Unit-2 : Satellite Communication Principles

| Unit 2-1 |

"Satellite is an object which goes around another object in free space due to mutual gravitational forces. The path traced out is according to Kepler's law".

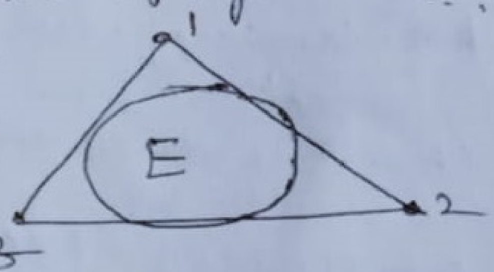
Introduction: In terrestrial comm due to radio horizon (bulging nature of earth) we use repeaters for long distance communication. Repeater is a Rx + Tx connected back to back for signal conditioning. This arrangement is not possible in hostile terrains like hilly region, forests, deserts, on sea/ocean.

Hence for long distance communication a satellite is better. Three geosynch satellites are sufficient for global comm.

Region 1 – Europe, Africa, Russia, China, Mongolia etc

Region 2 – N-S America, Greenland Canada

Region 3 – Asia, Australia, NZ, South Pacific



- f-bands are same as in μwave but additional bands like VHF(.1 to .3 GHz), UHF (.3-1 GHz), V (40-75 GHz), W(75-110 GHz) mm (110-300 GHz) & μm (300-3000 GHz) are also used.
- Some of the Satellite Services are

✓ FSS – Fixed —"— : linking Tel N/ws, Tx & Rx TV signals,
(C-band)

✓ BSS – Broadcasting —"— For DTH
(Ku band)

✓ MSS – Mobile —"— Land Mobile, Maritime (Marine), Aeronautical
(L)

✓ NSS – Navigational —"— GPS, Sat for Metrological (weather monitoring), search & rescue
(L)

INTELSAT — INternational TElecommunication SATellite is an organization of 140 member countries, of 3 regions using services of geosynch. satellites. [Unit-2-2]

R1 - AOR - Atlantic ocean region

R2 - IOR - Indian -"- -----

R3 - PR - Pacific -"- -----

Basic laws & Definitions

Satellite orbiting around earth follow basic planetary motion governed by kepler laws (J. kepler in 1571-1630). Newton derived these laws using principles of gravitation.

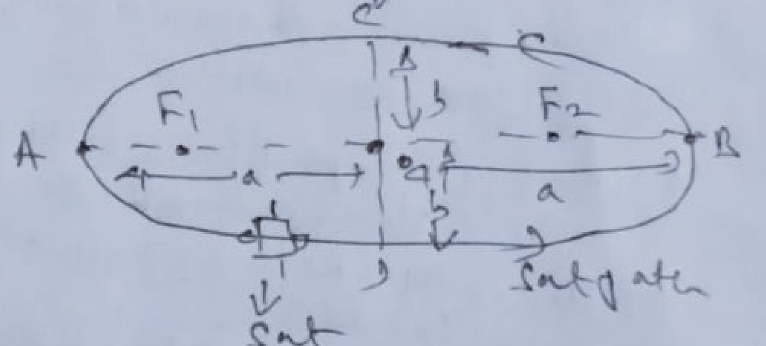
Kepler's first law: "Path followed by a satellite will be an ellipse"

AB - Semimajor axis length 2a

CD - -"- minor -"- -"- 2b

O - centre of ellipse

F_1 & F_2 - Focal points



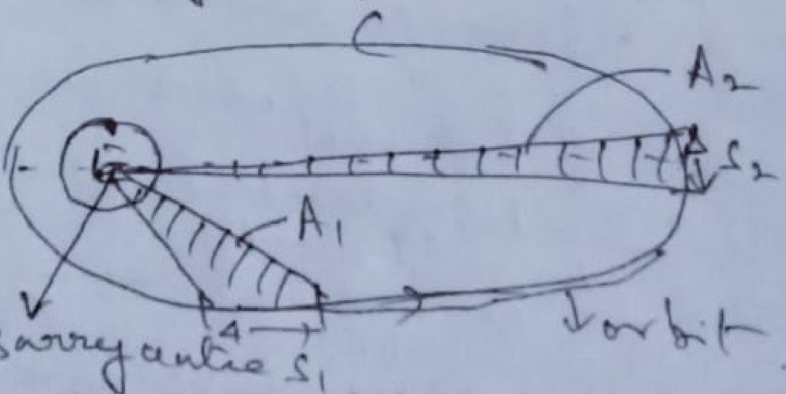
e (eccentricity) $= \frac{\sqrt{a^2-b^2}}{a}$ where $0 < e < 1$. If $e = 0$ for $a = b$ path becomes circular

Kepler's second law: - "For equal time intervals, sat will sweep out equal areas in its orbital plane, focussed at the barycentre"

For equal time intervals

$A_1 = A_2$

S_1 & S_2 distance travelled at instances t_1 & t_2



$V_2 < V_1 \Rightarrow$ Sat takes longer time to travel a given distance if it is farther from earth

Unit-3

Kepler's III law:- "Square of the periodic time of orbit is proportional to the cube of the mean distance between the bodies 'd'.

