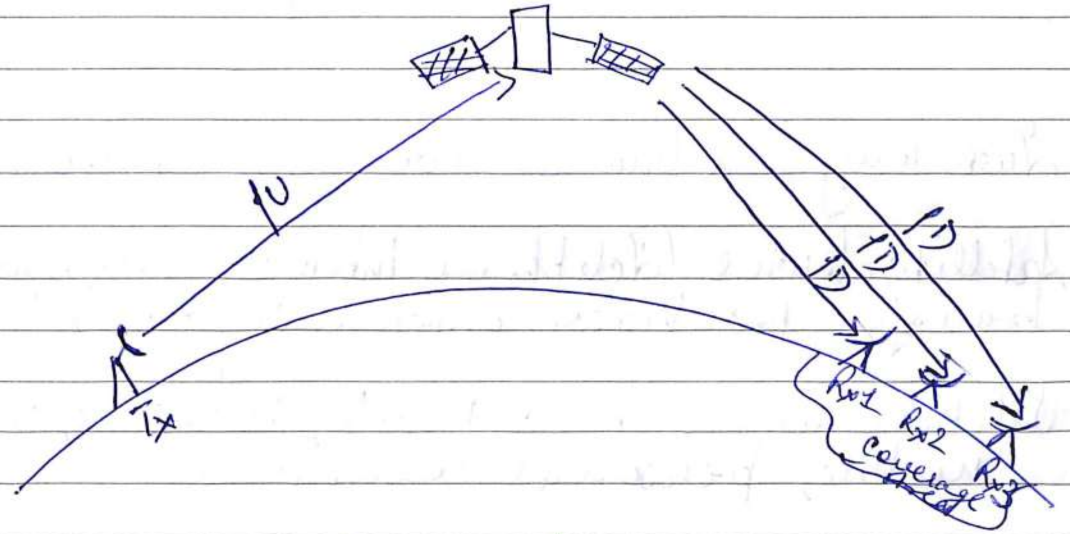
Microwave band is used for communications.

Common freq Bands & Typical Applications.

Freq Band	Name	Applications
<3KHz	Extremely low freq (ELF)	Submarine Comm^n
3KHz-30KHz	Very low freq (VLF)	Marine Comm^n.
30KHz-300KHz	Low freq (LF)	AM radio.
300KHz-3MHz	Medium freq (MF)	AM radio.
3MHz-30MHz	High freq (HF)	AM radio.
30MHz-300MHz	Very high freq (VHF)	FM radio, TV.
300MHz - 3GHz	Ultra hig freq (UHF)	TV, Cellular, Wireless systems
3GHz - 30GHz	Super High freq (SHF)	Satellites (Microwave)
30GHz - 300GHz	Extra high freq (EHF)	Satellites, radars.

ITU division of Regions for freq Allocation.

Region 1 : Region 2 ; Region 3.
Indian falls in Region3



One Way Link

Broadcast satellite Service (Radio, TV, Data broadcasting)
Data Collection Service (Hydro meteorological data Collect
Space operation service (Tracking, Telemetry, Command)
Safety Services (Search & Rescue, Disaster warning)
Earth Exploration Satellite Service (Remote Sensing)
Meteorological Satellite Service (Meteorological data dissemi
Radio Determination Satellite Service (Position location)
Reporting Service (fleet monitoring)
Standard freq & time signal Satellite service.
Space research Service

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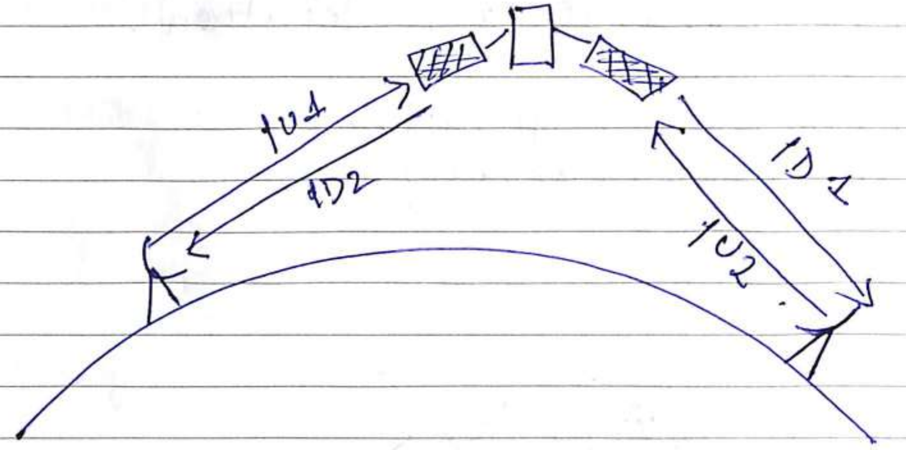

Two way link between two earth stations.

Fixed satellite service (Telephone, Internet Web browsing file transfer, fax, Video conferencing etc).

Mobile Satellite Service (Land Mobile, Maritime, Aeromobile, personal comm^n)

Satellite news gathering (Transportable & Portable)

Inter-Satellite Service.

12 SUNDAY

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Bands.	freq.	Application.
L	1-2GHz	Mobile Satellite Service (MSS), UHF TV terrestrial μwave & studio tv links, Cellular phone
S	2-4GHz	MSS, NASA & deep space research.
C	4-8GHz	Fixed Satellite Service (FSS), Fixed Service terrestrial μw)
X	8-12.5GHz	FSS military comm^n, Fixed service terrestrial earth exploration & meteorl satel
Ku	12.5-18GHz	FSS, BSS, fixed service terrestrial μw.
K	18-26.5GHz	BSS, FSS, fixed service terrestrial μw.
Ka	26.5-40GHz	FSS, fixed service terrestrial μw, local multichannel distribution service (LMDS)

BSS :- Broadcast Satellite Service
FSS :- Fixed Satellite Service
MSS :- Mobile Satellite Service.

Main Components of Satellite Communication.

1· Space Segment.
which is satellite.

Consists of
Receiver, amplifier & transmitter (its a repeater)

2. Satellite Control Centre.
Controlling part of satellite.

3. Earth Segment / Ground Segment.

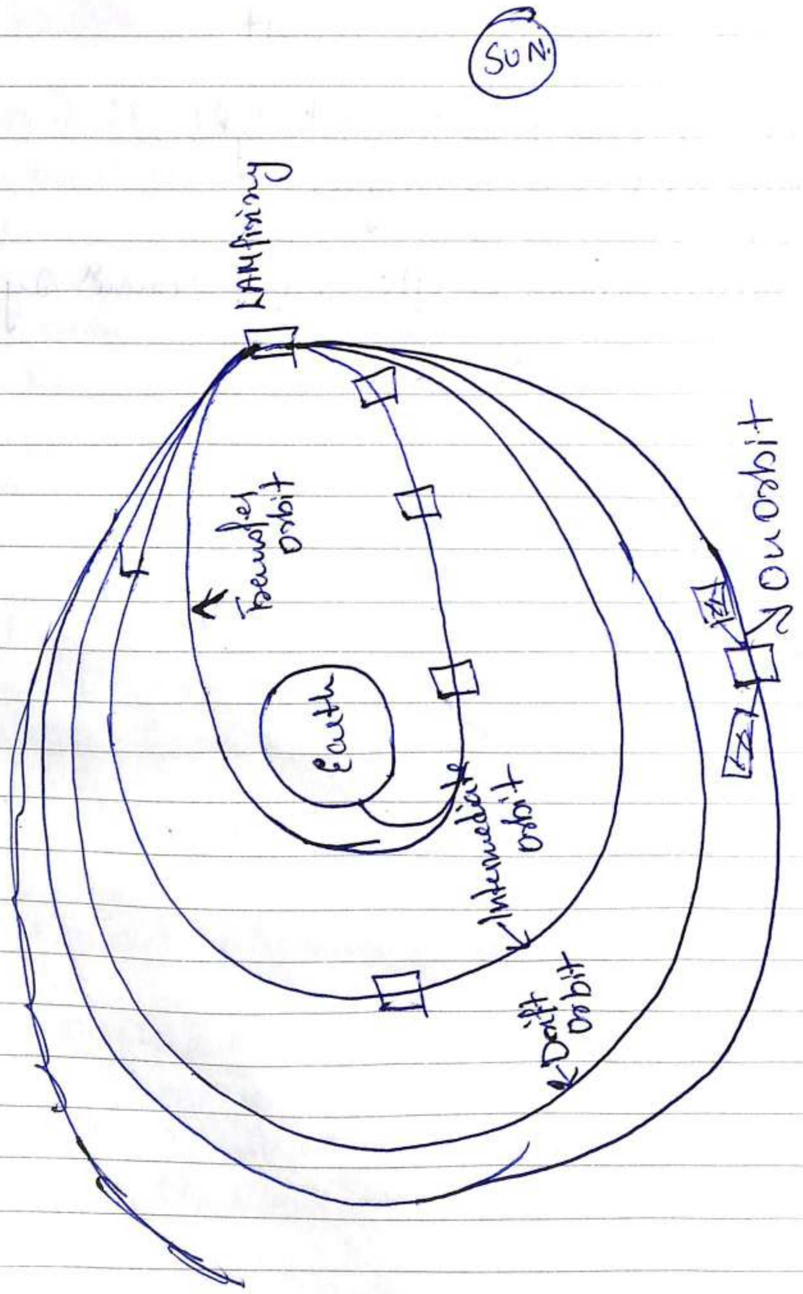
Ground Segment communicating to these transreceivers on the satellite. It is a transmitting as well as receiving station. It can be a small or large stations.

4. Medium :- which is the propagation medium through which signal will traverse.

What will be covered in orbit.

- Orbit period, Velocity & Orbit height.
- Satellite Visibility & look angles.
- Orbit raising.
- Orbital perturbation & effects on commn system.

Typical Orbit Raising Motion

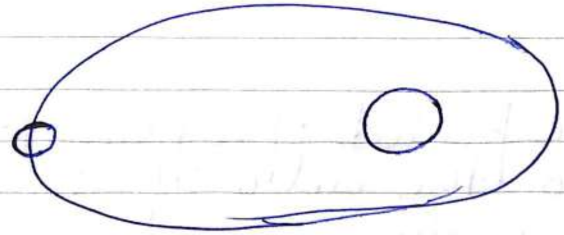


A satellite is launched from ~~eath~~ earth, then
9 it goes into a orbit which is known as transfer
orbit and from there rocket is fired and
10 again it takes a diffⁿ orbit and this orbital
height is slowly changed and the satellites
11 solar panel, antenna get's deployed i.e the
drift orbit & then finally it reaches the
12 intended orbit.

1 At each of these ~~orbit~~ positions satellite attains certain
position, velocity, height and it take
2 some time to orbit that.

3 Laws of planetary motion.

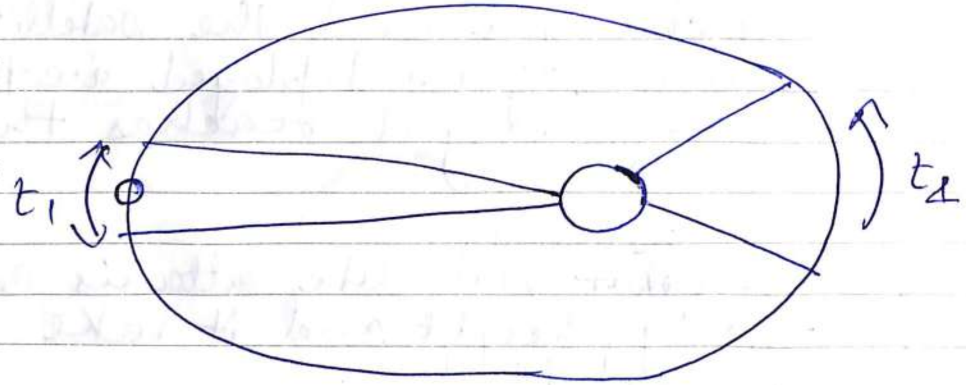
4 Law 1
The planets orbit in elliptical path with sun
5 at focus.



Same is true for satellites around earth.

Law2 :-

The line joining a planet to sun sweeps out equal space in equal time .



$t_1 = t_2$

Velocity of satellite is slower at apogee & faster at perigee .

Law 3 :-

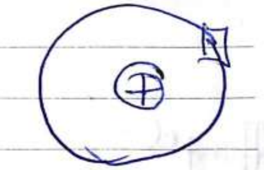
The square of the period of a planet is proportional to the cube of the mean distance from sun.

19 SUNDAY

Derivation for a circular orbit.
Centripetal force = Centrifugal force.

m = mass of body in Kg
v = vel. of body in km/s
r = radius of circle in km.

a = acceleration Km/s^2 .



$$F_{out} = m\frac{v^2}{r} .$$

$$F = m a \quad \text{Newton.}$$

$$F_{in} = m\frac{\mu}{r^2} .$$

$$\mu = GM = 398\ 600\ Km^3/s^2 .$$
$$= 3.986 \times 10^5\ Km^3/s^2$$

$$f_{in} = f_{out}$$

$$f_i = f_o$$

$$v^2 = \frac{\mu}{r} .$$

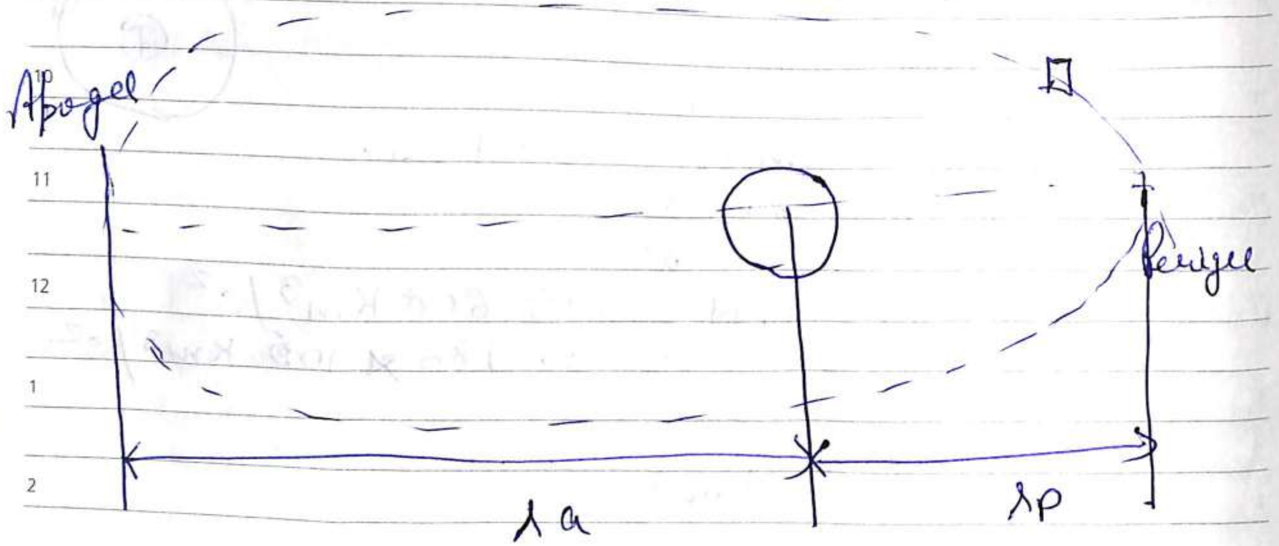
$$v = \left[\frac{\mu}{r}\right]^{1/2} Km/s .$$

$$T = \frac{2\pi r}{v} .$$

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

$$T^2 \propto r^3 .$$

Circle is a special form of ellipse.



eccentricity $e = \frac{r_a - r_p}{r_a + r_p}$

Semimajor axis $a = \frac{r_a + r_p}{2}$

Velocity at apogee $V_a^2 = \mu \left[\frac{2}{r_a} - \frac{1}{a} \right]$,

Velocity at perigee $V_p^2 = \mu \left[\frac{2}{r_p} - \frac{1}{a} \right]$

$a = \frac{r_a + r_p}{2}$.

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

Assume spherical earth radius = 6378km

Orbit ht is from the surface of earth. But it is calculated from centre so earth radius is to added.

Find velocity & period in circular orbit for.

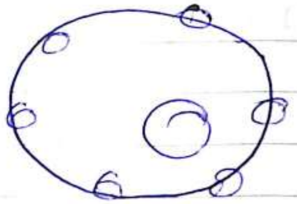
Orbit height r in Km.	Velocity V in Km/S	Orbit period T in S
1000	7.35	6307
20000	3.88	42635
40,000	2.93	99398

As we increase orbital ht, the velocity of satellite is reducing & it takes more time to reach the orbit Nor complete the orbit.

Satellites with lower orbit height goes out of visibility in short time.

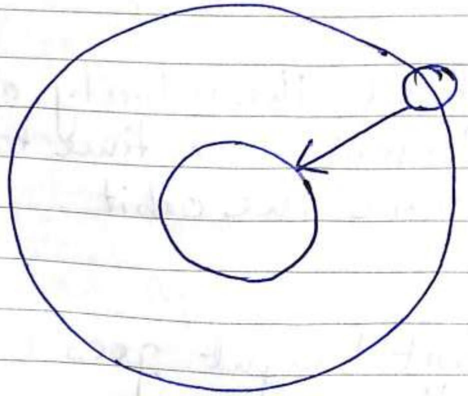
For un-interrupted comm^n satellite should be always visible.

For continuously either put a constellation of
9 satellites in low earth orbit



12 Make this satellite relatively stable wrt earth this can be done only when

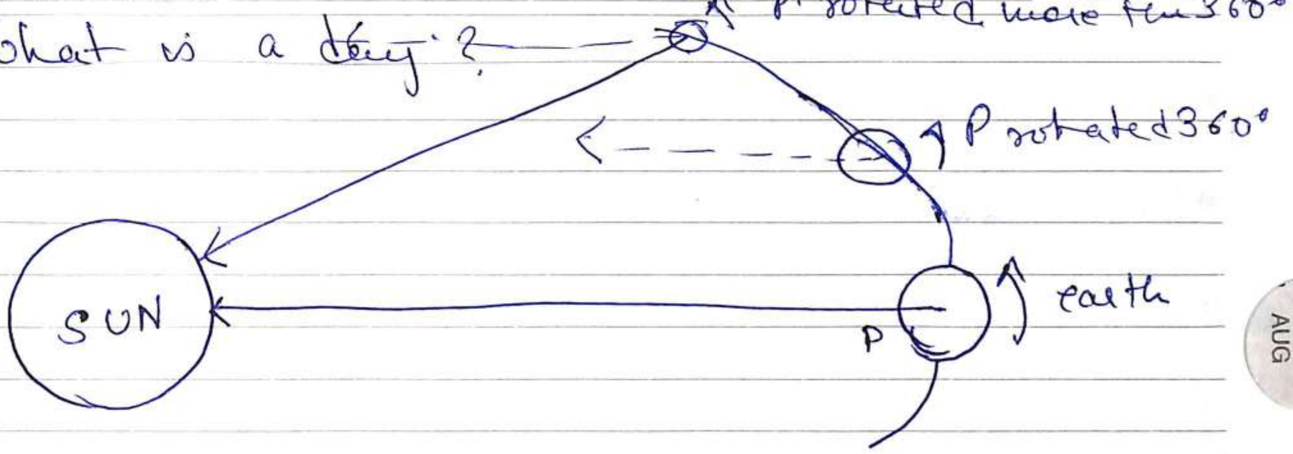
if the satellite orbit period is made same
2 as that of earth revolution around its own axis.



Satellite apparently remains stable w.r.t an observer on earth.

Earth revolves around its axis in a day

What is a day ?



1 Solar day :- time for consecutive occurrence of earth - sun centre & P are in line
2 = 24 hrs
= 86400 sec.

Sidereal day = one revolution of earth on its axis
4 = 0.987 of solar day
5 = 23 hr 56 min 4 sec = 86164 sec.

6 What is the orbital height for a circular orbit satellite with period of a sidereal day.

7
$$r = \left[\frac{T^2\mu}{4\pi^2}\right]^{1/3} = \left[\frac{(86164)^2 \times 3.986\times10^5}{4\pi^2}\right]^2$$

$\simeq$ 42,164 km from centre of earth, assuming earth to be spherical.

Assuming spherical earth with radii $\simeq$ 6378 km.
Orbital height = 42164 − 6378 = 35786 km

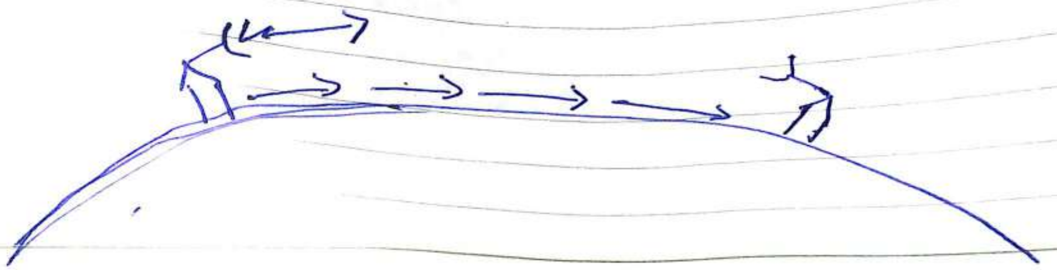
Advantages
- Capacity
- Vulnerability
- Reliability.

Why should we go for satellite commn?
or
what is the importance of Satellite commn?

Where the deployment of wired medium is difficult we go in for wireless commn using satellite commn.
In case of wireless / radio commn the freq used is μ-wave. So the maxm μ-wave freq that we have come across is in MHz i.e. from 3KHz to feco MHz. But with the help of wireless commn system freq used is low for higher capacity μ-wave
If we go for high capacity system then μ-wave cannot be used for that particular purpose we use high frequency so not only the f should be high, the B.W. & the distance should be also high because μ-wave commn we have certain limitations.
SC has specific purpose large capacity not as OFC but largest among wireless commn & freq used is high.

Existing mode of propagation of Radio waves:-

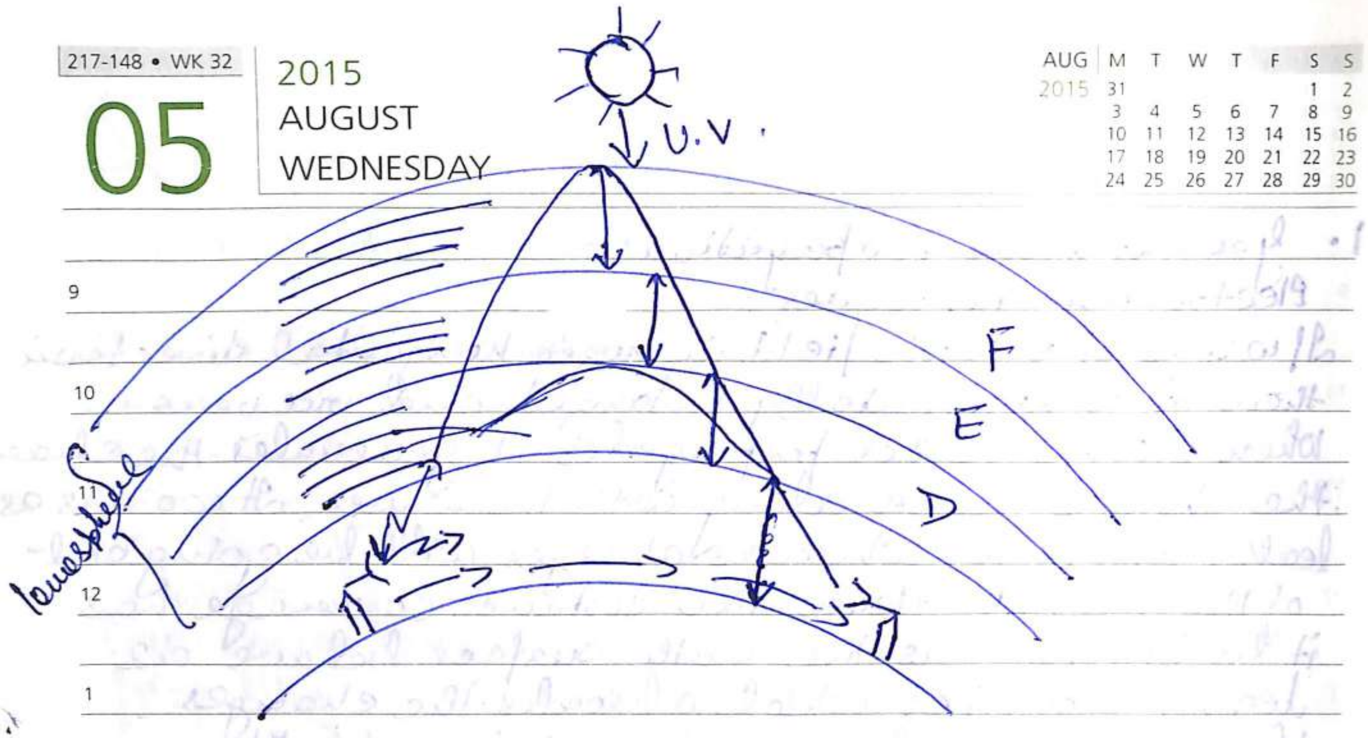
1.



1. Ground Wave Propagation:-
Electromagnetic waves.
If waves of electric field in ~~hozio~~ horizontal direction then it is horizontally polarized and vice versa.
When electric vector propagates it generates the charge. The charges move along with the waves. It works as leaky capacitor whereas charges will be going out of the ground. Hence the distance coverage has it limitation as the earth surface behave as leaky capacitor which absorbs the charges.
When operating at low freq it is used. They are appreciable when operating at 2MHz i.e. the medium wave propagation but distance coverage is less.
Aim large distance coverage & large B.W.

2. Sky Wave Propagation (2-30MHz).

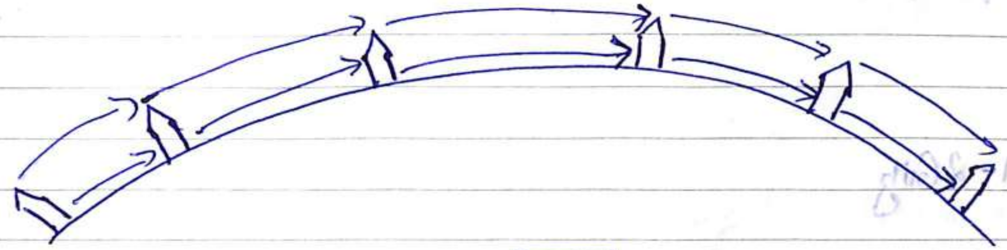
Make use of ionospheric layer around the surface of the earth. The antenna which are in the range of 50Km comes the ionospheric region. Because of UV rays of sun ~~the~~ it causes the ionization penetrates the medium and reaches the surface. The (+)ve & (-)ve charges are generated and the signal propagates so that it ~~ex~~ is directed to ionospheric layers where it causes variation in R.I. Depending on particular freq it will be reflected back to the surface of earth.

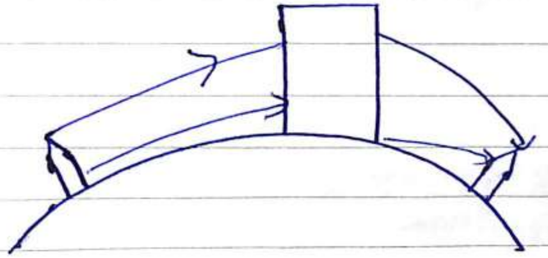


For each freq larger than 2MHz the particular layer for a particular freq the rays will be reflected. Each freq has it own layer from where it will be reflected back. If it goes beyond 30MHz then it will be not reflected and goes to space directly.

3. Space Wave Communication :- (2 MHz - 900MHz).

It does not work in space if the signal is made to propagate above the surface of the earth. Several no. of repeaters are used to cover large distance with the help of terrestrial comm^n system i.e. the μ-wave. If repeater not used max^m distance covered is 50-80 km because when radio wave propagates they are absorbed and when they come from various directions. The signal coming may lie same or opposite in phase. Satellite is a repeater in space which can bring pt.-pt comm^n for long distance coverage.





Used for satellite comm^n. As the 30MHz is crossed it reaches above the ionospheric region.

Satellite uses diff^n frequency.

4. Satellite Communication :- (Above more than 1GHz) (4GHz to 50GHz) normally used.

In order to avoid interference we have separate freqs for satellite comm^n so we are going for freq for covering larger distance. In distance coverage the carrier freq/B.W. is increased. It uses 100 of repeater to provide long distance coverage and larger freq. It is also used for intercontinental comm^n. It gives larger capacity.

why uplink freq higher than the downlink freq.

Reason for choosing the downlink freq low than the uplink frequency:-

a. Output power of the transponder amplifier.

limitation of the o/p power

the s/g is transmitted from the g.d. station to the satellite it traverses 36,000Km the signal power corresponding reduces at the satellite therefore with the help of transponder the power of the signal is enhanced so that the while sending back the signal can be appropriately retrieved.

To make the s/g appreciable lower s/g freq has been choosen. Power amplification can be done efficiently at low freq.

*It is most important factor because the final power amplifier in the transponder generates more power at lower freq than at higher freq.

b. Path loss

It is less at lower freq than at higher freq.

c. Beam Width

It should be wider as satellite would send energy ~~to th~~ to a large no. of earth stations. The frequency should be low.

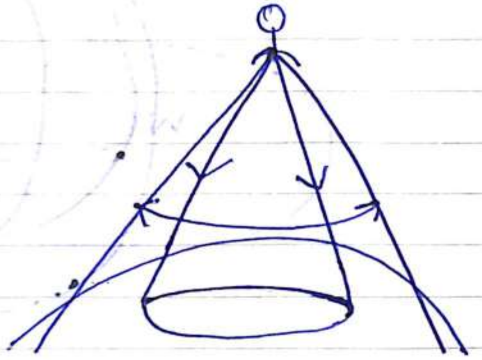
Lower when freq is lower.

↓

Area covered larger.

To avoid interference we use diff^n freq at UL & DL.

Ring around, (+) ve feedback.



d. Effective area of the receiving antenna.-

The effective capture area of the ground station antenna should ~~be~~ receive more energy and the effective area of the antenna is directly proportional to the square of the frequency.

Hence the freq (downlink) should be low.

Types of Satellites.

↓ Passive Satellite

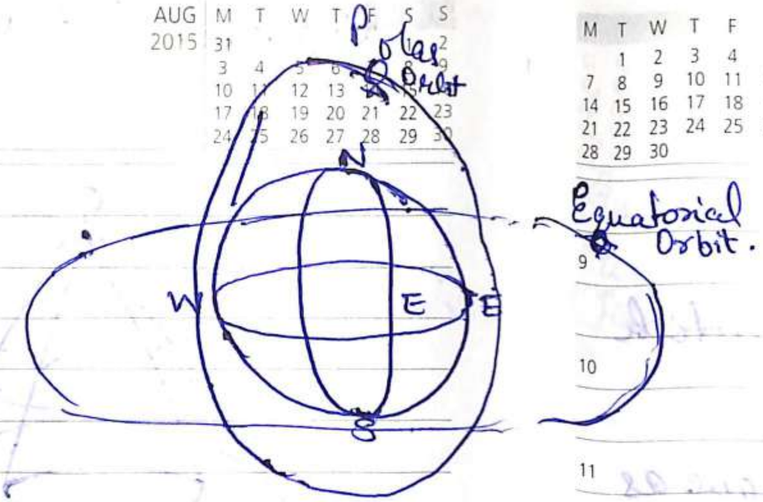
(No regeneration of s/g, the s/g is simply reflected back)

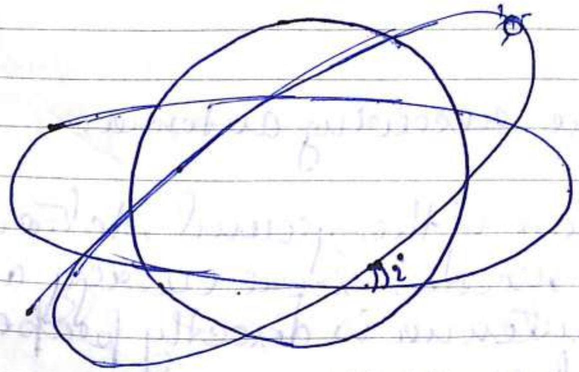
Eg:- moon. 10^{18} watt of s/g which was launched only 1 part of it was received.

↓ Active S. Satellite

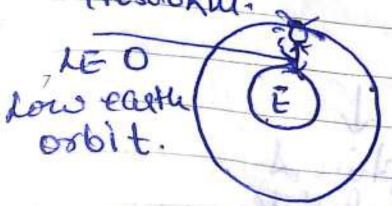
(the satellite which reprocess the s/g alongwith the amplification, it can generate its own signal.

M	T	W	T	F	S	S
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30





5 Depending on the altitude of the satellite.

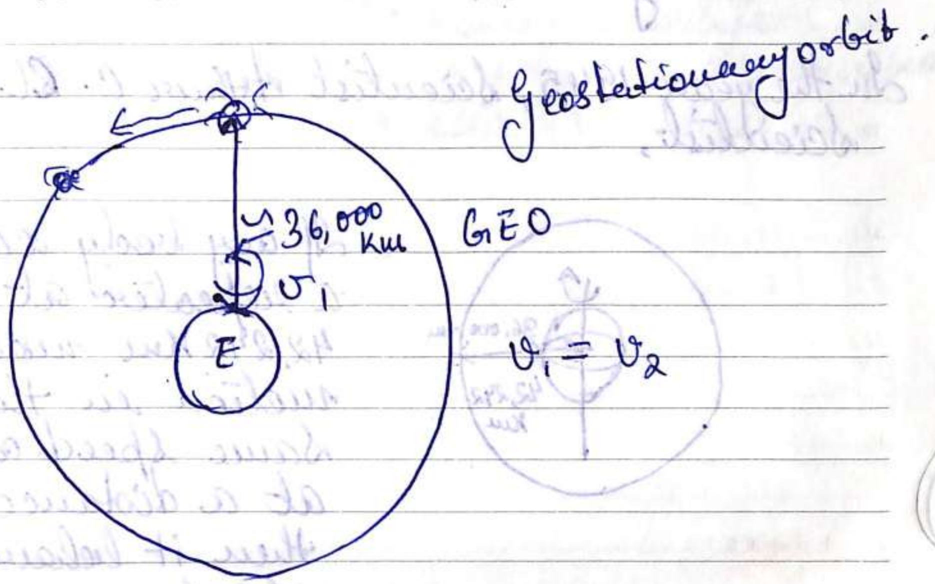


eg:- mobiles operate in this orbit

Medium earth orbit (MEO)

eg:- GPS System operates in this orbit, which includes 4 Satellites.

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

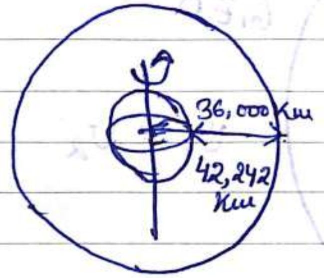


3 Most of commercial satellites are deployed at this orbit.

If the angular vel. of earth moving around it axis and
5 the satellite in GEO ~~moves~~ moving in its orbital path
around the earth is same, the person standing
6 at the surface of earth seems that they are
moving with same velocity. Therefore satellite
7 is observed to be stationary object in space
when deployed at 36,000Km. Therefore called the
geostationary orbit.

Evolution of Satellite Communication:-

In the year 1945, Scientist Arthur C. Clarck, British Scientist,



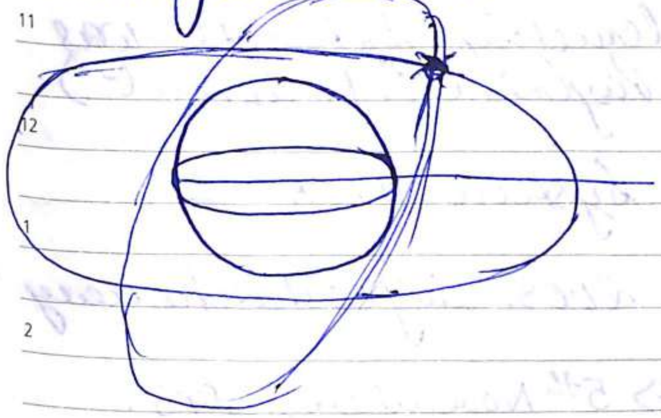
If any body can behave as a repeater at a distance of 42,242 Km moves in circular motion in the orbit with same speed as that of earth at a distance of 42,242 Km then it behaves as a stationary object.

In 1955, the scientist began working on this concept making the use of moon as a passive satellite.

In the year 1957, Russia launched the satellite SPUTNIK-I → first active satellite. It lasted for 21 days.
In the same year USA also launched its own active satellite Explorer-I it lasted for 5 months.

In the year 1958, NASA USA launched "SCORE"
In the year 1960, NASA launched "ECHO"
In the year 1962, AT&T & NASA launched TELSTAR-I.
It was the first satellite to transmit & receive.

In the year 1963, they launched the TELSTAR-II and it was transmitting the signal used for Telephone, Television, FASSIMILE and data transmission.
At the same time Russia launched it Molniya Satellite.



INTELSAT (Early Bird) with the combined effort of 11 nation in the year 1965.

INTELSAT - 1	242 voice channel 38 m
INTELSAT - 2	240 voice chan 68 Kg
INTELSAT - 3	1200 voice channel 152 Kg
INTELSAT - 4	4000 voice chanel 4
INTELSAT - 5	12,000 "

In 1986 - 6 voice channell 670 Kg

In the year 1975, Indian Satellite Program was started with LEO Satellite and the 1st Satellite was Aryabhatta for Rohini, Bhaskar LEO. Research Satellite

In the year 1981, first telemetary Satellite was APPLE (Ariane Passenger Payload Experiment)

Indian National Satellite System INSAT-I

⇓

Chandrayan → 22nd Oct, 2008. in Geostationary orbit.

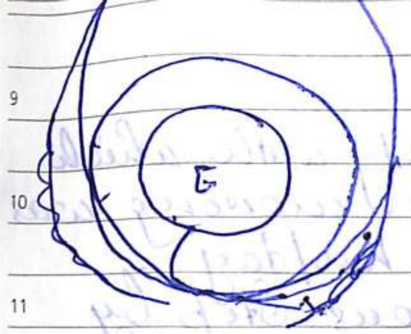
MARS Orbital Mission → 5th November, 2013.

PSLV:- Polar Satellite launch Vehicle ..

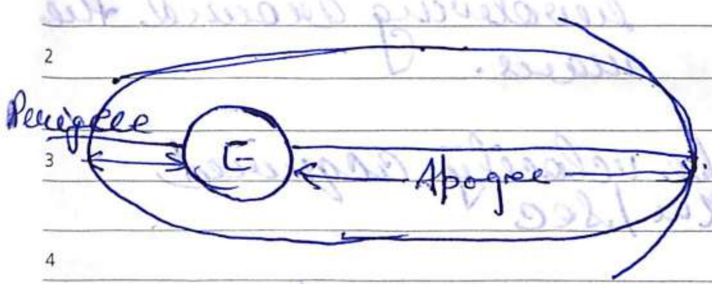
In order to launch satellite the vehicle is placed in the low earth orbit. After 1 or 2 revolution the speed of the vehicle is increased, then it follows the elliptical path. It continues to follow the path till it acquires geostationary orbit.

~~Straights~~

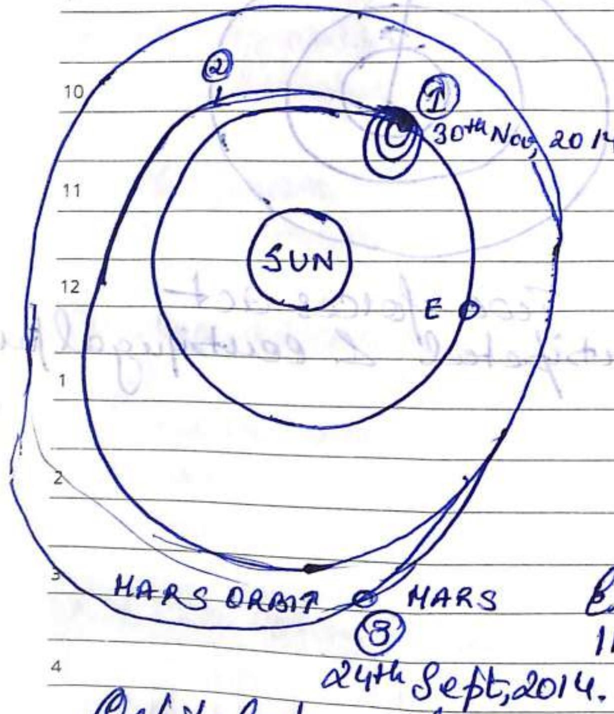
1. LEO
2. Transfer Orbit.
3. Geostationary Orbit.



Two forces act centripetal & centrifugal force.



MARS ORBITAL MISSION :-

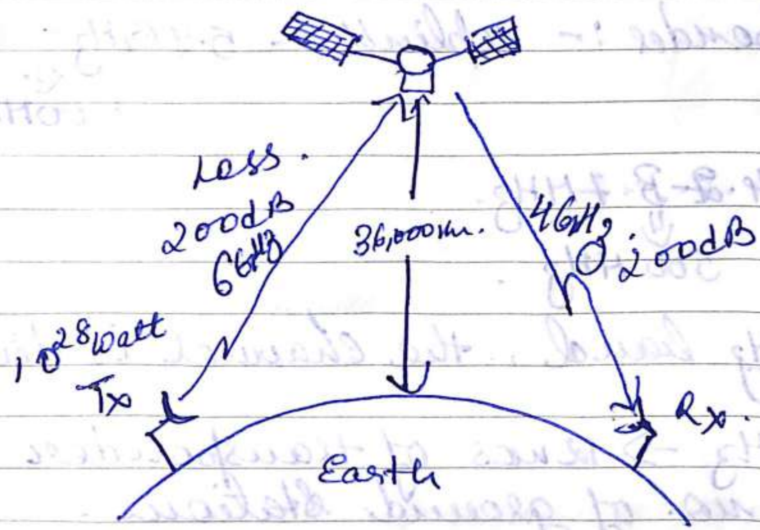


The velocity with which it was moving was 370 lakhs Km/day, tremendous. Step by Step it acquired the velocity so that it moves away from the earth and hence now its is revolving around the mars.

Escape velocity acquired 112 km/sec

Orbital Insertion in the mars was done on
5 24th Sept, 2014.
There were 3 phase in which it worked.
6 It took 298 days transit to mars. ~~It was susse.~~ Distance travelled was 780 crores km.
7 MARS travelled this distance to reach MARS. (780,000,000 km).

Satellite follows elliptical path in HOM.



3 Total loss = (200+200) = 400dB.

4 Minm power required at Rx = 10^{-12} Watt.

5 10^{28} Watt power has to be transmitted (minm power at the transmitter).

6 Minm

Active Satellites are needed so that ~~[illegible]~~ refraced
7 the Signal. (reprocessed)

Transponder at Satellite:- Reshape & Amplify.
C-Band => 6/4 GHz.

Positive feedback:- Superimpose of the Signal at the Satellite as high freq carrier sfg is transmitted.

Direction of

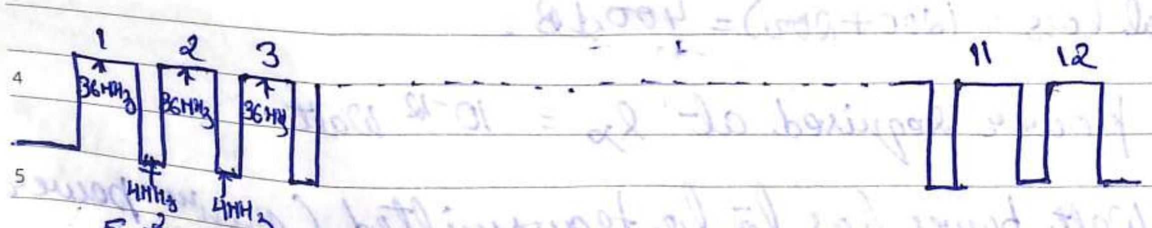
The amplifier at the satellite behave as oscillator.

At the transponder :- uplink :- 5.9 GHz - 6.4GHz
⇓
500MHz

Downlink :- 4.~~2~~-~~3~~.7MHz.
⇓
500 MHz.