i.e $d^3 = \mu/n^2$ ——(1) — under ideal condition (No drag from earth)

where n = mean motion of the satellite in rads/sec

μ = Earth's geocentric gravitational constant

$= 3.986005 \times 10^{14} m^3/sec^2$

orbital period of sat in secs is $= P = 2\pi/n$

Q:- Calculate approximately radius geo-synch orbit

Soln:- orbital period = 1 day = 86,400 secs

$\therefore n = \frac{2\pi}{86,400} = 7.272 \times 10^{-5}$ rads/sec

From (1) $d = (\mu/n^2)^{1/3} = 42,241 km$

As geo synch orbit is circular, d is the radius of the orbit

Kepler's law also gives following information:

1) Velocity of sat in its orbit (V_s)

$V_s = \sqrt{\frac{g_0}{r_e + h}}$ g_0 = Gravitational coeff or Kepler's coeff $= 3.9832 \times 10^5 km^3/sec^2$

r_e = radius of earth, h = height of orbit above earth.

Generally, $g_0 = GM$ where $G = 6.672 \times 10^{-11} N\text{-}m/kg^2$

M = Mass of earth $= 5.97 \times 10^{24} kg$

2) Time period of the orbit (T_s) $\boxed{\text{Unit 2-4}}$

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

From (1) & (2) it is clear that as $h \uparrow$, $T_s \uparrow$ & $V_s \downarrow$.

Some Important definitions

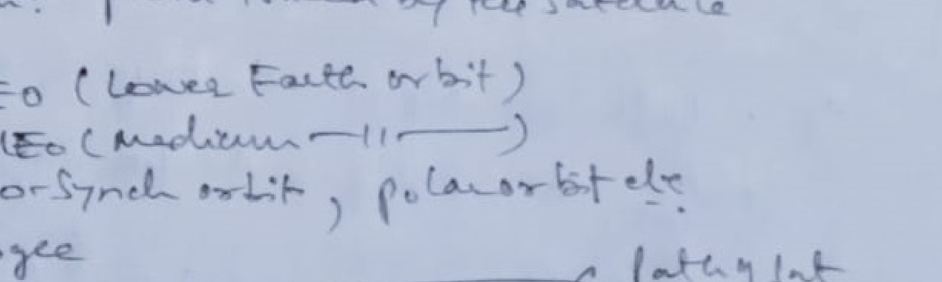
1. Primary body: Earth around which satellite revolves
2. Secondary body: Satellite which revolves around the pri. body
3. Satellite path: path traced by the satellite or orbit

   Ex: LEO (Lower Earth orbit)
   MEO (Medium — " —)
   Geo-synch orbit, polar orbit etc.

4. Perigee & Apogee (PG) (AG)

   Point of transition in its path very close to earth.

   — " — farthest from earth.



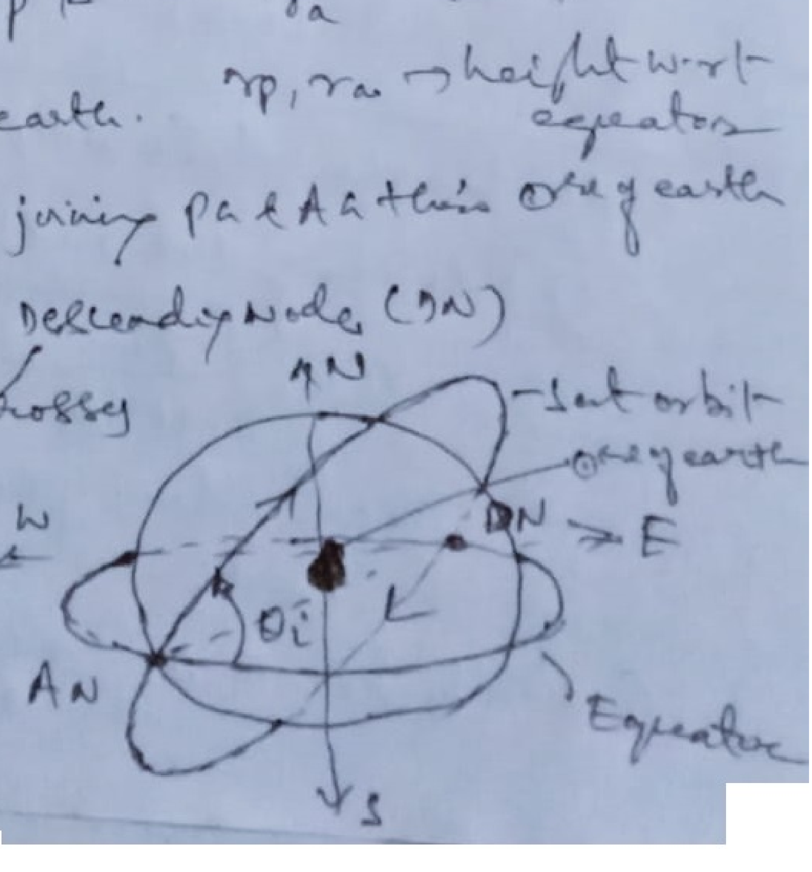
rp, ra → height w.r.t. equator

5. Line of aptides: Line joining PG & AG through centre of earth

6. Ascending node (AN) & Descending node (DN)

   Point where orbit of sat crosses the equatorial plane going from S to N.

   — " — N to S.



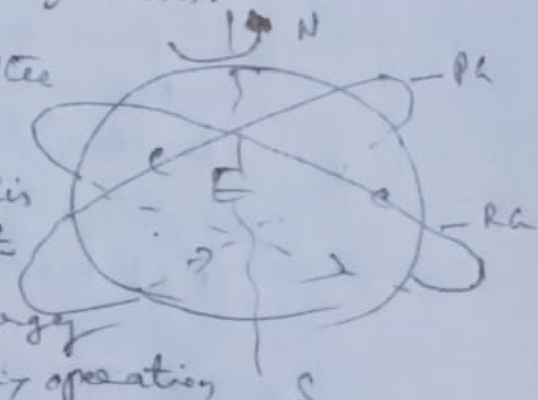
7) LN - line of Nodes: line joining AN & DN through Centre of the earth

8) θ_i — Angle of inclination of an orbit: Angle between earth's equatorial plane & orbital plane, measured at AN w.r.t equator going from E to N.

9) PG (Prograde) & RG (Retrograde) orbits

PG ↓ An orbit in which sat moves in the same direction as earth's rotation,

Here $0° < \theta_i < 90°$. Adv:- Earth's rotational vel provides thrust to vel of sat in its orbit saving energy for (i) launch (ii) house keeping operation



RG: Here the direction is opposite. $90° < \theta_i < 180°$

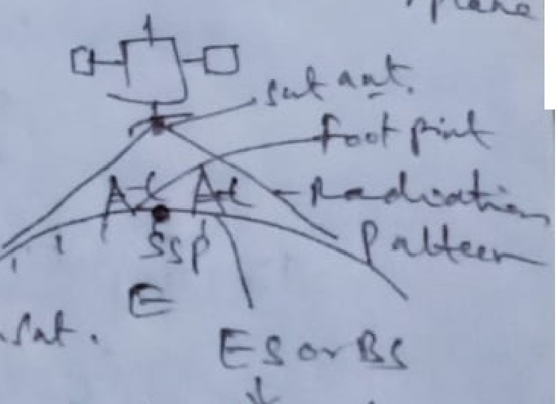
10) epoch:- position of a satellite in its orbit at a reference time.

11) orbital elements:- Artificial satellites are defined in terms of six orbital or keplerian set of elements

(i) a - semi major axis } gives shape of orbit
(ii) e - eccentricity
(iii) epoch (iv) perigee point w.r.t. earth's equatorial plane
(v) θ_i (vi) AN.

12) Satellite foot print:

Area covered by Sat ant on the earth's surface. ES or BS are covered for linking with sat.



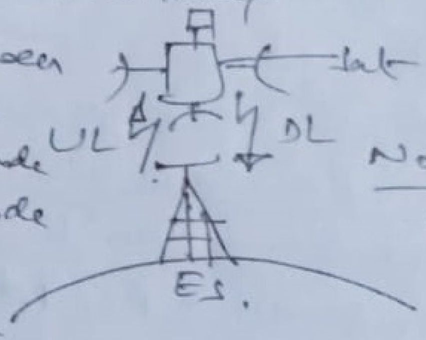
13) SSP - Sub satellite point

Point on earth directly below satellite. Here max signal reception by ES possible

14) UL - Uplinking & DL - Downlinking

UL - means link between ES & sat. Hence sat will be in Rx mode & ES -||- TX mode

DL -||-
-||-
ES -||- Rx -||-
-||- sat -||-



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Note:- To prevent interference between links two different freqs are used.

15) one sidereal day :- Time taken for one complete rotation of earth relative to fixed stars (eg: Sun).

(i) 1 mean solar day = 24 Hrs 3 min ~~56~~ 56.55536 secs a sidereal time

(ii) -||- sidereal -||- = 23 Hrs 56 min 04.09054 secs mean solar time.

16) orbital perturbations :- Drag or gravitational force acting on sat due to other heavenly bodies

This is due to no of reasons

- Gravitational pull due to -||- like Sun, moon, stars, planets etc.
- Non spherical earth effect
- atmospheric drag due to changing seasons
- Aerodynamic forces (wind currents)
- Solar pressure on solar panel
- mag field effect of earth on LEO & MEO sats.

17) Height geosynch orbit : $h \simeq 35,786$ km
$\simeq 36,000$ km

(Calculated as radius of geo synch orbit - earth equatorial radius) i.e (42164 - 6378) km

18) Antenna look Ls: Important in DTH installation to locate a sat. 3 parameters are required

- Earth's lattitude
- Earth's longitude
- Sat's longitude

→ Latitude of sub sat point.

19) Satellite launching & escape velocity :-   Unit 2-7

During launching of any satellite it will be under the influence of centrifugal force or gravitational pull of earth. If sat assumes a vel overcoming this it can leave ones atmosphere. This vel is called escape velocity (≈ 11.2 km/sec) i.e almost 33 times that of sound vel (330 m/sec) or several times of vel of a bullet fired from an AK47 (1.7 km/sec).

20) Payload :- This is the overall weight of sat including that of sat transponder, antennas, solar panels, fuel system, power supply, control subsystem etc.