Within 500MHz band, the channel is divided.

500 MHz → 12 nos of transponder corresponding to 12 no. of ground stations.



$\frac{500\ MHz}{12} = 41.6$

Each of these is of 36 MHz is divided by 4 MHz.
The capacity can be increased without increasing the bandwidth.
Reuse of freq can be applied for increasing the capacity of satellite without increasing the Bandwidth. This is done with the help of which capacity is increased using
a. Polarization Technique.
b. Spatial Beam Spot.

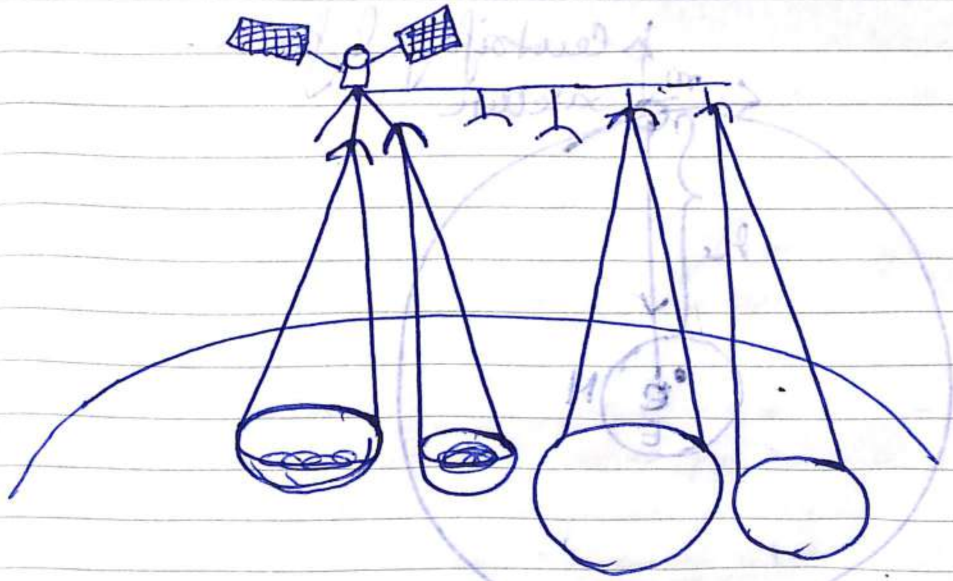
when HPA is sending then VPA will not Rx any sig from HPA & vice versa (insensitive to other polarized wave)
They are orthogonal to each other.

Polarization

a. Horizontally Polarized Wave
⇓
Horizontally Polarized Antenna

b. Vertically Polarized Wave
⇓
Vertically Polarized Antenna

Spatial Beam Spot

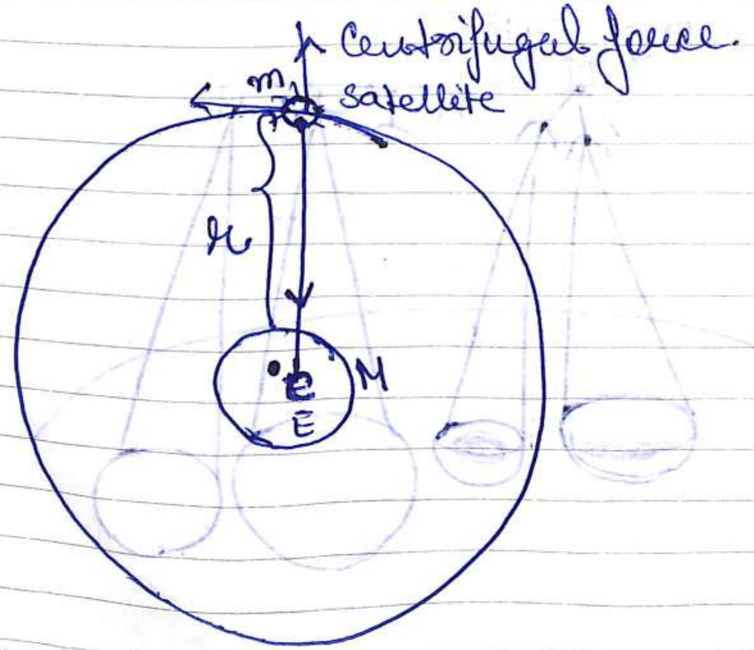


Making use of same freq; the same information can be received simultaneously on the surface of earth by using freq. reuse, thus increasing the capacity of the system.

Two forces acting on the satellite moving in its orbit in space:-

a) Centripetal force - Due to gravitational pull of the earth which is all the time acting.

b) Centrifugal force - Due to kinetic energy by the satellite due to its velocity with which it is moving in its orbit around the earth.



With the centrifugal force it tends to move the satellite away from its ~~prese~~ fixed orbit so as to place it in the higher orbit. Gravitational pull acting all the time

As soon as the satellite tries to go away from the fixed orbital path at the same time centripetal force acting on it to prevent it moving to higher orbit trying to keep it orbital path.

Although satellite is in free fall position, but its position is maintained by the two forces acting on it.

~~Because~~ The 2 forces are counterbalancing hence retained in its orbital path.

Centripetal Force $F_1 = \frac{d^2r}{dt^2} \cdot m$

Let m & M be the mass of satellite & earth respectively.

Centripetal force, $F_1 = m\frac{d^2r}{dt^2} = m\frac{M \cdot G}{r^2}$ ~~Km/sec~~^{2}.

where G is the gravitational constant $= 6.67 \times 10^{-}$ Nm^2/Kg^2.

where $a = \frac{MG}{r^2}$.

M is the mass of the earth $= 5.90 \times 10^{24}$ Kg.

Centrifugal force is $F_2 = \frac{mv^2}{r}$

where $\frac{v^2}{r}$ is acceleration.

$$F_1 = F_2.$$

$$\frac{mMG}{r^2} = \frac{mv^2}{r}.$$

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

$$\boxed{\because \mu = GM}$$

Let T be the time period of one complete revolution.

$$T = \frac{2\pi r}{v} = \left(\frac{\overset{= 2\pi r.}{2\pi r}}{\sqrt{\frac{\mu}{r}}}\right) = \frac{2\pi r^{3/2}}{\mu^{1/2}} \text{ sec}$$

$$24 \times 60 = T = \frac{2\pi}{60} \frac{r^{3/2}}{\mu^{1/2}} \text{ minutes.}$$

$$r^{3/2} = \frac{24 \times 60 \times 60 \times \sqrt{\mu}}{2\pi}$$

$$\boxed{r = 42{,}8[illegible]0 \text{ km}}$$

From the centre of the earth it is placed at 42,810km observes the satellite to be stationary. In the same time the earth completes its one ~~revolution~~ rotation along its axis.

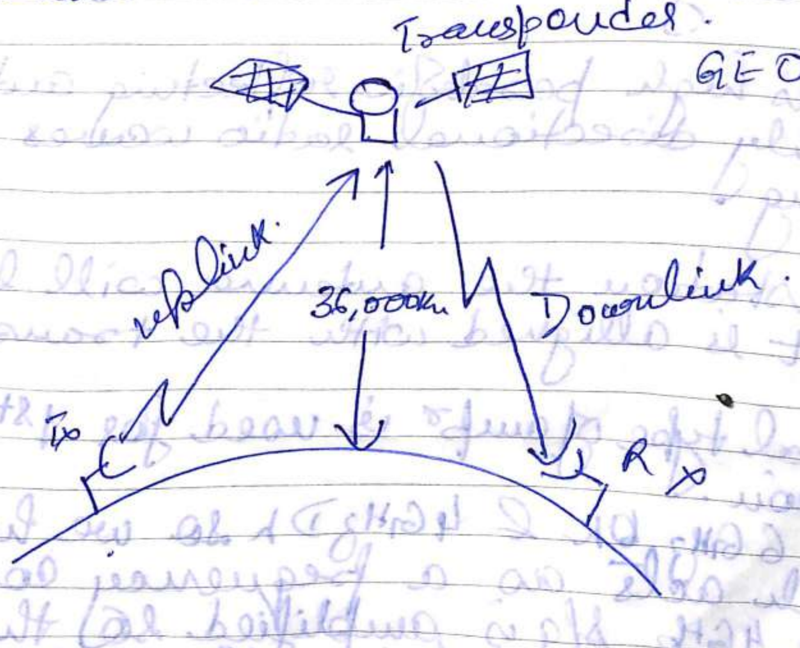
If elliptical then at certain instant of time the vel. will not be same as that of the earth if its elliptical path.

$v_1 \neq v_2$ elliptical path

$v_1 = v_2$ Circular path.

Satellite Systems Consists of three basic Sections:-

1) An uplink
2) A Satellite transponder
3) A downlink.

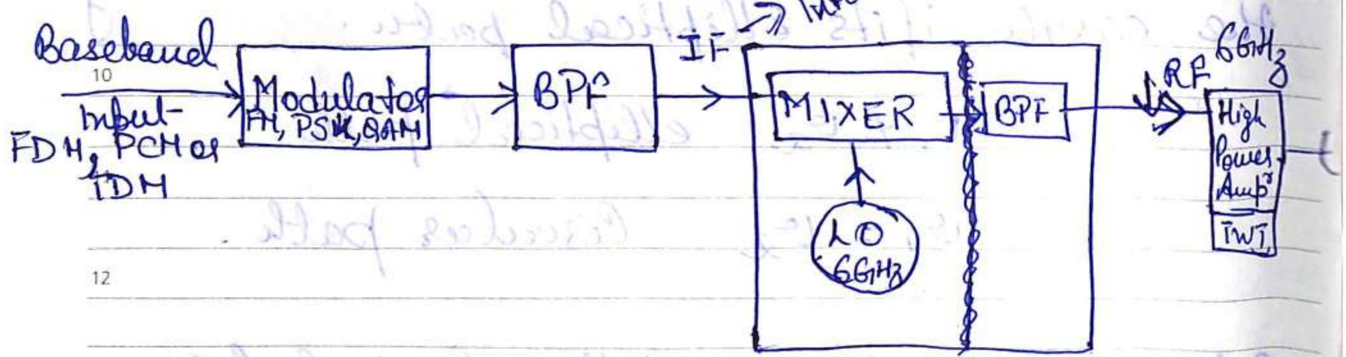


If C band is being used then the freqⁿ which is being transmitted from ground station will be converted to GHz range using the mixer.

Travelling Wave Tube :- They are klystron says puls

Uplink :-

IF → Intermediate frequency



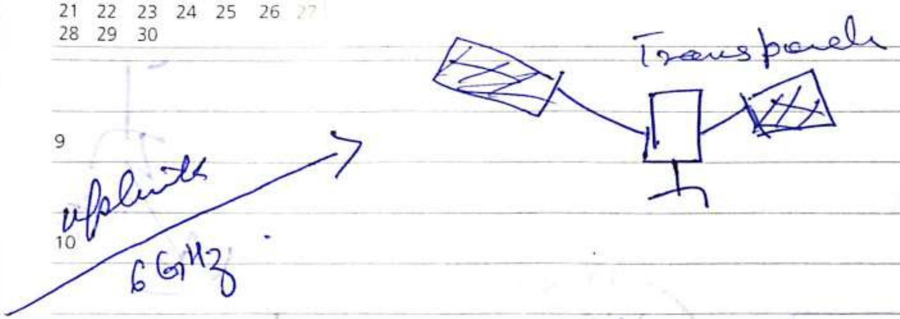
Depending on the band which is being used the LO will be generating the frequency & then mixed with the IF s/g to generate GHz frequency.

Antenna is high parabolic reflecting antenna and highly directional radio waves will be propagating.

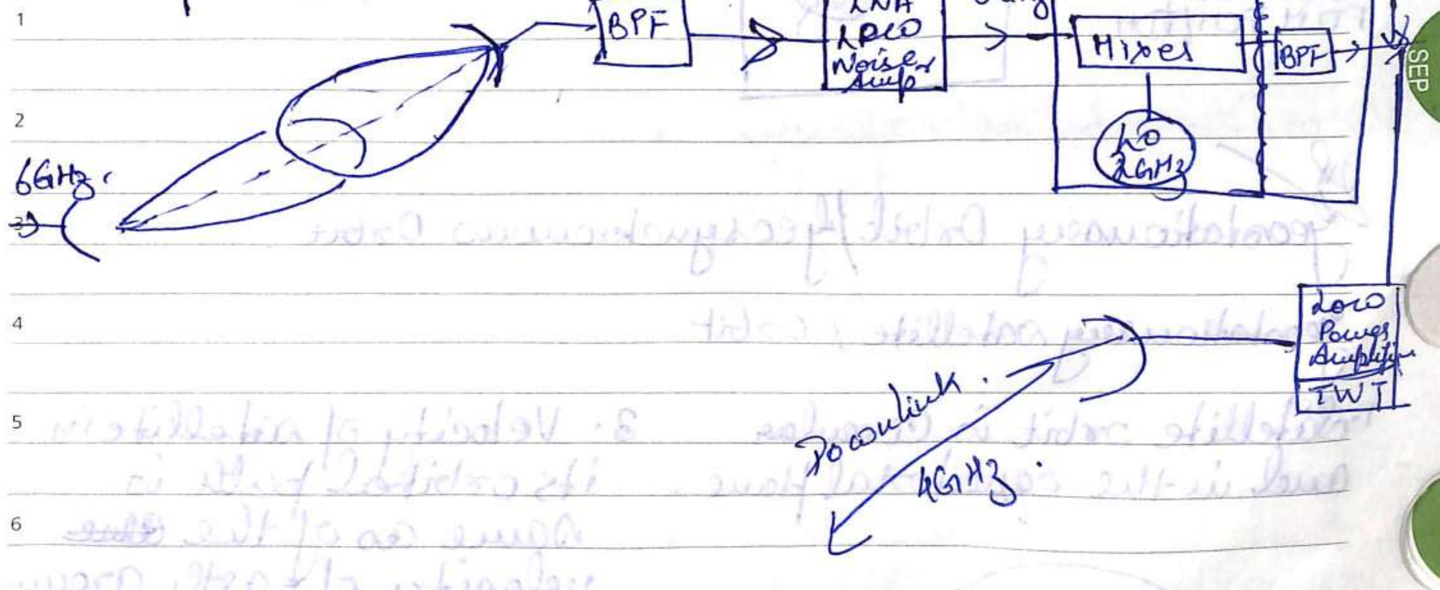
At ground station the antenna will be steered so that it is alligned with the transponder.

A very special type of amp^r is used for 1st stage of amplification.

In C-band 6 GHz UL & 4GHz DL so we have a mixer which acts as a frequency converter stage. The 4GHz s/g is amplified so that it reaches the ground station. The amp^r used has limit



Transponder .



Transponder is used to convert higher frequency to lower frequency level .

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31 2015 AUGUST MONDAY

AUG 2015	M	T	W	T	F	S	S
	31					1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
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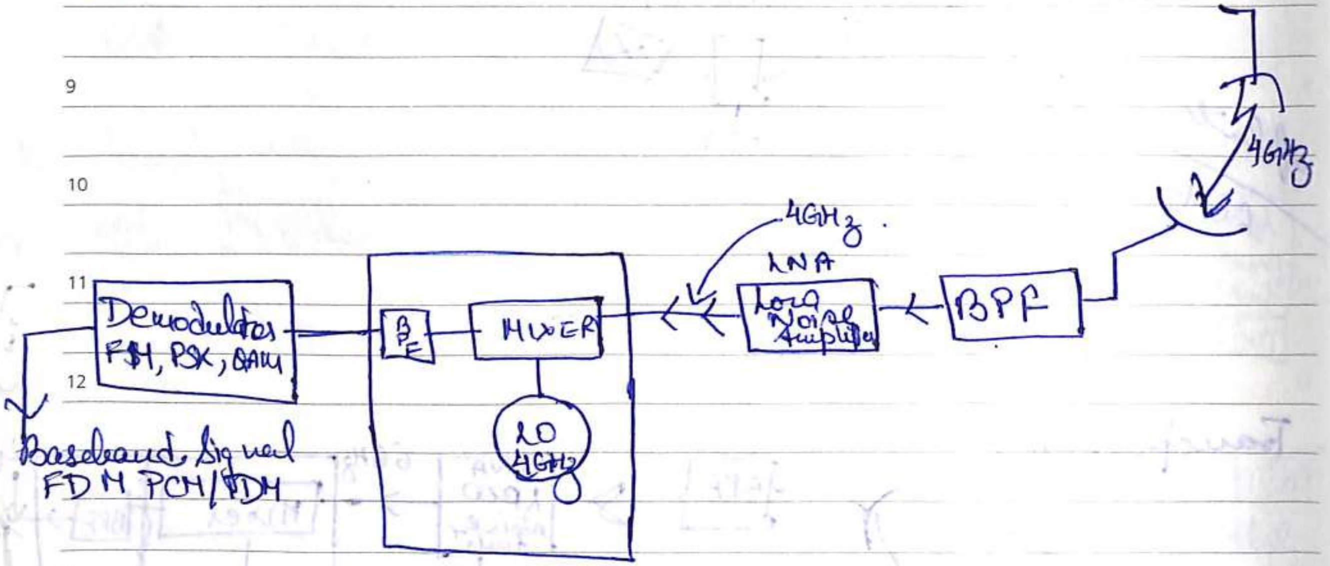


Geostationary Orbit/Geosynchronous Orbit.

Geostationary satellite / Orbit

1. Satellite orbit is circular and in the equatorial plane.

2. Deployment of satellite is at approximately 36,000km away from the surface of the earth.

3. Velocity of satellite in its orbital path is same as of the ~~Abc~~ velocity of earth around its axis. $v_1 = v_2$

4. Satellite completes one revolution of the earth in 24 hours

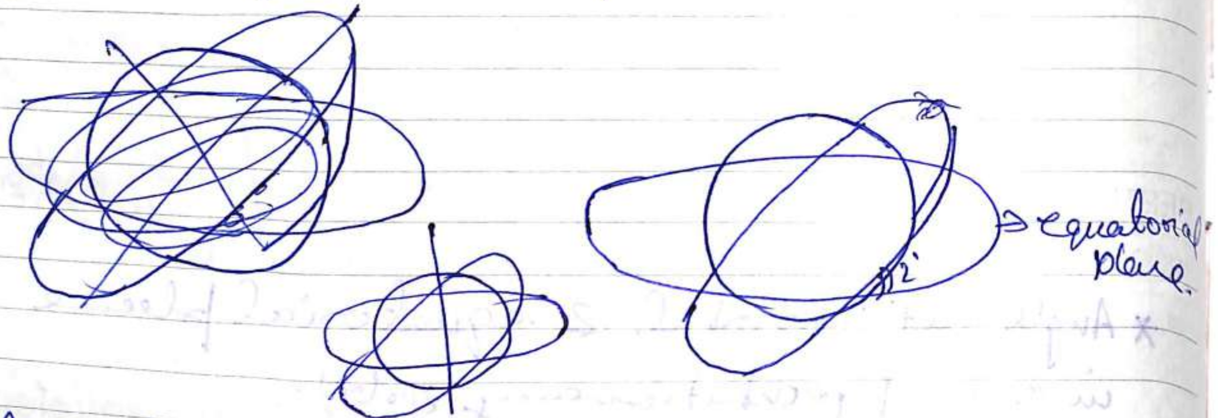
rotation

VIP

Mesh - Nodes are connected directly, dynamically & non hierarchically to as many other nodes as possible & cooperate with other to ... efficien...

Geosynchronous Satellite/Orbit.

1. Orbital path is not circular and not in the equatorial plane but rather makes a small angle with the equatorial plane. (elliptical in shape).



2 It is also deployed at 36,000 km away from the surface of earth.

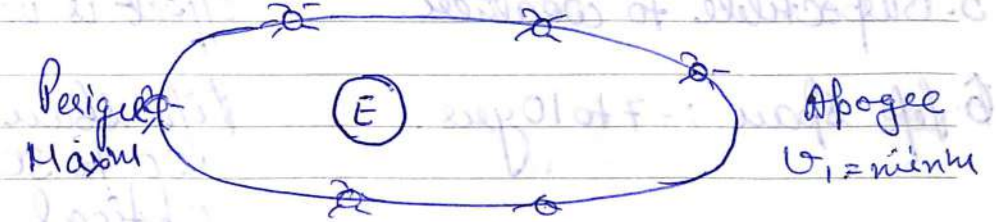
3. Velocity of the satellite in its orbital path is not the same as of the earth around its axis. If v_1 is the velocity of satellite v_2 is the velocity of the earth then $v_1 \neq v_2$

4 It also completes one revolution of the earth in 24 hours.

Although it is deployed at 36,000 km & revolution in 24 hrs but its velocity of satellite will be varying in orbital path. May be large at some point and smaller at some point.

Star topology -> All nodes are connected to a central connection pt, like hub or a switch.

$v_1 = \text{min}^m$.



Therefore geostationary satellite acts as geosynchronous satellite but vice versa is not possible.

At diffn instant of time vel. will be diffn therefore it will not be stationary.

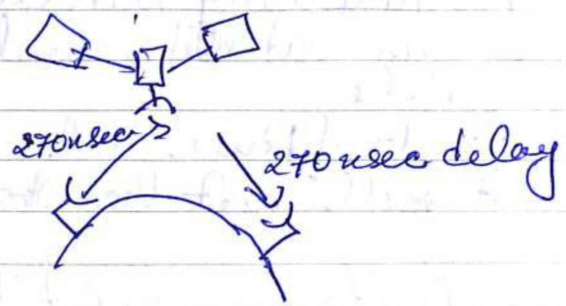
Advantages & Difference betn terrestrial & satellite commn.

Comparison of Satellite & Terrestrial Communication System...

Satellite Communication	Terrestrial Communication
1. Star Topology.	Mesh Topology.
2. Satellite is a critical component if it fails then it results into a total failure of the network.	Node failure do not affect the entire n/w. The n/w is fault tolerant.
3. It is broadcast in nature.	Point to point in nature
4. Large distance 500ms delay (240ms) delay in voice communication.	Distance is smaller, 40 usec max delay

Life of satellite is affected by the fuel that is stored in the satellite. If fuel is finished the life of the satellite is finished.

5. Suspectible to weather	Effect is very much lower
6. Life span :- 7 to 10 yrs.	Life span is large (is less) 20 to 30 yrs with Optical fibre.
7. Coverage area is more	Coverage area less



Delay is reduced in satellite commn as a result of combination of the satellite and terrestrial communication.

Geosynchronous Orbit.

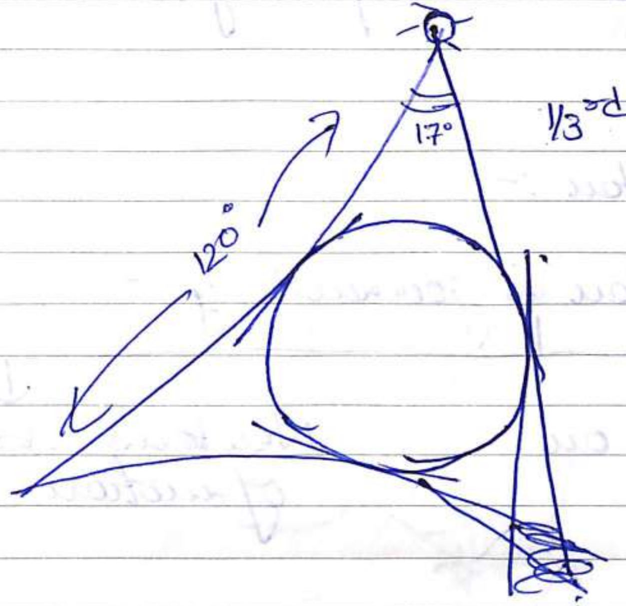
Advantages of Satellite Commn

1. Satellite remains almost stationary in respect to a given earth station and therefore expensive tracking equipment is not required.

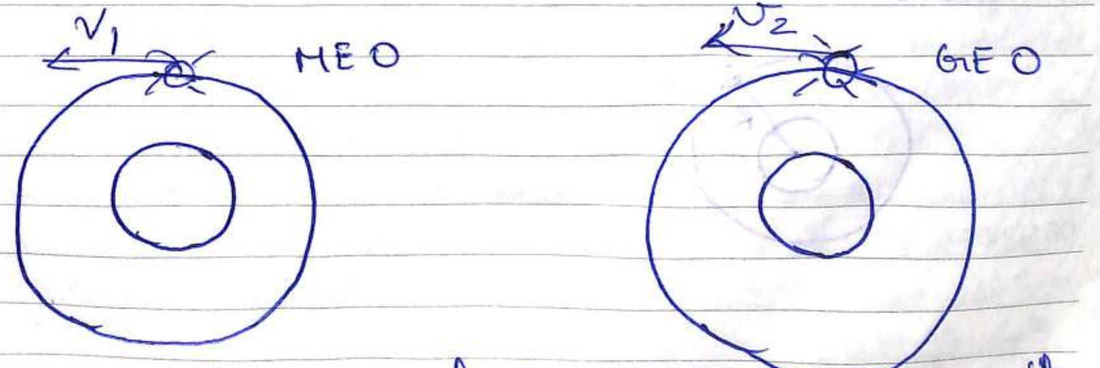
Earth antenna will always be steering so that it tracks the satellite but it is a very tedious process but it is done so that better communication takes place.

Once the satellite is stationary then the angle of antenna at the ground station can be easily maintained.

LEO or MEO the no. of satellites more in case of geostationary or geosynchronous orbit.



MEO or LEO would require 50, 60 or even more satellite to cover the whole earth where as GEOstationary orbit requires only 3 satellites to cover the whole whole earth.



$v_1 > v_2$ as the two forces are acting on it.

For commu^n on particular surface of the earth.

Orbital Equation :-

According to Newton :-

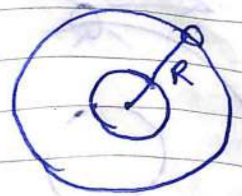
Orbital Motion is governed by :-

Newton's Gravitational force on the satellite

Newton's second law of motion.

$$G\frac{m_1 m_2}{r^2}$$

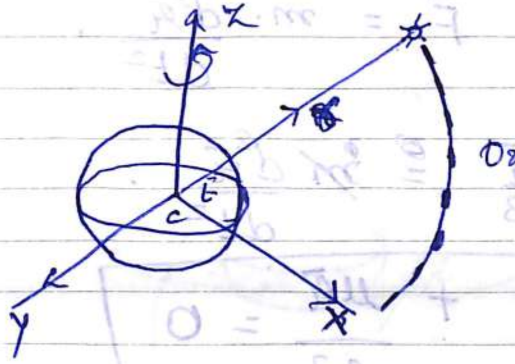
If the distance betn satellite and earth is very large then



Newton's Second law of motion.

Sum of PE & KE will be constant :-

Cartesian Coordinate System :-



The Cartesian coordinate system uses geographical axis of the earth as the principal axis and this is the initial coordinate system to describe the relation betn satellite & earth. The cartesian system uses geographical axis as pricipal axis. The rotational axis is of the earth is along the Cz where C is the centre of the earth & Cz passes through geographical north pole. Axis Cx, Cy & Cz are orthogonal to each other and Cx and Cy passes through the earth geographic equator.

Vector r denotes the ~~moving sa~~ distance of the satellite from the centre of the earth.

i & e will give the shape of elliptical path ~~as~~

All the six elements helps in determining the location of elliptical path as well as to know the shape and size.

$$F = -GMm\frac{\bar{r}}{r^3}$$

where r^3 is scalar qty & $\bar{r}$ is vector qty.

where $\frac{\bar{r}}{r}$ is the unit vector.

Also the force :- F = mass × acceleration.

$$\bar{F} = m\cdot\frac{d^2\bar{r}}{dt^2}.$$

Hence,

$$-\underbrace{G M}_{\mu}\cancel{m}\frac{\bar{r}}{r^3} = \cancel{m}\frac{d^2\bar{r}}{dt^2}.$$

$$\underbrace{GM}_{\mu}.$$

or

$$\boxed{\frac{d^2\bar{r}}{dt^2} + \frac{\mu\bar{r}}{r^3} = 0}$$

Six undetermined Constants :-

Orbital elements that explains the orientation towards the earth.

Orbital elements are :-

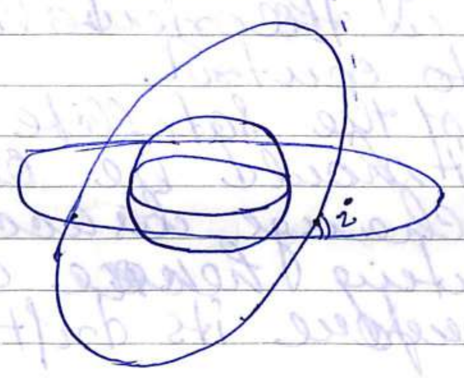
1. a → Semi-major axis of the elliptical path :-
2. e → eccentricity of the elliptical path
3. i → angle of inclination,
4. M_0 → term used for locating the angular position of the Satellite.

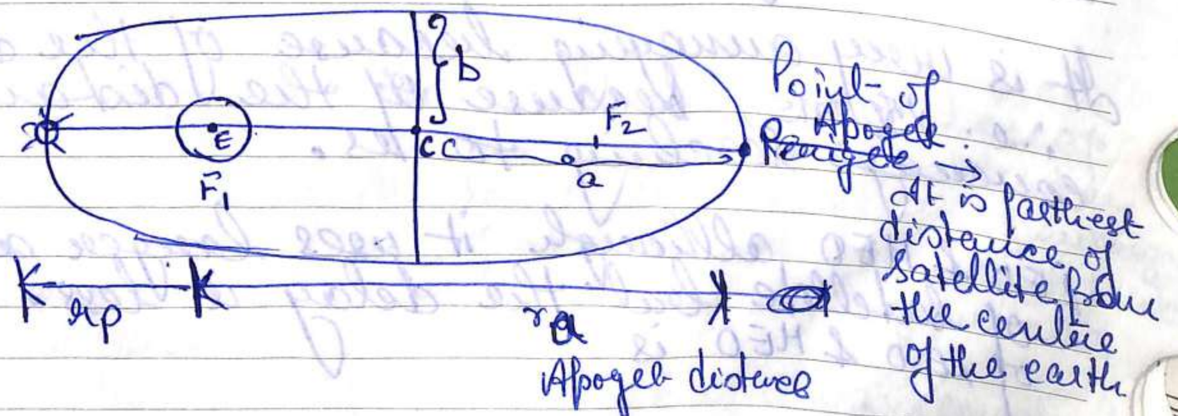
When it is circular path :- $r_a = r_p$

when it is elliptical path :- $r_a \neq r_p$

e = eccentricity which gives the shape of the path.

5. RA :- Right Assention.
6. W :- Argument of Perigee.





Advantage of Geostationary Orbit.

1. 3 Satellite
2. Doppler effect is totally nullified. Various forces are acting on the satellite because of various planetary bodies which are attracting the ~~fa~~ satellite which causes disturbance in the orientation of antenna so in order to control. But drifting of the satellite should be known. It should be observed ~~so~~ because of change as accelerating or deaccelerating hence affecting the velocity therefore its drift needs to be observed.

Disadvantage.

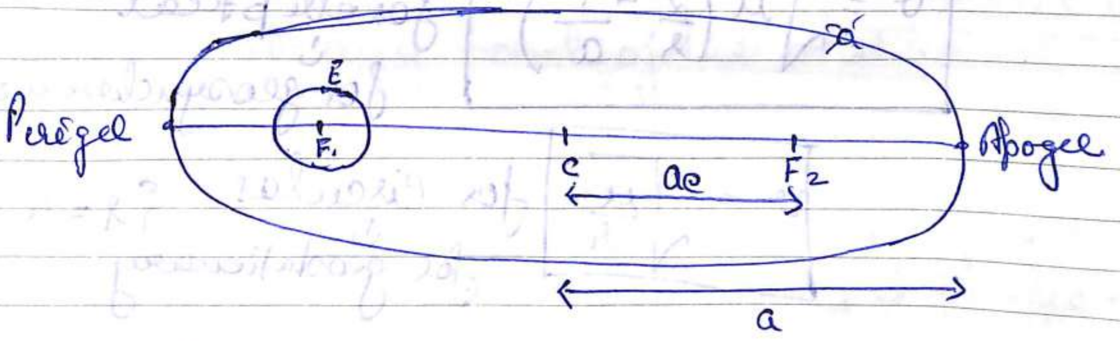
It is very annoying because of the delay i.e. 250 ms, because of the distance coverage reaching to us.

LEO & MEO although it uses larger amount of satellite but the delay is less. Maintenance of LEO & MEO is

Kepler's law of Motion of planetary body :-

There are 3 Kepler laws :-

First law of Kepler :-
Orbit of satellite around earth is of elliptical path. Centre of the earth lying at one of it focus of the ellipse. Elliptical orbit is characterized by its semi-major axis and its eccentricity.



Conservation of energy :-
For any elliptical motion, the law of conservation of energy is valid at all the points on its orbit when satellite is moving. The law of conservation of energy states that the energy can neither be created nor be destroyed, can only be transformed from one energy to other.
It means that the sum of KE & PE is always constant.
The value of constant is = $-\left(\frac{Gm_1m_2}{2a}\right)$

a = semi-major axis m_1 = mass of earth.
m_2 = mass of satellite.

UNIT-II

Satellite Sub-Systems

$$KE = \frac{1}{2} m_2 v^2.$$

$$PE = -\left(\frac{Gm_1m_2}{r^2}\right)$$

$$-\left(\frac{Gm_1m_2}{r}\right) = \frac{1}{2} m_2 v^2$$

$$v^2 = Gm_1\left(\frac{2}{r} - \frac{1}{a}\right)$$

$$\frac{Gm_1 \cancel{m_2}}{2a} = \frac{1}{2} \cancel{m_2} v^2$$

$$\frac{Gm_1}{a} = v^2$$

$$KE + PE = -\frac{Gm_1m_2}{2a}$$

$$\frac{1}{2} m_2 v^2 - \frac{Gm_1m_2}{r^2} = -\frac{Gm_1m_2}{2a}$$

$$\frac{1}{2} m_2 v^2 = Gm_1m_2\left(\frac{1}{r} - \frac{1}{2a}\right)$$

$$v^2 = Gm_1\left(\frac{2}{r} - \frac{1}{a}\right)$$

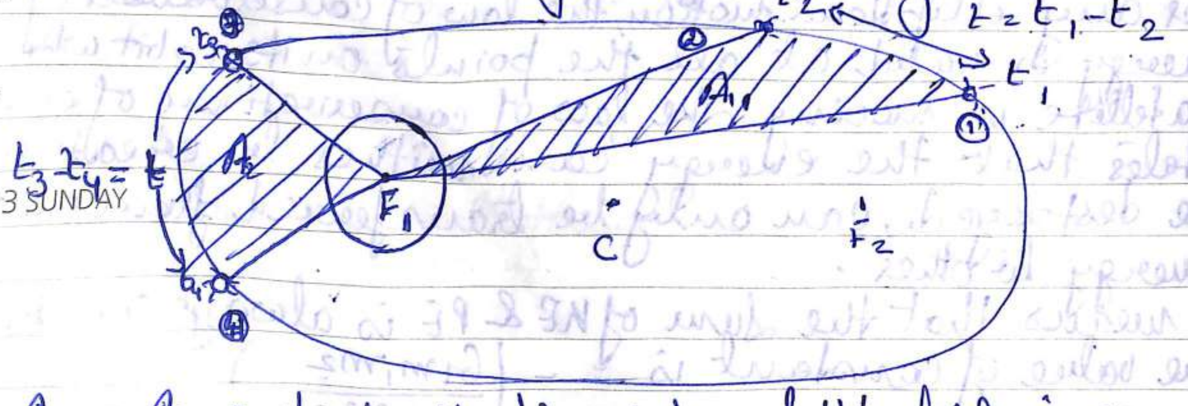
mass of earth

$:- \; Gm_1 = \mu$

$$\boxed{v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}}$$ for elliptical ↓ for geosynchronous.

$$\boxed{v = \sqrt{\frac{\mu}{r}}}$$ for circular $\{r = a\}$ ↓ for geostationary

Second law (Law of conservation of Momentum).



$A_1 = A_2$ = during the time interval 't' which is equal

- Line joining the Satellite & the centre of the earth sweeps equal area in the plane of the earth in equal time.

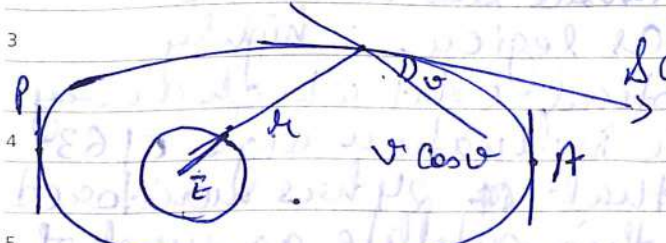
* ∴ The line joining the centre of earth's surface and satellite sweeps equal area in the plane of orbit in equal interval of time.

$$\frac{dA}{dt} = \text{Constant}.$$

Rate of change of swept out area is given by :-

$$\frac{dA}{dt} = \left(\frac{\text{Angular momentum of the satellite}}{2m_2}\right)$$

Hence, Kepler's 2nd law is the law of conservation of momentum which implies that the angular momentum of the satellite of mass m is given by the product of the radius and the component of the linear momentum perpendicular to radius vector is constant at any point of the orbit.



Satellite velocity vector.

- velocity at apogee - slowest
- Velocity at perigee = highest

Angular momentum of the satellite of mass is given by $mr^2\omega$. where, ω is angular velocity of the radius vector

Further, this implies that the product $mr^2\omega = mr r\omega$

$= m \cdot \omega r \cdot r = m v' r \rightarrow$ remains constant.

Here, v' is the component of satellite velocity is the direction ⊥° to the radius vector is expressed as $v \cos \vartheta$

where,

ϑ = the angle b/w direction of motion of satellite and the local horizontal which is plane ⊥° to the radius.

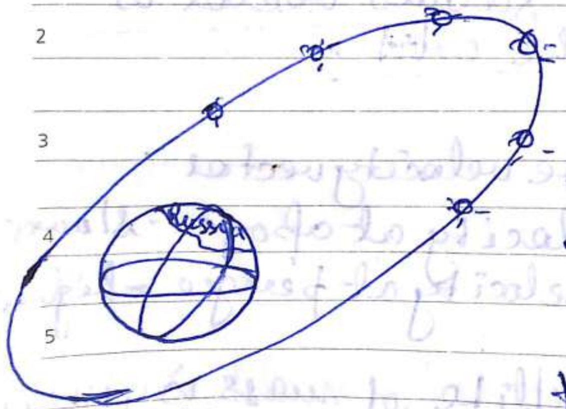
$\because \{ v = 0$ (in circular) $\}$.

This leads to the conclusion, $r v \cos v$ is a constant.

-> Product reduces to rv in case of circular orbit bcoz $v = 0$ & this also happens at the point of apogee and perigee.

$$v_p r_p = v_a r_a = v r \cos v$$

Now, this concludes that velocity component $v' = \omega r$ is inversely proportional to distance r. It means that qualitatively satellite.



• Russia lies in northern polar region. ∴ highly elliptical orbit which a very large inclination angle of 63° so that ~~of~~ 24 hrs monitored by this satellite as most of the time it will cover Russia.

In 1963.

∴ It is difficult for geostationary to look into this polar area.

Third law:-

According to this law, law of periods, any satellite which is revolving around the earth the period is proportional to the cube of the semi-major axis of the elliptical path.

$$\boxed{T \propto a^3}$$

In this circular orbit.

$$\frac{G m_1 m_2}{r^2} = \frac{m_2 v^2}{r}$$, replacing $v = \omega r$.

$$\frac{G m_1 m_2}{r^2} = \frac{m_2 \omega^2 r^2}{r} = m_2 \omega^2 r.$$

$$\omega^2 = \frac{G m_1}{r^2} \qquad \frac{G m_1}{r^3}$$

$$\therefore \omega = \frac{2\pi}{T}.$$

$$\left(\frac{2\pi}{T}\right)^2 = \frac{G m_1}{r^2} \qquad \frac{G m_1}{r^3}$$

$$T^2 = \left[\frac{4\pi^2}{G m_1}\right] r^3.$$

$$T = \left[\sqrt{\frac{4\pi^2}{G m_1}}\right]^{3/2}.$$

$$\boxed{T = \frac{2\pi}{\sqrt{\mu}} r^{3/2}}$$ for circular path.

This eq^n is also applicable for elliptical path as 'r' can be ~~@~~ replaced by a.

where, a = semi-major axis
r = radius of earth.

for elliptical path :- $\boxed{T = \frac{2\pi}{\sqrt{\mu}} a^{3/2}}$

Orbital Elements :-

a, e -> indicates the size and shape of the elliptical orbit.

i -> indicates how the satellite orbit is inclined with the equatorial plane as ascending node.

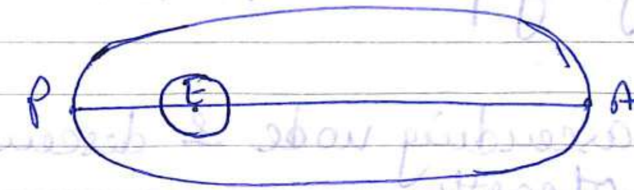
M_0 -> Mean Anomaly -> shows the position of satellite in its orbital path in fixed reference time k/a Epoch

✓ Anomalas

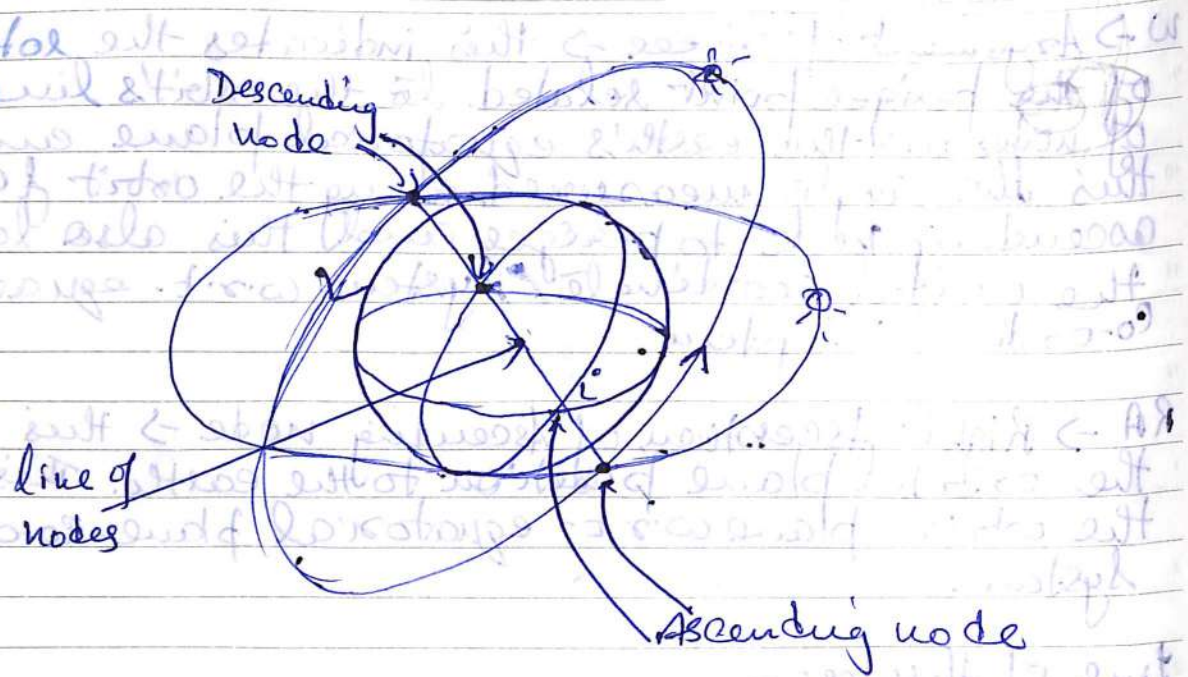
w -> Argument of Perigee -> this indicates the rotation of the perigee point related to the orbit's line of nodes in the earth's equatorial plane and this the angle measured along the orbit for ascending node to perigee and this also locates the orbital coordinate system w.r.t. equatorial co-ordinate system.