→ three types - medium (few kgs), Normal (few 100 kgs), Heavy (few tons)

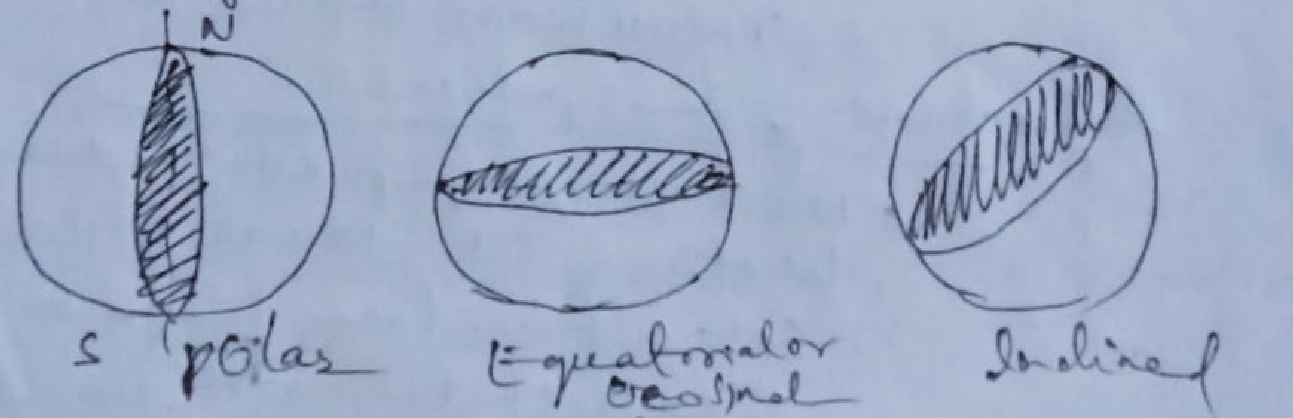
As payload ↑, cost of launching also ↑.

In a sat, 40 to 50% of payload corresponds to the fuel.

21) Bus : This interconnects various payloads, controls (attitude, orbital & thermal), CTT (command & Telemetry func).

22) Transponder :- Active element of sat, which is a transceiver (TX & RX connected back to back) and an antenna. A sat has no of transponders. Thro this UL & DL possible with ES.

23) orbital plane : plane in which sat orbits



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24) Sun Synchronous orbit:-

An orbit in which a satellite passes every location at the same mean solar time each day or sat passes the equator & latitude at the same time each day.

25) Eclipse of sat:- All sats in space undergoes eclipse during certain period when its solar panel is eclipsed by the shadow of the earth i.e earth comes between sat & sun. This effect is severe in Geosynch sats during equinoxes (21st march & 23rd sept).

Why satellite comm.:

1. They are wideband n/ws, they support large no. of chls between continents
2. Economical in long distance comm as compared to terrestrial lines.
3. Easily accessable at any point on earth irrespective of terrain.
4. can be deployed in hostile terrain like sea, ocean, hilly, deserts etc.
5. Back bone of our internet
6. Supports Various Services
   Tel linking, Mobile n/ws, Education, metrology, rescue works, Defence, etc.

Advantages of Geosynch orbit:-

- No tracking equipment required
- location of sat remain within line of sight 24x7
- sat ant has large foot print & hence no. of earth stations can be connected/covered

Unit 2-9

- 3 Sats are sufficient for global coverage
- Good quality of service to rural & urban areas.
- No Doppler shift in frequency
- θ_i is 0.

Disadvs: -
- ES in lattitudes > 81.5° in N & S hemisphere can't access.
- Rx signal strength is weak
- Time delay in UL & DL > 270 msec
- As h is large more power full launching vehicles needed.
- Larger path loss for signals, signal has to travel thro different Layers of atmosphere
- Congestion of orbit because of more no. of Sats.

$h \simeq 36,000km$ $(= 35786 km)$

Satellite orbit - orbit is path of the satellite

Unit 2-11

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* LEO: (Lower Earth orbit): orbit below an altitude of 1000km. Useful for mobile comm. But large no of sats are required for continuous comm. As height is low, power required is small & hence hand held Tx/Rx can be used. Disadv:- life of sat is limited. Rotation period is about 1 hr 30 min. Visibility quarter hour

* MEO: (Medium Earth orbit): Altitude 1000km to 2000km. located above or below Van Allen belt. Sat has intermediate circular orbit. longer life, fewer sats required. Appl:- telephone, e-mail, FAX etc. Rotation period 5 to 12 Hrs, Visibility period 3 hr

* HEO: Highly eccentric orbit. Used by countries near polar regions (Russian, Greenland etc) Height of orbit 20,000 km.

* GEO: Geosynchronous earth orbit Altitude 36,000km above earth equator. L(ang) Vel of Sat = L(ang) vel of earth around its poles. This is also called geostationary orbit.

Indian Senario

April 19th 1975 - Aryabhatta - (French Guyana)
July 18th 1980 - Rohini thru SLV (Sat launch vehicle) (Sriharikota)
1987 - ASLV - Augmented SLV
INSAT - Indian National Sat INSAT 1, 1D, 2B...
(4A, 4C, 4B) in C & Ku bands, ~~for distance~~
Edusat - for distance learning
2008 - Chandrayan - Moon mission
GSAT - for Teleeducation | medicine.
DCP - Data collection platform al [illegible] - Dis astronomy

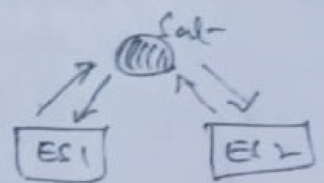
NSAT applications: 1) NICNET - National Information Centre N/W (a data Comm N/W)
2) SBRTN - Satellite based rural Telegraph N/w - Works in TDM/TDMA mode (C-Band)
3) Radio broadcasting message & data to AIR PTI & news broadcasting this
4) Std time & metrological data Tx.

Sat-Comm Syst : 1) Space Segment 2) Earth or ground Segment
3) link Segment

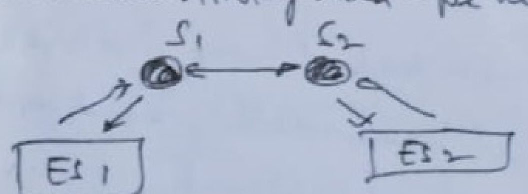
1) Space Segment → It mainly consisting satellites
* Airspace < 100km altitude from earth's surface
* Outer or Cosmic space 100km to 42,000km. Here centrifugal force is predominant
* Deep space > 42,000km

✓ Satellites
- passive - No onboard signal processing, just reflectors
- active - uses Bend pipe technology in Transponders to do freq & power translation

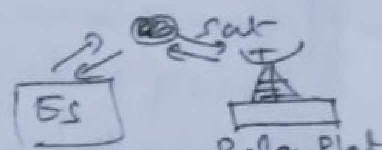
✓ Satellite Systems a) Ground to ground (in LoS applns)



b) Ground cross link ground - for not in LoS regions



(c) Ground to relay platform



Relay Platform

✓ Space segment consisting a) power supply b) solar panels/arrays
lennas d) Transponders c) Attitude control / Sensor Ckts.

(a) Power supply:- Electrical power is needed for
* constant rotation of payload * to overcome losses due to drags
* maintain house keeping circuitry * source power amplifiers/transponders
etc * Miscellaneous.

✓ Distribution of power will be
Transponders 5%.
House keeping operation 12%.
power amplifier for DL 80%.
miscellaneous like charging batteries, compensate line losses etc 3%.

✓ Redundancy in the form of back ups are used for power supplies

g) Transponder:-

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"A TX & RX connected back to back to an ant" i.e. a Tranceiver

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There will be no. of transponders in a sat. Each transponder operating in a specific band has a b.w allocated.

eg: In C band, total b.w is 500MHZ which is divided into no. of Sub bands which is allocated to a transponder. Typically 36MHz with 4MHz guard band 12 transponders can be accomodated. To

Unit 2-14

loss failures occur due to bus failure (o.c or s.c), component/system

32 failure, random stray EMI/RFI pickups (shielding can be provided)

* Rechargable Ni-Cd, Ni-H_2, Ag-Zn (Silver Zinc) batteries are used. Most sats have 50% backup to cope eclipse effect.

Charging time < 16 Hrs, Nickel hydroxide batteries are popular because of stability & long life. SMPS supplies are popular with protection

h) Solar panels/arrays:- Solar sails provide power. These are unfolded (area 10 to 20 m^2) during launching & after sat is placed in its orbit they open up (→ 10 to 15 m). Si & GaAs photocells are used, where GaAs has high η, tolerance temp stability etc. In g, amorphous silicon are also used.

Temp range -190° to 60°c, a cell can provide up to 1.1 to 1.5V

i) Sat antenna:- Requirements like ✓ Structure - Stable, Steerable, foldable, rigid etc.

✓ pattern of beam ✓ type of feed (horn/dipole)

✓ type of polarization ✓ beamwidth, bandwidth

✓ Directivity/directive gain ✓ efficiency

Types:- parabolic reflector in ES, omnidirectional ant (→ Telemetry, Tracking & command)

in TT&C, global horn during transfer of sat from one orbit to other, global beam ant in Geo Synch sats, multiple feed antennas are popular