RA -> Right Ascension of Ascending node -> this relates the orbital plane position to the earth. This locates the orbital plane w.r.t. equatorial plane co-ordinat system.

Line of Apsides :-
This the line joining apogee & perigee through the centre of earth.



Ascending node :- Point where orbit crosses the equatorial plane going from south to north.



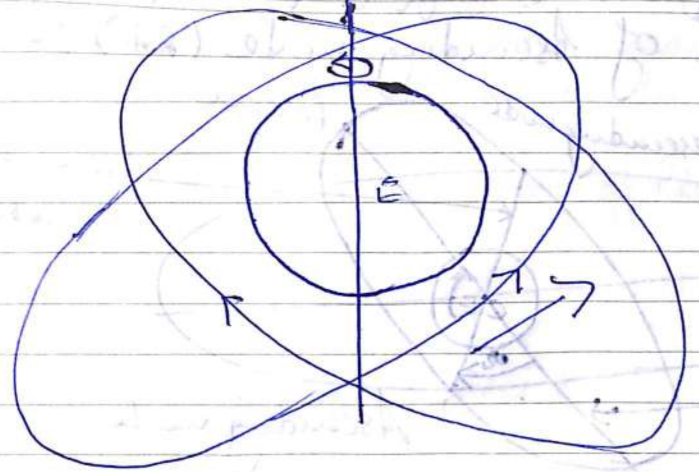
Descending node:-
Point where the orbit crosses the equatorial plane while going from north to South.

Line of nodes:-
Line joining the ascending node & descending node through Centre of earth.

Angle of Inclination:-

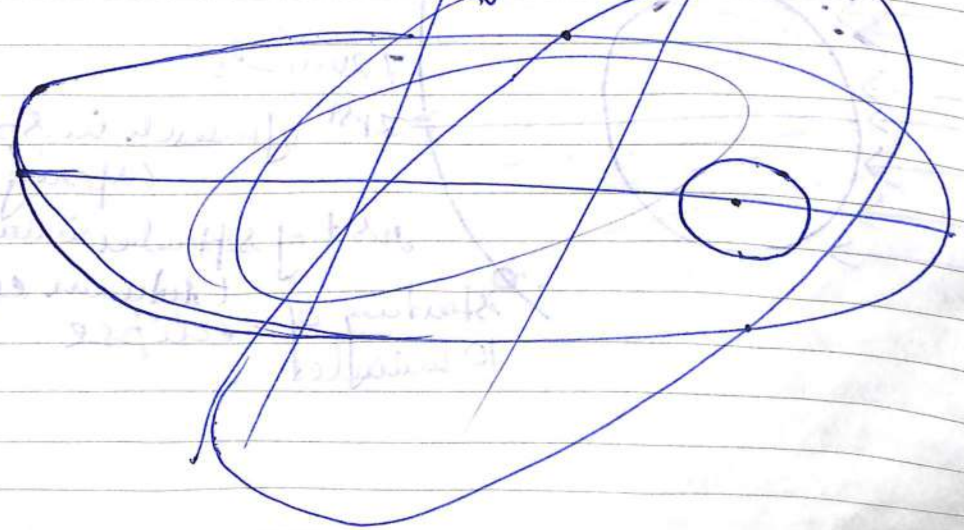
Angle made by the orbital path with the equatorial plane at the ascending node.

Prograde Orbit:- (Direct Orbit):-
An orbit in which the satellite moves with the same direction as of the earth rotation



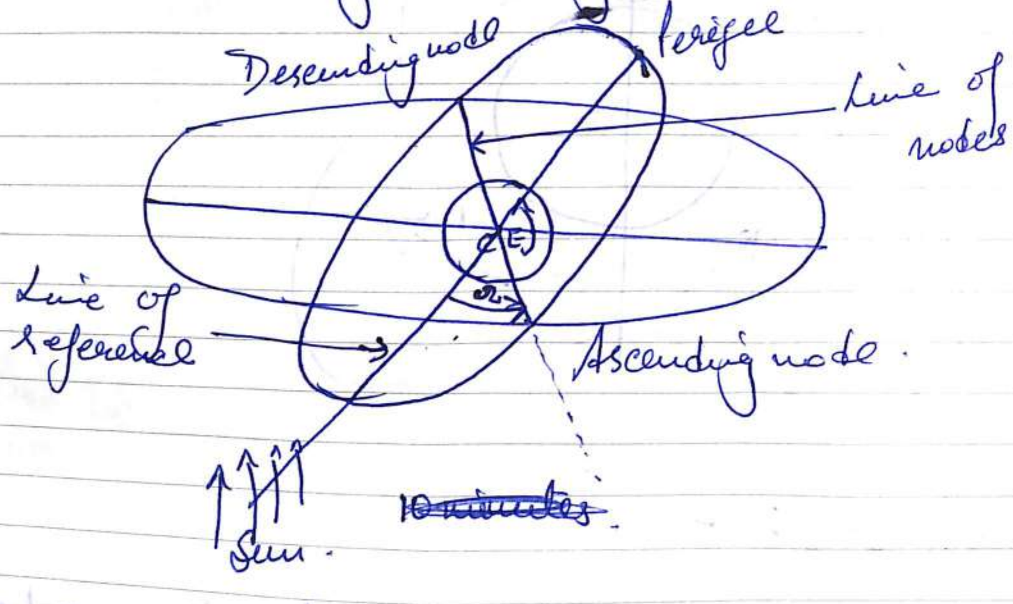
Retrograde Orbit:-
An orbit which is in counter direction of earth rotation.

Right Ascension of Ascending node (RA):-

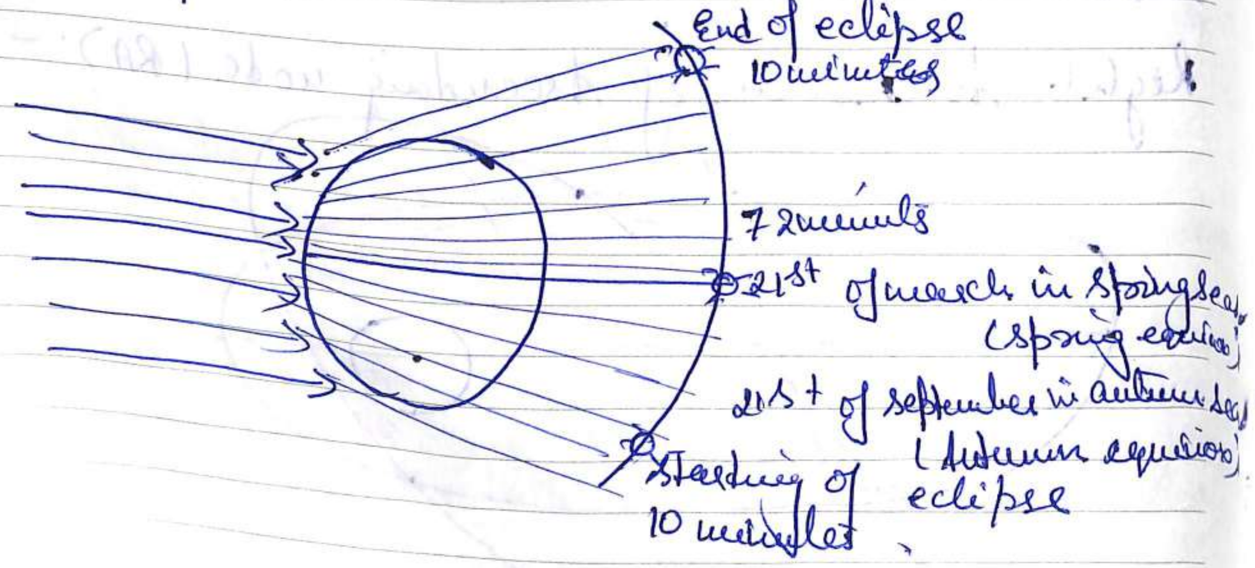


Look angle is the angle at which the antenna is placed as such that it faces the satellite. Because of deviation of satellite antenna proper commun cannot takes place.

Right Assertion of Ascending node (RA) :-



Solar Eclipse.

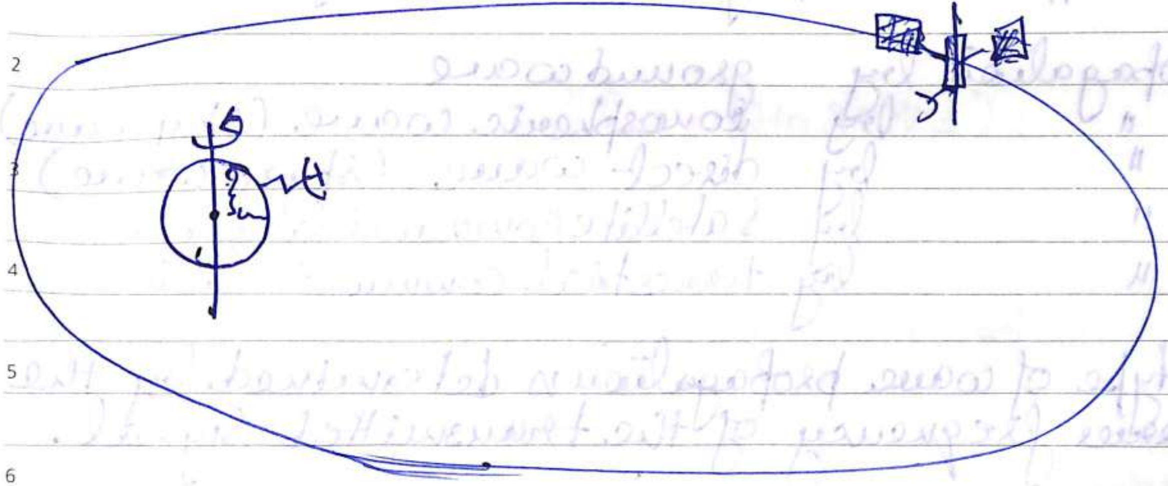


GSLV first places in transition orbit i.e. elliptical orbit then the geostationary orbit.

- Spring equinox is taken of reference t/a first point of Aries.

- RA is the angular separation of line of nodes and line of reference.

Atmospheric Drag :-



If the satellite is stable and moving along the orbital path then there is matching of radiation pattern of satellite antⁿ & g.s. antⁿ and if not stable then it may move in diffⁿ direction which causes misalignment of radiation pattern. Forces acting on satellite body because of solar radiation pressure, planetary bodies & oblateness of the earth. ~~In the~~, gravitational pull, mass accumulation at the equatorial plane.

Because of oblateness of the earth it will disturb the ~~Sat~~ stability of satellite,
Therefore gravitation pull effective in case of LEO & MEO

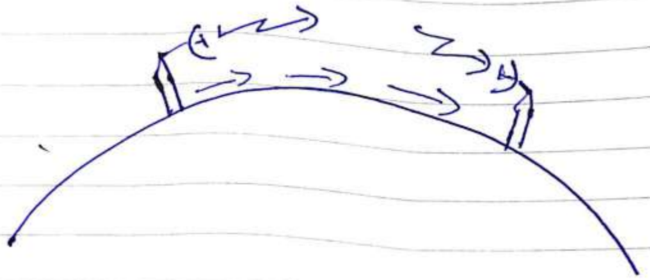
Propagation of Radio waves :-

The propagation of em waves bet^{n} Tx ant^{n} & Rx ant^{n} very complex. It is nevertheless important to distinguish the different propagation methods of em waves.

- Propagation by ground wave
- " by ionospheric wave (sky wave)
- " by direct wave (space wave)
- " by satellite communication.
- " by terrestrial communication

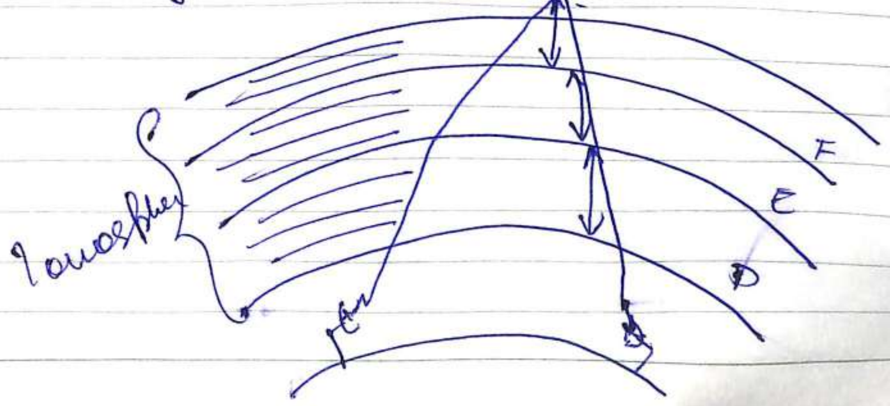
The type of wave propagation is determined by the carrier frequency of the transmitted signal.

Ground wave (≤ 2MHz)
Em waves are conducted / propagated via the boundary of ground and atmosphere. A ground wave radio sig is made up of a number of constituent waves. If the ant^{n} are in direct LOS then there will be a direct wave as well as a reflected sig. In addition to this there is a surface wave. This tends to follow the curvature of earth and enables coverage beyond the horizon. These surface waves generate charge. The charge is absorbed by the earth as it behaves as a leaky capacitor. Hence distance coverage comes out as attenuation as some charges are absorbed by earth.



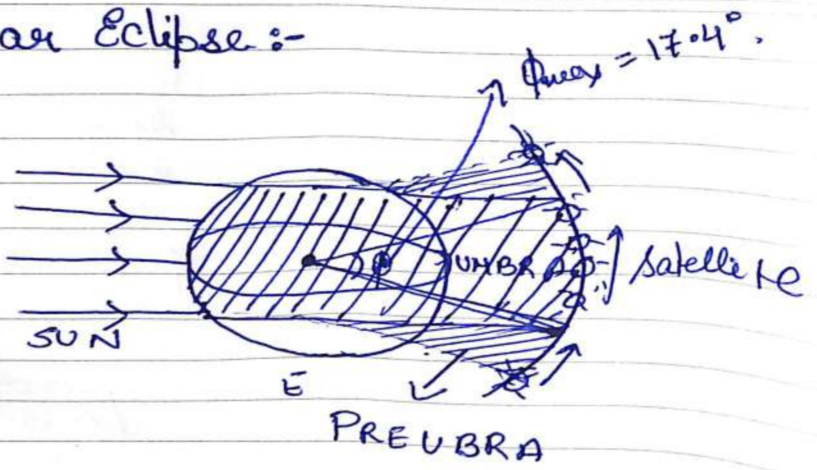
Propagation by Ionosphere (2 to 30MHz).

Em waves are reflected by the ionosphere. They ionospheric waves after reflection by ionosphere are once again reflected by the earth surface. At a height of bet^{n} 50 & 500km above the earth surface diff^{n} layers are filled with electrical charged atoms called ions. These ions are positively or negatively charged. The ionization is due to the U.V. rays radiated by the sun.



when solar eclipse is likely to occur, when the battery gets discharged then the battery should be discharged. light energy coming from sun is not reaching the satellite i.e. transponder may not work properly. Solar eclipse has got its importance.

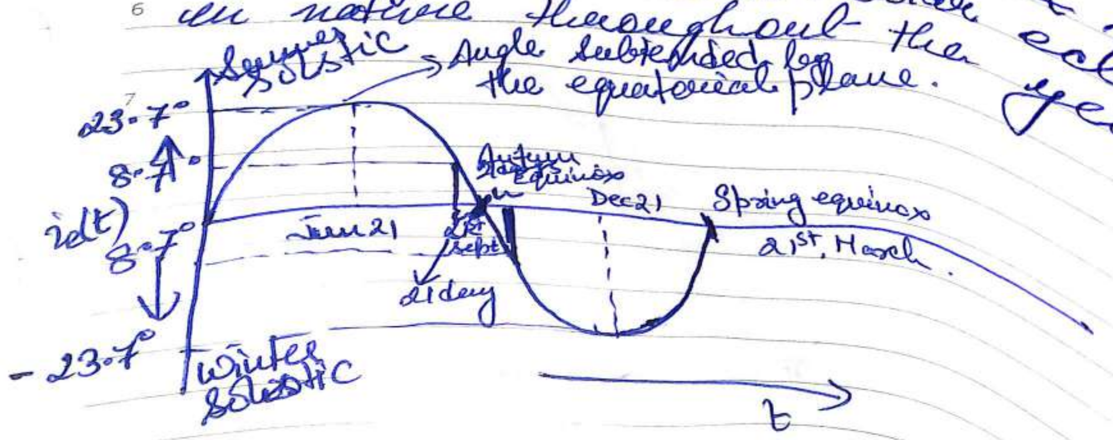
Solar Eclipse :-



when sun-rays are falling

During Equinox, duration of days & night are equal

It lasts for 72 minutes. Solar eclipse is periodic in nature throughout the year.



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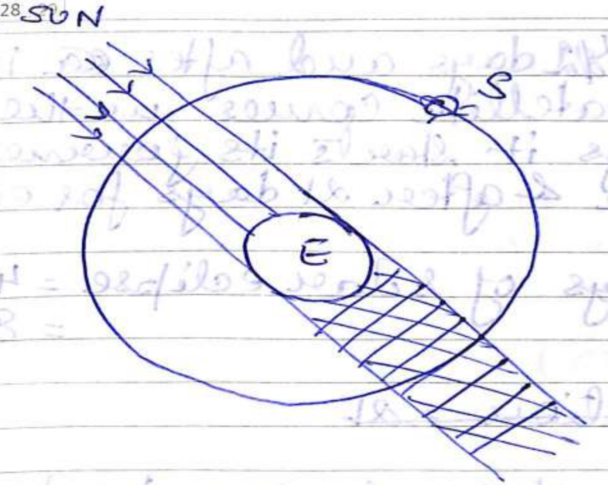
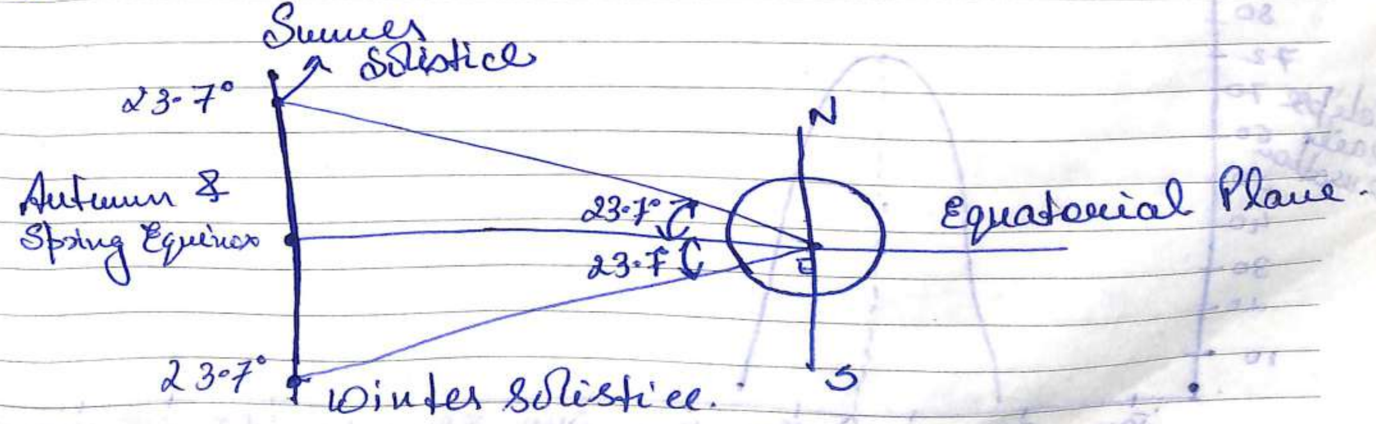
when sun-rays does not allign with the equatorial plane resulting in darkness on the satellite.



ie(t) is the angle made by the sun-rays with the equatorial plane of earth and this is also varying throughout the year. It is the maxm angle the sun rays subtend to the earth equatorial plane just touching the surface of the earth thus stopping of partially light is reaching the sun. It happens twice in a year.



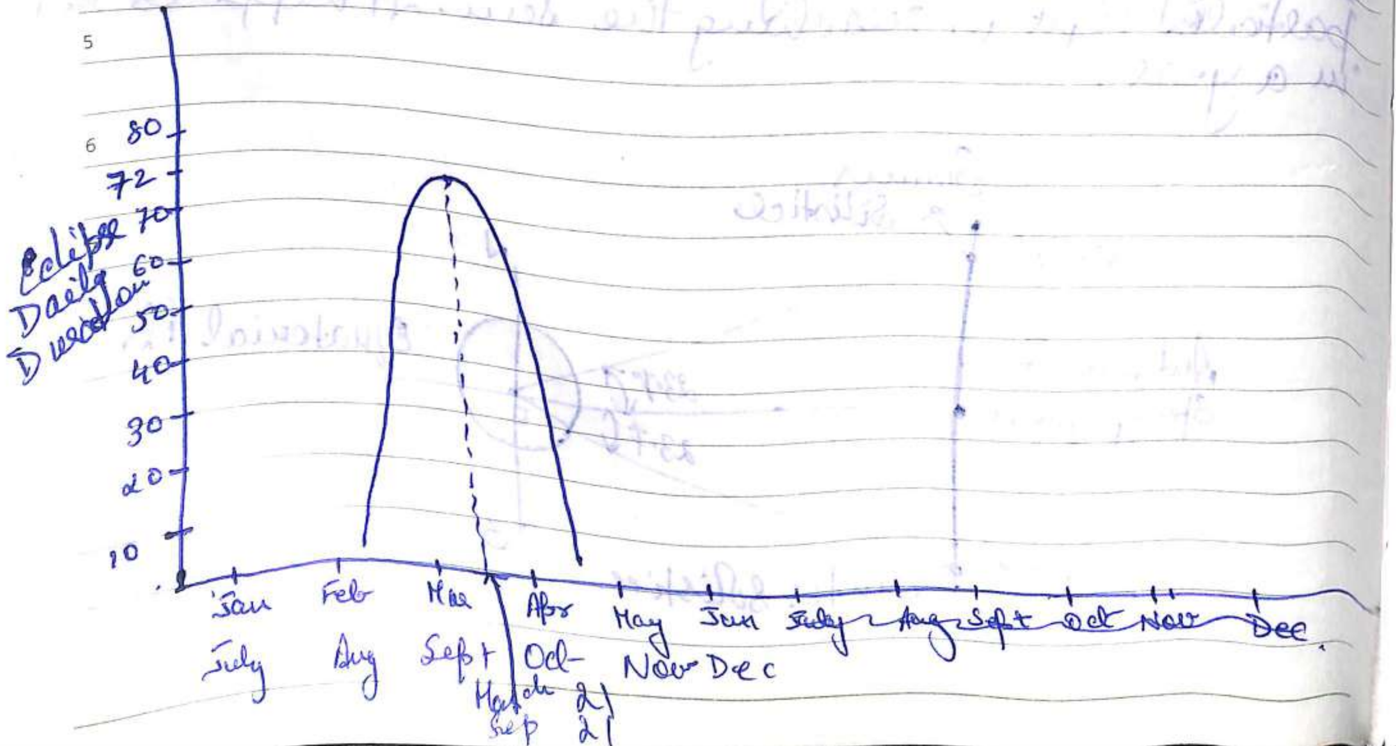
Solar eclipse occurs for ~~42~~ 42 days and after ~~a~~ a interval of six months, the satellite comes in the solar eclipse. In 42 days it starts its journey towards equinox (i.e- before & after 21 days for equinox).

In one year, total days of solar eclipse = 42+42
= 84 days.

~~Spring equinox duration = 21~~

Solar eclipse during spring season duration = 21 days
autumn season duration = 21 days
42 days

Duration of eclipse in one day is 72 minutes.



Φ_{max} is the max^m angle it makes with the centre of earth in the umbra region.

$$\Phi_{max} = 180° - 2\cos^{-1}\left(\frac{R_e}{R_0+R_e}\right)$$

R_e is the earth's radius (6378 Km)
R_0 is the distance ~~from~~ of the satellite from the surface of earth (35,786 Km).

$$\Phi_{max} = 17.4°.$$

$$\frac{1}{2} \text{ of } \Phi_{max} = 8.7°.$$

Equinox starts when sun rays starts making 8.7° angle with the equatorial plane.

$$t_{max} = \frac{17.4°}{180°} \times 24 \text{ hours} \simeq 72 \text{ minutes}.$$

How much time it takes to begin of the equinox and after equinox?

Total days in year = 365.

$$t = \frac{365}{\pi} \sin^{-1}\frac{8.7}{23.7°} = 21 \text{ days}.$$

Because of these perteabations, olientation of satellite is distributed towards the gnd station and inorder to maintain the satellite in its orbital path.

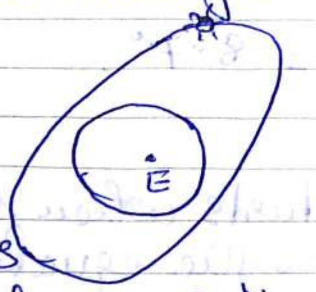
Hence, from the first day of the eclipse to equinox and from equinox to the last days of eclipse. These batteries needs to be changed.

So that it provides battery to the transponder when it covers the equinox region.

Duration of solar eclipse is more as compared to lunar eclipse.

General

Orbital Perturbation :- (Change in the orbital path when it is moving in its path) disturbances.



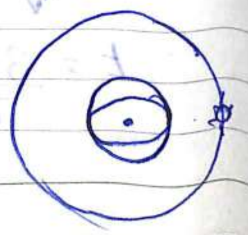
Along with centrifugal & centripetal force acting on the satellite moving in its orbital path which are necessary for keeping it in its orbit; there are certain other forces acting on the satellite - perturbations.

Orbital perturbations are the forces due to the various planetary bodies (sun, moon)

Sun is about 3 million times more in mass than moon but it is 400 times farther away from the satellite / earth,

So effect of the sun is half times the effect of moon.

1. Forces due to planetary bodies.



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is not tangential rather normal

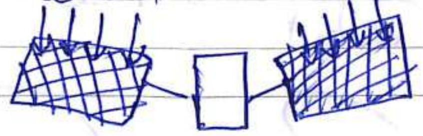
Forces acting on the satellite alway try to move it away from its fixed orbital path which is circular for geostationary orbit & orbital path & 0°. no more remains circular & in equatorial plane. This will go on increasing with years if not checked.

And hence will be highly inclined with the equatorial plane within 1 year, the angle made may be 0.75° to 1° ? & if not encountered it may rise to 15° in 27.5 yrs.

And hence no longer will be a geostationary orbit.

So orbital perturbations are disturbing the inclination of satellite with the equatorial plane.

2. Solar Radiation Pressure.



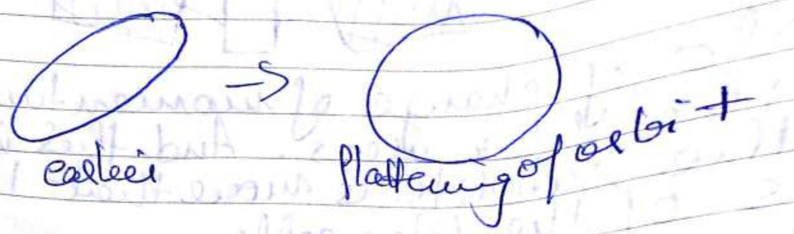
It is the rate of change of momentum of the photons striking the solar users. And this is more if the mass of the satellite is more that the dimension of the wings of the solar cells.

And hence the orbital path will be changed to elliptical. Because it is always singing towards the solar cells.

The pressure due to solar radiation tend to change the shape of the orbit from circular to elliptical.

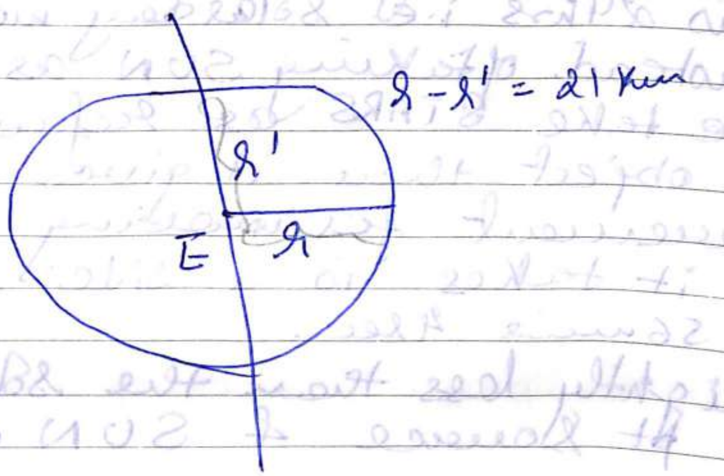
At local sunrise, it will be in the prograde orbit.

At local sunrise, the motion of satellite will be against the direction of motion. And the local sunset, it is with the direction of motion of satellite.
So during sunrise, when it is opposed, it will be deaccelerating and during sunset it is accelerating.
And these 2 have the effect of flattening of the elliptical orbit



3. Oblateness of the Earth.
Earth is not actually circular in shape but rather flattened in the polar region.
Mass of the E in the equatorial plane is larger.
There is a bulging in the equatorial plane.
Because of these 2 reasons create change in the uniformity of the shape of the E

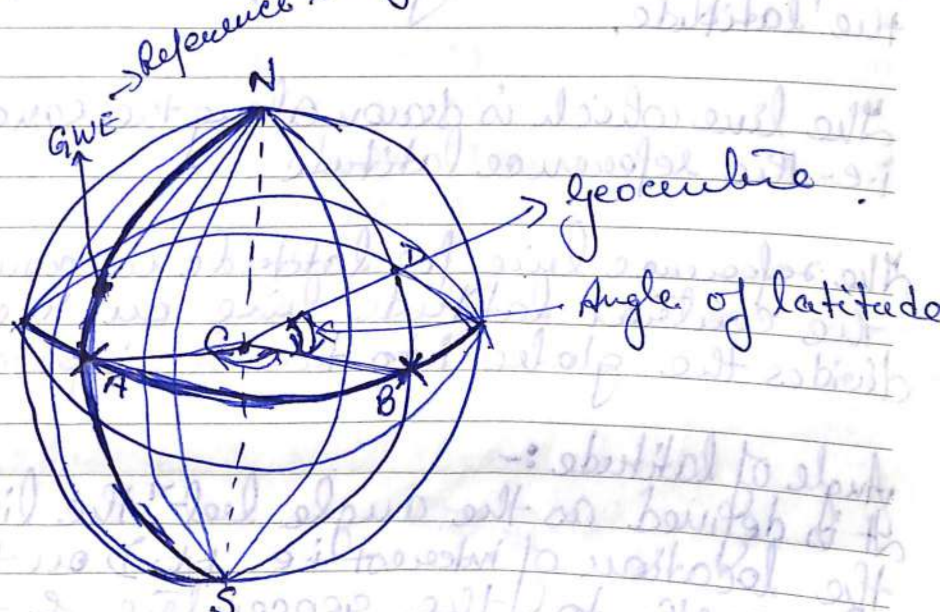
Gravitational pull of the E is not uniform. Hence because of flattening & bulging reasons.
And ∴ proper comm^n with the ground stn antenna can't take place because the orientation is disturbed.



Side Real Day, & Solar Day.

Solar Day :-
The time taken by earth to revolve around the Sun is 24hrs i.e. Solar day moving around its axis. But instead of taking SUN as the reference but we take STARS as reference which is a pt-object then it gives more accurate measurement for moving around the time it takes is a side real day i.e. 23hrs 56mins 4sec.
It is slightly less than the solar day
STAR pt Source & SUN is nebular.
↓
It gives accurate measurement of revolution time.

Satellite Acqusition:-



Longitude:- It is the line drawn from the north pole to the south pole from on the earth surface is called longitude, Meridian.

The line which passes through the Green which of England is called reference longitude and is Known as the Prime Meridian.

Every line is called meridian but the reference line is called prime meridian.

Latitude :-

The line that is drawn from the west to east on the surface of earth along the equatorial plane is called the latitude.

The line which is drawn along the equatorial plane i.e. the reference latitude

The reference line for latitude measurement is the central latitude line on the equator which divides the globe into two hemisphere.

Angle of latitude :-
It is defined as the angle bet^{n} the line drawn from the location of interest i.e. pt: D on the surface of the earth to the geocentre & the intersection of equator and meridian on which the pt. of interest lies.

Angle of longitude :-
It is defined as the angle bet^{n} the line ~~drawn from~~ ~~the~~ connecting the geocentre and the intersection of the prime meridian and the equator and the reference latitude is known as angle of longitude.

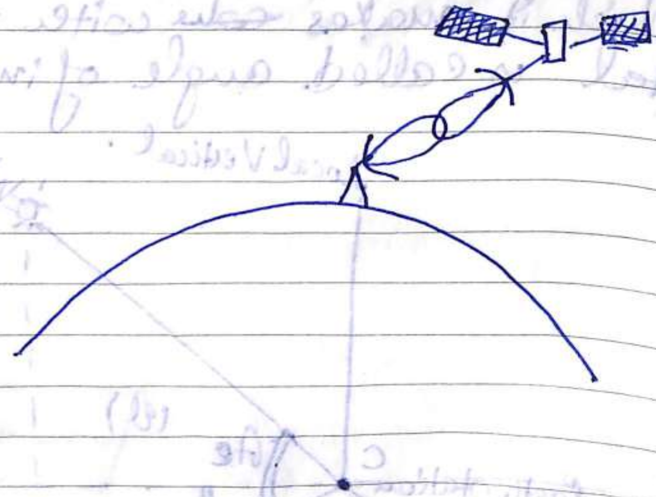
Angle of longitude
The designation E or W is usually added to the angle in degrees to indicate whether the angle is measured towards east or west

Angle of latitude
or N or S whether the angle is measured towards north or south.

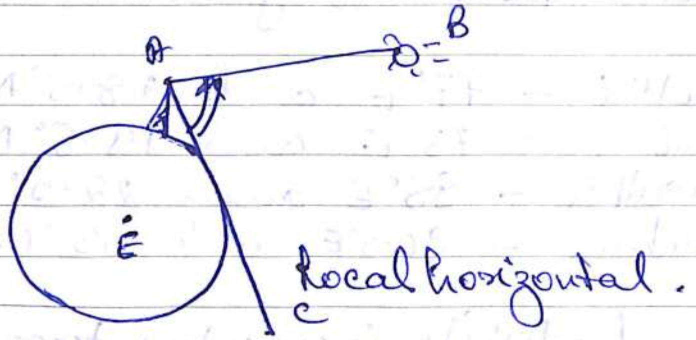
If the point of location for ground station is positioned in Delhi then it is given as :-

Delhi - 77° E and 28.5° N.
Bombay - 73° E and 19.5° N.
Calcutta - 88° E and 22.5° N.
Madras - 80.5 E and 13 °N.

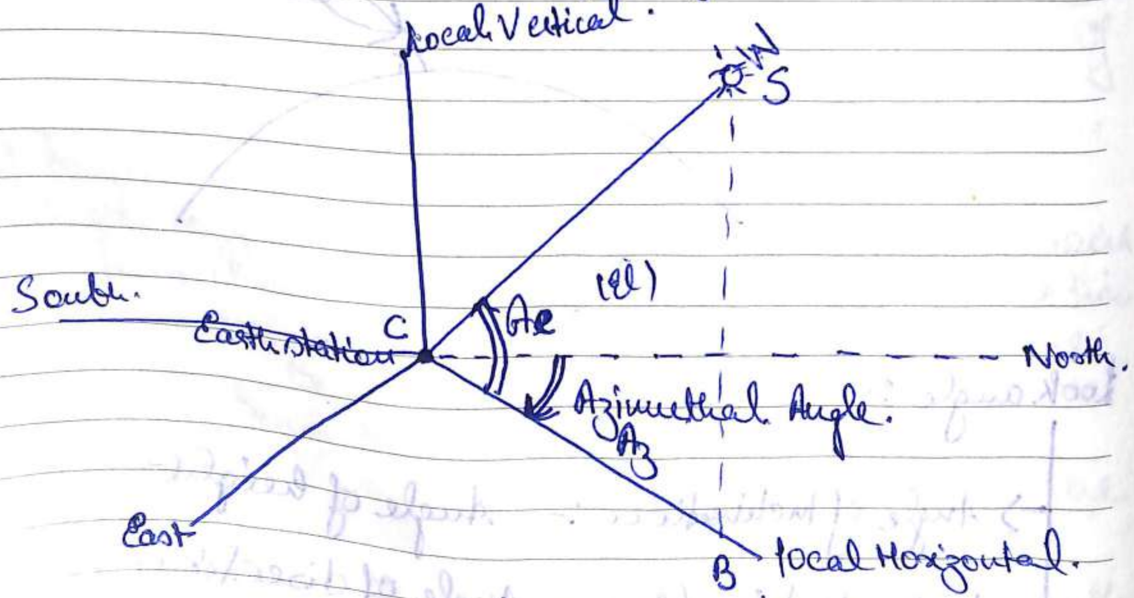
Antenna of satellite is oriented towards the earth having some latitude & longitude



Look angle :-
- Angle of Inclination :- Angle of height
- Angle of Azimuth .- Angle of direction.



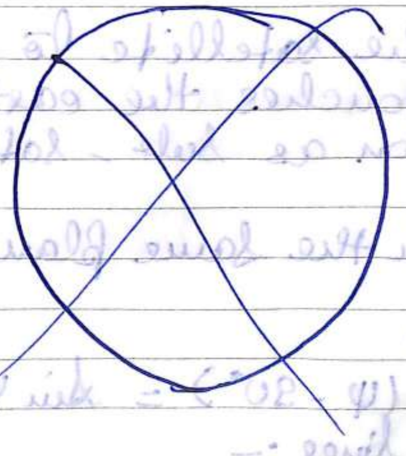
The angle make by the radio waves propagatin from g.s. towards the satellite and the angle which it makes ~~the~~ with the local horizontal is called angle of inclination.

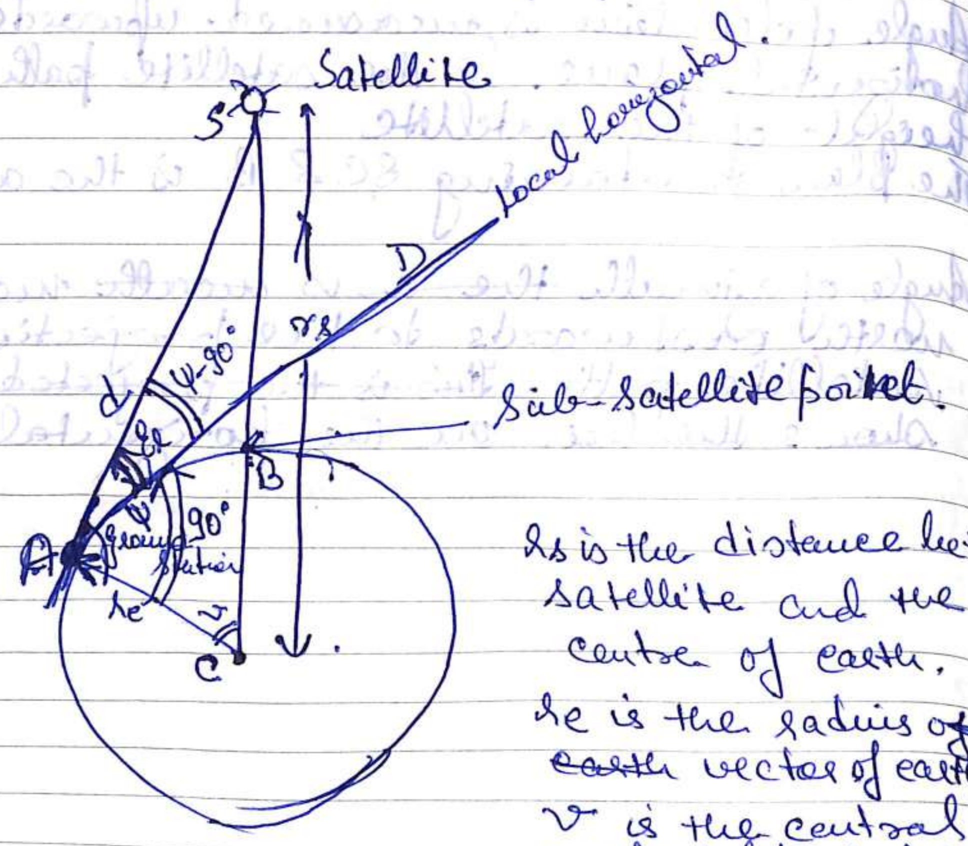


Freq large - antenna of satellite will be larger.
larger antenna - larger no. of channels

Angle of elevation is measured upwards from the local horizontal plane to the satellite path. i.e. gives the height of the satellite
The plane containing S,C & B is the angle of inclination.

Angle of azimuth ~~the a~~ is ~~meath~~ measured from north eastwards to the projection of the satellite path. ~~This is the projected line which shows the lie~~ on the horizontal plane.





d is the distance of ground station from the satellite.

r_s is the distance betn satellite and the centre of earth.
r_e is the radius of ~~earth~~ vector of earth.
γ is the central angle subtended betn r_e & r_s.

The line joining the satellite to the centre of the earth when it touches the earth surface then that pt. is known as Sub-satellite point.

Pt. S, A, C are ~~the~~ in the same plane (white board).
In the ΔSAC

$$E_l = \psi - 90°$$

$$\cos E_l = \cos(\psi - 90°) = \sin\psi.$$

By the law of Sines:–

$$\frac{r_s}{\sin\psi} = \frac{d}{\sin\gamma}$$

$$\text{or } \sin\psi = \left(\frac{r_s}{d}\sin\gamma\right).$$

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

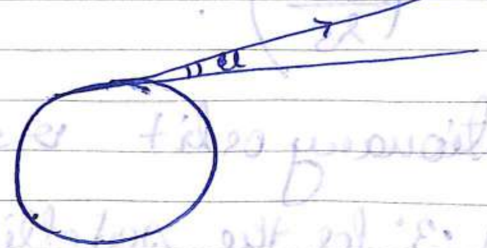
$$\left(\frac{r_s}{d}\right) = \left\{\frac{1}{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos\gamma\right]^{1/2}}\right\}.$$

$$\because \sin\psi = \frac{r_s}{d}\sin\gamma$$

$$\cos E_l = \frac{r_s}{d}\sin\gamma.$$

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

If E_l is larger then, it will have shortest distance towards the satellite and vice versa.



Visibility of satellite comes into picture depending upon the inclination angle.

Visibility of Satellite.

∵ the earth ~~station~~, the ~~centre~~ of ~~the earth~~ & the Sub-~~Satellite pt.~~ lie in the ~~same plane~~

For the satellite to be visible from the earth station its elevation angle E_l must be above some minimum value (or {0° not possible but there should be some min^m value & that min^n elevation angle is 5°} which is atleast 0°. A positive or 0 elevation angle requires

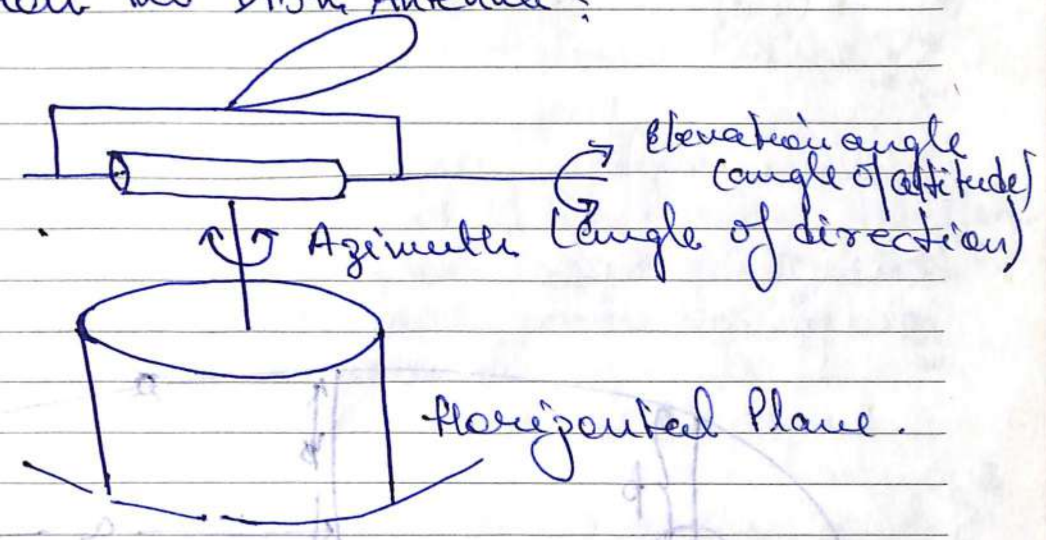
$$r_s \geq \frac{r_e}{\cos \nu}$$

This means that the max^m central angle ν i.e. separation of the ground station ~~from~~ the Sub-Satellite point and is limited by

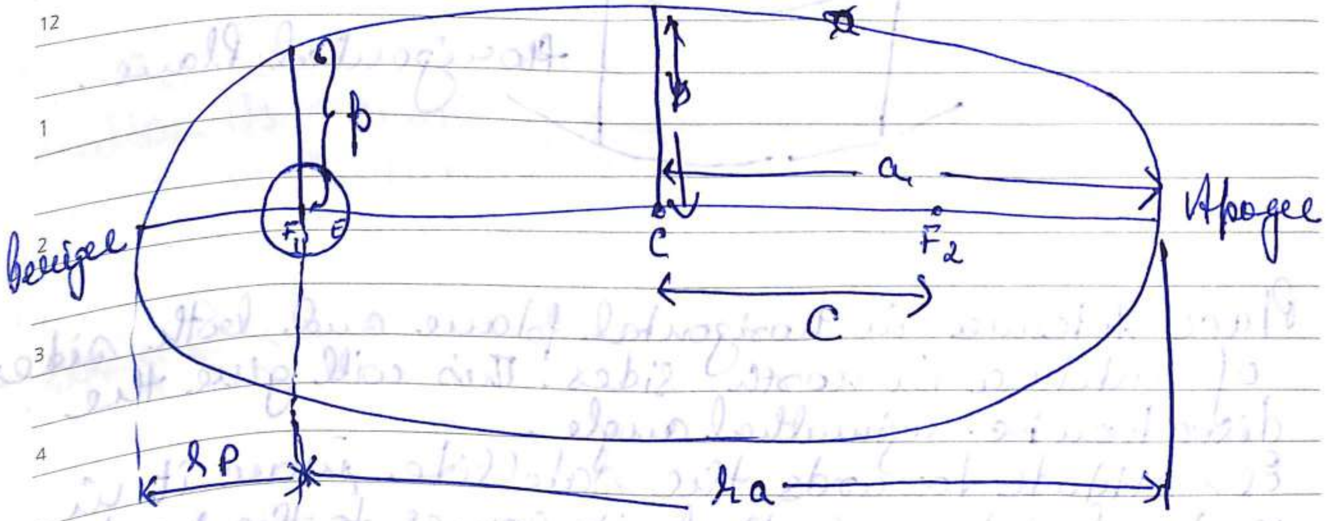
$$\nu \leq \cos^{-1}\left(\frac{r_e}{r_s}\right).$$

For a nominal geostationary orbit $\nu \leq \cos^{-1}\left(\frac{r_e}{r_s}\right)$ reduces to $\nu \leq 81.3°$ for the satellite to be visible.

How to position the Dish Antenna?



Place Antenna in horizontal plane and both sides of antenna in north sides. This will give the direction i.e. azimuthal angle.
E_l:- altitude towards the satellite, move it in vertical plane so that it comes to the particular angle of elevation this leads to achieving of E_l angle.



Eccentricity 'e' $= \frac{c}{a} = \frac{r_a - r_p}{r_a + r_p} = \frac{\sqrt{a^2 - b^2}}{a}$.

$$a = \frac{r_a + r_p}{2}.$$

$$r_a = a + c = a(1+e)$$

$$r_p = a - c = a(1-e)$$

Semi-latus rectum $p = a(1-e^2) = \left(\frac{2 r_a r_p}{r_a + r_p}\right)$

$$b = a\sqrt{1-e^2} = \sqrt{r_a r_p}.$$

Assignment :-

1. ~~Why the k~~ What is the name of the Regional Russian Satellite and why it is made highly inclined & what is its angle of inclination and which particular law of kepler supports this requirement.

Q. Geostationary orbit is always geosynchronous but the reverse is not true explain.

3. The orbital period of satellite is 650 minutes. Determine the semi-major axis of the elliptical orbit. given $g = 6.67 \times 10^{-11}$ & $M = 5.98 \times 10^{24}$ kg.

*4. Apogee & Perigee of a Elliptical satellite orbit are 3000 km and 200 km. Determine eccentricity semi-major axis & the semi-minor axis.

5. A satellite is moving in an elliptical orbit with a ~~perigee &~~ apogee & perigee at a distance of 35000 km & 500 km respectively from the surface of the earth. If the radius of earth is 6370km. Determine the velocity of the satellite at any point in its orbit.

6. 2 satellites are moving in an elliptical eccentric angle with the same perigee, but diffn apogee distances. Satellite 1 is having

a orbital period of 5hrs & semi-major axis 20,000 Km, while the orbital period of satellite 2 is 2hrs 50 minutes. Determine the Semi-major axis of the satellite path.

*6. Semi-major & minor axis of the elliptical orbit are 20,000km & 16,000km respectively. Determine the apogee & perigee distance.

*7. What is the term First Point of Aries & what is its importance in the determination of position of satellite in space.

8. Velocity is of two types:-

1. Tangential velocity changes the dimension of the orbital path.
Because of the moon, it affect it in such a way that it
more tangential
angular to the tangential velocity.

NOVE

WK	
44	30
45	2
46	9
47	16
48	23

Nominal Mean Velocity

Nominal Velocity (η_0) = when the earth is perfectly circular.

$$\eta_0 = \sqrt{\frac{\mu}{a^3}}$$. → when earth is perfectly spherical.

Because of the oblateness of the earth, this velocity is disturbed this comes out to be

(Mean Velocity) $$\eta = \eta_0 \left[1 + \frac{K_1 (1 - 1.5 \sin^2 i)}{a^2 (1-e^2)^{3/2}} \right]$$

Gravitational pull is affected because of the oblateness of the earth.

Atmospheric Drag :- → Perturbations :-

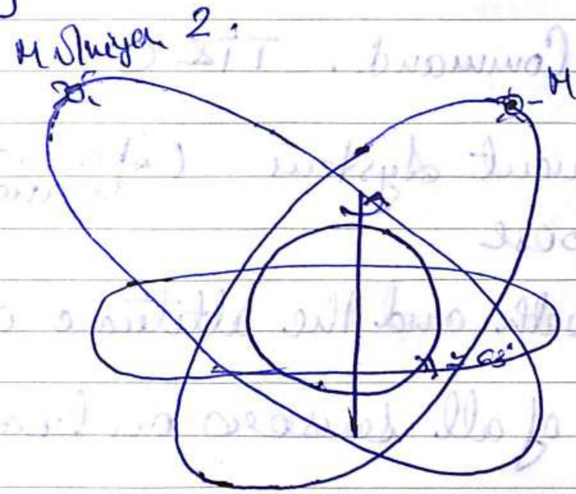
The effect will be more in case of LEO, Gravitational pull will be more. due to oblateness & bulging in the equatorial region. Therefore forces acting are not uniform therefore effecting the stability

Molniya always illuminating the ~~radio~~ w. Russian region with radio waves. 12hrs, 63°.

The apogee of Molniya orbit is is at 39152 km and perigee distance is 500km and the orbital period is 11hrs 58 min ≃ 12hrs and orbital inclination is 62.9°.

To illuminate the Russian region we need 2 Molniya satellites. Molniya 1 & 2 are separated i.e.

the orbital plane of these 2 satellites are separated by 180°



Thus illuminating the Russian energy 24hrs.
Law of conservation of momentum is followed.

Capacity of satellite can be increased by making using the same frequency again i.e. Reuse frequency factor.

1.
2.

Atmospheric Drag.

M	T	W	T	F	S	S
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16	17	18	19	20	21	22
23	24	25	26	27	28	29

Mechanism By Which Satellites Are Maintained In Orbital Path.

Telemetry, Tracking and Command. TT&C
⇓
Satellite Management System (Spacecraft management)
⇓ Purpose

1. To maintain the orbital path and the altitude of the satellite.
2. To maintain the status of all sensors on board satellite.
3. Switch on and off section of Communication System on large geostationary orbit. (Status of all circuitry if we want to replace then standby is also available)

TELEMETRY:-

Various s/g are telemetered that are required to process the healthiness of the satellite.

Purpose:-

1. Altitude Information :-
We have earth and sun sensors deployed on the satellite to maintain the altitude of satellite.
2. Environmental Information :-
Such as the magnetic field intensity as well as direction is continuously being measured.
3. Space-craft Information:-
i) Pressure of the storage ~~tank~~ (fuel) in the ~~spacefran~~ Spacecraft tank.

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	1	2	3	4	5	6
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14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

ii) Voltage and current of the power conditioning system.
iii) Temperature of the various system devices. (temp^{r} of devices needs to be measured with the help of sensors so that they can be replaced or appropriate connection can be done).
iv) Critical Voltage and Current in various electronic circuits.
v) Status of each subsystem and the position of switches in the communication system.

Tracking :-
It takes place in ground station.

Tracking is primarily performed at the g.s. It is the technique used for primarily determining the current orbit of the spacecraft and is used for ~~this~~ maintaining the correct orbital path. In order to do this, the velocity and acceleration of satellite is measured to establish the change in orbit and it is done with the help of gasjets, thrusters (small rocket motors) which are to be fired to maintain velocity & acceleration to bring it to the orginal orbital path.

Command:-
All the S/gs coming from satellite to g.s is received and processed further if there is any change then it will send the processed signal. If fuel is going to finish then the satellite needs to be replaced so

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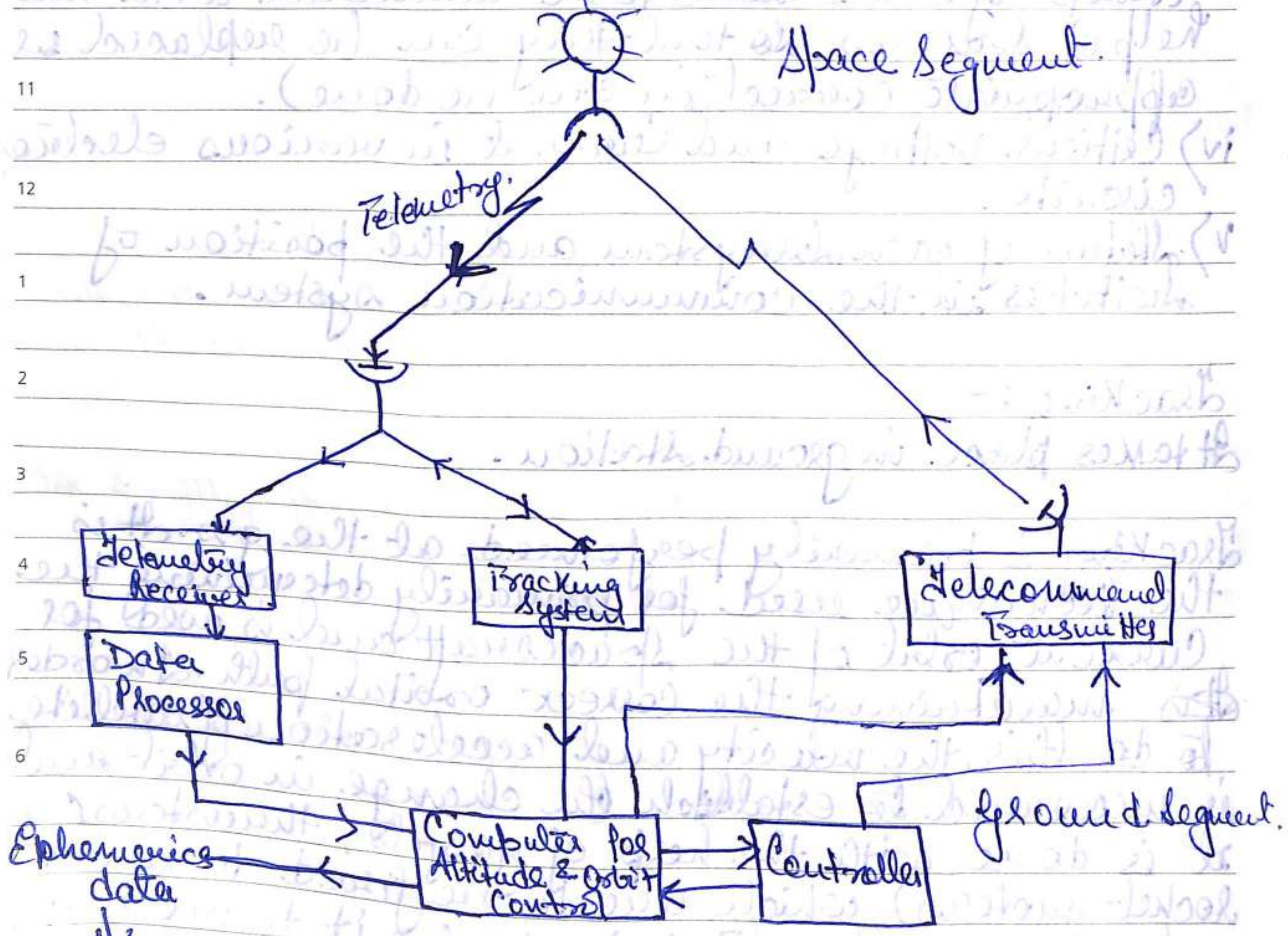
that the services are not stopped.



08 SUNDAY

(Orbital elements also called ephemeric data)

Telecommand transmitter

For launching on equatorial position.

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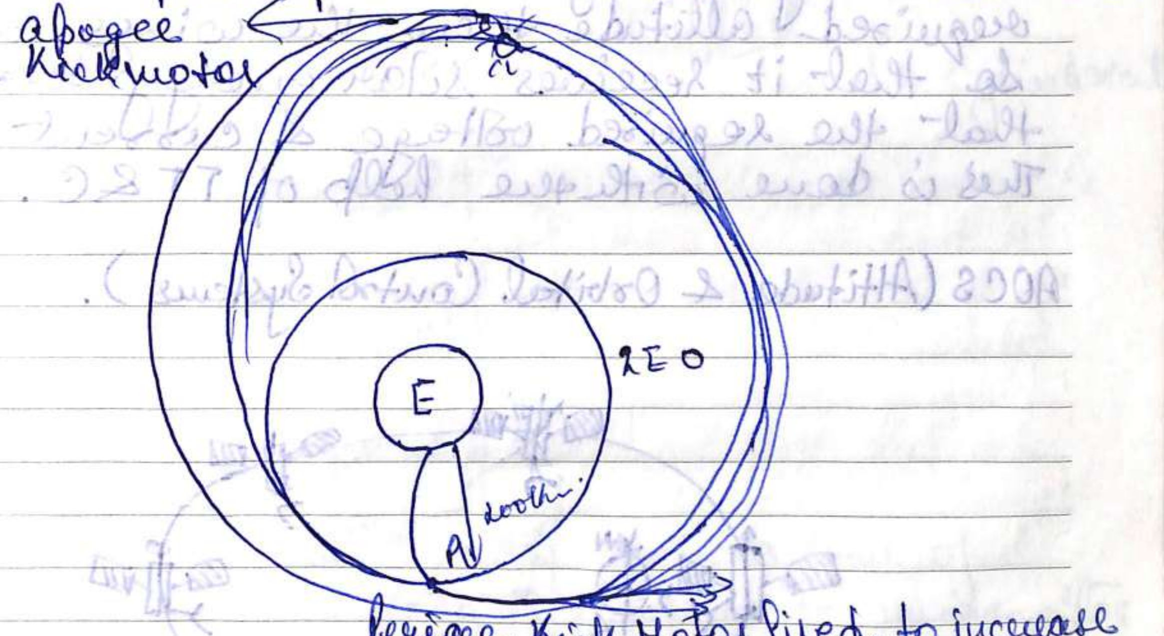
28	29	30	31				

~~For~~ A secure ~~&~~ & effective command structure is very necessary to the successful launch & operation of any communication satellite. Commn System is used to make changes & corrections to the orbit & control during the launch it is used to control the firing of the apogee & perigee kick motors and to spin up or to extend the solar cells



Perigee Kick Motor fired to increase the velocity to acquire the elliptical path and that is called the (Hohmann Orbit) or Transfer orbit.

So that we get the appropriate apogee point from the surface of the earth.

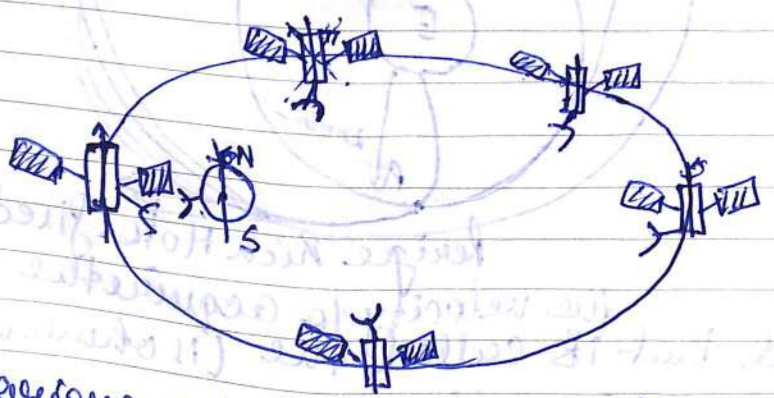
35,80

the velocity with which earth is moving is same as that of satellite if loss then the no. of signals will be zero.

Range measurement is done with TT&C

Once 35,585 Km is reached then apogee Kick motor is fired then it further increases the velocity then it will achieve the circular orbit. Various apogee Kick motors are fired so that circular orbit is obtained i.e. the geostationary orbit. Initially solar wings are folded when it achieves the required altitude then the wings are opened so that it receives solar energy ~~so that~~ so that the required voltage & current is acquired. This is done with the help of TT&C.

AOCS (Altitude & Orbital Control Systems).



Due to various external forces continuously acting on satellite Wobbling of satellite due to disbalancing. Hence, causes the altitude disturbances
This disbalancing is counteracted by AOCS. It is done in two ways:
(a)

AOCS

Spin Stabilization
1. Simple Spin.
2. Dual Spin
3. Triple Spin.

Body Stabilization
(Three axis body Stabilization).

Spin Stabilization:-
In this the body of the satellite is made cylindrical in nature.

Body moves along its axis with a spin of 30 to 100 rpm. When body is rotating it generates gyroscopic torque (stiffness) and that produces torque which is in opposition to torque generated due to external forces. The torque is counteracted by spinning satellite body and the satellite is called Spin Stabilized satellite.
The spinning of satellite is done in two ways:
gravitational pull
Sun, moon, radiation pressure, oblateness of the earth. So that made cylindrical in shape.

1. Simple Spin. → directional antenna

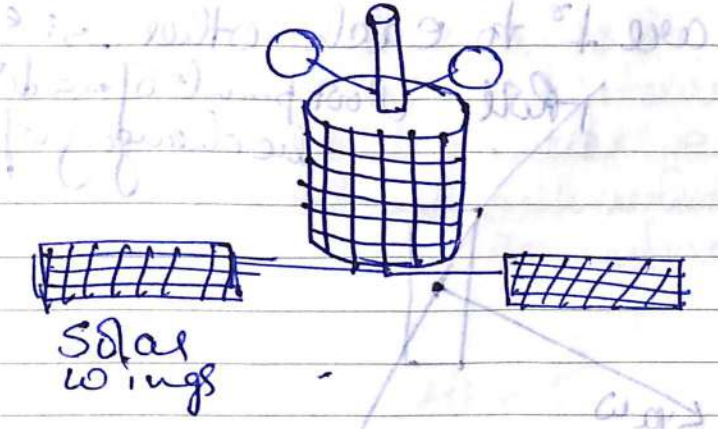
An antenna (array antenna) at the top of the body of the satellite & body is spinning.

2. Dual spin.

In this along with array antenna there is despun antenna, moving counter direction of the satellite.

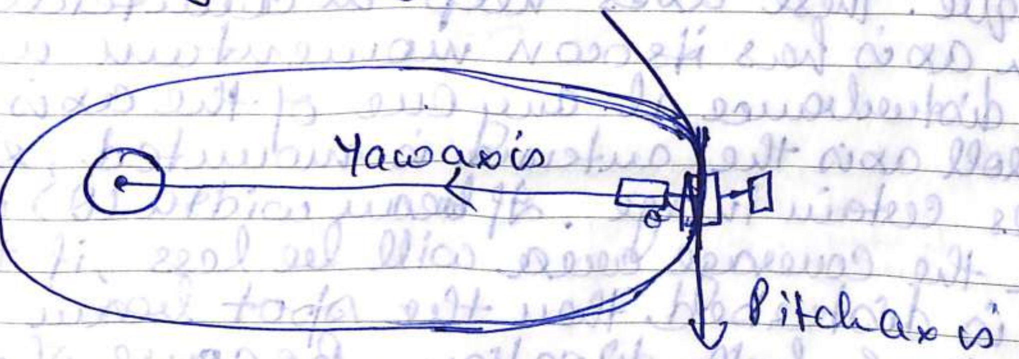
3. Triple Spin.

It has solar wing along with array & despun antenna.



Body Stabilization :-

Three axes body stabilization



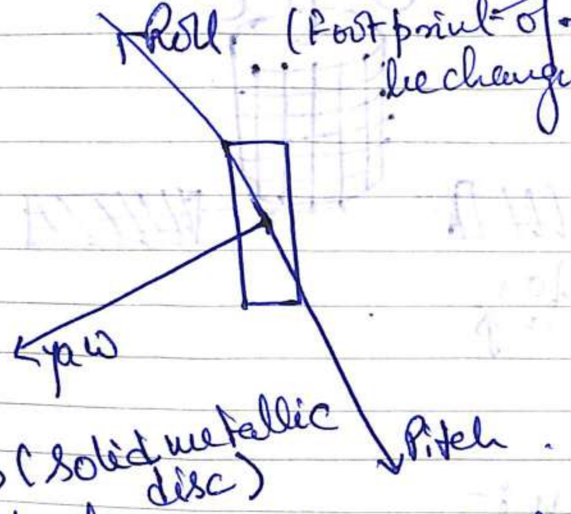
The axes tangential to the orbital path is known as Roll axis.

The other is towards the earth and is in orbital plane known as yaw axis.

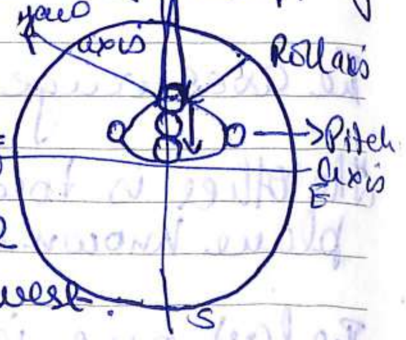
The last one is perpendicular to the orbital plane is known as pitch axis.

All the axes are ⊥r to each other → i.e. the spot

(Foot print of radiowaves will be changing up & down).



Momentum wheels are provided which rotate with speed variation. This results in development of torque. These axes help in counteracting. Each axis has its own momentum wheels. When disturbance at any one of the axis, suppose the roll axis the antenna is mounted, spot beam makes certain image. If beam width (θ) is small then the coverage area will be less, if the roll axis is disturbed then the spot beam moves in north & south direction. Because of shift of spot beam that carries information therefore the s/g that is to be Rx will not be adequate enough ~~and~~ ~~then~~

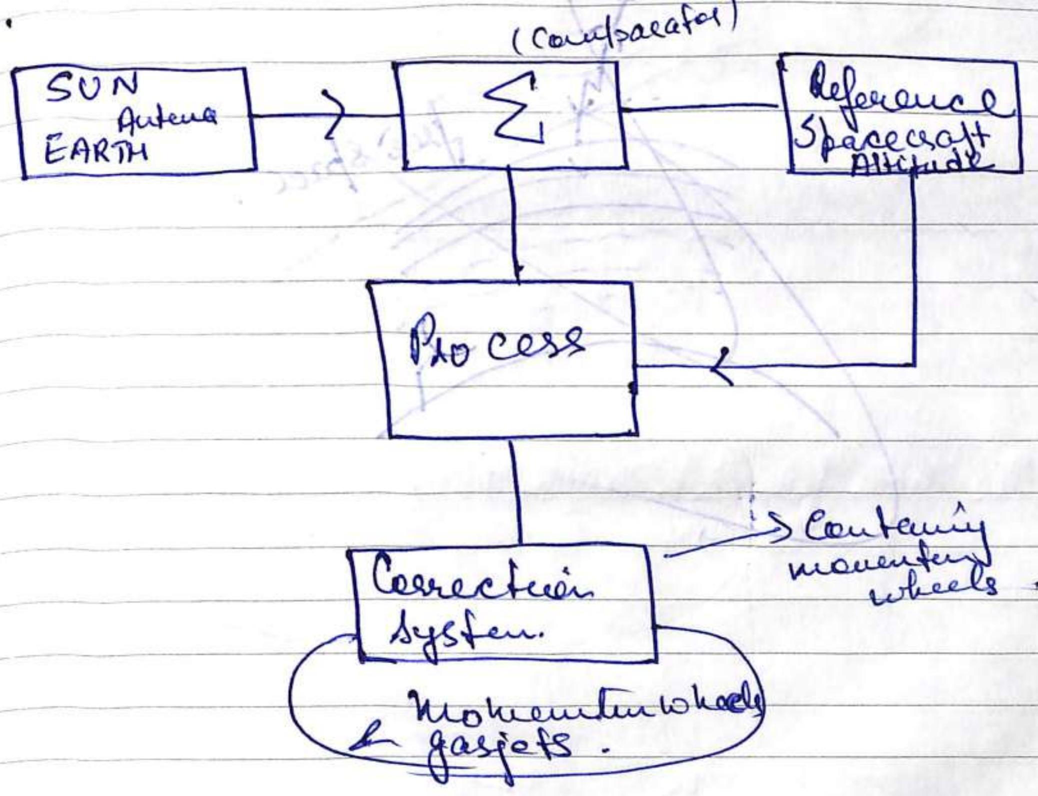


Disturbance towards ~~south~~ pitch axis the spot beam moves in east and west.

Disturban of yaw axis, the spot beam moves circularly.

Disturbance of any of the axes it will bring mis-alignment. So this needs to be counteracted for that we need 3-body axes i.e. Each axis will have the momentum wheel.

The three axes can be counteracted individually



Body Stabilization.

Momentum wheels are operated by the signals i.e. AOCS.

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17 2015 NOVEMBER TUESDAY

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These causes the loss of the signal.
The Sfg that comes form satellite that has to overcome the hurdle. We need to retrieve the information from the satellite.

11

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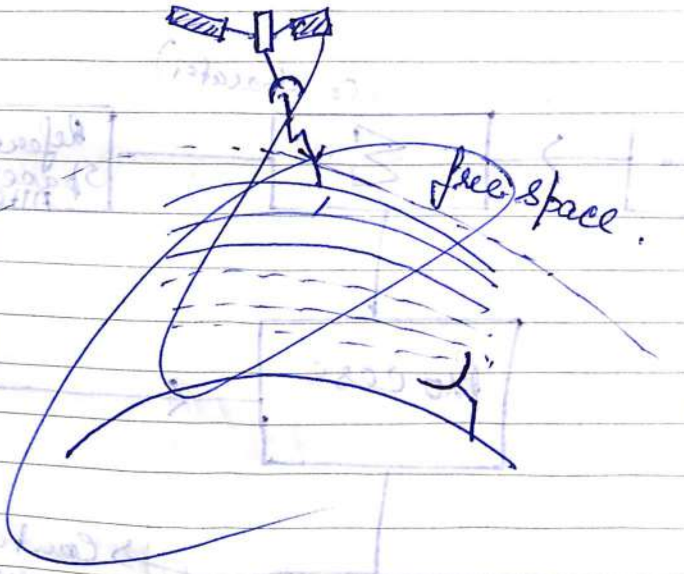

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2015 NOVEMBER WEDNESDAY 18

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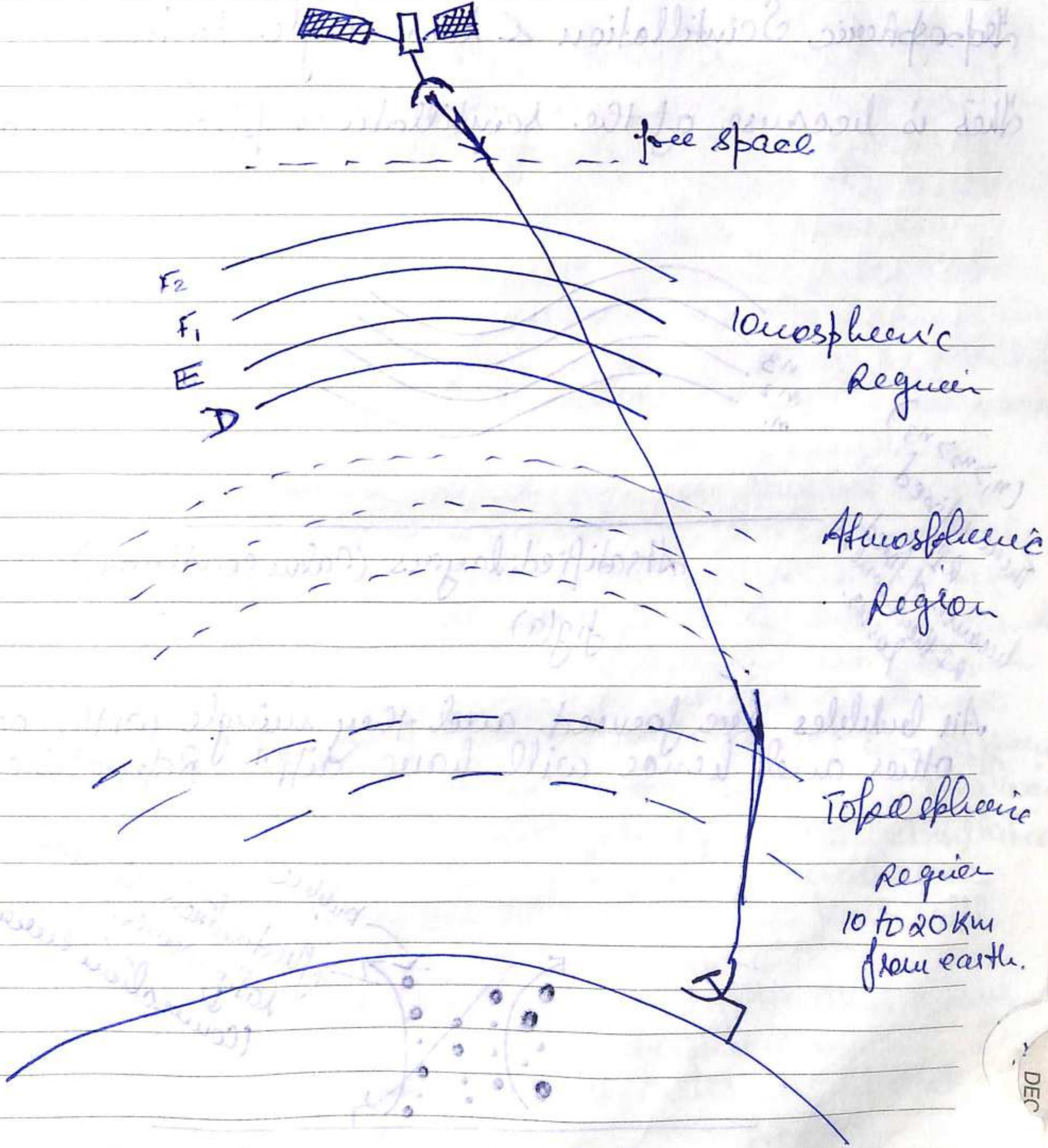
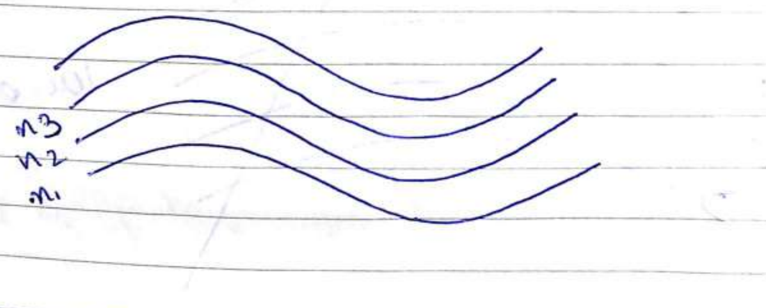


The purpose of discussing all this is to determine the losses

Tropospheric Scintillation & Low Angle Fading :-

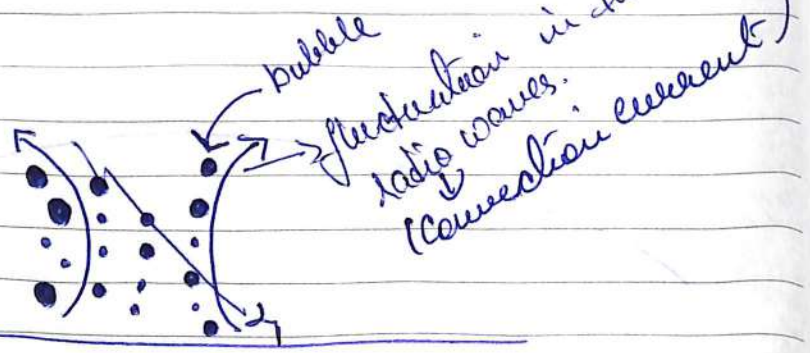
This is because of the scintillation phenomenon.



$(n_1 > n_2 > n_3)$
There is fixed RI because of fixed RI there will be losses.

Stratified layers (Calm condition)
fig(a)

Air bubbles are formed and they mingle with each other and hence will have diffn Refractive Indices.



Turbulent mixing (Convective Condition)
fig(b)

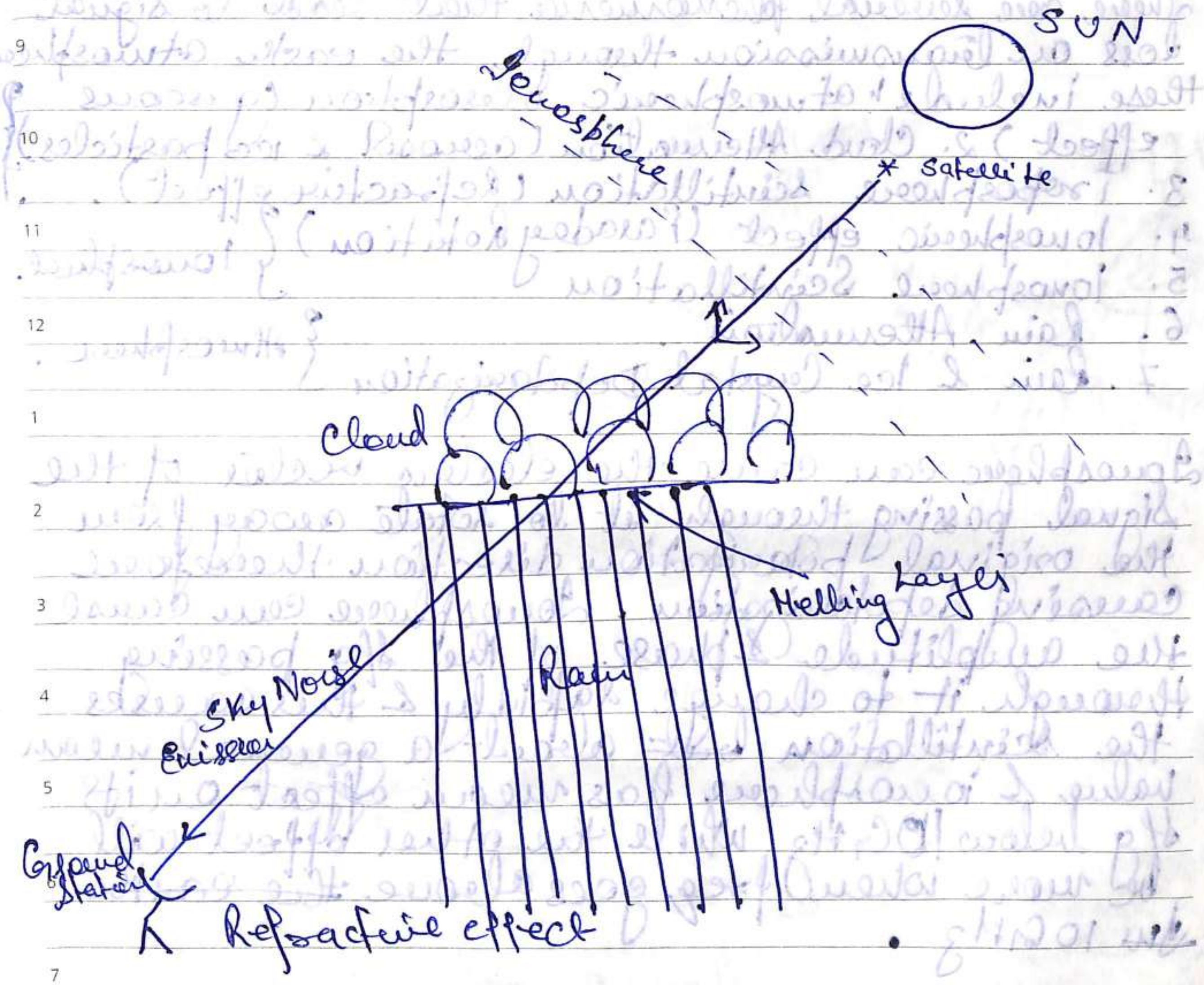
~~when ra~~
The atmosphere close to the ground sometimes called the boundary layers ~~too~~ is rarely ~~stable~~ still. The energy from the sun warms up, it heats up the surfac of the earth and the resultant convective activit agitates the boundary of the layer. This agitation results in turbulent mixing of different parts of the boundary layer causing small scale variation in the RI. Fig(a) shows ~~the calm~~ that the air is ~~found~~ to calm and there is no agitation and the boundar layers are formed. Each layer is having slightly different RI's. decreasing as we go away from the surface of the earth. Fig (b) the earth's surface has become heated up by the energy from the sun and the resultant convective activity has mixed the formerly separated layers ~~an~~ they transform the earlier separated layers into bubbles that have diffn RI's. The turbulent mixing of the lower atmosphere layers will ~~travel~~ cause relatively ~~rather~~ rapid fluctuatio in a s/g passing through it which is called scintillat & when a s/g encounters the turbulent atmosphere the rapid variation in the RI's along the path will lead to fluctuation in the received signal.
Since it mainly occurs, in the space of 4 to 5 km above the surface of the earth i.e. the tropospheric region therefore the fluctuation of radio waves due to this happening is called Tropospheric Scintillation.

Same phase - Constructive ; opposite phase - Destructive .

Low Angle Fading :-

When radio waves are coming in tropospheric condition because of turbulence and reaches the destination.

When the elevation angle falls below 10°, a second propagation effect becomes noticeable and that is called low angle fading. It is the same phenomenon as multipath fading in traditional terrestrial path. A Sig transmitted from the satellite arrives at the earth station Rx antenna through diffⁿ paths with diffⁿ phase shifts. On combination the resultant waveform may be enhanced or attenuated from the normal clear sky level. Signal enhancement has been observed to the 8 dB on 3.3 degree path at 11.2 GHz.



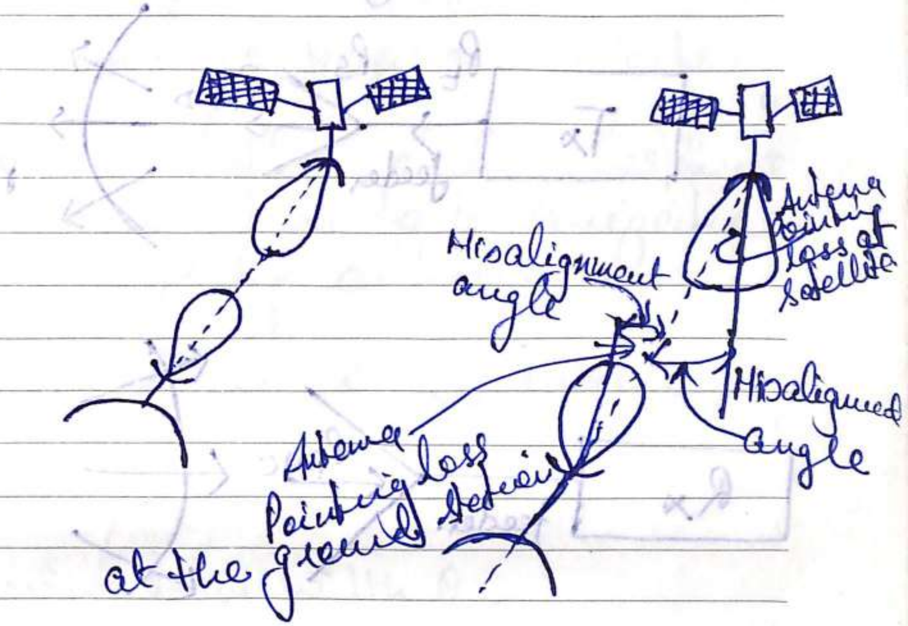
There are several phenomena that lead to signal loss on transmission through the earth atmosphere these include 1. atmospheric absorption (gaseous effect) 2. Cloud Attenuation (aerosol & ice particles) } Troposphere
3. Troposphere Scintillation (Refractive effect).
4. Ionospheric effect (Faraday Rotation) } Ionosphere.
5. Ionosphere Scintillation
6. Rain Attenuation
7. Rain & Ice Crystal Depolarization } Atmosphere.

Ionosphere can cause the electric vector of the signal passing through it to rotate away from the original polarization direction therefore causing depolarization. Ionosphere can cause the amplitude & phase of the sig passing through it to change rapidly & this causes the scintillation ~~but~~ about a general mean value & ionosphere has mean effect on its sig below 10GHz while the other effect will be more when freq goes above ~~the earth~~ ~~the~~ 10GHz.

Rain attenuation is very important loss greater than 10GHz because it can cause greater attenuation.

Ku and Ka band rain attenuation is almost entirely caused by absorption. At Ka band there is a small contribution fro by large rain drops.

Antenna Misalignment Losses :-

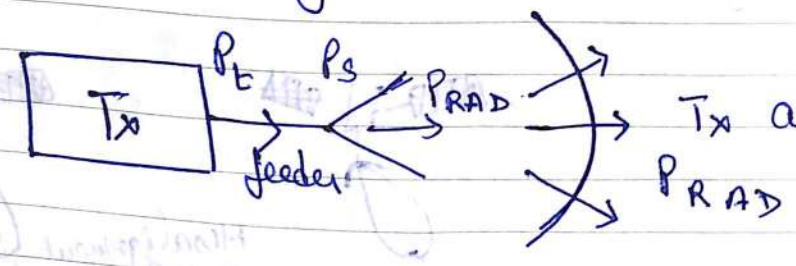


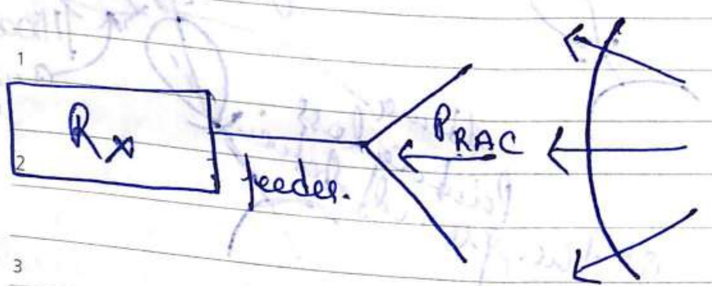
This is rectified with the help of AOCS.