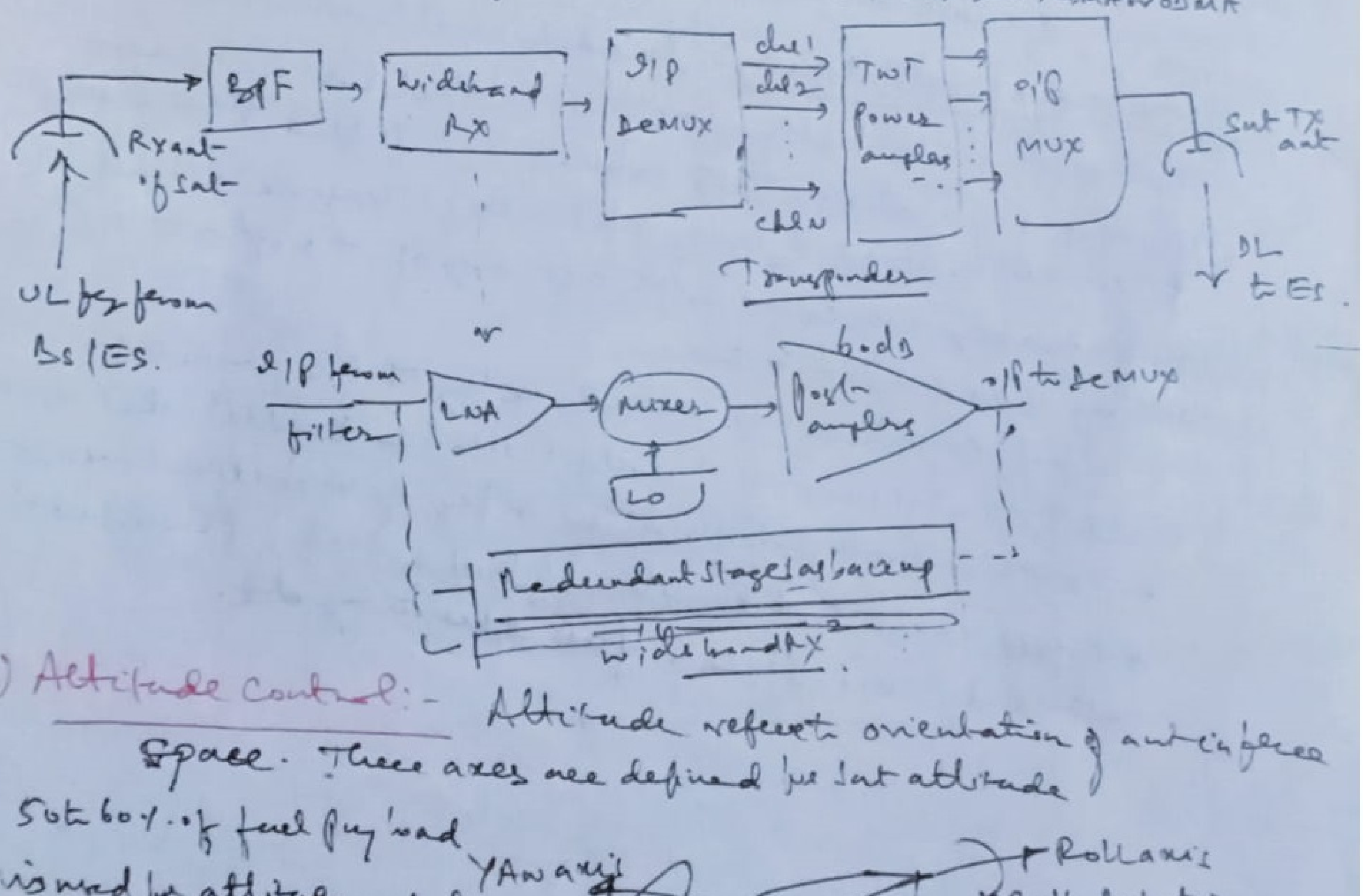
✓ CFRP (Carbon Fiber Reinforced plastic) is widely used because of • light weight • good dielectric strength

• Stable char in temp range -165°c to +120°c

2) Transponder:-

"A TX & RX connected back to back to an ant" i.e a Tranceiver
There will be no. of transponders in a sat. Each transponder operating in a specific band has a b.w allocated.

eg: In C band, Total b.w is 500 kHz which is divided into no. of sub bands which is allocated to a transponder. Typically 36 MHz with 4 MHz guard band & 12 transponders can be accomodated. To increase spectral eff, freq reuse scheme are used. B.w can be enhanced to 2000 MHz or 2 GHz by using spot beam antenna. No. of ES can access the same Sat by multiple access like FDMA, TDMA, CDMA or ODMA



c) Altitude control:-

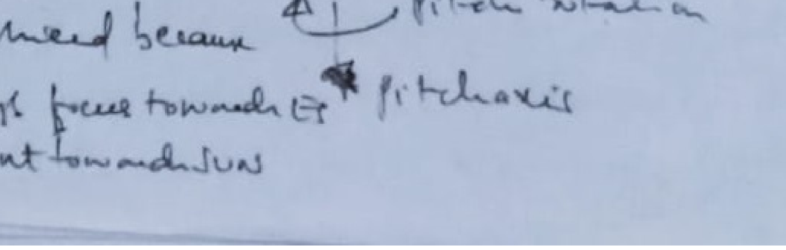
Altitude refers to orientation of ant in free space. Three axes are defined for sat attitude

50 to 60% of fuel payload is used for attitude control.

Altitude control sensors determine attitude control

Altitude control is required because

* sat ant must always focus towards ES
* make solar panel point towards sun



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Earth Segment (ES) / Earth station - complexity depends on the type of signals it has to handle.

* Annul various torques acting on the sat to prevent drifting. (i.e house keeping operation)

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* overcome thermal effects

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Sat orientation in free space is measured by using 4 sensors on board. Drift-correction measures are taken by transmitting control signals from ES. This is called attitude manoeuvre.

Torques on board are generated either by passive or active methods.

✓ In passive there is no drain on power system/energy supplies. uses the spin & gravitational pull stabilization mechanism.

✓ In active we use fuel like "Hydrazene" ignition which generates the control torques.

<u>House keeping / station keeping</u>: In additional to attitude control sat must also be kept in its correct orbital slot against various perturbations. Jets on board are pulsed regularly to correction steps (every 2 to 3 weeks). These are called station keeping manoeuvres with accuracy of $\pm 0.05°$ to $\pm 0.1°$ both in E-W & N-S directions.

orbital corrections are carried out by TT&C from ES.

Data TX in Telemetry signals include * attitude information * environmental information * freq of meteoric impact * space craft information (such as temp, power supply volt conditions, stored fuel quantity etc.