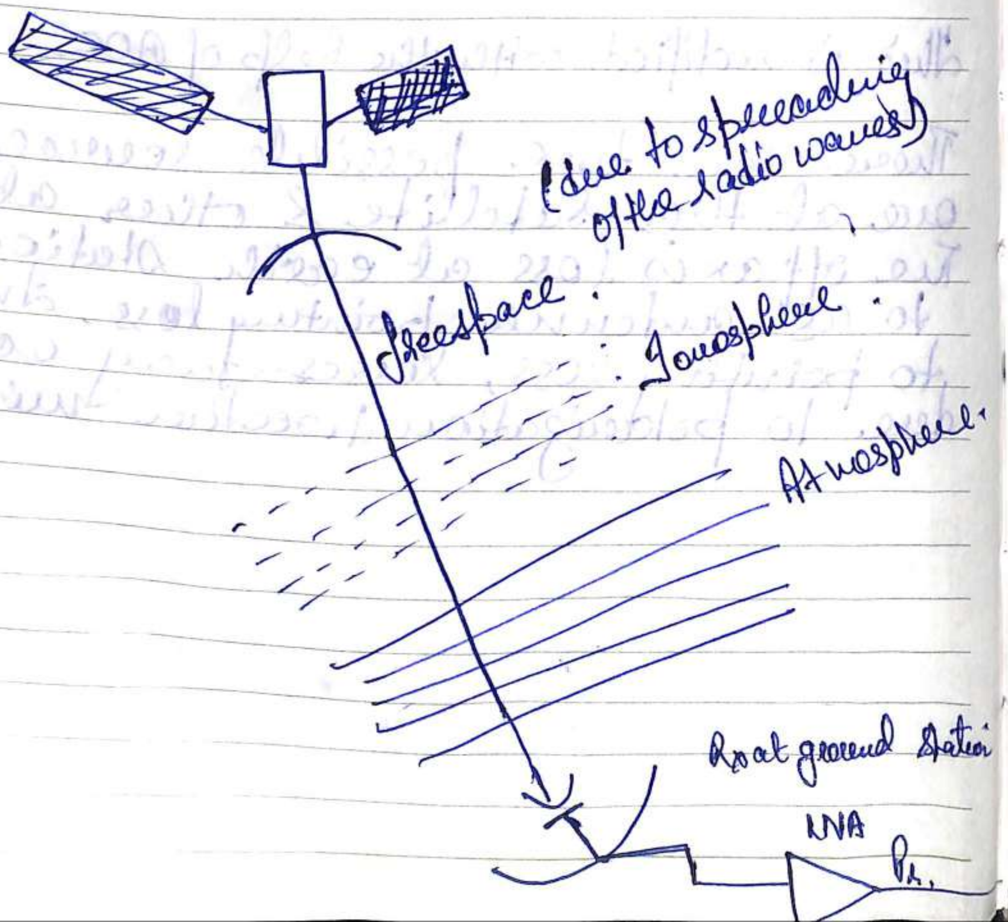
There are two possible sources of excess losses one at the satellite & other at e-station. The off axis loss at earth station is referred to as antenna pointing loss. In addition to pointing loss, losses may occur at antenna due to polarization direction misalignment.

Waveguide - Known as feeder. Some losses in feeder and some at the antenna.

Losses Occuring At Antennas.







Mainly considering free space loss.

$4\pi d^2$ - omnidirectional antenna out of these only proportion of it will be intercepted by Rx antenna.

Losses

1. Losses between Tx output & Tx antenna.
2. Attenuation due to precipitation and clouds.
3. Free space loss.
4. Attenuation due to atmosphere and ionosphere.
5. ~~Polarization due~~ Losses due to polarization mismatch between Tx & Rx antenna.
6. Losses due to antenna depointing.
7. Losses between Rx antenna & Rx inputs.

Link Design.

Directional antenna having beam width θ.

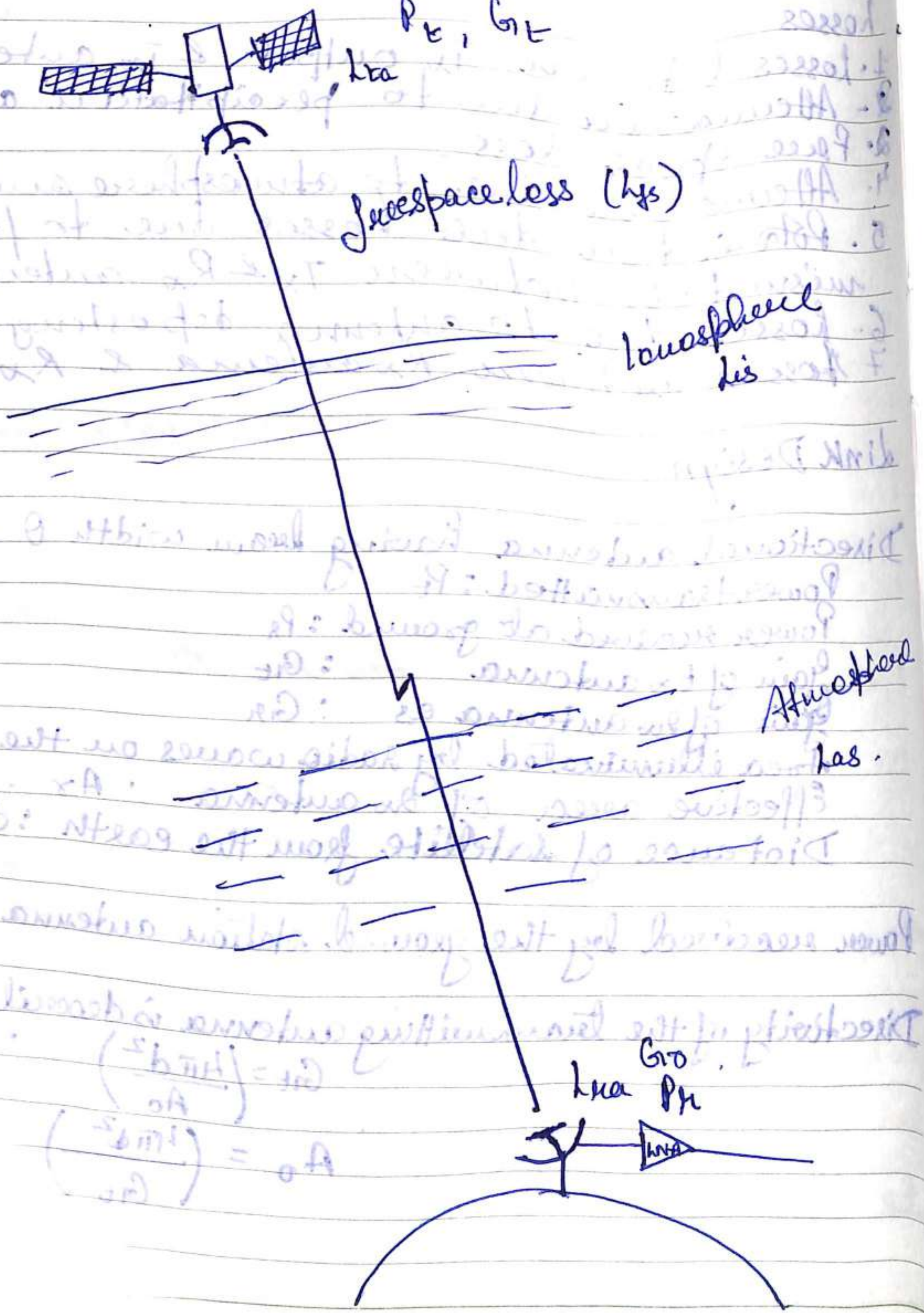
Power transmitted : P_t
Power received at ground : P_r
Gain of tx antenna : G_t
Gain of Rx antenna as : G_r
Area illuminated by radio waves on the surface of earth : A_0
Effective area of Rx antenna : A_r.
Distance of satellite from the earth : d

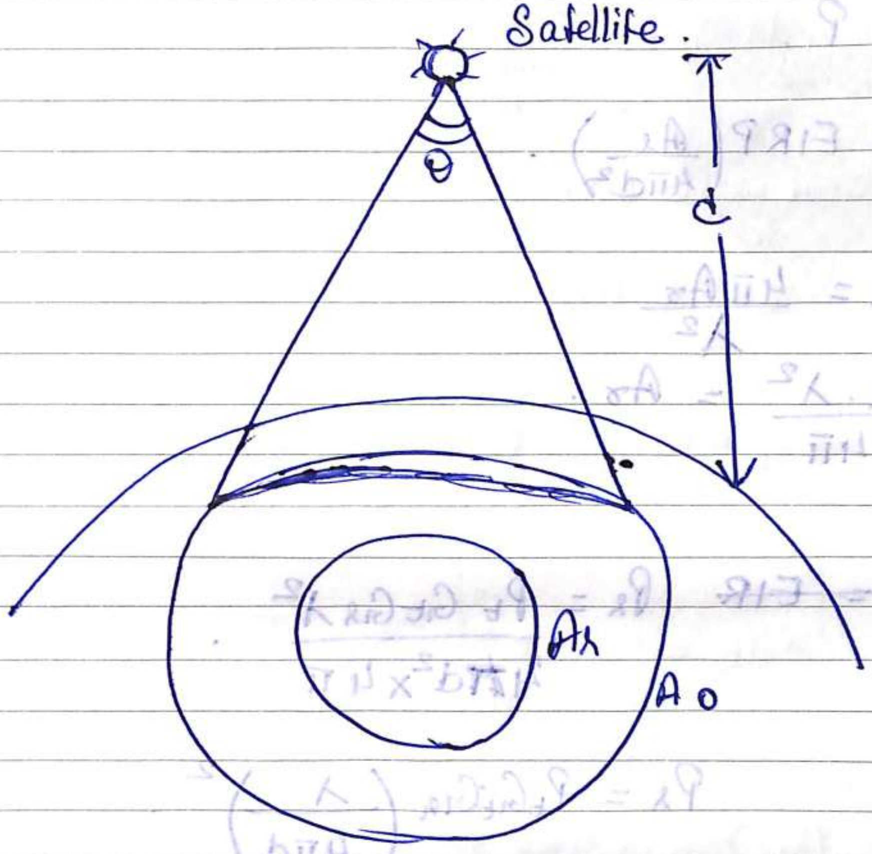
Power received by the ground station antenna $P_r = P_t \frac{A_r}{A_0}$.

Directivity of the transmitting antenna is described by its gain:-

$$G_t = \left(\frac{4\pi d^2}{A_0}\right)$$

$$A_0 = \left(\frac{4\pi d^2}{G_t}\right)$$





$$P_r = P_t\left(\frac{A_r}{A_0}\right)$$

$$P_r = P_t \cdot \frac{A_r}{\left(\frac{4\pi d^2}{G_t}\right)}$$

$$P_r = P_t G_t \cdot \frac{A_r}{4\pi d^2}$$

EIRP :- Effective Isotropic radiation power of radiative

$P_tG_t = EIRP$.

9

$$P_r = EIRP\left(\frac{A_r}{4\pi d^2}\right).$$

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Now,

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$$G_r = \frac{4\pi A_r}{\lambda^2}$$

12

$$\frac{G_r\cdot\lambda^2}{4\pi} = A_r.$$

1

2

~~$P_r = EIR$~~ $$P_r = \frac{P_t G_t G_r \lambda^2}{4\cancel{\pi}d^2\times 4\pi}.$$

3

4

$$P_r = P_tG_tG_r\left(\frac{\lambda}{4\pi d}\right)^2.$$

5

6

or

$$P_r = \frac{P_tG_tG_r}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

7

$$\left[P_r = \frac{EIRP\times G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}\right] \longrightarrow \text{Unit :- Watts}$$

$$\left(\frac{4\pi d}{\lambda}\right)^2 \rightarrow \text{free space loss.}$$

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53 28

~~$\ldots$~~ $\Rightarrow \lambda = \frac{c}{f}$

$c = f\lambda$

$\therefore P_r = \frac{\text{Effective Isotropic Radiative Power} \times \text{gain of ground st. antenna}}{\text{Free space loss}}$.

Power Attenuation in dB is α_{dB}

$$\alpha_{dB} = 10\log_{10}\frac{P_t}{P_r}$$

$$\alpha_{dB} = 10\log_{10}\frac{P_t}{\text{EIRP}\times G_{r}/\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$\alpha_{dB} = \frac{P_t \times (\lambda/4\pi d)^2}{\text{EIRP} \times G_r}.$$

Free Space Loss $(L_{fs}) = \left(\frac{4\pi d}{\lambda}\right)^2.$

$$L_{fs}(dB) = 10\log_{10}\left(\frac{4\pi d}{\lambda}\right)^2.$$

$$L_{fs}(dB) = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right)$$

$$= 20\log_{10}4\pi + 20\log_{10}d - 20\log_{10}\lambda$$

$$= 20\log_{10}4\pi + 20\log_{10}d + 20\log_{10}\left(\frac{f}{c}\right)$$

$$= 20\log_{10}4\pi - 20\log_{10}c + 20\log_{10}d + 20\log_{10}f$$

$$= 22 - 20\log_{10}3\times10^8 + 20\log_{10}d_{km}\times10^3 + 20\log_{10}f_{MHz}\times10^6.$$

Watts

$$\boxed{L_{fs}(dB) = 32.5 + 20\log_{10}d_{km} + 20\log_{10}f_{MHz}.}$$

If frequency is in GHz & d in km.

$$\boxed{L_{fs}(dB) = 92.4 + 20\log_{10}d_{km} + 20\log_{10}f_{GHz}}$$

If we considered all other losses incurred in the path i.e. $L_{ta}, L_{fs}, L_a, L_{I}, L_{ra}$

$$[P_r]_{dB} = [\text{EIRP}]_{dB} + [G_r]_{dB} - [L_{fs}]_{dB} - [L_{ta} + L_a + L_I + L_{ra}]_{dB}.$$

$$\underset{\text{Watts}}{P_r} = \frac{\text{EIRP} \times G_r}{\text{Path loss} \Rightarrow L_{fs}}.$$

$$[P_r]_{dB} = [\text{EIRP}]_{dB} + [G_r]_{dB} - [L_{fs}]_{dB}.$$

Because of the noises, undesirable, planetary bodies when it is.
Electronic circuitry of rx also generates the noise.
Noises can be external – planetary bodies or atmosphere & ionosphere
internal noise because of electronic circuitry i.e. the thermal noise.

Thermal noise :-

It creates rise in tempr.

There are two types of noise generated i.e. thermal noise generated in the lossy component of antenna as well as the receiving circuitry. Thermal like noises are picked up by the antennas as radiation from the planetary bodies.

Thermal noise :- Random movement of molecules, atoms electrons in resistive and active component of the receiver. This in turn generates noise temperature. It is ~~also related~~ called the thermal noise as the tempr of the bodies is the statistical root mean square value of the velocity of the motion of these particles like molecules, atoms electrons in components. It is also called white noise or the Johnson Noise. ~~As it is well spread~~ Due to the randomness of the motion of the particles. Noise power is evenly spread up over an entire frequency spectrum.

Acch to the kinetic theory, motion of these particles at absolute tempr i.e. 0°K. Therefore the noise power generated in a resistive component is proportional to the tempr as well as the BW.

$P_n \propto T \cdot B$.

where B is the BW over which it is being measured.

T is the tempr.

$P_n = KTB$

where K is the Boltzmann's Constant.

1.38×10^{-23} J/K.

Now, $P_n = \frac{V_n^2}{4R}$, where V_n is the equivalent noise v/g and R is the matched impedance

$P_n = \frac{(KTB)^2}{4R}$.

$KTB = \frac{\sqrt{4KTRB}}{4R}$

$\frac{\sqrt{4KTRB}}{4R}$

$V_n = \sqrt{4KTRB}$.

If I_n is the noise current.

$I_n = \sqrt{\frac{4KTB}{R}}$

In satellite commn, we have a low noise receiver and it is very necessary to differentiate or measure noise in increments as small as 10ths or 100ths of decibels and noise figure is inadequate for measurement of such calculation which is very precise.

Incremental changes in noise has to considered & in order to know the performance of the comm we need to know the Carrier to noise ratio.

$T_e = T(F-1)$

T is the environmental temperature in degrees Kelvin (°K)
T_e is the equivalent noise temp^r (K)
F is the noise factor (unitless).

$$F = \frac{(S/N)_{in}}{(S/N)_{o/p}}$$

$$F = \left(1 - \frac{T_e}{T}\right)$$

$\frac{T_e}{T} = (F-1)$

$F = \left(1+\frac{T_e}{T}\right)$

Carrier to Noise Ratio

$$\frac{C}{N} = \frac{P_r}{KT_eB} \Rightarrow \frac{(EIRP)\times G_r}{\text{Free space loss}} = \frac{(P_t \times G_t)\times G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}.$$

$$\frac{C}{N} = \frac{EIRP \times G_r}{L_{fs} \cdot KT_eB}.$$

T_e or T_n } Corresponding to
B_e or B_n } noise

P_r = amount of power rx at the gnd. stn.

$$\left[\frac{C}{N}\right]_{dB} = [EIRP]_{dB} + [G_r]_{dB} - [L_{fs}]_{dB} - 10\log_{10}K - 10\log T_e - 10\log_{10}B.$$

$$\left[\frac{C}{N}\right]_{dB} = [EIRP]_{dB} + \left[\frac{G_r}{T_e}\right]_{dB} - [L_{fs}]_{dB} - 10\log_{10}K - 10\log_{10}B.$$

Here, N is the noise power.

M is the figure of merit → ratio of the gain of rx antenna to eq. noise temp^r.

$10\log_{10} 1.38\times10^{-23} = 228.6$

[~~EIRP~~]$_d$

$$= [EIRP]_{dB} + M - [L_{fs}]_{dB} - 10\log_{10}1.38\times10^{-23} - 10\log_{10}B.$$

$$= [EIRP]_{dB} + M - [L_{fs}]_{dB} - 228.6 - 10\log_{10}B.$$

↳ B.W. of noise.

N_0 = Spectral noise power density.

$N_0 = \frac{N}{B}$ = noise power per unit B.W. $= \frac{KTB}{B} = KT$.

$$\left(\frac{C}{N_0}\right) = \frac{\text{Carrier}}{\text{Noise power density}} = \frac{P_r}{N_0} = \frac{P_r}{N/B} = \frac{P_r}{KTB/B} = \frac{P_r}{KT}$$

~~$\left(\frac{C}{N_0}\right)_{dB} = [P_r]_{dB} + 10\log_{10}B$~~

$$\left[\frac{C}{N_0}\right]_{dB} = [P_r]_{dB} - 228.6.$$

$$= [EIRP]_{dB} + [M]_{dB} - [L_{fs}]_{dB} - 228.6.$$

$\because [P_r]_{dB} = [EIRP]_{dB} - [L_{fs}]_{dB} + [G_r]_{dB}.$

Due to various planetary bodies, antenna.

Noise:- Undesired Radio frequency.

Noises:-

1. Noise Temperature :- KTB
2. Equivalent noise temperature :- KTeB.

↓ Environmental + Electronic circuitry.

~~Te = F(~~

The measurement is incremented. ← $T_e = T(F-1)$

Noise Input + Noise RF.

$N_0 = \frac{N}{B}$ = Carrier Noise ~~Ratio~~ Density.

$$\left[\frac{C}{N_0}\right]_{dB} = [EIRP]_{dB} + M_{dB} - L_{s\,dB} - 228.6.$$

Noise Power At the Receiving Circuitry:-

Carrier to noise density ratio in receiving ground station of Satellite System.

Let T_{rf}, T_M, T_{if} be the equivalent noise temp^r of LNA, mixer and IF and G_{rf}, G_M, G_{if} be the gain of the LNA mixer and IF stage of Rx circuitry.

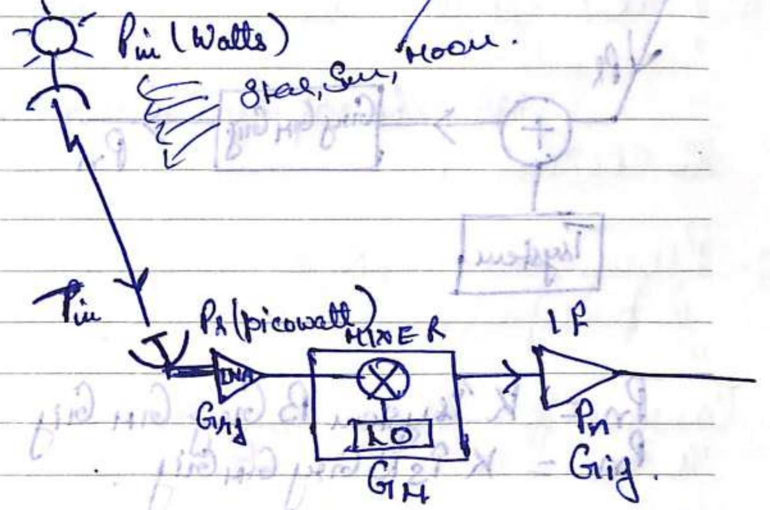
Let T_{in} be the i/p noise temperature of the RF section.

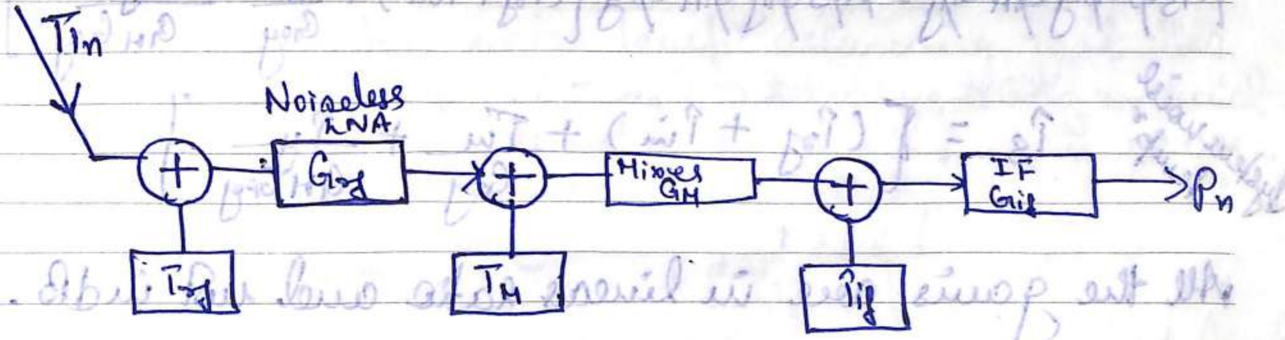
T_e

Pn is the total noise of Tin + LNA power) + Mixer (power) + IF (power)

Each stage has its own equivalent noise temp^r

including the noise





Equivalent Noise generated of the above block Diagram. (Rx CKt)

$\because T = KTB$.

Considering the noise power

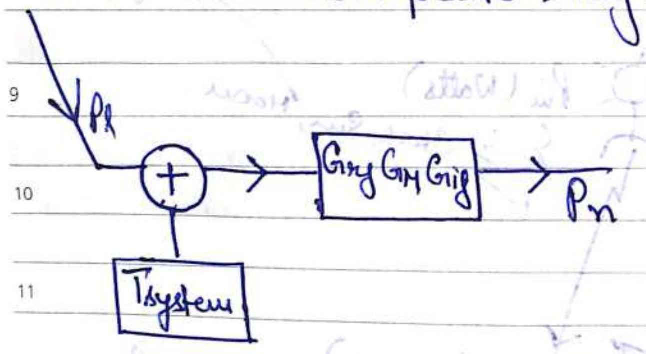
Total Noise Power at the o/p of the Grd. St. Rx

$$P_n = K T_{if} B G_{if} + K T_M B G_M G_{if} + K(T_{rf} + T_{in}) B G_{rf} G_{if} G_M.$$

$$P_n = K B G_{if} G_M G_{rf}\left[(T_{rf} + T_{in}) + \frac{T_M}{G_{rf}} + \frac{T_{if}}{G_M G_{rf}}\right].$$

$\rightarrow K T_S B G_{rf} G_M G_{if}$.

Composite Diagram of the Rx Circuitry.



$$P_n = K\,T_{system}\,B\,G_{ry}\,G_H\,G_{ij}.$$
$$P_n = K\,T_s\,B\,G_{ry}\,G_H\,G_{ij}.$$

$$K T_s \cancel{B}\,\cancel{G_{ry}}\,\cancel{G_H}\,\cancel{G_{ij}} = \cancel{K}\cancel{B}\,\cancel{G_{ij}}\,\cancel{G_H}\,\cancel{G_{ry}}\left[(T_{ry}+T_{in}) + \frac{T_H}{G_{ry}} + \frac{T_{ij}}{G_H G_{ry}}\right]$$

System noise tempr
$$T_s = \left[(T_{ry} + T_{in}) + \frac{T_m}{G_{ry}} + \frac{T_{ij}}{G_H G_{ry}}\right]$$

All the gains are in linear ratio and not in dB.

Figure of Merit.

$$M = \frac{G_R}{T_s} = \frac{\text{Rx antenna gain } (G_R)}{\text{Total i/p noise tempr } (T_s)}$$

$$[M]_{dB} = G_{dB} - 10\log_{10} T.$$

Higher the value of figure of merit better is the performance of the receiving side.

Assuming that G_{ry}, G_m, G_{ij} are in ratios not in dB.

Noise Power Density (N_0) :-

$N_0 = \frac{N}{B}$. Noise power per unit Bandwidth.

$$K = 1.38 \times 10^{-23}\ J/K.$$

$$10\log_{10} K = 10\log_{10}(1.38) + 10\log_{10}(-23)$$
$$= 1.399 - 230.$$

Q. Calculate the system noise tempr assuming that the mixer has a gain of 0dB (G_m), assuming 4GHz rx and gains noise tempr as T_{in} is 25K, T_{ry} is 50K, T_{ij} is 1000K. and T_m is 500K. G_{ry} is 23dB, G_{ij} is 30dB.

$$T_s = \left[(T_{ry} + T_{in}) + \frac{T_m}{G_{ry}} + \frac{T_{ij}}{G_H G_{ry}}\right]$$

$$G_{ry} = 23dB = 199.5262$$

$$G_H = 0dB = 1.$$

$$G_{ij} = 30dB = 1000$$

$$T_s = \left[(50+25) + \frac{500}{199.5262} + \frac{1000}{1 \times 199.5262}\right]$$

$$T_s = 75 +$$

Q. What do you understand by $\frac{G}{T}$ ratio ? Prove that

Figure of merit. It shows the performance of Rx circuitry.

Q. Prove that C/N at the i/p of a detector in the Rx is proportional to (G/T)

Q. Carrier to noise density ratio of 90dBHz is required at a Rx having a G/T ratio as 12dB. Given that the total loss in the link is 196 dB. Calculate the required EIRP.

$$90 = EIRP + 12 - 196 - 228.6 .$$
$$90 = EIRP + (-412.6)$$
$$EIRP = 90 + 412.6$$
$$[EIRP]_{dB} = 502.6\ dB$$

Q. A Rx system has antenna noise tempr 60°K and Rx noise figure is 9dB. Calculate the system noise tempr & To is 290

$$T_e = T(F-1).$$

$$T_S = T_a + T(F-1) .$$

$$= 60 + 290(7.9432 - 1)$$
$$= 60 + 290 \times 6.9432 .$$

Q. For an equivalent noise BW of 10 MHz & total noise power of 0.0276pW. Determine the noise density & the equivalent noise tempr.

$$N_0 = \frac{N}{B} = \frac{0.0276 \times 10^{-12}}{10 \times 10^6} = 2.76 \times 10^{-3} \times 10^{-12} \times 10^{-6}$$
$$= 2.76 \times 10^{-21} .$$

$$N_0 = K T_e B .$$

Q. A geostationary satellite is located at a distance of 3000 Km with an operating freq 14.25GHz. Gain of the transmitting & Rx antennas are 15 & 20 respectively. If the transmitter power is 200KW. Calculate the power Rx by the receiving antenna.

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2} = \frac{200 \times 10^3 \times 15 \times 20}{\left(\frac{4 \times 3.14 \times 3000}{14.25}\right)^2}$$

$$= 60000 \times 10^3 / \left(\frac{37680}{14.25}\right)^2 = \frac{60000 \times 10^3}{(264}$$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{14\cdot25\times10^9} =$

Q. Determine the power received by the satellite located at 40,000 Km from the surface of the earth, satellite operating at 11 GHz & has EIRP as 21dB watt. Gain of the Rx antenna is 50.5dB.

$[P_r]_{dB} = [EIRP]_{dB} + [G_R]_{dB} - [L_{fs}]_{dB}$.

$[P_r]_{dB} = 21 + 50\cdot5 -$

$L_{fs} = \left(\frac{4\pi d}{\lambda}\right)^2 = \frac{4\times3\cdot14\times40{,}000\times10^3}{0\cdot02727}$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{11\times10^9} = 0\cdot2727\times10^{8-9} = 0\cdot2727\times10^{-1}$

$= 0\cdot02727$.

$L_{fs} =$

Q. The antenna design is matched into a Rx. The noise tempr of antenna & Rx are 40K & 100K respectively. If the Rx B.W. is 36MHz. Determine its noise power.

$P_n = KTB$.

Q. A satellite at a distance of 40,000 Km from the pt. on the surface of earth radiates a power of 200watts from an antenna with a gain of 17dB in the direction of observer. Find the flux density at the Rx pt. and the power Rx by an antenna with an effective area of 10 m².

Flux density $f = \frac{P_t G_t}{4\pi d^2}$.

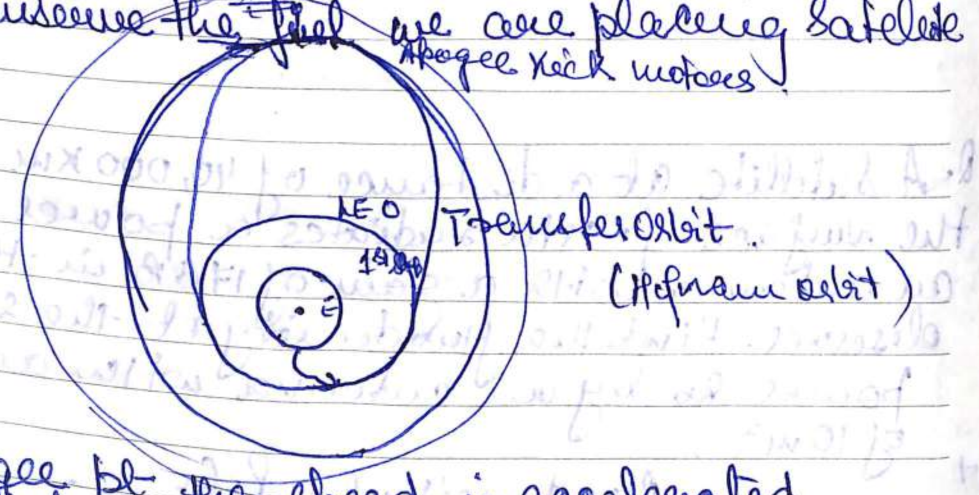
Pr effective area = Total power received.

Q. For an equivalent noise BW of 10 MHz & total noise power of

Q. Determine the carrier to noise density ratio for a Rx with a 80 dB Watt carrier power and equivalent noise tempr of 240 K and BW of 10 MHz.

Steps to launch satellite on at final orbital path

Maintenance :- Make satellite stable.
change in orbital path :- due to acceleration or deceleration.
Disorientation :-
Sufficient fuel should be there.
In order to conserve the fuel we are placing satellite in steps.



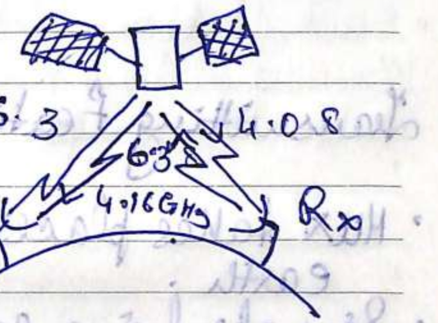
From perigee pt the speed is accelerated and that will be an elliptical path.
If the stage is not required then the kick motors are fired so that it reaches the desired orbit. so that it reaches the 36,000 km above the surface of earth.

With the help of GSLV which is very powerful, it has placed the satellite into the transfer orbit and then the geostationary orbit].
IInd Term.

Multiple Access Technique :-

A) Intelsat I

Single Access



Freq. Used :-
1) 6.3 GHz Uplink
4.8 GHz Downlink.

2) 6.38 GHz Uplink.
4.16 GHz Downlink.

Total Satellite capacity B.W. 500 MHz } used by the pair of ground station.

when no. of Tx & Rx increases, satellite capacity needs to be shared.

B) Intelsat II
Multiple Access

SUNDAY 20

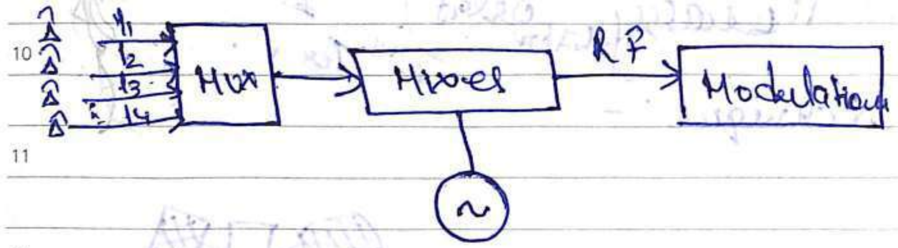
Multiple g. sts. shared the full capacity of the satellite audio, video & data.

Full satellite capacity is shared with multiples of gnd station ∴ service increases.

UNIT-III

Propagation effects

Multiplexer:- Many to one



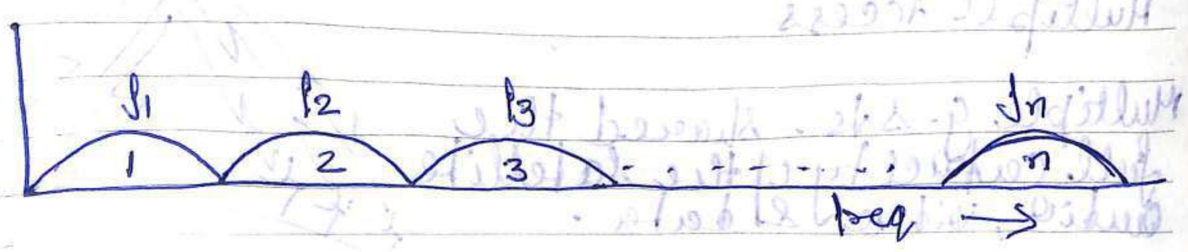
Transmitting features:-

- Mux takes place at one geographical position of earth.
- Signals being combined from various subscribers then fed to tx.
- Multiple access technique is a traffic feature, taking place at satellite.

There are three techniques:-

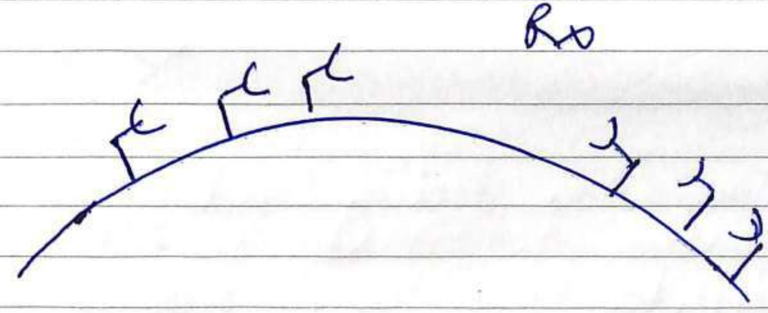
i) FDMA - Frequency Division Multiple Access.
ii) TDMA - Time Division Multiple Access
iii) CDMA - Code Division Multiple Access

i) FDMA

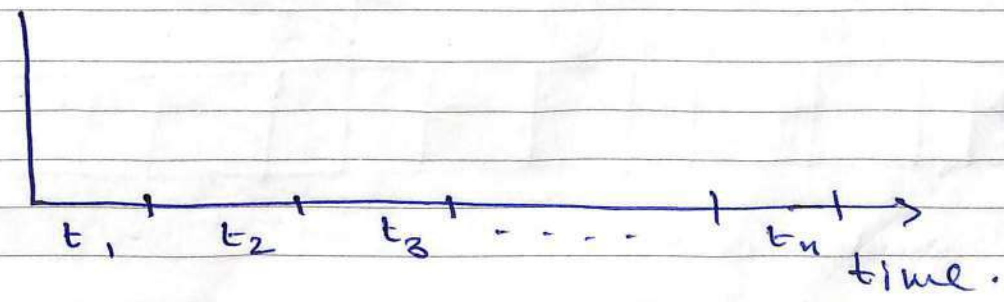


i) · Total BW available is subdivided into various freq band in which Tx is transmitting the sig.
· Time is not limited.

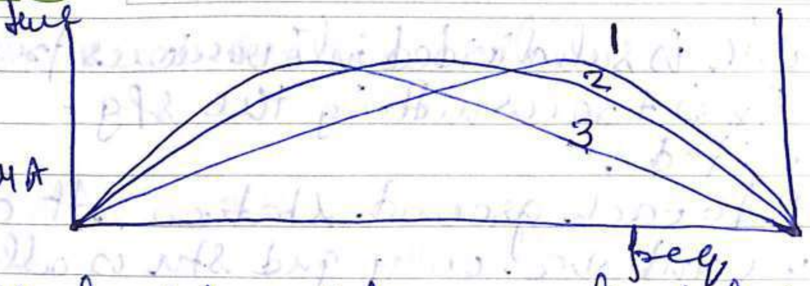
ii) · Time is alloted to each ground station. At a particular time interval only gnd stn is allowed to transmits.
· freq is not in limitation.



ii) TDMA



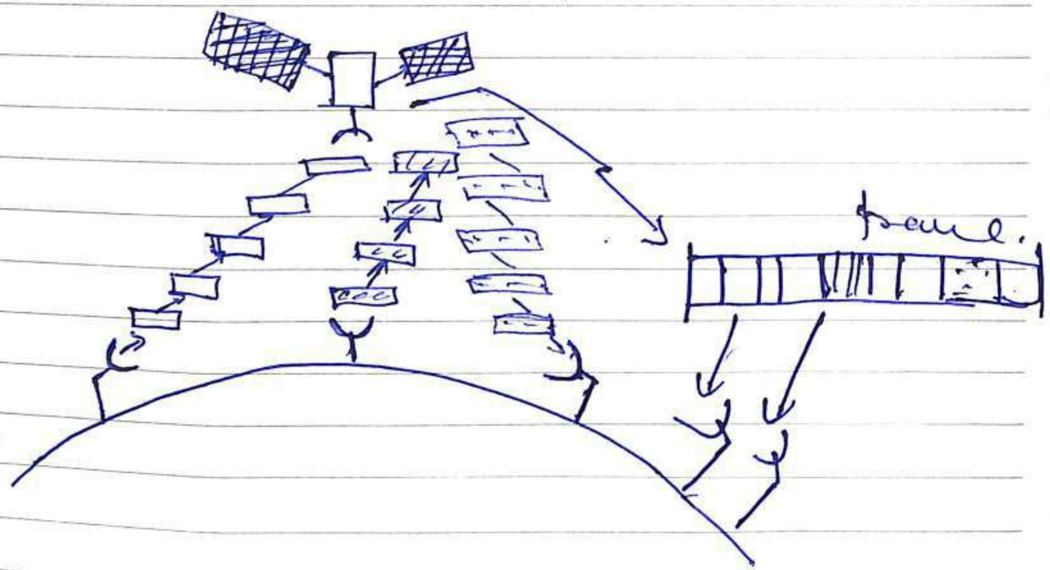
iii) CDMA



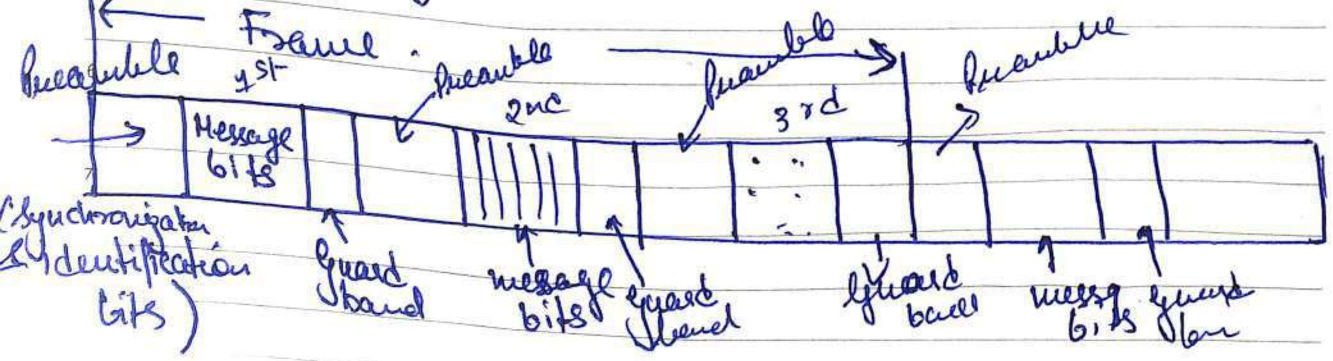
- neither limitation of freq nor limitation of time.
- Each station have special codes at Tx side & Corresponding key is available at Rx side to unlock the information.

Case 1'

TDMA :- (Time Division Multiple Access).



Burst of information being send from 3 ground stations.
At the satellite they are in queue and forms the frame.



Frame

Frame duration 125 μs to 20msec.
normally 2msec.
During that time information is being sent.

When s/g is sent to g.s it is the frame that is being sent to g.s.
Full capacity of satellite is being utilized.
Seperately being sent at diffn intervals of time.

Preamble :- which particular g.s. is being is sent identity is being shown and by the g.s. of particular synchronization.

CDMA :- Code Division Multiple Access
Single channel narrowband signal can be spreadup
Special code being provided to each ground station and the rx has also a particular code which is extracted using correlation technique.
The mssg is correlated with the code that is coming. so that they can match & extract the mssg. Other mssgs are noise to them.
It is widely being used in satellite communica & mobile communication.

Narrowband Interference.

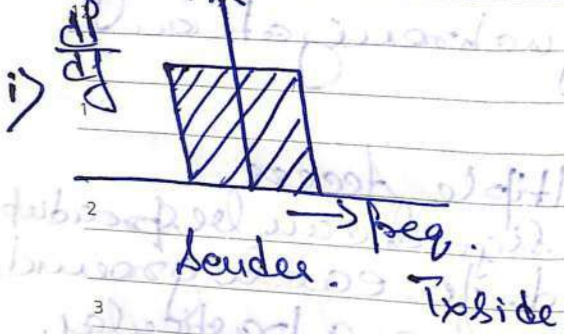
Kind of a noise. It is being tackled by the CDMA technique / counteracted by CDMA.

Special code modulated by information bit & the information is spread over the band width with the help of the special code higher bits.

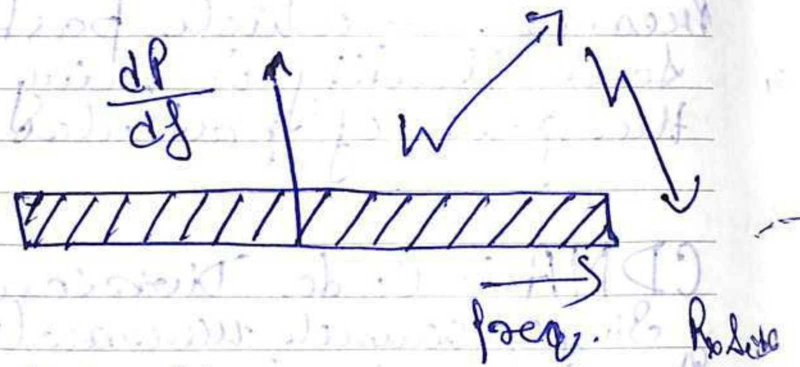
Special Code
⇓
Higher no. bits than the information bit.

Eg 16 bits
1000 bits.

i)



ii)



Spreading technique

Energy contained within the information will remain same even if it is spread over large band width. Overall spectral power density remains unchanged.