& sent thro different carriers to ES.

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Telemetry is DL operation to ES.

b) Tracking: ES keeps track of sat in its orbit using on board sensors & transponders. This is both UL & DL signals

c) Control: Using data sent by satellite thro carriers we can control • altitude • attitude • orbital path • parking place • work LS by command sent by ES either in manual mode or automatic or program track mode. This is thro UL.

- Generally C band (4 to 6 GHz) is used for TT&C since losses in this band is small. For better tracking Narrow beam width ant & high SNR (60dB) are used.

- command word format will be around 32 bits long to sent at a low bit rate of 100bps.

1	2 3 . . . 6	7 8	9 10	11 . . . 16	17 . . 32
Start Bit	Sat Address	Decoder Address	Mode	Mode Addresses	MSB . . . LSB Command information

- TT&C systems are made fool proof by encasing ~~them~~ it in "Faraday cage" to prevent any interference.

- Additional Telemetry information like altitude information, environmental information, frequency of meteorite impact, space craft information like temp, power supply voltages, conditions, stored fuel quantity etc are also sent.

ES-TX are characterized by EIRP (Effective Isotropically radiated power) = $P_t G_t$

ES-RX —— " —————— CNR & G/T ratio.

Earthstation:

Transmitter:-

a) Source processing:- Converting the base band information video/(Audio)/Internet to packet format. If signal is in Analog domain A/D conversion is required {Sampling, quantization, coding}. After conversion to digital format signal will be fit into a packet form.

1	2	3	4	5
Packet No	Address field of transponder	Format of data	Information signaling error correction data	data

b) Source Conditioner:- Analog signals are band limited first to prevent cochl or adjchl interference using filter ckts. e.g. Voice signal BW ≈ 3KHz, video ≈ few MHz etc. Pre-amplifn is done to increase the CNR or SNR. In FM modln we use compander (compressor-expander) to compensate for the noise. Digital samples are multiplexed to increase of η of Txn.

c) Modulator + up converter:- In analog format we use AM, FM, PM, PCM etc. In digital we use ASK, FSK, PSK, QPSK etc. carriers are used for modln. The signals are frequency converted to RF from IF.

d) o/p stage: This is mostly built using TWT or klystron amplifier. To build up the signal for long distance commn. This improves CNR or SNR of the sat-Txn.

TX is characterized by $EIRP = P_t G_t$.

Receiver:-

a) I/p RF stage:- This will be a LNA to build the signal that is received, which has undergone path loss during Txn.

b) Down converter/Demodulator: RF signal is converted to IF using a SHR. In case of analog we use detectors but in digital we use coheeal or non-coheent dectectoer.

UNIT2-17B

c) Signal conditionee :- This will amplify thee, If signals & compensates for compression done in thee TX. Signals are Demux

d) Source recovery :- D/A convecter is used to convert thee signal & information are recovered.

where G = Gain of RX, T = RX Noise temp

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- $(CNR)_{UL} > (CNR)_{DL}$ because limitation of power generated in sat.

- Specifications of ES:-

✓ common IF used is 70MHZ, In some cases 140 to 400MHZ are also used.

✓ Mobile service providers use a portion of 3400-4200MHz band for their feeder lines

✓ Crystal LO are used

✓ High power amplrs are TWT / klystron / solid state power amplrs

eg: In C-band o/p power may be between 500w to 3kw b/w 40MHZ.