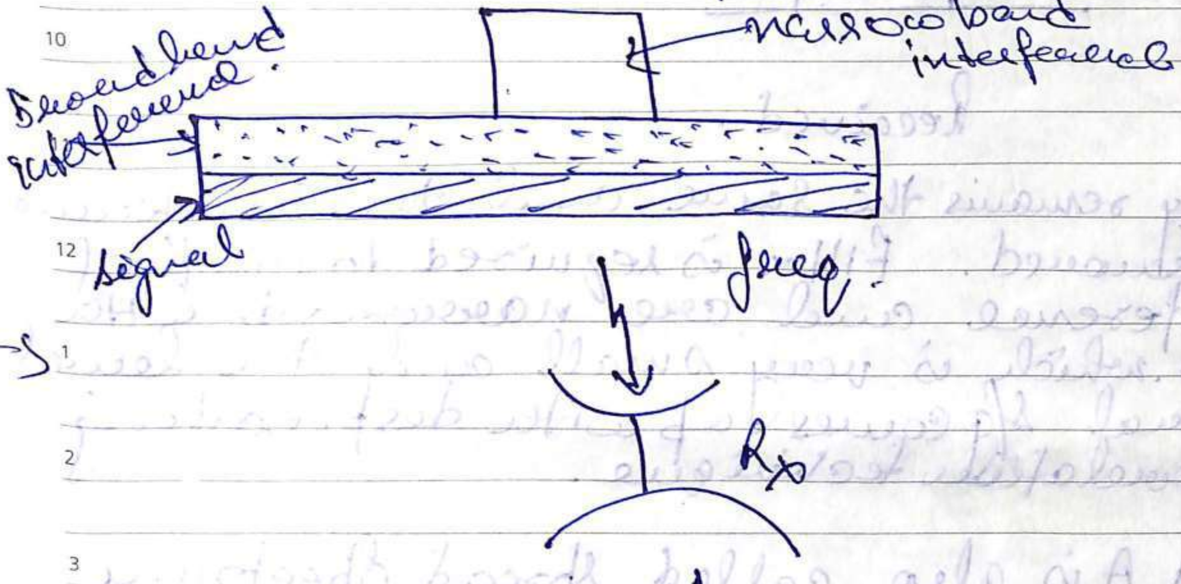
Eg. From gnd stn it goes to satellite and then comes back. It suffers various interferences.

▨ User signal.

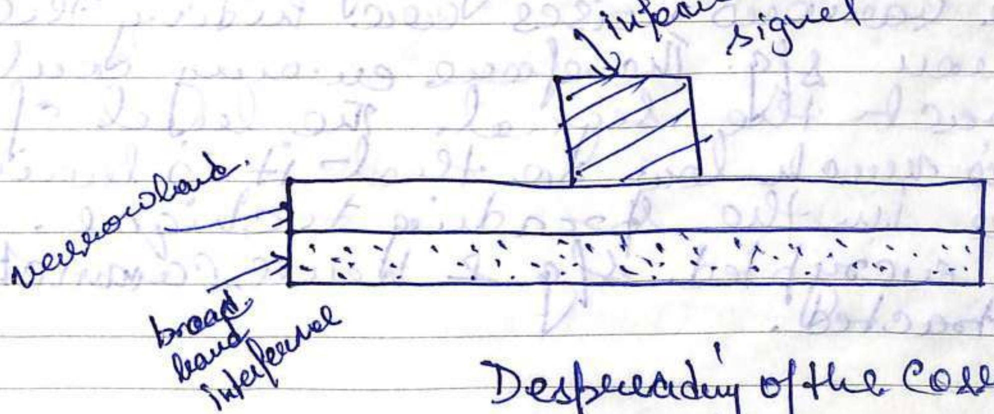
▒ broad band interference.

☐ Narrow band interference.

In this the user sig is mixed with the broad band & narrow band interference.



Despreading of the correlating signal



Despreading of the correlating signal.

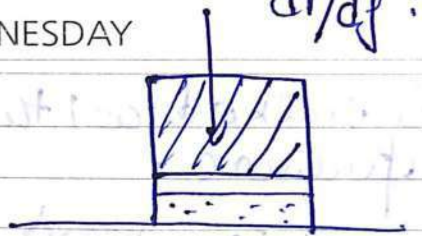
Rx circuitry is complicated as it has to do despreading

2015
30 DECEMBER
WEDNESDAY

DEC 2015	M	T	W	T	F	S	S
		1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31			

⇓ filter / chopping

dP/df .



Received.

The energy remains the same and the interferences are removed. Filter is required to chop of the interference and are narrowed with its help. which is very small and the level of actual sig comes up with despreading and correlation technique.

The CDMA is also called Spread Spectrum Multiple Access.

The sig is distributed among higher freq range and the various noises are hiding the information sig. Therefore enemy could not extract the signal. The level of the sig is much low so that it is buried in noises in the spreading techique. It is an encrypted sig & hence cannot be extracted.

Teleph

1. Comp
2. IP ba
3. Intern
4. Wise
5. Smar

Mathe

Clas

1. Asso
2. Corr
3. Sou

4

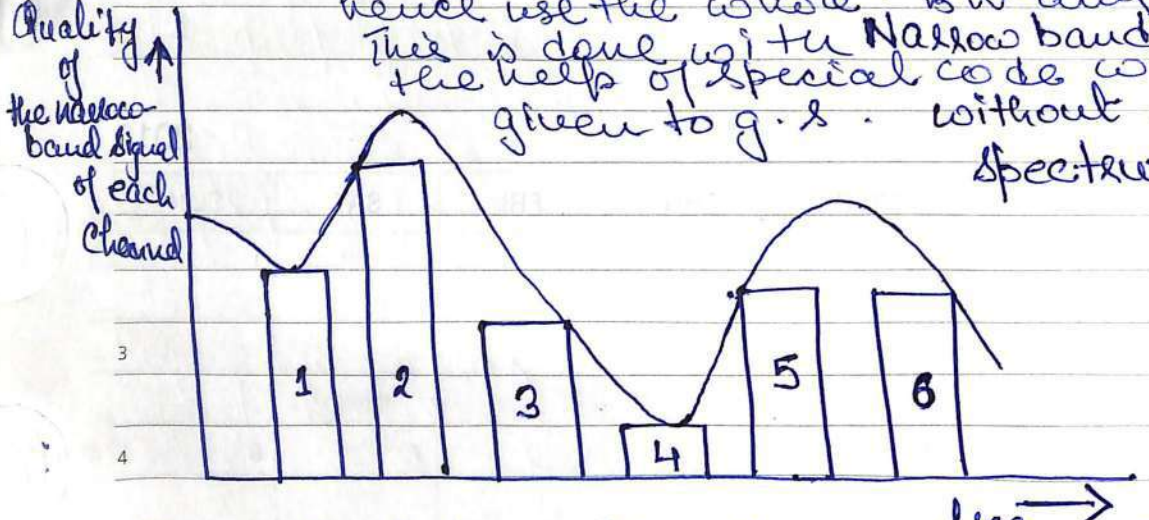
In FDMA each g.s. has been given a portion of freq B.W. alloted to the g.s. Each g.s has been alotted a freq range. It is just a part of the whole freq. range so that it can transmit the s/g at any time only but what is the freq that is alotted

Spread Spectrum Multiple Access SSMA SPMA

↓

Code Division Multiple Access CDMA.

Multiple channels:- Full freq B.W. is used by the transponder at any time. Neither restriction of freq & time and hence use the whole BW any time. This is done with Narrow band Interference the help of Special code which is given to g.s. without Spread Spectrum.



After code is given it will carry the information & hence made available to particular g.s.

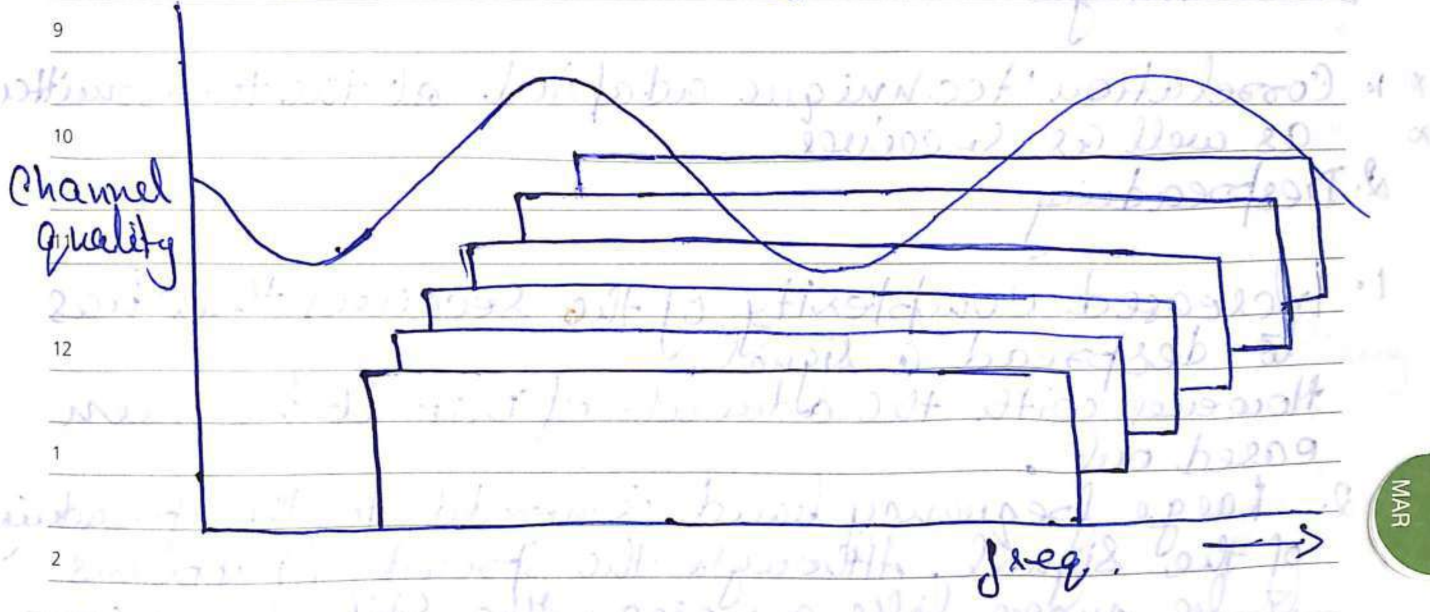
Quality of signal depends upon the frequency as well as the time.

Shows ∐ the energy of each channel which shows the quality of channel.

Channel 3 & 4 have very low energy. The extraction of information from these 2 channels will be difficult.

In diag freq is partially available to each channel.

The situation of channel will differ with time. Whatever may be the time the channel will be spread up. The channel has been brought to lower level i.e. to the noise level. The information hidden behind the noise so they cannot be easily extracted.

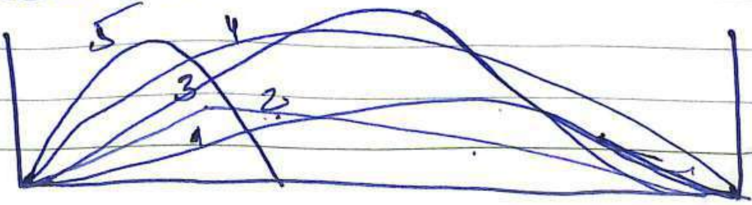


The information s/g is broadened with the help of special codes using FDMA

Advantages :-

1. Co-existence of several signals without co-ordination
2. Robustness against narrow-band interference
3. Relatively high security
4. Characteristics like background noise.
5. Resistance to multiple fading
   * and resistance to jamming

Because of these advantages it is used for military applications.



Codes are shared bet^n t_x & r_x

In TDMA, time is restriction, smaller time has been given to each g.s. Burst of carrying freq can be send.

Disadvantages :-

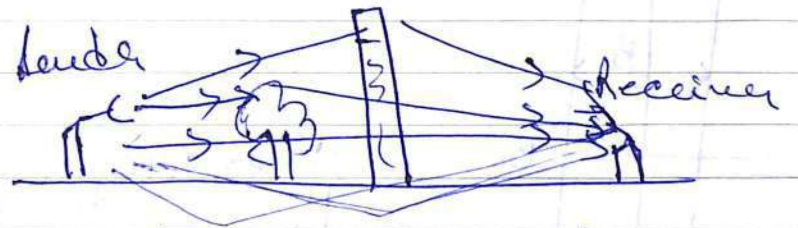
1. Correlation technique adapted at the transmitter as well as receiver.
2. Despreading

1. Increased complexity of the receiver that has to despread a signal. However with the advent of DSP it has been eased out.
2. Large frequency band is needd to the spreading of the signal. Although the spread s/g appears to be more like a noise. The still ~~keeps~~ raise the noise levels of background and may interfere with other transmission channels until unless special measures are taken.

∵ Jamming signal is a narrow-band signal. The actual signal is a broad-band signal which is spread up. Required for blocking the tx signal it can only affect a portion of the spread up of the actual signal and larger amount of actual signal still remains unblocked and is not affected by the jamming signal.

The s/g coming from diffn path as compared to direct s/g will not be in phase. So Correlation technique is adopted to match the similarity if not then rejected. If it reaches the Rx also then it will only partially effect the system.

In multi-path fading



The actual s/g which is being send is reaching through multiple paths. The s/g may be constructive or destructive in nature.

s/g are in same in phase

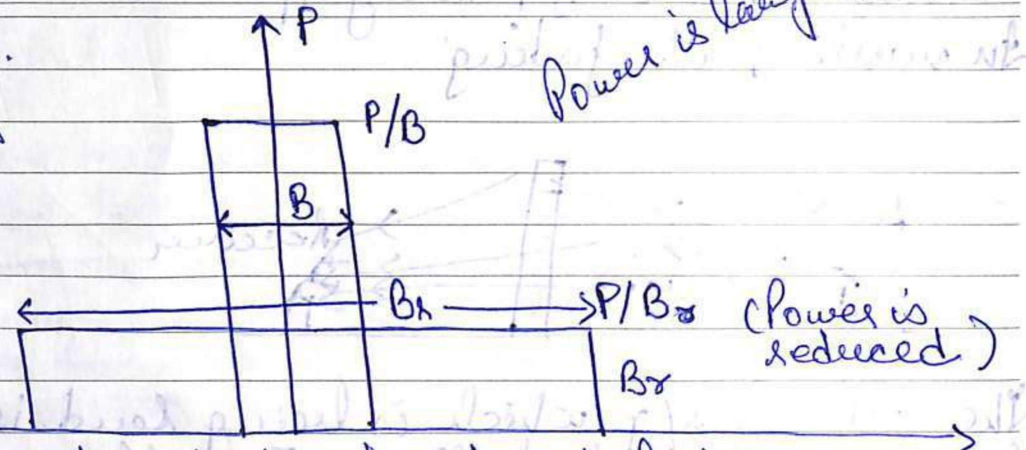
s/g are in out of phase

therefore fading occurs (the energy of s/g reduces because of multi-path fading)

Mostly the s/g will be in constructive phase as there is resistance to multiple fading.

∵ spread spectrum s/g have uniform energy over a larger BW at a given time only a small portion of the spectrum will undergo fading. Multiple path resistance properties are due to the fact that the delayed version of the transmitted signal which is spread up to a larger BW will have poor correlation with the original signal and will appear as another uncorrelated user and which will be ignored/discarded by the receiver

Power Spectral density (PSD) is very large.



Power is large

(Power is reduced)

Avg power density is reduced so that it can frequency.
1 is hide itself below the noise power density. At the Rx the sig accumulated along with noises. * larger coding sig which is higher in frequency will
2 ~~broaden the~~ modulate the information signal which is of lower frequency.

How is Spread Spectrum done?

Two types of Spread Spectrum.

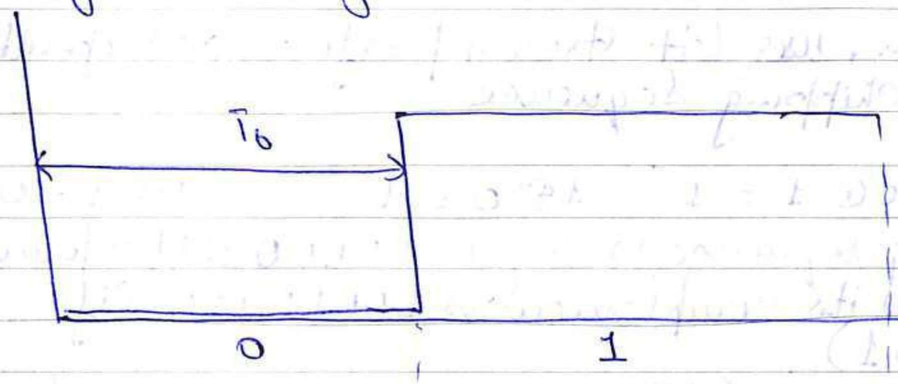
1. Direct Sequence Spread Spectrum (DSSS)
6. Full frequency is used.
2. Frequency Hopping Spread Spectrum
7 Hopping of sig from one frequency to another bit by bit or by an interval from bit to bit.

* No unauthorized Rx can extract the information. Similarity betn coded tx sig & Rx sig is done with the correlation technique.

---

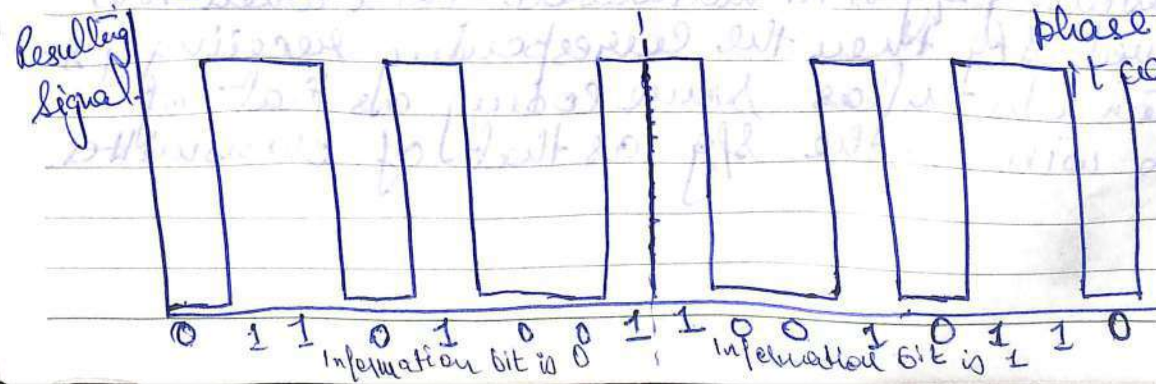
1. DSSS

Information signal bit.



Code is being repeated after interval of time
Coding sig modulates the information signal

Change in phase occurs when it come across 1 bit



Spreading takes place depending upon the frequency/bit rate from few KHz to MHz → Spreading becomes 1 to 100 or to 1000.

In DSSS System, user bit stream perform XOR operation/function with chipping sequence

$0 \oplus 0 = 0$ $0 \oplus 1 = 1$ $1 \oplus 0 = 1$ $1 \oplus 1 = 0$

So The chipping sequence is :- 01101001 (if information bit is 0) and its complement is 10010110 (if information bit is 1)

Chipping sequence is 8 bit sequence, it chips the lower frequency s/g i.e. the information s/g.

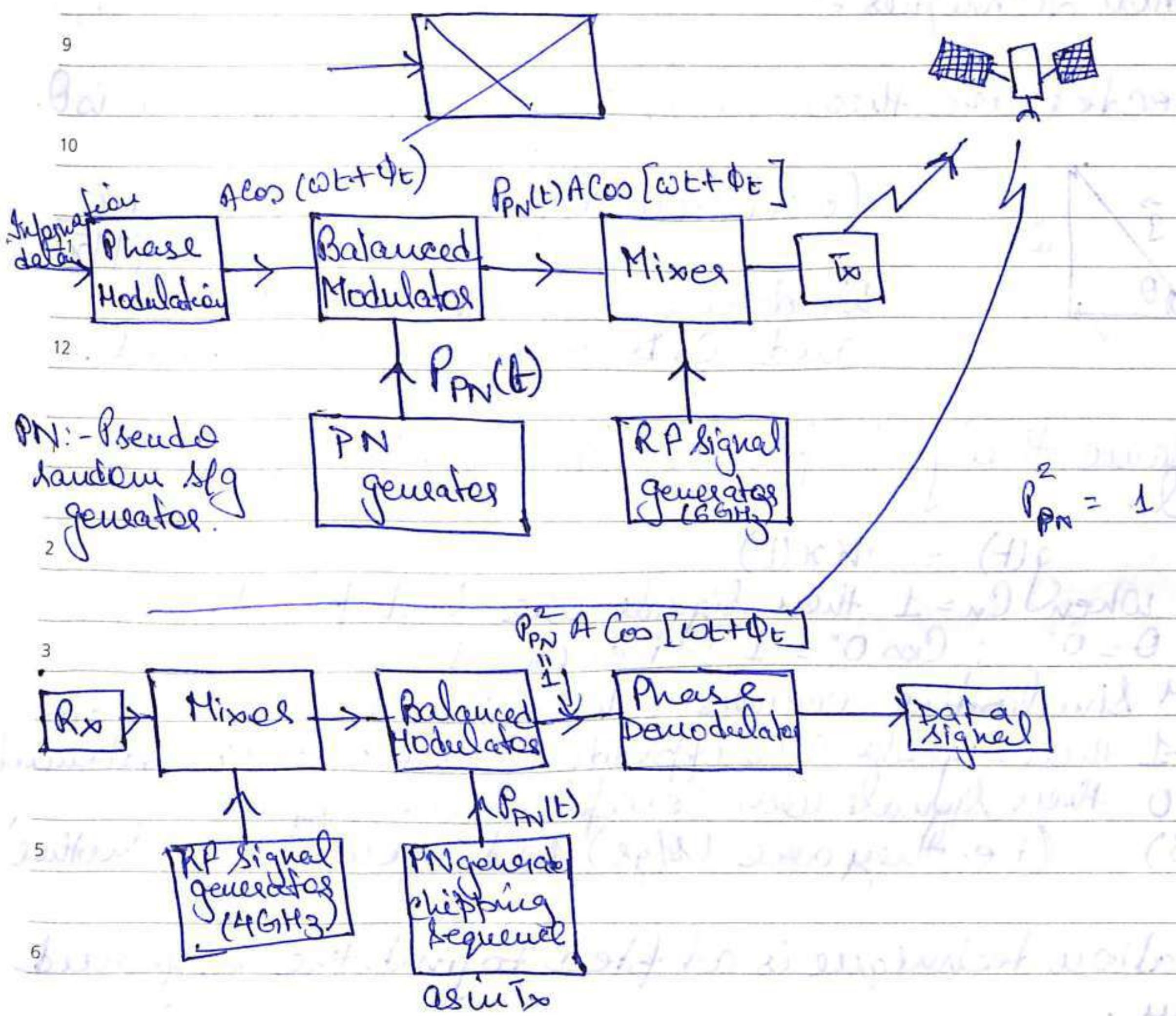
Spreading factor :-

Bit duration of information s/g is T_b
Bit duration of coding/chipping s/g is T_c
Then spreading factor is given as:-

$$(\text{"S"}) \text{ spreading factor} = \left(\frac{T_b}{T_c}\right)$$ determines the BW of the resulting signal.

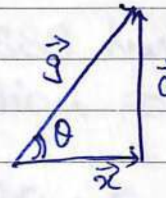
The resulting s/g is RF modulated then when it is received s/g then the corresponding receiving g/s station which has same coding as that of the Tx will rx the s/g as that of transmitter

Phase modulated data s/g will be chipped off.



Correlation Techniques :-

Two vector are there and angle between them is θ.



Correlation Coefficient $C_n = \cos\theta = \frac{\bar{g}\bar{x}}{|\bar{g}||\bar{x}|}$

We observe that $-1 \leq C_n \leq 1$.
and C_n is never greater than 1.

The same thing happens to the two different signal.

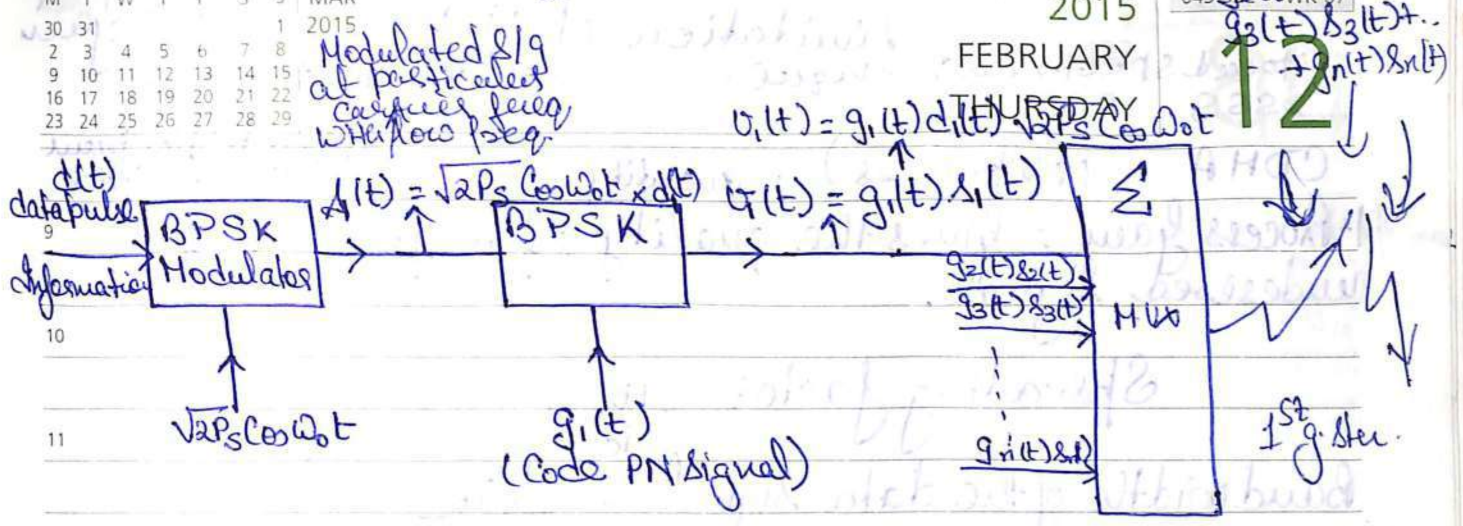
$$g(t) = Kx(t)$$

When $C_n = 1$ then signals are best friends.
when $\theta = 0°$; $\cos 0° = 1$; i.e. $C_n = 1$
Max^m similarities occurs when $C_n = 1$. $\theta = 0°$
& $C_n = -1$ then signals are opposite to each other / (worst enemy) $\theta = 180°$
$C_n = 0$ then signals are complete strangers.
$(\theta = 90°)$ (i.e. they are (s/gs) orthogonal to each other)

Correlation technique is adopted to find the Rx ground station.
The similarity betn s/gs or the chipping sequence is assessed.

Why the signal is being spread up?
Encryption from unauthorized uses.

$\because P_s = \frac{1}{2} A^2 \Rightarrow A = \sqrt{2P_s}$



Tx Side.

1st ground Station:-

$$g_1(t)\, g_1(t) s_1(t) + g_1(t) g_2(t) s_2(t) + \dots + g_1(t) g_n(t) s_n(t)$$

$$= g_1^2(t) s_1(t) + g_1(t) g_2(t) s_2(t) + \dots + g_1(t) g_n(t) s_n(t).$$

Integral of $g_1(t) g_2(t) = 0$ & $g_1^2(t) = 1$.

$$= s_1(t) + 0 + 0 + \dots + 0.$$
$$= s_1(t).$$

S/gs that are transmitted are orthogonal to each other. All PN s/g are orthogonal to each other so that dissimilarity occurs. Hence we are able to extract information

How to extract the signal with DSSS?

chips s/g :- because data s/gs are chipped to small portion.

Spread spectrum Technique.
DSSS.

Limitation of CDHA :- Process gain
Broader spectrum
Spread spectrum characteristics.

CDHA (Properties) :

1. Process gain = gives the quality (quantity) of rejection of undesired signal.

$$\text{Spreading factor} = \frac{T_b}{T_c}$$

$$\text{Bandwidth of the data signal} = 1/T_b$$

$$\underset{(\text{CHIP})}{\text{Bandwidth of the Code signal}} = 1/T_c$$

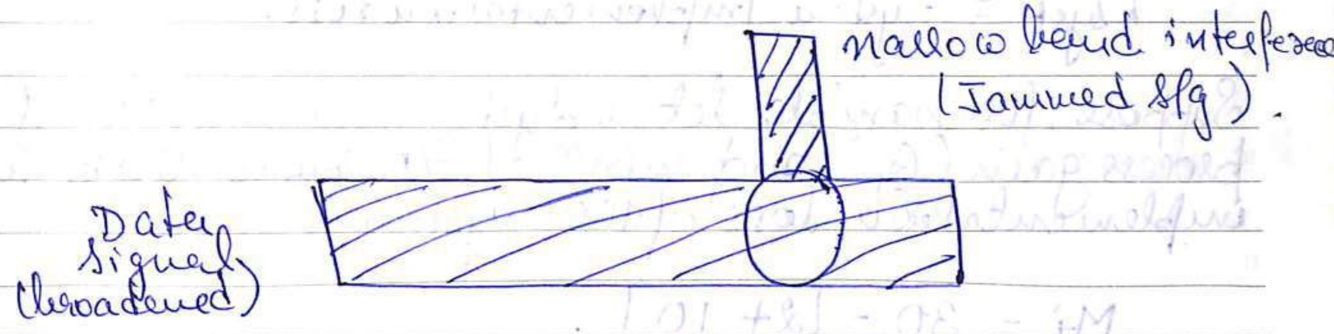
$$\text{Process gain} = \frac{\text{Bandwidth of chip signal}}{\text{Bandwidth of data signal}} = \frac{\text{B.W. of pg}}{\text{Datarate of signal (Rnp)}}$$

$$= \frac{1/T_c}{1/T_b} = \frac{T_b}{T_c}.$$

Process gain determines three things :-

1. No. of users :- no. of g.s. (>/ users) that can be allowed in a system. (g.s. in satellite).
2. This can also indicate the amount of multipath fading effect rejection.
3. It makes the jamming signal (Narrowband freq. s/g.) difficult. (rejection of the signal).

s/g undergoes phase change when coming from multi path. effect of multipath is reduced. Therefore when correlation technique applied they will be not similar and hence can be nullified or reduced.



Even in the presence of jamming s/g still the s/g can be extracted as it affect only a portion of broadband signal as it is narrow-band. They can be still extracted. During de-spreading technique the narrowband s/g is broadened hence its power is reduced. with the help of notch filter this information can be extracted. Hence not able to interfere with the data signal.

2. Jamming margin :-
It expresses the capability of the system to perform in hostile (interfering) environment.
This takes into account the requirement of useful system output signal to noise ratio i.e. called the minimum signal to noise ratio at the output of (S/N)out the system

$$\text{Jamming Margin}(M_J) = \{G_P - [L_{\text{system}} + (S/N)_{\text{min out}}]\}$$

Evaluation is done with this expression.

The useful (S/N) at o/p is taken into account which is min

L_{systt} = System Implementation Loss.

Suppose, for example let a System with 30dB of process gain (G_p) and min^m $(S/N)_{o/p}$ is 10dB and implementation loss of the system is 2dB.

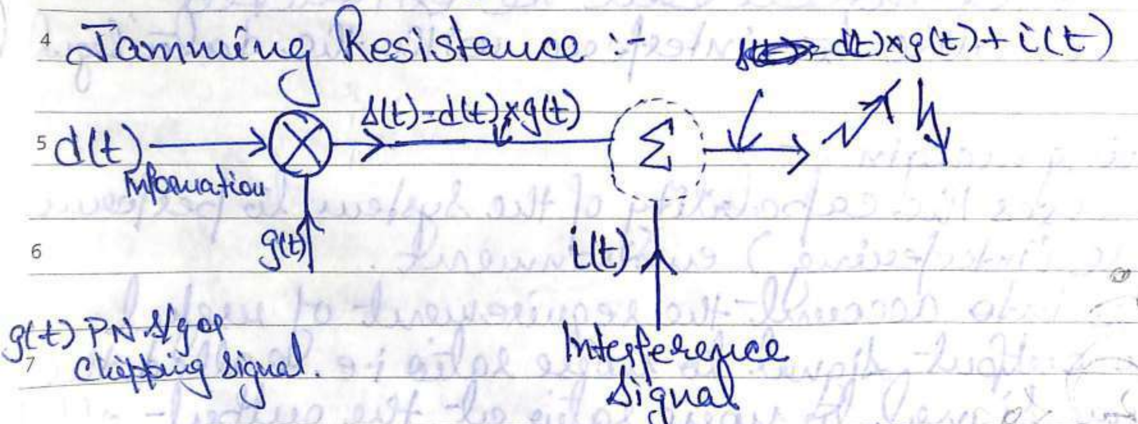
$$M_j = 30 - [2 + 10].$$
$$M_j = 18\text{dB}.$$

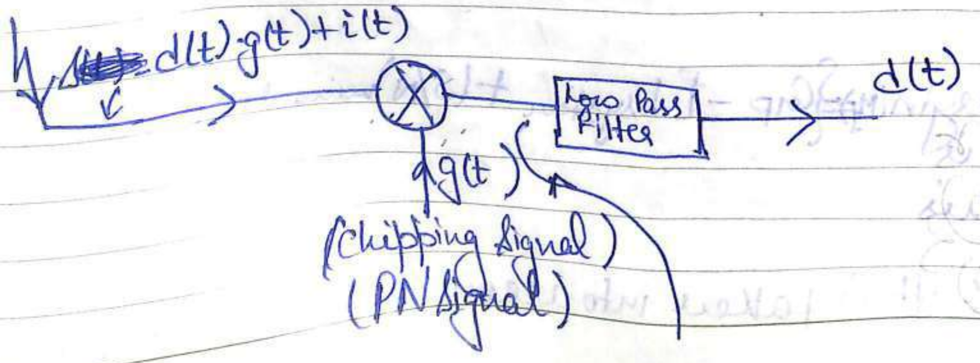
$$(M_j) = G_p - [L_{sys} + (S/N)_{o/p}]$$

It means that the system cannot be expected to operate with interference more than 18dB above the desired signal.

How Jamming Signal Is Removed?

Jamming Resistance :-





$$[d(t) \cdot g(t) + i(t)]\, g(t) = g^2(t) \cdot d(t) + i(t)\, g(t)$$
$$= d(t) + i(t)\, g(t).$$

At receiving end, despreading is done which results in broadening of narrow-band signal.

1. Multipath fading
2. Make use of any frequency.
3. Jamming Signal.

Comparison of the three Multiple Access Technique :-

CDMA; FDMA; TDMA.

SN.	Parameter	FDMA	TDMA	CDMA.
1.	Spectrum Utilization for Single station	It does not use full bandwidth	It uses full BW within alloted time	It uses full bandwidth throughout operation.
2.	Analog / Digital	Generally analog	Digital	Digital.
3.	Interference	Interference may occur.	Interference may occur.	Interference is eliminated.
4.	Synchronization	Difficult Process (Demand Assigned)	Difficult Process (Demand Assigned)	Easy.
5.	Intermodulation Distortion.	Present	Not Present	Not Present.

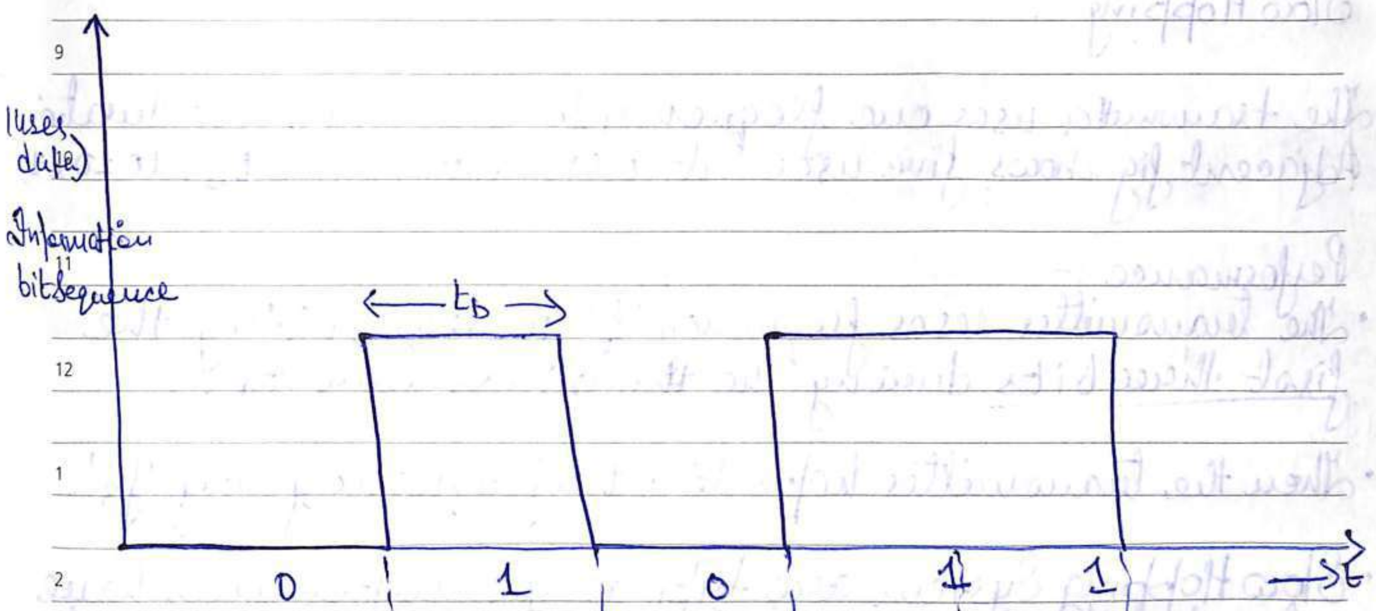
6. Secrecy (Interception)	Almost insecure	Better than FDMA	Fully secured.
7. Jamming.	Exist	Exist	Does not exist.
8. Bit Rate	Medium	High	Low.
9. Flexibility	Poor	Better	Best.
10. Cost	Low	High	Lowest.

Spread Spectrum Technique

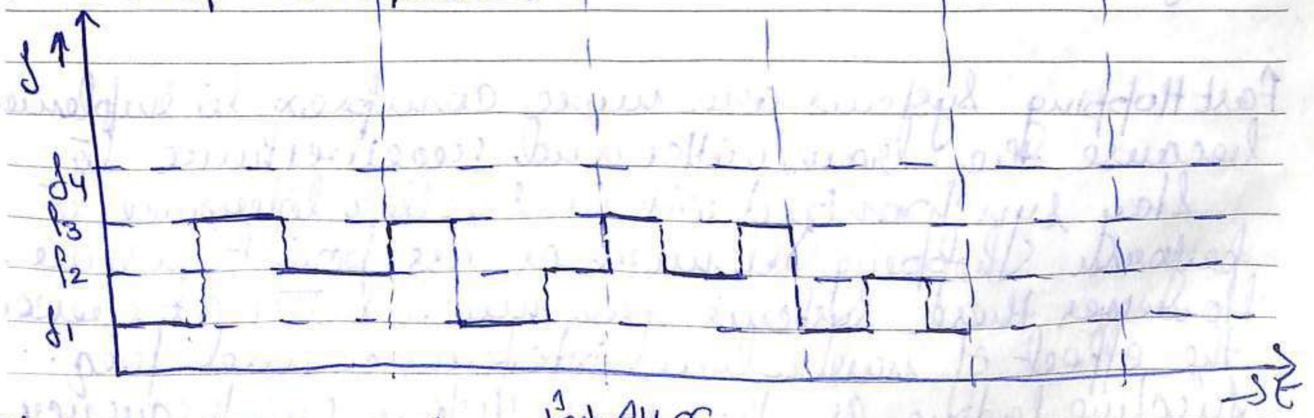
- ↓ DSSS
  Direct Sequence Spread Spectrum
- ↓ FHSS
  - Slow FHSS
  - Fast FHSS

  Frequency Hopping Spread Spectrum.
  ↓
  Total B.W is split up into many channels of smaller BWs plus guard space between the channels.

0110100 1
01011



Slow FHSS
1 hop in 3bit period.



3 hops in 1 bit period
Fast FHSS

In FHSS the freq is changing bit by bit

Slow Hopping.

- The transmitter uses one frequency for several bit duration
- Adjacent fig shows five user bit with bit period t_b. (01011)

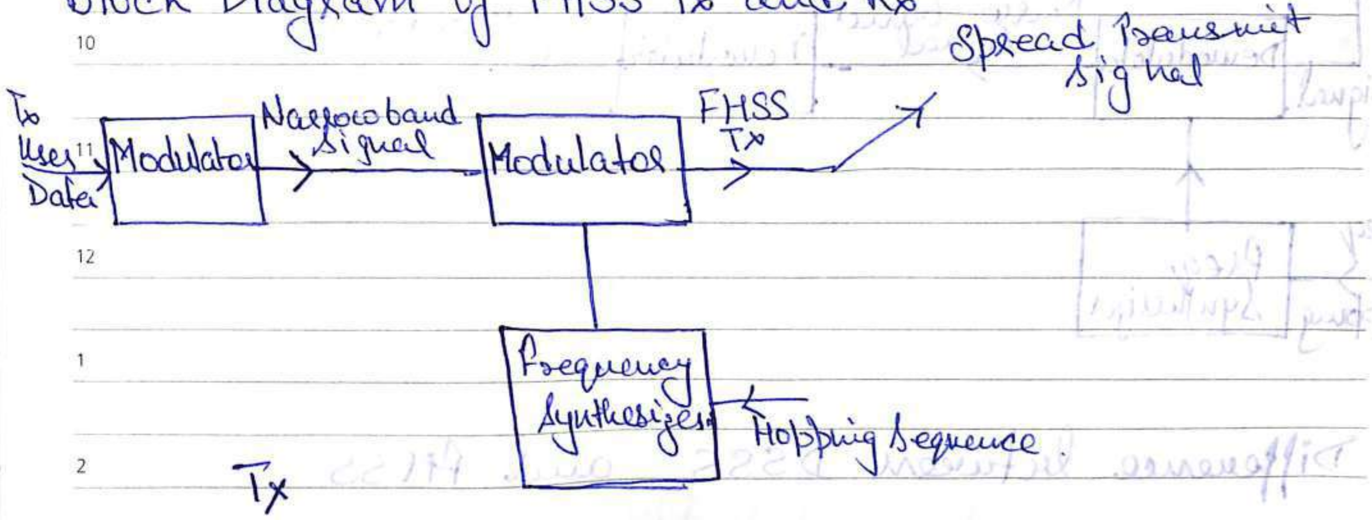
Performance :-

- The transmitter uses frequency 'f_2' for transmitting the first three bits during the ~~the~~ dwell time t_d.
- Then the transmitter hops to other frequency say 'f_3'.
- Slow Hopping System are typically cheaper and have relaxed tolerance but they are not as immune to narrow band interference as fast hopping.
- Dwell time 't_d' is the time spend by the transmitter on a particular / certain channel with a certain frequency.
- Hopping sequence is the pattern of the channel usage in a particular sequence

Fast Hopping Systems are more complex to implement because the transmitter and receiver have to stay synchronized within smaller tolerance to perform hopping at more or less point in time. However these systems are much better at overcoming the effect of narrowband interference and freq. selective fading as they only stick to one frequency for a very short time

Fast FHSS more immune to narrowband interference

Block Diagram of FHSS Tx and Rx



In this, the first step in transmitter is the modulation of the user data according to one of the digital to analog modulation scheme such as BPSK, FSK etc and the result is a narrowband signal. If FSK is used with a freq f_0 for binary 0 ; f_1 for binary 1.

In next step FH. is performed based on the hopping sequence and the hopping sequence is spread using the frequency synthesizer generating the carrier frequency f_i

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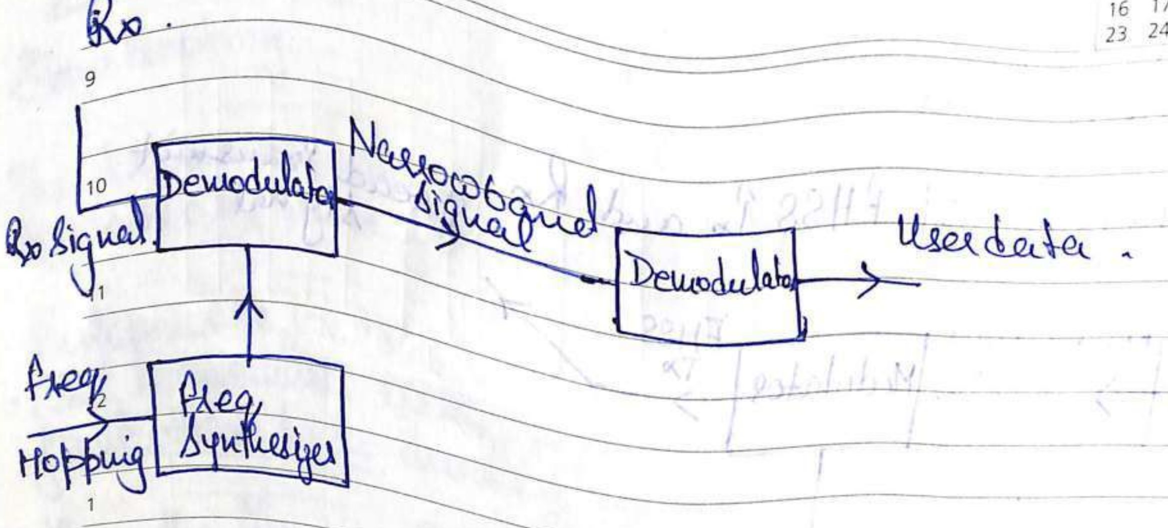
2nd modulator uses modulated narrowband sig and carrier freq. generate a new spread signal with frequency f_j

$f_i + f_0$ for '0' bit
$f_i + f_1$ for '1' bit

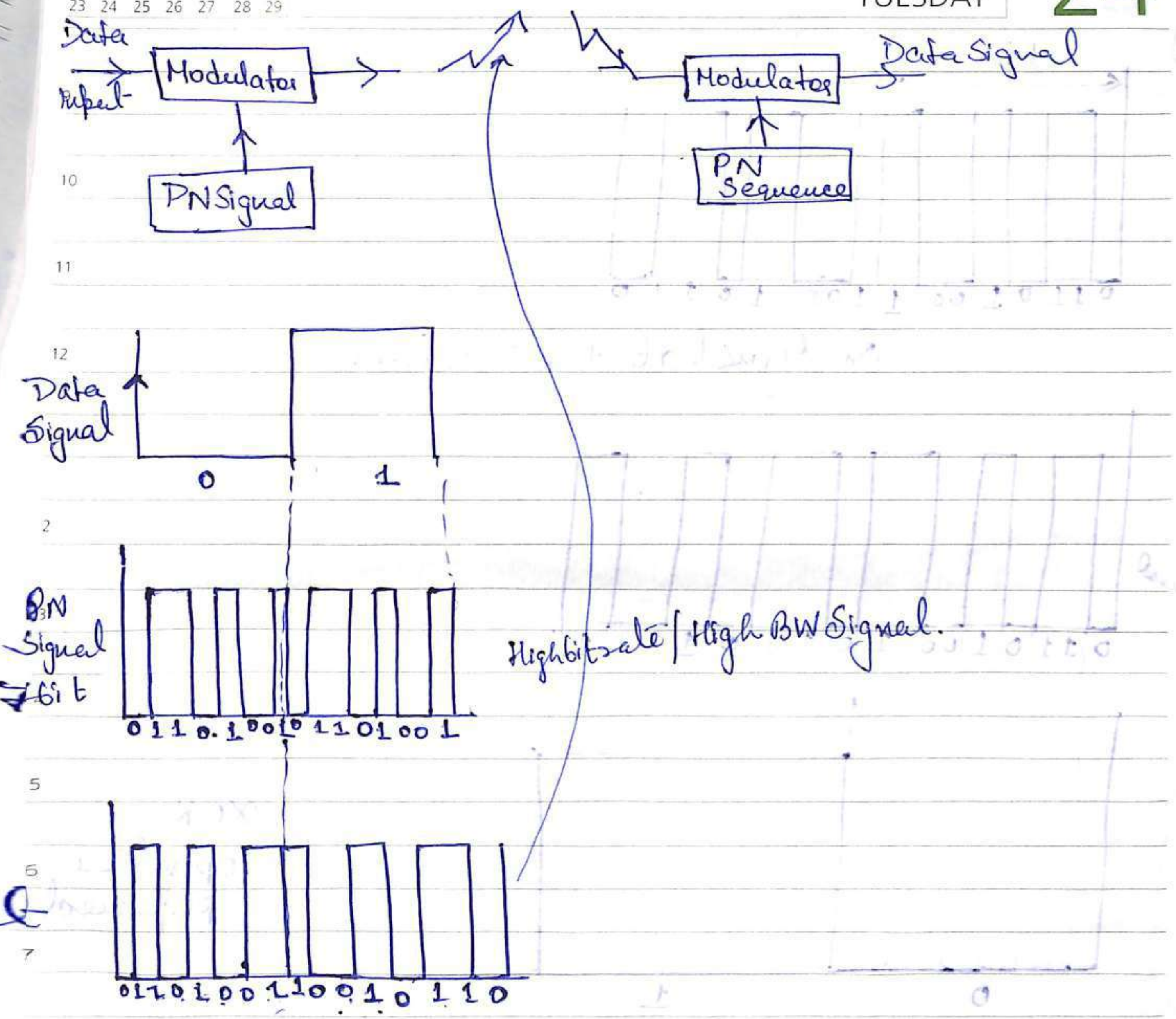
Rx.



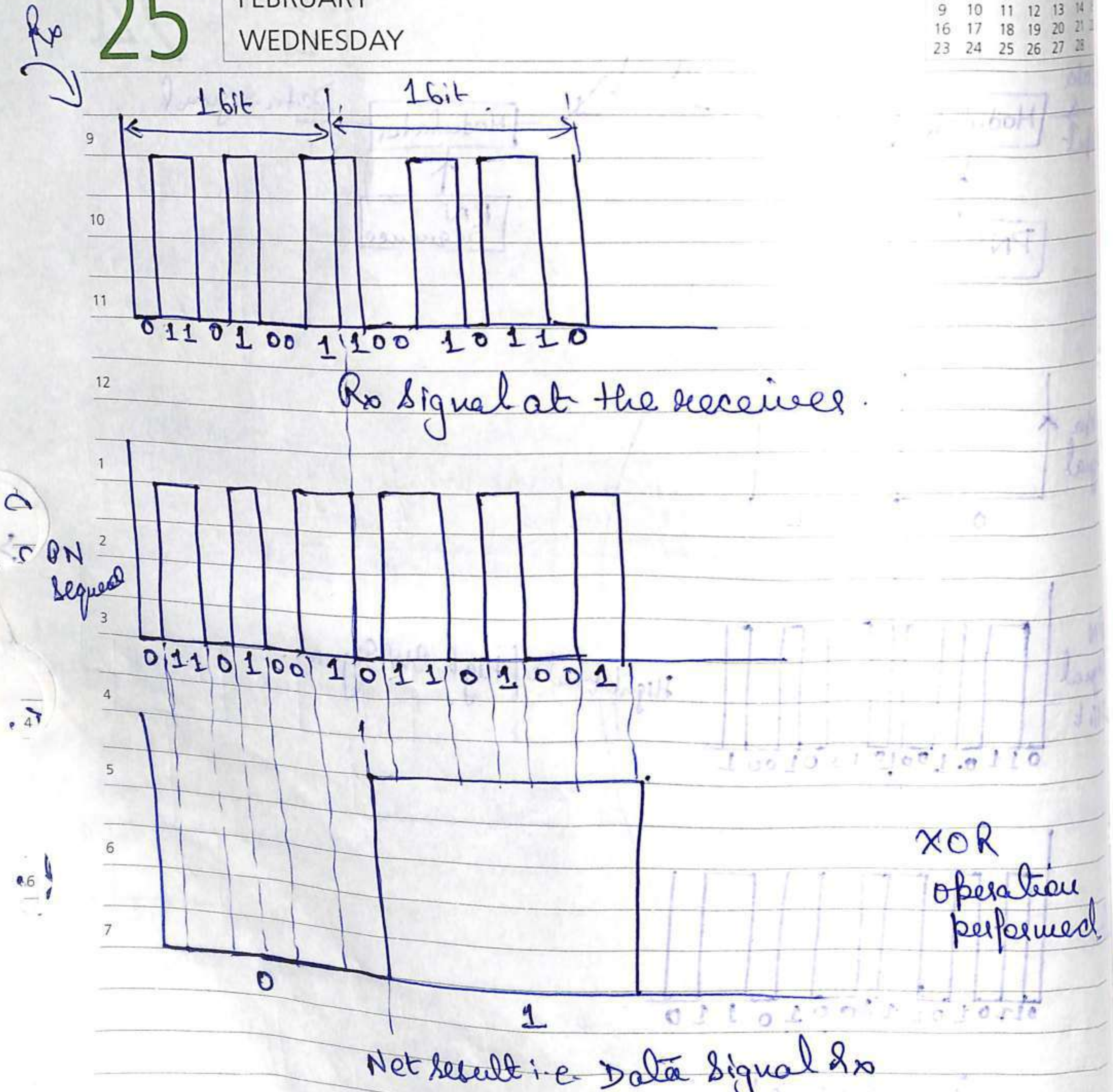
Difference between DSSS and FHSS.

1. Compared to DSSS spreading is simpler using FHSS system.
2. FHSS system uses only a portion of the total band at any time while DSSS system ~~uses~~ always use the total BW available.
3. DSSS system on the other hand are more resistant to fading and multi-path effect.
4. DSSS sigs are much harder to detect without knowing the spreading code and the detection is rather virtually impossible.

DSSS.



Tx Signal.



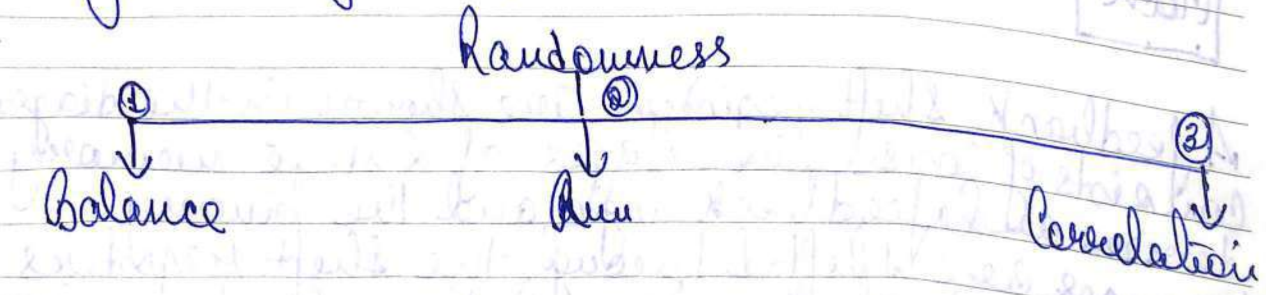
XOR gates are used for generation & regeneration of Signals.

PN Sequence Generation (Pseudo Noise Signal Generation) OR (Pseudo Random Signal)

- It is random signal but deterministic type.

Circuit for implementing PN Signal contains.

- LFSR (Linear Feedback Shift Registers) are being used containing n-bits. (n shift registers are used)
- There are 1 to n-1 XOR gate.
- Presence or absence of gate corresponds to presence or absence of a term in the generator polynomial.
- Though the type of PN sequence used in Spread Spectrum System are deterministic but they have the statistical properties of a sampled white noise and to an unauthorized listener/user these appear to be truly random signal and randomness will be governed by these parameters.

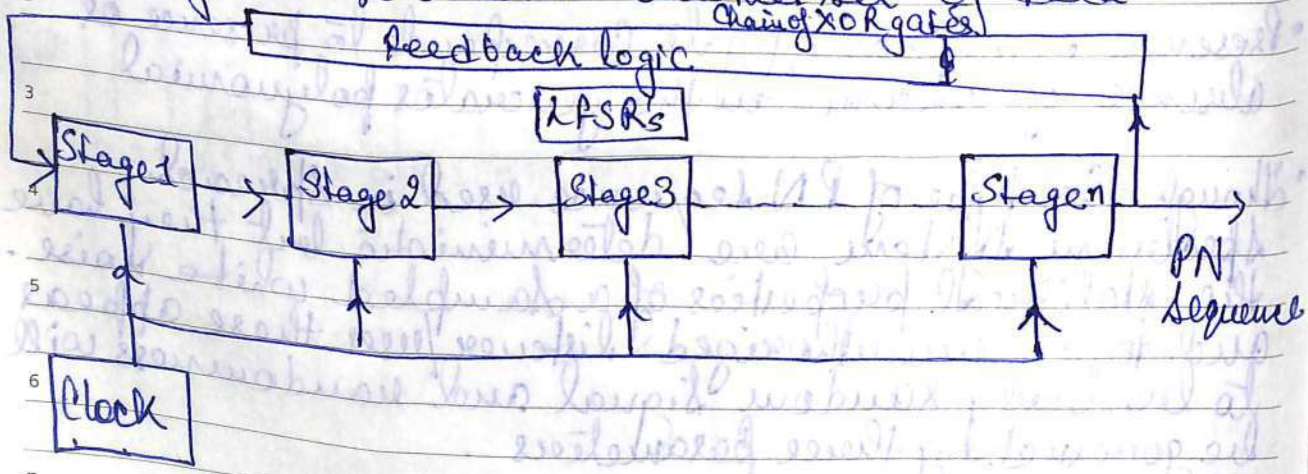


o/p going to chain of all XOR gates.

Balance:-
In a long sequence the fraction of binary 1's should approach half.

Run:-
Run is defined as sequence of all 1's or sequence of all 0's

Correlation:-
It is the concept of determining how much similarity 1 set of data has with another set of data.



A feedback shift registers are shown in the diagram consists of consecutive stages of 2 state memory devices and a feedback logic and the binary sequences are shifted through the shift registers in response to clock pulses and the o/p of various stages are logically combined and fed back as the i/p to the 1st stage wherein the feedback logic ckt consists of XOR gates.

2nd Term End.

Suppose shift register contains say 'm' bits so there are 1 to m-1 XOR gate.)

SUNDAY 01

UNIT-IV

Earth Station Technology

III^rd Term.

Antenna:-

9

Satellite Antenna

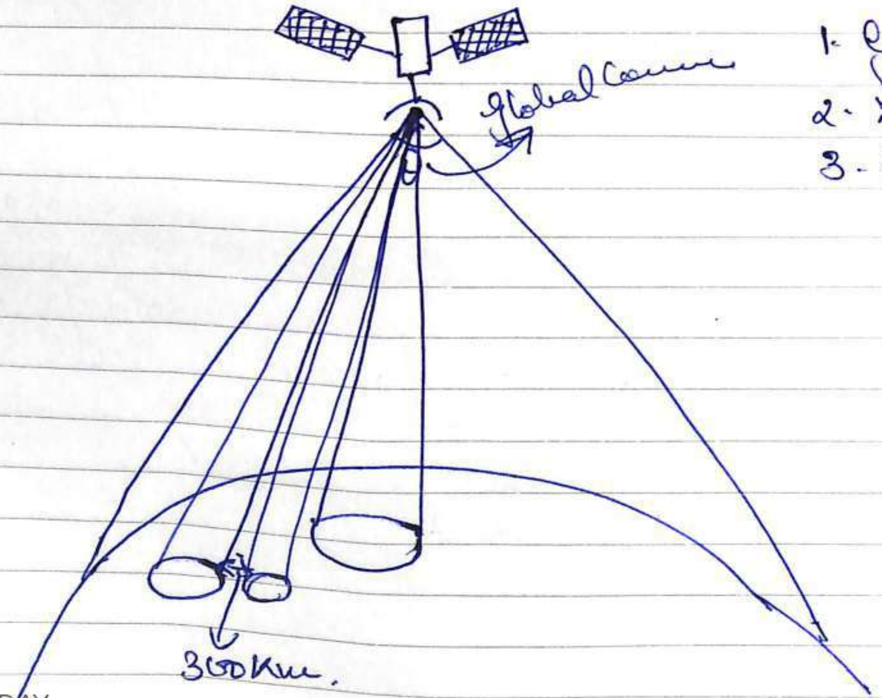
10

Deployed on Satellite. | Deployed on earth station. (Tx & Rx).

12

1

1. Global Coverage.
2. Zonal Coverage
3. Spot Beam.



2

3

4

5

6

7

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9 Global coverage :- Beam width should be high.
Beam width = 17.20
1/3^rd of the globe covered.

10 Highly directional antennas are used that have global coverage and covers
11 1/3^rd of the globe and beam width of 17.2°

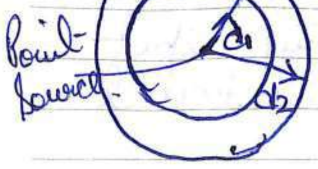
12 Zonal Coverage :- 2° to 7°.

1 Spot Beam :- 0.5°.

2 Depending on the area that is to be covered by the radio waves that are propagated from
3 Satellite to the earth station with diffⁿ beam width. Same freq is used when distance betⁿ
4 them is 300 Km apart with the help of spot beam. therefore capacity of the Satellite
5 can be increased.

6 Two types of antennas are used:- (General category of Antennas are two)

7 Omnidirectional Antenna. (Usually designed to be deployed on Satellite) when satellite is in process of being placed in its orbit. top ali fale | Directional Antenna.



the tracking and command (T & C) from earth to satellite & vice versa. during placement of satellite in its final orbit.

MAR 2015	M	T	W	T	F	S	S
	30	31					1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29

Omnidirectional Antenna,

Point source distributing radio waves all around
9 in 360°

Directional Antenna.
Radio waves propagated in particular
11 direction. Highly ~~ra~~directive antenna.
in particular direction then gain comes
12 into picture.
Antennas are used when the satellite is finally
1 deployed in its orbit
are used for both tracking and command after the
2 satellite is positioned into its final orbit as
well as to provide earth (global & zonal) and
3 spot beam coverage.

4 Area of the earth covered by the satellite depends
upon 1) its location in space in GEO.
5 2) ~~frequency~~ its carrier frequency and.
3) Gain of the antenna.
6 Larger the directivity of antenna and larger the gain.
In spot beam only a portion of earth's surface
7 is illuminated and hence they are highly directivity.

Highly directional antennas deployed on both satellite and earth station.

For illuminating a country or country spot beam is used which are highly directional.

M	T	W	T	F	S	S	APR 2015
		1	2	3	4	5	
6	7	8	9	10	11	12	
13	14	15	16	17	18	19	
20	21	22	23	24	25	26	
27	28	29	30				

9
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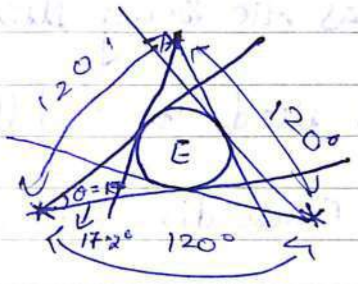
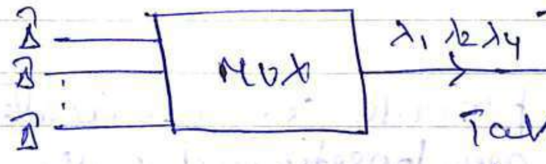


12 Diff^n bet^n Multiplexer & Multiple Access.

MUX:- Transmitting feature
1



send to single channel
2 Takes place at one geographical
3 At particular locations on the earth's surface
ground location.
4

Diag of MULTIPLE ACCESS.
5 S/g from diff^n station to satellite and
6 (from diff^n geographical location)
7
then they are finally accessed at the satellite
this is how capacity of satellite technique
using multiple access technique.
Has traffic feature.

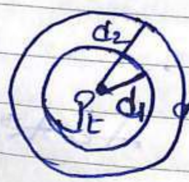
Various Types of Antennas Are Being Used :-

Types of Antennas Used In Satellite Communication:

i) Wire Antenna. -> Omnidirectional Antenna.
ii) Horn Antenna.
iii) Reflector Antenna. } -> Directional Antenna.
iv) Array Antenna.

Wire Antenna
Omnidirectional Antenna :-

Primarily at VHF & UHF to provide communication to TT&C system. These are positioned with great care on the body system of satellite, in an attempt to provide omnidirectional coverage.



Wire antenna placed in the centre.

Amplitude decreases with the increase in distance.

Power Density of the antenna (Omnidirectional mode)
i.e. $P_D = \left(\frac{P_t}{4\pi d^2}\right)$ where d is the radius of the sphere.

P_D is the power density in Watts/m^2.
P_t is the power point source in (W)
d is the radius of sphere in (m)

This shows that the P_D away from the source will depend upon the i.e. proportional to the power of the source and inversely proportional to square of the distance.

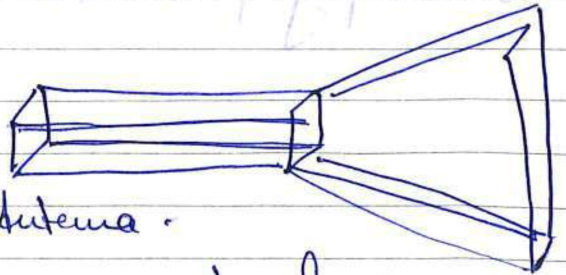
Characteristic Impedance of the free space :-

$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$ where, μ_0 is the permeability of free space i.e. 1.26×10^{-6} H/m.
$= 377$ or $120\pi\ \Omega$

ϵ_0 is the permittivity of the free space i.e. 8.85×10^{-12} F/m.

Horn Antenna.

It is the basic antenna i.e. directional antenna for covering larger distance on the surface of the earth. It acts as a feeder to the reflector surface of the antenna or itself.



Horn Antenna.

$P_D = \frac{P_t}{4\pi d^2}$

$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = 377$ or 120π
μ_0 is the permeability
of free

They are used at μ-wave frequencies when relatively wide beam is required as a global coverage. Horn is a flared portion of the waveguide that provides an aperture.

Gain of a antenna is how much capable it is of

sending radio waves in a particular direction i.e. gives the directivity.

M	T	W	T	F	S	S
30	31					1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Aperture is several times of wavelength wide & provides a good match betn tx waveguide & the free space. Horns are also used as feeds for reflector either singly or no. of horns can be used. Horns & reflectors are example of the aperture antenna. that launches a wave

into free space
and it is very
gain ~~greater of~~
of less than
For higher gains
width a reflector
used.

from waveguide
difficult to find
23dB or beamwidth
10 dB with horn antenna
have narrow beam
antenna must be

Reflector Antenna.

Lower the freq, larger the aperture of antenna.

Reflector antenna is simply parabola.

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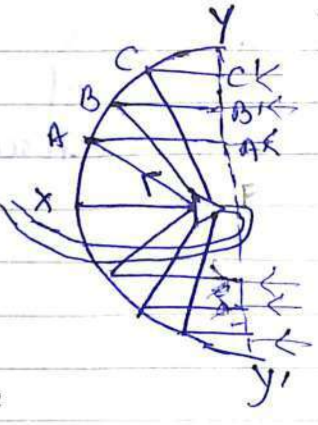
M	T	W	T	F	S	S	APR 2015
	1	2	3	4	5		
6	7	8	9	10	11	12	
13	14	15	16	17	18	19	
20	21	22	23	24	25	26	
27	28	29	30				



Aperture of the parabola is the ratio of the focal length & the diameter of parabola.

$$A = \left(\frac{FX}{YY'}\right) = \frac{\text{Focal length}}{\text{Dia of Parabola}}$$

If rotated 360° it becomes paraboloid.

Parabola is 2D & Paraboloid is 3D

Assuming the light source is placed at the focal length of the parabolic reflector all the waves originating from the focal pt. will be reflected by the inner surface of the parabola and they will be travelling the same distance to the mouth of the reflector (antenna) and becomes highly directional

$$FA + AA' = FB + BB' = FC + CC' = \text{constant}$$

All the reflected wave will accumulate at pt source.

It is therefore clear that an omnidirectional source of light are ~~or~~ horn antenna ~~placed at the~~ generates a highly directional beam of light. Alternatively if a parabolic reflector intersects a beam of light the intercepted beam of energy will be concentrated at the focal pt. of the reflector. It is therefore very clear that the energy collected from large surface will be concentrated in a small area i.e. focal pt & this is indicative of parabolic reflector amplification characteristic

Parabolic reflector power gain :-

$$G_p = \frac{4\pi A_{eff}}{\lambda^2}$$

G_p is the power gain i.e. (the ratio)
A_{eff} is the area of reflector (m^2)
λ is the operating wavelength (m).

$$A_{eff} = K \cdot A.$$

K is the efficiency factor. (how much efficiently it is converting the s/g at the focal point).

A is the area of reflector:

$$A = \frac{\pi D^2}{4}.$$

$$A_{eff} = \frac{K\pi D^2}{4}.$$

$$\frac{4\pi \cdot K \cdot K D^2/4}{\lambda^2}$$

$$A_{eff} = K \cdot \frac{K D^2}{4}$$

$$= \frac{K^2 D^2}{4}.$$

$$\therefore G_p = \left[\frac{K\, 4\pi (\pi D)^2}{\lambda^2\, 4}\right]$$

$$= \left[\frac{K \pi^2 D^2}{\lambda^2}\right] = K \pi^2 \left(\frac{D}{\lambda}\right)^2.$$

Let $K = 0.65$

~~= 0.65~~ $G_p = 6\left(\frac{D}{\lambda}\right)^2$.

∴ Gain the function of the aperture ratio.

Earth Station :-

It is divided into two parts :-

1) A RF Terminal.
2) A Baseband Terminal

1) A RF Terminal
This consists of upconverter, downconverter, a high power amplifier and low noise amplifier and the antenna.

2) A Baseband Terminal
This consists of baseband equipments, an encoder, decoder modulator and demodulator.

Signals are tx & rx by the antennas. Hence they need to be considered precisely.

Large interception of radiation power of antenna leads to high transmission power.

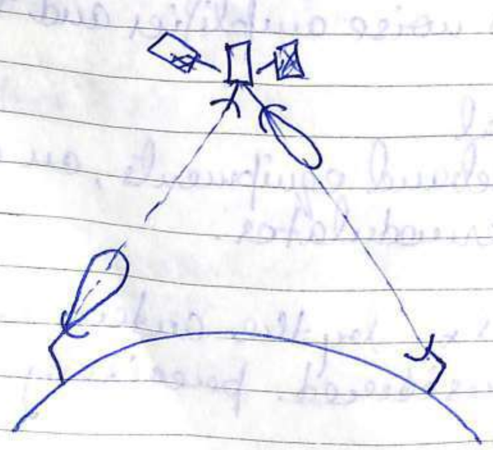
Earth Station Antenna
⇓
Basic Requirements :-

1. Highly Directive gain :-

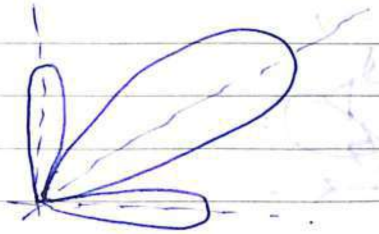
It must focus its radiated energy in a desired direction

(low side lobe level)

It must focus its radiated energy in narrowbeam to illuminate the satellite antenna in both Tx & Rx mode to provide the desired uplink & downlink carrier power. Also the antenna radiation pattern should have low side lobe gains.



To reduce the interferences into other satellite & terrestrial System



Side lobe large then interfere with other satellite S/ms or terrestrial system hence side lobe should be low so that even if it interferes it have low effect.

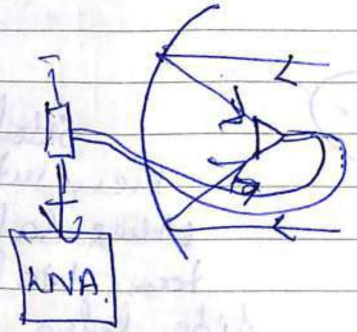
2. Low noise temperature :-

Antenna must have low noise temp^{r} so that the noises do not become dominant on the Rx side.

The effective noise temp^{r} of the Rx side of earth station which is proportional to the antenna temp^{r} ~~should~~ can be kept low to reduce the noise power with the downlink ___ carrier BW and to achieve low noise characteristics the antenna radiation pattern must be controlled in such a way so as to minimize the energy radiated into sources other than the satellite.

Also, ohmic loss of the antenna that contribute ~~Att~~ directly to its noise temp^{r} should be reduced This includes the ohmic loss of the waveguide that

Connects to the low noise amps.



3. Antenna should be easily steered.

In order to maintain the directivity of antenna so that it targets the satellite antenna so it should be easily steered to maintain the look angle.

It is required so that a tracking system may be employed to pt the antenna beam accurately towards the satellite taking into account the satellite drifts in position. This is essential for minimizing the antenna pointing loss.

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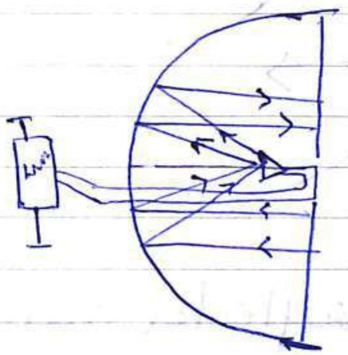
Antenna pointing loss means that the alignment of radiation pattern should be maintained.

misalignment of radiation pattern should be minimized

Dipole antenna suitable for VHF & UHF & not suitable for higher frequencies, hence considerably its size decreases with increase in frequencies thus affecting the transmission of signals.

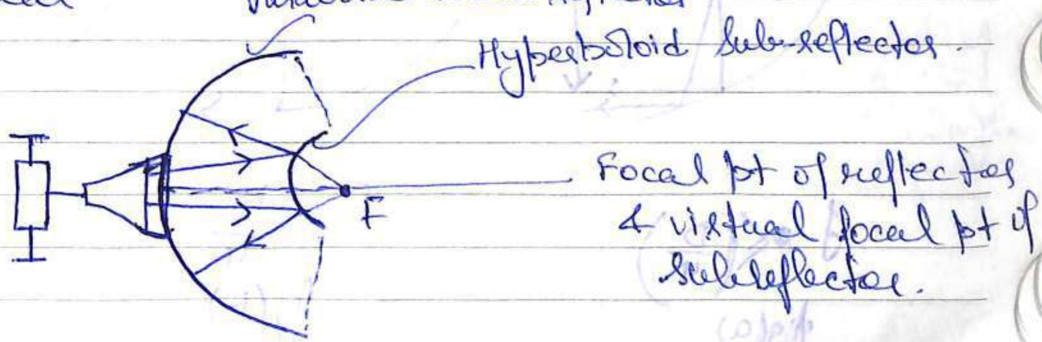


Paraboloid Reflector Antenna.

Cassegrain Reflector Antenna. (Modification of paraboloid reflector antenna)

In this waveguide is avoided.

Highly directional antenna.



It is a dual reflector antenna which consists of paraboloid main reflector ~~and~~ whose focal pt is coincident with the virtual focal pt of hyperboloid. Feed pt at the rim itself.

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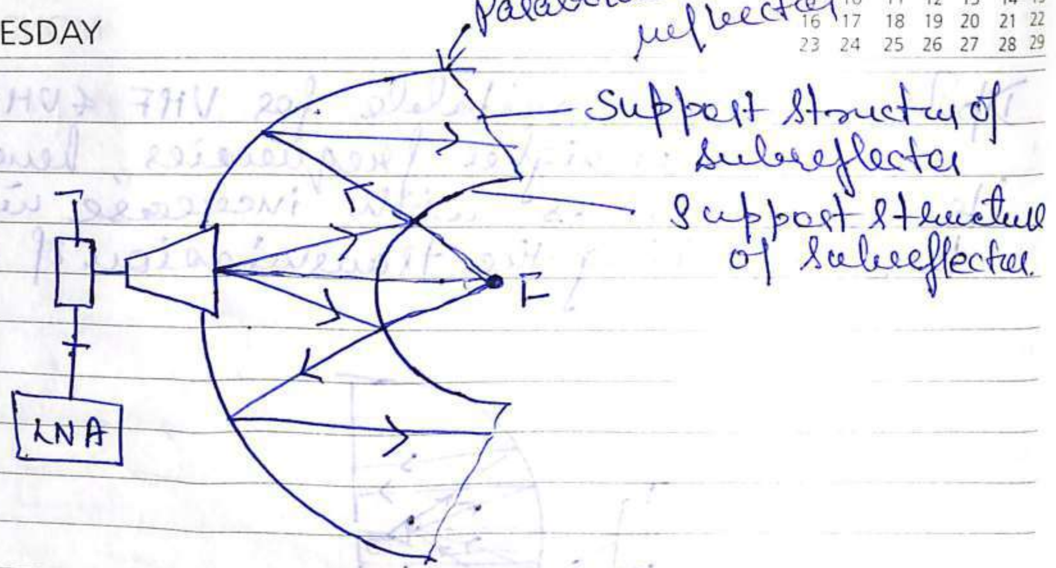
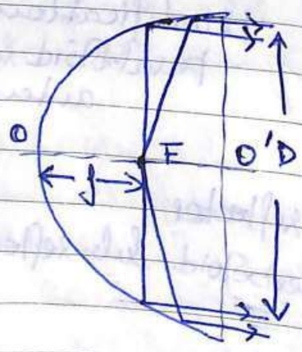
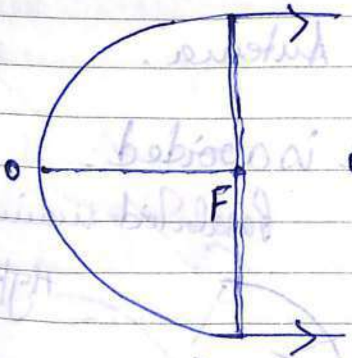


In case of paraboloid reflector antenna.



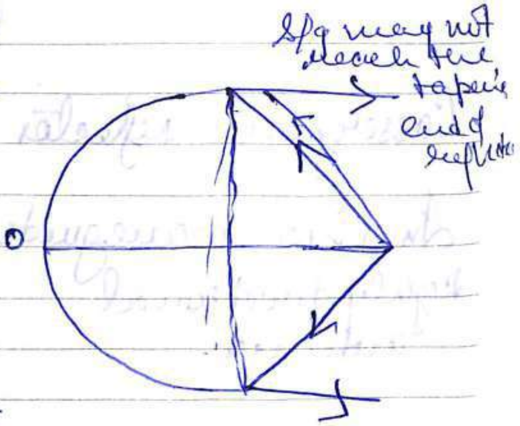
$f < \left(\frac{D}{4}\right)$

fig(a)



$F = \frac{D}{4}$

fig(b)



$F > D/4$

fig(c)

Best position of the feeder is 2.

At $F = \frac{D}{4}$. then the focal pt will be on the line of the axis of the mouth.

$F < \frac{D}{4}$ focal length will be less

$F > \frac{D}{4}$ focal length will be greater than the

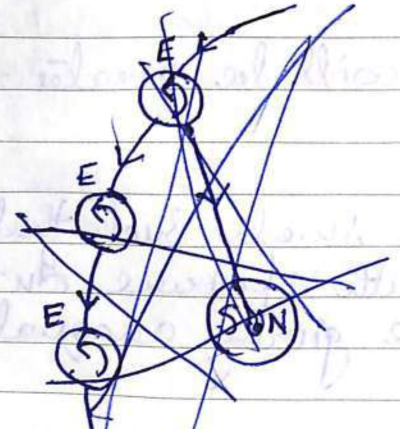
In fig (a) focal length is small such that the focus lies well inside the mouth aperture. In this case it is difficult to get a source giving adequately uniform illumination.

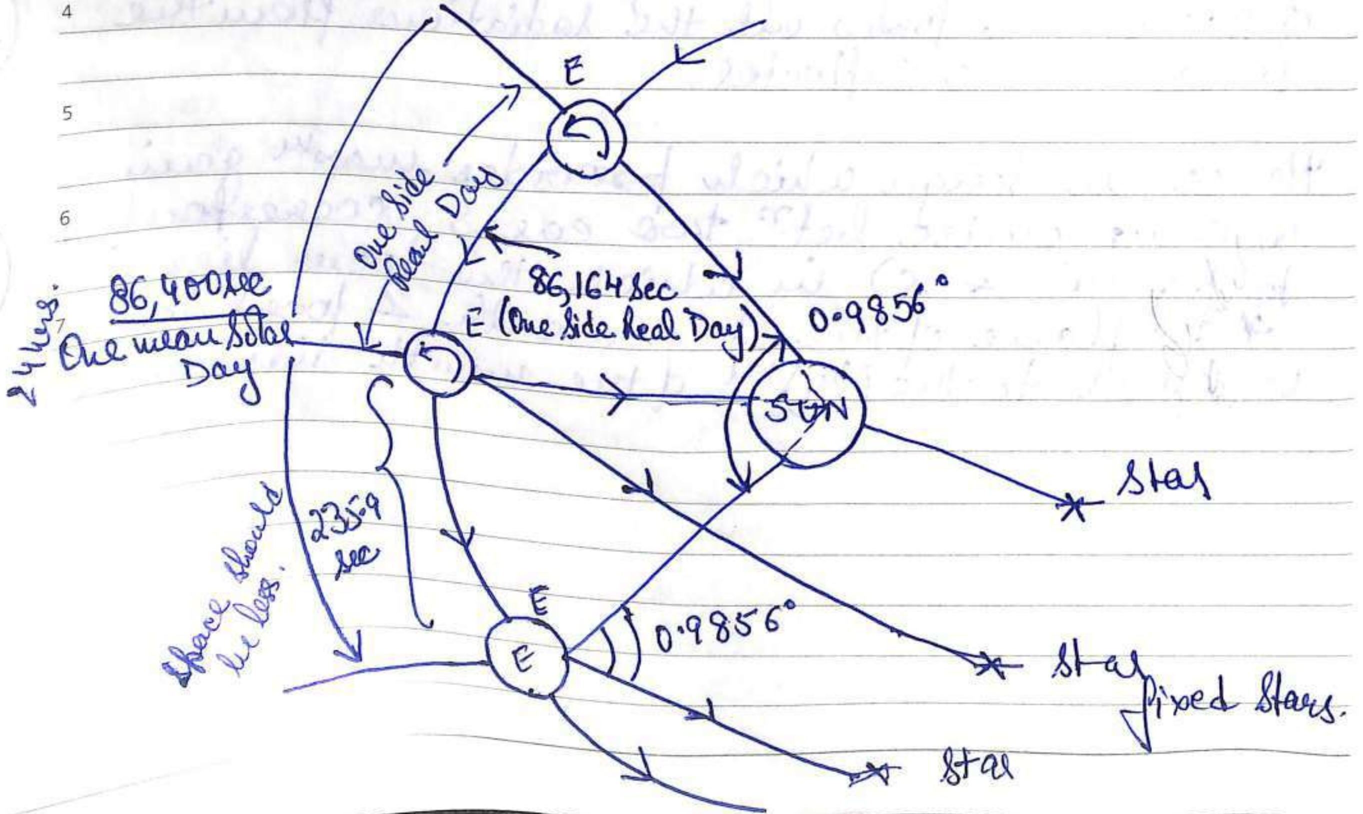
In fig (c) focal length is going beyond the mouth so in this case when focal length is large such that the focus lies beyond the open mouth it becomes difficult to focus all the radiations from the source on the reflector.

Hence the design which provides max^m gain is a compromise bet^n two cases corresponding to fig (a) & (c) in which the focus lies in the plane of the open mouth & focal length is equal to the (1/4)^th of the mouth diameter.

PM-SM

Side Real Day :-





80
~~70~~
150

83
56
139

Side Real Time is time measured relative to fixed Star.

It is seen that one complete rotation of the earth relative to the fixed stars is not a complete rotation relative to the Sun. This is because the earth moves in its orbit around the Sun.
A Side Real day are one rotation of the earth relative to the fixed Stars is less than the Solar day.

One Solar day is 24 hrs $= \overset{h}{24} \times \overset{m}{60} \times \overset{sec}{60}$
$= 86,400$ sec.

Measurement of the longitude on the earth surface require the use of side real ~~day~~ time.
Therefore hence, we see that the Satellites orbital period must be synchronized with the earth's rotation in interial space. The earth's period of rotation i.e. T_E is not a mean Solar day of 24hrs but is rather the side real day of 23hrs 56min 4.1 sec
The geometry is illustrated in the figure.
Length of the tropical year is 365.242 days.
So the earth travels in its orbit at an average rate of
$\frac{360°}{365.242} = 0.9856°$ per day.
The earth must rotate through an angle of $360° + 0.9856°$ $= 360.9856°$ in one $\overset{mean}{\wedge}$ Solar day. w.r.t. SUN.
Which is by definition the average time interval such that the meridian will allign itself with the SUN from one noon to the next.

mean solar day > mean side real day
by 235.9 sec.

This mean solar day is equal to 86,400 sec. Therefore, hence the time for the earth to rotate 0·9856° part one rotation is $\frac{0·9856°}{360·9856°} \times 86,400 = 235·9$ sec.

The side real period of rotation = 86,400 sec − 235·9 sec
= 86, 164 sec.
= 23 hrs 56 min, 4.09 sec.

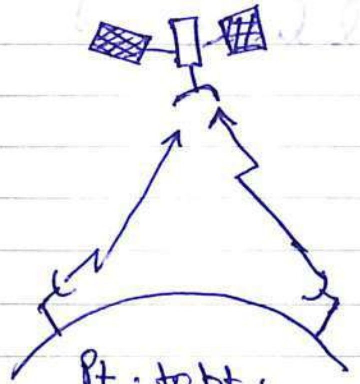
For calculation in satellite communicate one mean side real day is taken into consideration rather than one mean solar day.

1. mean solar day = 1·0027 37 9093 mean side realday
= 24 h 3 min, 56·55536 side realday
= 86,636·55536 mean side realday

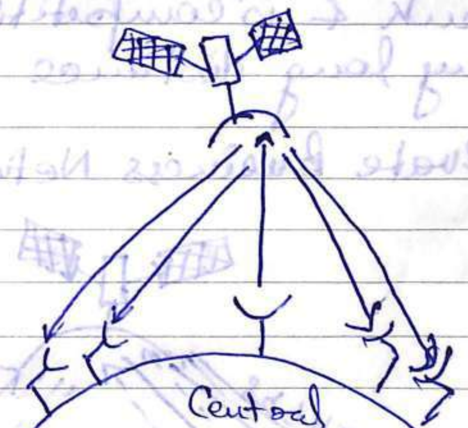
2: Mean Side Real Day = 0·9972 69 5664 mean solarday.
= 23 hr 56 min 04·09054 mean solar time
= 86,144·09054 mean solar seconds

Application of Satellite Communication:-

1. T.V. Broadcasting
2. Long Distance Telephone Tx.
3. Private Business Network.



Pt. to pt. Satellite Commn



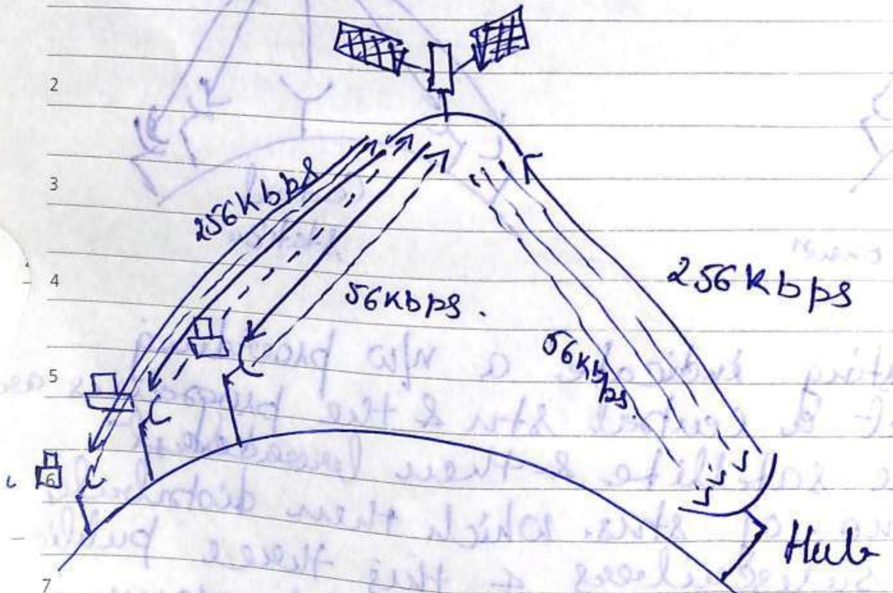
Central Station.

1. T.V. Broadcasting indicate a n/w providing programming at a central stn & the programs are txed to the satellite & then broadcast down to a no. of stns. which then distributes to various subscribers & this three public broadcasting n/w distributes its TV programming to various users by exclusively using the satellite channels. Most recent application is DBS (Direct Broadcast Satellite) where Tx-power is 160 w to 240 w. and the antena diameter is 0.5 to 0.8 m. Eg:- DTH.

2- Long Distance Telephone Transmission.

The satellite transmission is also used for PTP trunk b/w TV exchange offices in public telephone n/w. It is the optimum medium for high usage ~~international~~ trunk & is competitive with terrestrial systems for many long distance international links.

3. Private Business Network.



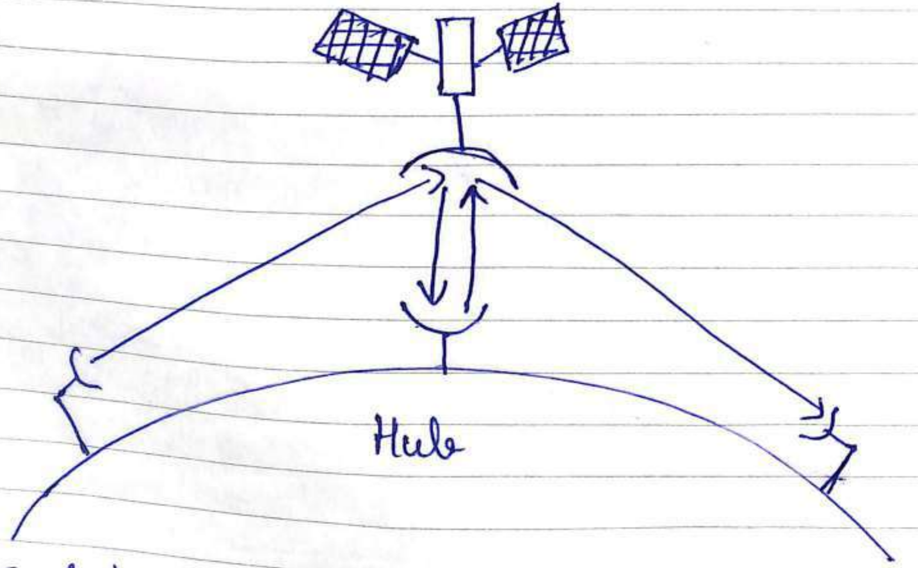
VSAT
Configuration using a Hub.
(Very Small Aperture Terminal)

VSAT retransmitted Satellite power = 20 to Antenna
9 diameter = 1 to 3 meter 50W.
Freq = Ku band.

10

Most VSAT systems operate in Ku band with earth stn
11 antenna diameter of 1-2 m & Rx - Tx power of 20 to 50 W. The earth stn Tx power is 1 to 2W. Earth stn are usually organized in star n/w in which the earth stn connect to the central hub stn through GEO satellite
1 and data rates on the lines are from few 1000 bps upto 256 Kbps.

2



VSAT Systems are used to link/connect business houses and stores to a central computer systems so that sales transactions can be completed more rapidly than by using Telephone lines & a modem ∴ Central office can rapidly distribute & collect info from a large no. of location in a region.

VSAT:-

9 These are used for providing one-way or two way.

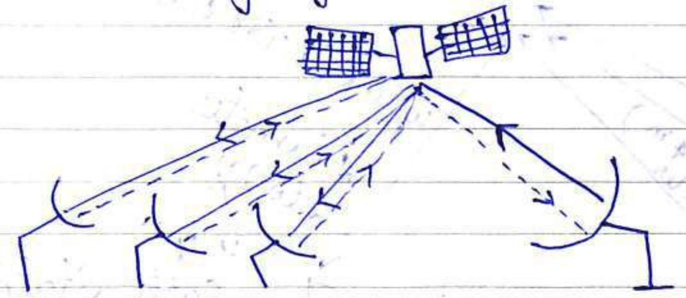
i) Data broadcasting
10 ii) point to point voice service
iii) one way video broadcasting service.

11

VSAT networks are ideal for centralised networks with
12 central HUB and a no. of geographically dispersed terminals.

1 Applications:-

i) Small or medium business with central office.
2 ii) Banking institution with branches all over the century.
iii) Reservation system.
3 iv) Airline Ticketing System.



7 Advantages:-

i) Wide geographical coverage
ii) High Reliability
iii) Low Cost
iv) Independance from terrestial Commn infrastructure.
v) Flexible n/w configuration.

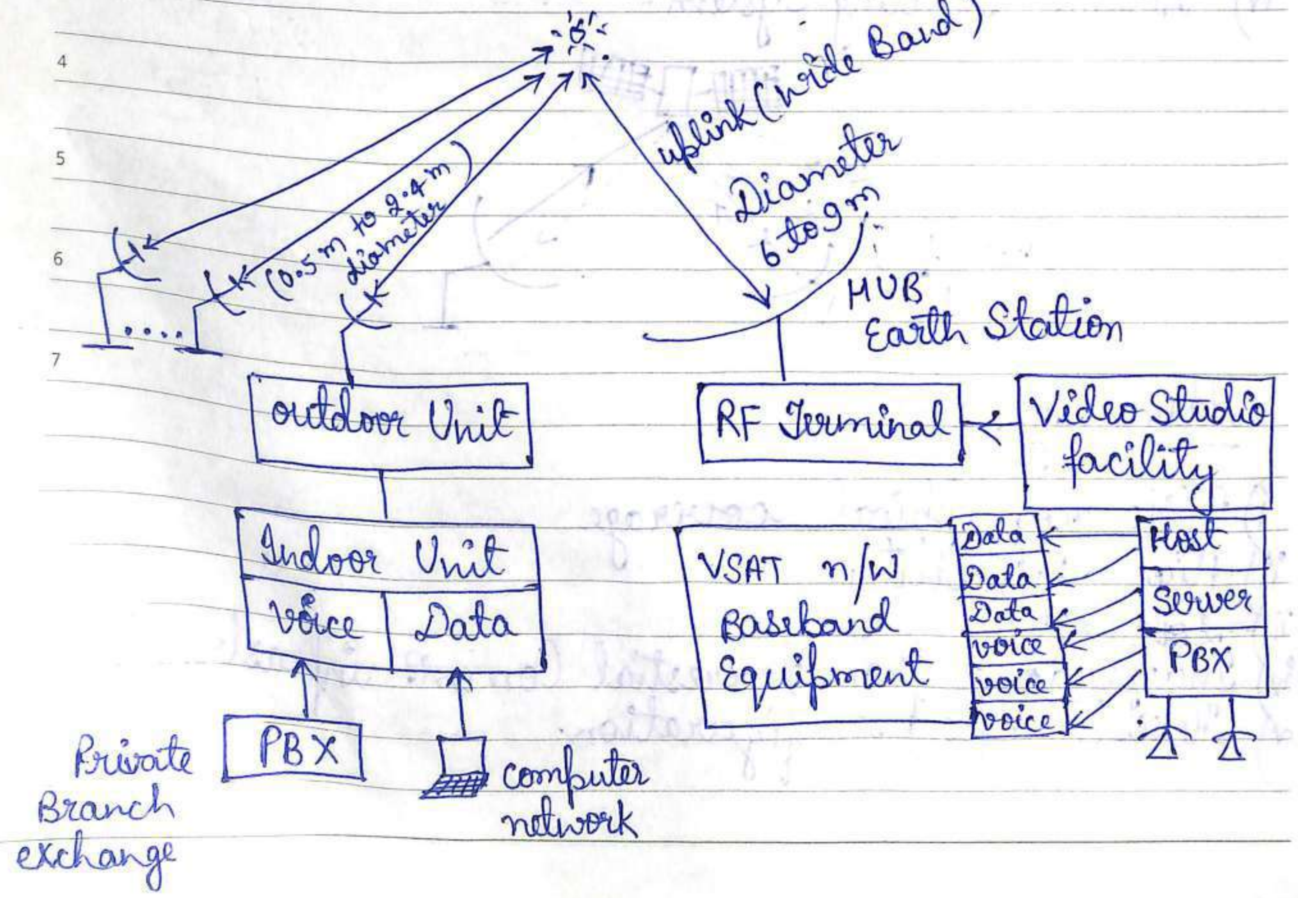
Disadvantages :—

i) Delay b/w transmission and reception of data (around 250 msec.—one way) due to use of GEO satellite.

Typical n/w shown with adjacent figures :—

i) Ground Segment :- Consisting of high performance Earth Station and large no. of low performance terminals referred as VSAT.

ii) Space Segment :- The GEO satellite acting on a common link between the HUB and the VSATs.



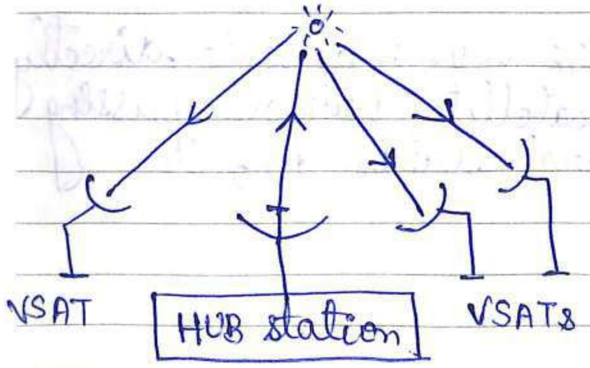
The HUB station consists of visually a large performance earth station comprising of an outdoor antenna or diameter 6 to 9 m for transmission & then it also consists of the RF antenna for coupling for uplink (wideband) on one digital carrier per network.

It also consists of baseband equipments comprising modems, multiplexer & encoder as well as a control centre for managing the n/w & various kinds of interfacing equipments to support wide varities of terrestial link. These terrestials links connects the sub-station to the headoffice or the data processing centre from where data has to be broadcasted.

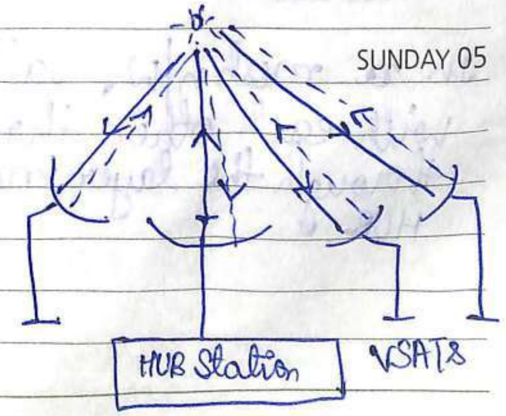
VSAT terminals are smaller & simpler in design as compared to the HUB station & comprise of outdoor antenna having diameter of (0.5 m to 2.4 m), RF terminal comprises of upconverters & power ampr. for uplink in case of bidirectional n/w.

Topology :—

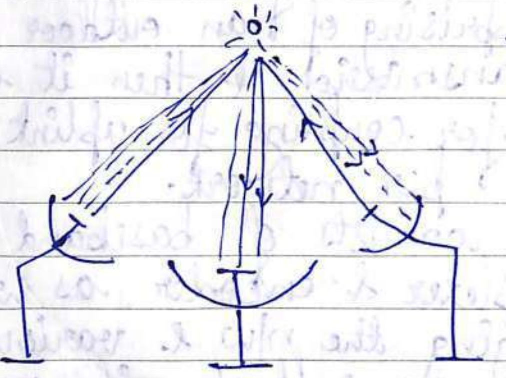
(i) Unidirectional star n/w



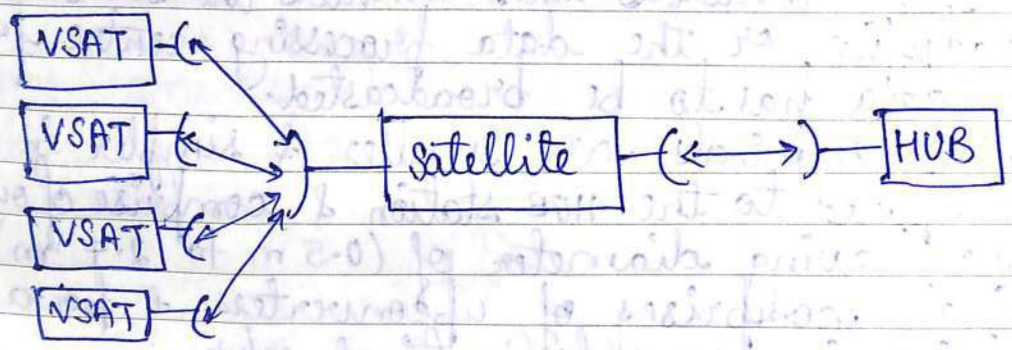
(ii) Bidirectional star n/w



iii) Mesh network



There is no HUB.
∴ Direct Comm^n

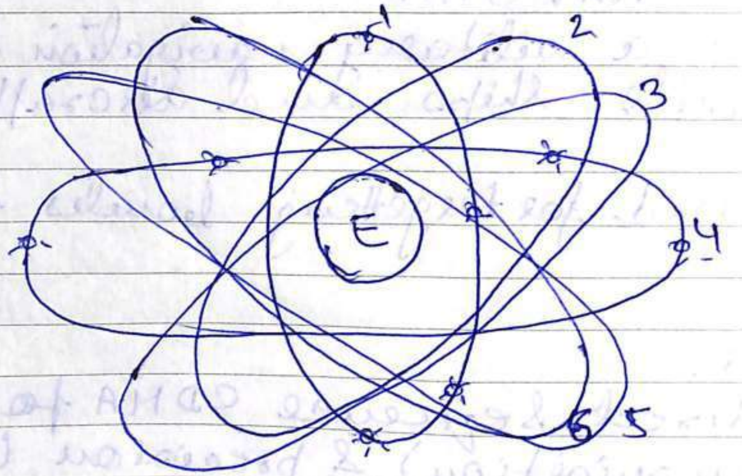


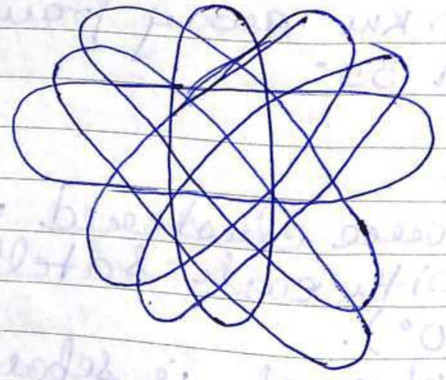
In a mesh n/w, all the VSATs communicate directly with each other through the satellite without passing through the layer master control station i.e, the HUB.

GPS (Global Positioning System) :- Satellite based.

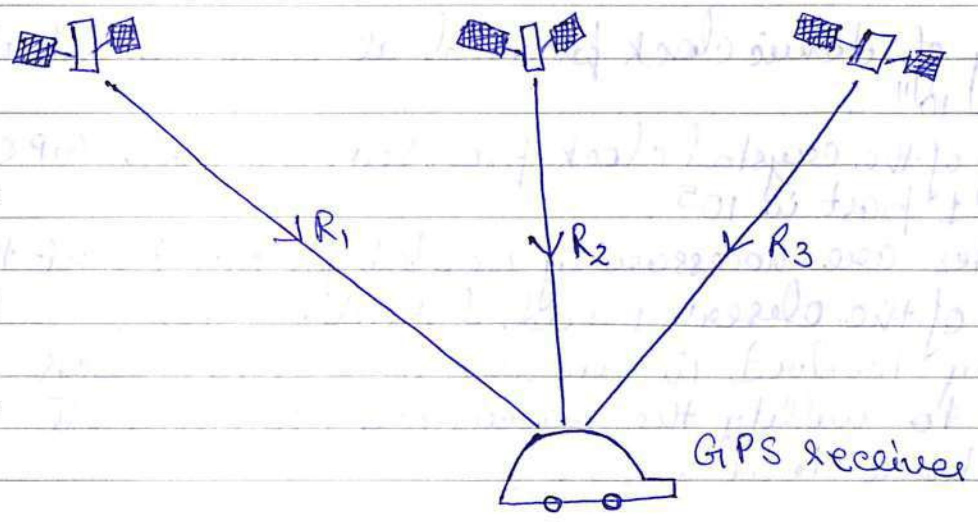
Originally called "NAV STAR"
Was developed as a military navigation system for guiding Missile, ships and aircrafts to their targets.
This was also used for targetting bombs & cruise missile.

Salient features.
- The GPS uses direct sequence CDMA for both C/A (Coarse acquisition) & precision (P codes) transmission.
- GPS uses 24 satellite in MEO orbit at an altitude of 20, 200 Km away from the surface of earth, inclined 55°.
- 4 in each orbit.
- GPS satellite are clustered in a groups of 4 satellite with each satellite orbit (separated by 60°).
(Ascending node of each is separated by 60°).
- The orbital period is approx. half the side real day (11hrs & 58 minutes).
(The time bet^n consecutive crossing and any particular longitude in the earth by any star, other than SUN).





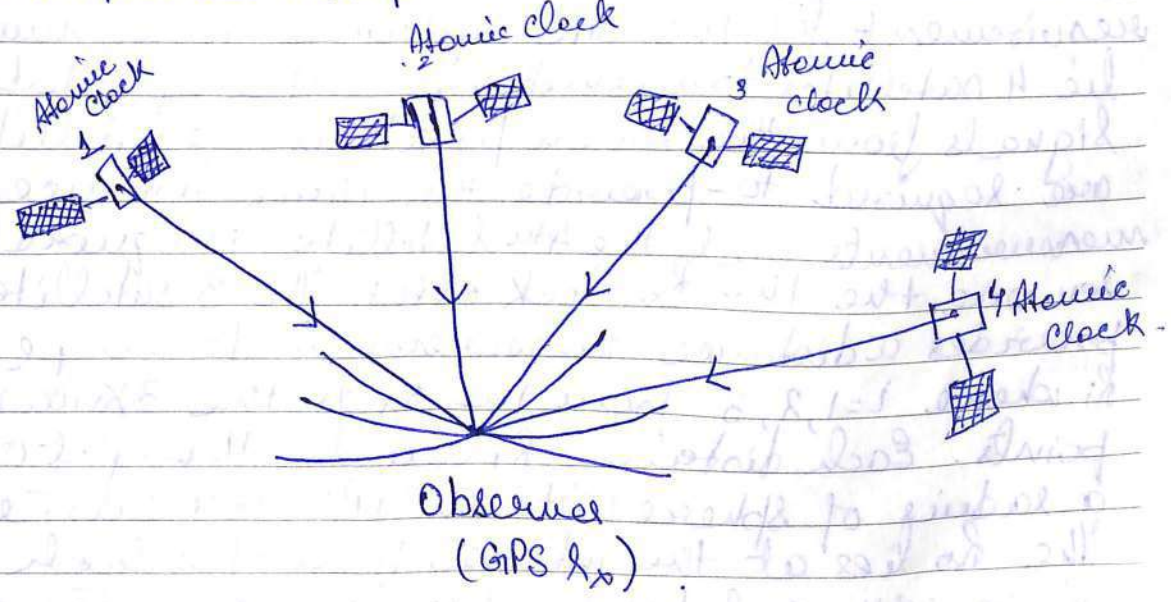
- There are total 6 orbits on which a cluster 4 satellite each will revolve around the earth.
- The orbits of 24 satellites ensures that at any time anywhere in the world GPS receiver can pickup the signal from atleast 4 satellites.



$$\underset{\text{Range}}{PR_i} = \underset{\text{Delay (time)}}{T_i} \times \underset{\text{Speed of signal}}{c}$$

GPS Rx - Crystal clk.

Position location Principle:-



→ Accuracy of atomic clock provided at each satellite is 1 part in 10^{11}.

→ Accuracy of the crystal clock provided at each GPS receiver 1 part in 10^5.

- 3 satellites are necessarily needed for pin-point the position of the observer and 1 satellite for inaccuracy involved in atomic or crystal clock (in order to nullify the inaccuracy) to calculate the pseudorandom range.

GPS system uses one way transmission from satellite to users so that user does not require at t_x but only a GPS R_x and the only quantity, the GPS R_x has to be able to measure is time for which propagation delay and hence the range to each satellite can be measured and ; basic requirement for the GPS system is, there must be 4 satellites transmitting suitably coded signals from the known position. 3 satellites are required to provide the three distance measurements and the 4th satellite is required to remove the the R_x clock error. The 3 satellites provides a distance measurements of range R_i where $i=1,2,3$ from the R_x to the 3 known points. Each distance R_i can be thought of as a radius of sphere with a GPS as a centre. The R_x lies at the intersection of 3 such sphere with a satellite of centre of centre of each sphere. Locally at the R_x, the spheres appear to be planes. The basic of principle of geometry is that intersection of the 3 planes completely defines a point. ∴ 3 satellites through measurement of their distance to R_x, define the R_x location closed to the surface of the earth. There is another pt. is outer space where the 3 spheres intersects but it is easily eliminated in the calculation process.

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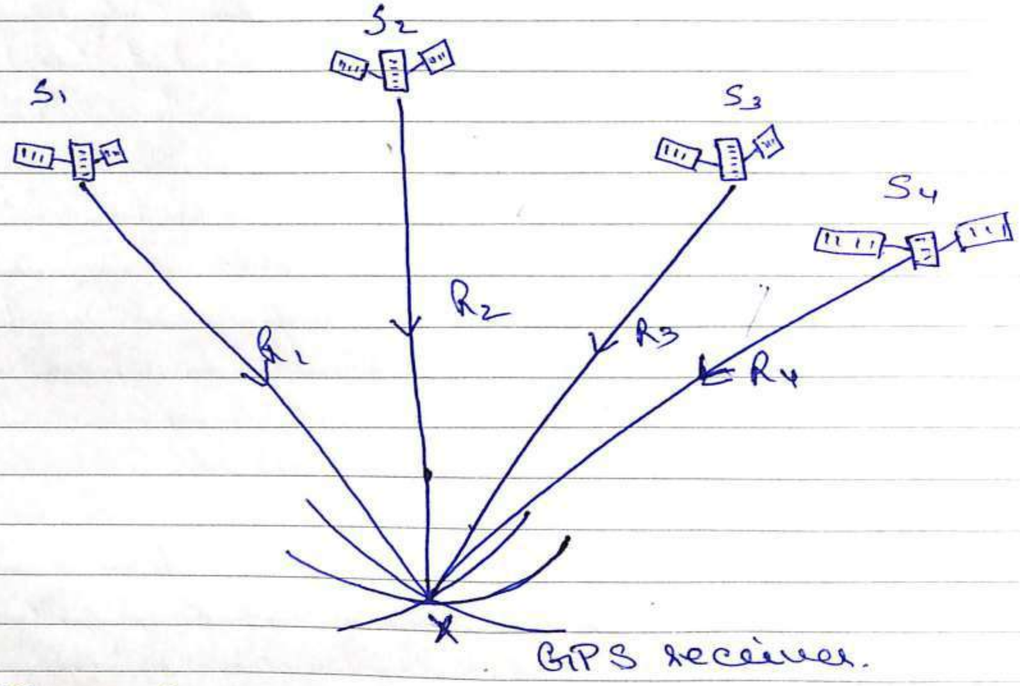
GPS



MEO :- 20,200 Km.
min^{m} 4 Satellites.

Trilateration method of position measurement of an object on the surface of earth.

All the spheres which are drawn and the distance bet^{n} known & unknown position gives the position of the object. Four spheres are drawn.

Ephemerics (Keplerian Elements).
a, e, Mo, ω, RA, ė.
3 positions known & one unknown.

Origin at the centre of the earth.

Geographical Equatorial Coordinate System

Rectangular coordinate systems are being used.

Earth Cent~~ered~~ Earth fixed (ECEF) Coordinate System.

GPS r_x is located at pt. X at the radius of ~~th~~ spheres, where 3 spheres of radii r_1, r_2, r_3 intersect and the centre of the 3 spheres are the 3 GPS satellites i.e. S_1, S_2, S_3. If the distance r_1, r_2, r_3 are measured the location pt. x can be uniquely defined. We define the coordinate of the GPS r_x and satellite in a rectangular coordinate system with its origin at the centre of the earth. This is called ECEF coordinate system.
Z-axis of this coordinate system is directed to the earth north pole.
X-axis and Y-axis are ~~at~~ the equatorial plane. X-axis passes through the meridian through the Greenwich of England. (longitude will be 0)
Y-axis passes through 90° east meridian. The ECEF Coordinate system rotates with the earth.
The receiver coordinate is U_x, U_y, U_z.
Satellite have coordinate system (x_i, y_i, z_i) where $i = 1, 2, 3, 4$.
Since the distance 'R' between the two objects 'A' and 'B' in a rectangular coordinate system as

SUNDAY 19

$$R^2 = (X_A - X_B)^2 + (Y_A - Y_B)^2 + (Z_A - Z_B)^2.$$

Hence the eq^{n} which relates the pseudo range to time delay are ranging eq^{n} :-

Atomic clocks at satellite & crystal clock at the Rx therefore leads to offset and this offset is given by τC

X_1 - ~~object~~ - satellite
U_x - ~~satellite~~ Rx

3 unknown eq.

$$(X_1-U_x)^2+(Y_1-U_y)^2+(Z_1-U_z)^2 = (PR_1-\tau C)^2.$$
$$(X_2-U_x)^2+(Y_2-U_y)^2+(Z_2-U_z)^2 = (PR_2-\tau C)^2$$
$$(X_3-U_x)^2+(Y_3-U_y)^2+(Z_3-U_z)^2 = (PR_3-\tau C)^2.$$
$$(X_4-U_x)^2+(Y_4-U_y)^2+(Z_4-U_z)^2 = (PR_4-\tau C)^2.$$

4 eq^n & 4 unknowns.

Where τ is the Rx clock error i.e. the offset.

The position of the satellite at the instant of time it sends the timing signal which is actually the long sequence of bits which is obtained from the ephemeris data tx along with the timing signal. The Rx calculates the coordinate of the satellite related to the ~~sender~~ centre of the earth i.e. X_i, Y_i & Z_i. And then solves the 4 ranging eq^n for the 4 unknown using standard numerical technique for the sol^n of non-linear simultaneous equation. The 4 unknowns are the location of the GPS receiver i.e. defined by U_x, U_y & U_z related to the centre of the earth & the clock offset torque & Rx position is being referenced to the surface of the earth & can be displayed in latitude, longitude & elevation.

In GPS Rx there are 24 satellites in total so that any object, anywhere, anytime throughout the globe. They are bifurcated into 6 orbits each having 4 satellites & they are visible by one object from the surface of the earth.

U_x, U_y, U_z - 3 unknowns & ~~4th~~ one, related to τC which is the offset) (offsetting the time)

GPS Signal Structure :-

GPS signal contains three types of information

i) Pseudorandom code
ii) Ephemeris Data
iii) Almanac Data.

1. Pseudo random Code (PRN Code) :-

* PRN code is an id code that identifies which satellites is transmitting information and is used for Pseudo range calculation.
* Each satellite transmits unique PRN code.

2. Ephemerics Data :-

(a, e, i, RA, ω, M₀)

* Contains data information about the health of the satellite, current data and time.

3. Almanac Data :-

* Tells the GPS receiver where each satellite should be at any time during the day. It also contains information on clock corrections and atmospheric data parameter.

All these informations is transmitted at two microwave frequency ; L_1 :- 1575.42 MHz.
L_2 :- 1227.60 MHz.

All satellite transmit on the same frequency but with different codes. However diff^n codes are transmitted by each of the satellite. This enables GPS receivers to identify which satellite is transmitting the signal.

Two types of Codes are used for transmitting the signal from satellite

↓ Coarse Acqusition (C/A) (Civilian Purpose, Uncrypted Code)

⇓

L_1 :- 1575.42MHz → Modulated by 1.023Mbps PN sequence

& L_2 :- 1227.60MHz → Modulated by 10.23Mbps.

↓ Precision Code (P Code) (Encrypted, Military)

⇓

L_2 :- 1227.60MHz.

↓

This carrier frequency is modulated with 10.23Mbps pseudorandom (PN) bit sequence.

Also Called

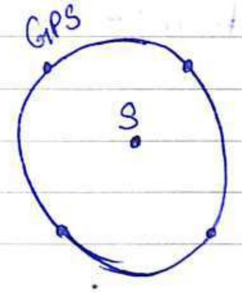
Geocentric Equatorial Coordinate System.

⇓

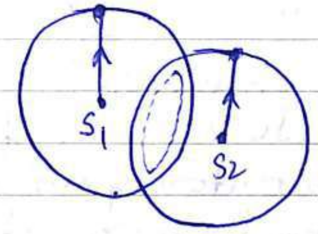
Earth Centred Earth Fixed Coordinate System.

helps in Determining the range and time correction.

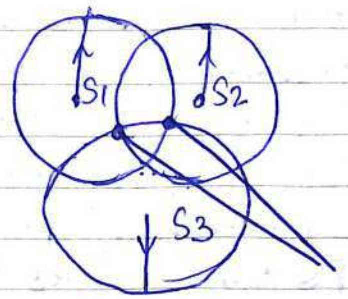
At any pt of the sphere, radii from the Centre of GPS Sx.



If position of 1 satellite known then it the object lies at any pt on the sphere.



2 satellites position is known and the position of the object on the centre of earth will lie on the intersection of the two circle we will have the object.



If position of 3 satellite is known then the ~~object lies at 2 pts~~ unknown position of object can be determined by using trilateration method and ephemeric data

2 pts are there where we still don't know the ~~GPS~~ position where GPS Rx lies. Hence mathematical formulation is used to pin pt. the GPS receiver. One is real & other is virtual thus can be with the help of virtual ~~correct~~ one can be discarded.

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No LEO & GEO ; HEO is used so that the no. of satellites required are 24 only.

More satellites will be required

i) Distance
ii) Because polar region will not be covered.

Constituents of GPS System :-

1. Space Segment :-
2. Control Segment :-
3. User Segment :-

Space Segment	Control Segment	User Segment
1. Space Segment contains 24 satellites constellation placed in 6 orbits (4 satellite in each orbit)	1. There are / Comprises of World Wide network of 05 monitoring stations and one master control station.	Includes All military & Civilian GPS receivers intended to provide position, velocity time information
2. Satellite orbit is circular (HEO) at an altitude of 20,200 Km inclined at 55° to the equator.	2. Each monitor station provided with high fidelity GPS Rx and an oscillator to continuously track all the GPS Rx in view	GPS Rx are either hand held or installed on aircraft, submarines, ships tanks, cars & trucks.
3. Orbital period half the side real day (11hr, 58min)		
4. Separation of the satellites in one orbit / same orbit is 60°.		
5. All GPS Rx satellites are equipped with atomic clock having very high accuracy upto 3 nano second and satellite transmits sigs on two frequency i.e. L_1 :- 1575.42MHz L_2 :- 1227.60MHz.	3. The data from these stations are send to the master control stations which computes the precise and updated information on satellite orbit and clock station every 15 minutes.	Most GPS Rx tracks the path of the user as they move. They also tell us the distance they have travelled, their speed & time of travel.

UNIT-V

Satellite Packet Communications

Satellite Packet Communication

1. Introduction

Satellite communication refers to radio-link (microwave Line of Sight) communication using one or more radio frequency retransmitters located at great distances from the terminal earth stations. The use of satellite in communication systems has become so habitual it is almost taken for granted. The ubiquity of direct to home (DTH) satellite dishes in cities around the world is a testimonial to this fact. These antennas are used for reception of satellite signals for television. Satellites also form an essential part of the communication system worldwide carrying a large amount of data and telephone traffic in addition to multimedia signals. The use of satellite technology for communication purposes comes with attendant important features, which are not readily available through other means of communication namely:

1. A satellite in the geosynchronous orbit effectively covers close to 120 degree sector of the earth surface, thus making beyond-LOS communication a reality, i.e. communication is possible beyond earth curvature (which sets the limit line of sight).
2. Satellite communications is not concerned with either political or geographical boundaries.
3. Satellites provide both fixed and mobile communication service, the former is called fixed satellite service (FSS), while the latter interconnects with moving object (e.g. aircraft) from a ground control station.
4. Satellites offer last-mile communication solution to remote communities that may be difficult to access otherwise.
5. Satellite communication is employed in remote sensing for prospecting natural resources as well as monitoring atmospheric conditions.
6. Three communication satellites situated at the geostationary altitude and spaced 120 degrees apart could interconnect over 90% of the earth.
7. A satellite communication network is easily expandable.

Every communications satellite in its simplest form performs the task of transmitting information from a source earth station to the satellite (this is called the uplink). This is followed by a retransmission of the received and processed information from the satellite back to the ground (this is called the downlink). The downlink may either be to a select number of ground stations or it may be broadcast to all receiving terminals in the satellite's footprint. We focus on specific protocols or methods guiding access to the medium used for transmission and retransmission of packets (messages) to and from the satellites. These protocols are referred to as Medium Access Schemes. Medium Access Control (MAC) schemes are mechanisms for sharing a single link. MAC schemes are essentially multiplexing schemes. Message access on any system can be of three types:

1. Conflict-free Scheme
2. Contention (random access) Scheme
3. Reservation (controlled access) Scheme

There are also hybrid schemes between contention and reservation. We consider the message transmission by FDMA using the M/G/1 Queue under the Conflict-free Scheme and message transmission by TDMA using Pure ALOHA, Slotted ALOHA, Tree Algorithm and Packet reservations under the Contention/Random Access Scheme.

2. Message Transmission by FDMA

With Frequency Division Multiple Access (FDMA) the entire available frequency channel is divided into bands and each band serves a single station. Every station is therefore equipped with a transmitter for a given frequency band, and a receiver for each band. To evaluate the performance of the FDMA protocol, we assume that the entire channel can sustain a rate of R bits/sec which is equally divided among M stations i.e. R/M bits/sec for each. The individual bands do not overlap as such there is no interference among transmitting stations. This allows for viewing the system as M mutually independent queues. Each of these queues has an individual input process governing the packet generation process for that user. If the packet length is a random variable P, then the service time afforded to every packet is the random variable $T = MP/R$.

To evaluate the throughput of the individual station we note that every bit transmitted is a "good" bit and thus the individual throughput is the fraction of time the individual server is busy. The total throughput is M times the individual throughput while the average packet delay can be obtained by applying Little's result to the individual queue. In general, all parameters relating to FDMA can be obtained by applying known results of the corresponding queue discipline.

a. M/G/1 QUEUE

Consider a queuing system, in which arrivals occur according to a Poisson process with parameter and in which x is the service rendered to the customers, is distributed according to a distribution (t). In such a queuing system, an outside observer sees the number of customers in the system as equal to that seen by an arriving customer, which equals that seen by a departing customer. The following holds for an M/G/1 queuing system:

$$D = x + W = x + \frac{\lambda x^2}{2(1-p)}$$

Where: D= Average delay time; $p = \lambda x$= Load factor; W= Queuing time.

Therefore, for an FDMA system, considering a typical user that generates packets according to a Poisson process with rate λ packets/sec and its buffering capabilities are not limited, the time required for the transmission of a packet is . Each node can therefore be viewed as an M/G/1 queue since each packet size is not constant. Thus, using the known system delay time formula for M/G/1 queuing systems we get that the expected delay of a packet is:

$$\mathbf{D=T+\frac{\lambda T^2}{2(1-\lambda T)}}$$

And the delay distribution is given by,

$$D^* = X^*(s)\frac{s(1-p)}{s-\lambda+\lambda X^*(s)}$$

Where (s) is the Laplace transform of the transmission time.

3. Message Transmission by TDMA

In the time division multiple access (TDMA) scheme the entire time frame is divided into time slots, pre-assigned to the different stations. Every station is allowed to transmit freely during the slot assigned to it, that is, during the assigned slot the entire system resources are devoted to that station.

Techniques based on contention are suitable for traffic that is bursty in nature. Centralized control is absent in a contention-based system, as such when a node needs to transmit data, it contends for control of the transmission medium. The major advantage of contention techniques is simplicity, as they are easily implementable in individual nodes. The contention techniques are efficient under light to moderate network load, but performance rapidly degrades with increase in load level. Message transmission by TDMA can be done using the ALOHA protocol, packet reservation and tree algorithm.

The ALOHA scheme was invented at the University of Hawaii for the purpose of interconnecting remote stations and data terminals to a central server over a packet radio network. The ALOHA model *vis-a-vis* satellite communications uses satellite connections between earth stations. The model consists of three top-level modules: an earth station (earth segment), a central satellite station (space segment) that serves as the communications link between the earth stations and a statistics module. Towards achieving the objective of a simple design, some functions such as satellite round-trip delay, collision detection, and transmission delay are implemented on the satellite. Any collision detected during the receipt of a packet by the satellite is tagged before onward broadcast to receiving earth stations. A continuous retransmit process is initiated by the transmitting earth station until it receives the original packet back without the collision flag. At which point the packet is discarded, and the transmission of the next packet in queue commences. Suffice to note here that all packets are equal in size and both pure and slotted ALOHA operations are supported by the earth station module

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a. Pure ALOHA Satellite Packet Switching

Stations are allowed random access of the satellite through a common radio frequency band and the satellite broadcasts all received signals on a different frequency band. This enables the stations to perform their duty of monitoring for the presence of packet collisions. The stations implement the simplest protocol; whenever it has a packet to send, it simply does so. In this setup, packets will suffer collision and colliding packets are destroyed. A station determines whether any of its sent packets has suffered a collision or not by monitoring the signal sent by the satellite, after the maximum round-trip propagation time.

If all packets have a fixed duration of T, then a given packet will suffer collision if another station starts to transmit at any time from T before to until T after the start of the packet. This gives a vulnerable period of 2T. The channel utilization can be calculated based on this assumption. The channel utilization, measured as the channel throughput S, in terms of the available channel capacity G is given by $S = Ge$!!! S is maximum and equals $1/2e$ at $G = 1/2$, which is approximately 0.18. This value is referred to as the capacity of the pure Aloha channel i.e. 18%.

b. Slotted ALOHA

The Pure Aloha implemented with a slotted channel variation is known as the slotted Aloha protocol. For the slotted Aloha variant, all packets are of equal length and time is slotted. The packet transmission time a full slot. Packets are only transmitted in the next subsequent slot to their arrival slot. It also assumes that there is no buffering, i.e. a station never has more than one packet to transmit in a single time slot, in which case, the station would have needed to buffer one or more packets for subsequent transmission. To accommodate the “*no buffering*” assumption, it assumes that there is an infinite number of stations, with each new arrival from a new 'source' station. Inevitable collision occurs if more than one station venture to transmit packets in one and the same time slot, and consequently the receivers cannot receive the packets correctly. Successful transmission happens only when there is exactly one packet transmitted in a slot. If no packet is transmitted in a slot, the slot is called idle. If there is a collision, the colliding packets are retransmitted at a later slot after a randomly chosen back-off period. Such packets are also called backlogged packets.

Slotted ALOHA was developed as an improvement on the efficiency of pure ALOHA. In this protocol, the channel is divided into slots equal to T (duration of packet transmission). Packet transmission is initiated only at the beginning of a slot. This reduces the vulnerable period in half from 2T to T and improves efficiency significantly by reducing the probability of collision. Channel utilization, measured as throughput S, in terms of the available channel capacity G is given by $S = Ge!!$. This gives a maximum throughput of 37% at $G = 1$ i.e. 100% of offered (available) channel capacity.

c. Tree Algorithm

This is a collision resolution protocol (CRP). As opposed to the instability of the ALOHA protocol, the efforts of CRP are concentrated on resolving collisions as soon as they occur. Here, the fixed-length packets involved in collision participate in a systematic partitioning procedure for collision resolution, during which time new messages are not allowed to access the channel. The stability of the system is ensured provided that the arrival rate of new packets to the system is lower than its collision resolution rate. The tree-type protocols have excellent channel capacity capabilities, but are vulnerable to deadlocks due to incorrect channel observation.

The basic form of the Collision Resolution Protocol is the Binary-Tree Algorithm. According to this protocol when a collision occurs in a slot r, all stations that are not involved in the collision wait until the collision is resolved. The stations involved in the collision split randomly into two subsets. The stations in the first subset retransmit in slot $r + 1$, while those in the second subset wait until all those in the first finish transmitting their packets successfully. If slot $r + 1$ is either idle or contains a successful transmission, the stations of the second subset retransmit in slot $r + 2$. If slot $r + 1$ contain a fresh collision, the procedure is repeated. A collision is resolved when the all the transmitting stations know that all packets involved in the collision have been transmitted successfully. The time interval starting with the original collision (if any) and ending when this collision is resolved is called Collision resolution interval (CRI). The Operation of a binary-tree protocol can also be described by the Stack Algorithm.

The performance of the binary-tree protocol can be improved in two ways. The first is to speed up the collision resolution process by avoiding certain, avoidable, collisions. The second is based on the observation that collisions among a small number of packets are resolved more efficiently than collisions among a large number of packets. Therefore, if most CRIs start with a small number of packets, the performance of the protocol is expected to improve. Examples of improved binary-tree protocols are:

1. The Modified binary-tree protocol:- Its operation requires ternary feedback, i.e., the users have to be able to distinguish between idle and successful slots.
2. The Epoch Mechanism:- Its operation models the system in such a way that the CRI starts with the transmission of exactly one packet (yields a throughput of 1) by determining when packets are transmitted for the first time.
3. The Clipped binary-tree protocol:- This improved on the Epoch mechanism by adopting the rule that whenever a collision is followed by two successive successful transmissions, the packets that arrived in .

d. Packet Reservation

Dynamic channel allocation protocols are designed to overcome the drawback faced by static conflict-free protocols, which involves (inefficient) under utilization of the shared channel, especially when the system is lightly loaded or when the loads of different users are asymmetric. The static and fixed assignment in these protocols, cause the channel (or part of it) to be idle even though some users have data to transmit. With dynamic allocation strategies, the channel allocation changes with time and is based on current (and possibly changing) demands of the various users. The more responsive and better usage of the channel achieved with dynamic protocols does not come for free: it requires control overhead that is unnecessary with static protocols and consumes a portion of the channel. An example of a protocol that belongs to the family of dynamic conflict-free protocols is the Mini Slotted Alternating Priority (MSAP) protocol. It is designed for a slotted system, i.e., one in which the time axis is divided into slots of equal duration and where a user's transmission is limited to within the slot (this represents a TDMA system).

The MSAP protocol guarantees conflict-free transmission by way of reservation. All these protocols have a sequence of bits precede serving to reserve or announce upcoming transmissions (this is known as the reservation preamble). To ensure freedom of transmission conflicts it is necessary to reach an agreement among the stations on who transmits in a given slot. This agreement involves collecting information as to which are the ready stations, i.e., those who request channel allocation, and an arbitration algorithm by which one of these stations is selected for transmission.

This latter mechanism is nothing but imposing a priority structure on the set of earth stations each of which constitutes a separate priority class. The MSAP protocol handles properly various such structures. The priority enforcement is based on the observation that if in the most recent slot the channel was allocated to station i then it must have been the one with the highest priority. Defining the priority structure is thus the determination of the transmission order after the transmission of a station. There are three types of priority structures: a) Fixed, b) Round-Robin and c) Alternating priority structures. Next, MSAP identifies the station with the highest priority among those wishing to transmit, by means of reservations. Denote by t the maximum system propagation delay, that is, the longest time it takes for a signal emitted at one end of the network to reach the other end. Let every slot consist of initial M-1 reservation "*minislots*" each of duration t, followed by a data transmission period of duration T, followed by another *minislot*. Only those users wishing to transmit in a slot take any action; a user that does not wish to transmit in a given slot remains quiet for the entire slot duration. Every station wishing to transmit knows its own priority. The specific choice of the minislot duration ensures that when a given user transmits in a minislot all other users know it by the end of that minislot allowing them to react appropriately. The additional minislot at the end allows the data signals to reach every user of the network. This is needed to ensure that all start synchronized in the next slot, as required by the reservation scheme.

If all slots are used, i.e. in the highest possible load circumstances, the maximum throughput is:

$$S = \frac{T}{T + Mt} = \frac{1}{1 + Ma}$$

Where $a = \Delta\ t\ T$= characteristic parameter of the system, M is the number of minislots.