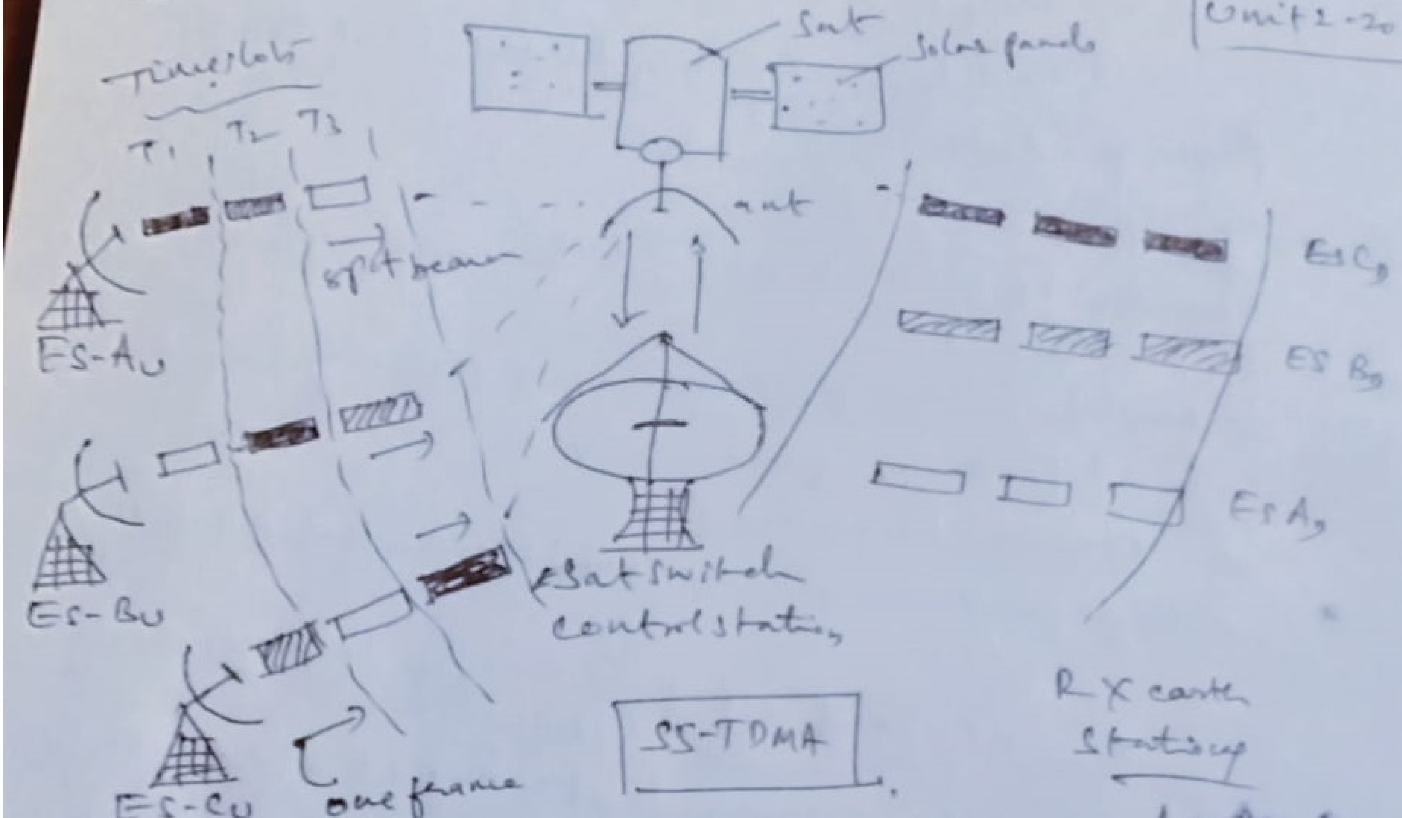
✓ SCPC - single carrier/chl is used to avoid interference.

✓ For UL & DL by ES it must be in the foot print of sat- antenna.

SS-TDMA: Satellite Switched TDMA

- Each earth station accumulates packets & TX them in the form of bursts.
- Multiple spot beams are used for UL & DL TXns
- Interconnection between UL & DL beams are predefined by high speed switch matrix located in the satellite.
- complete working of the SS-TDMA is represented in the Fig given in P no Unit-2-20.

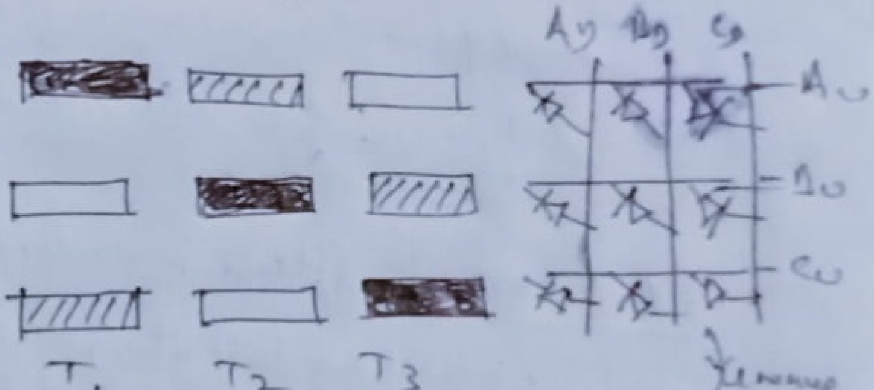
Unit 2 - 20



SS-TDMA

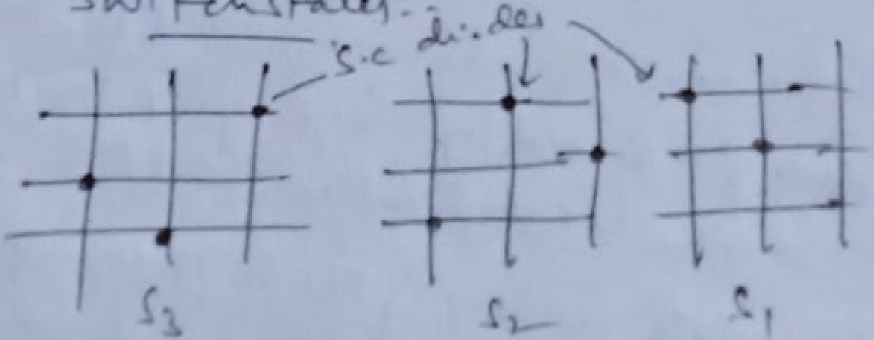
TX earth stations

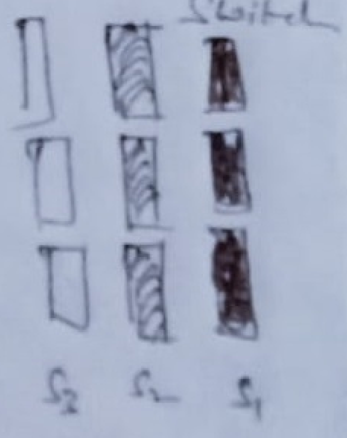
packet data to A
— " — B
— " — C



Traffic pattern 3/1

Switch states:





Satellites for mobile communication

Unit 2-21

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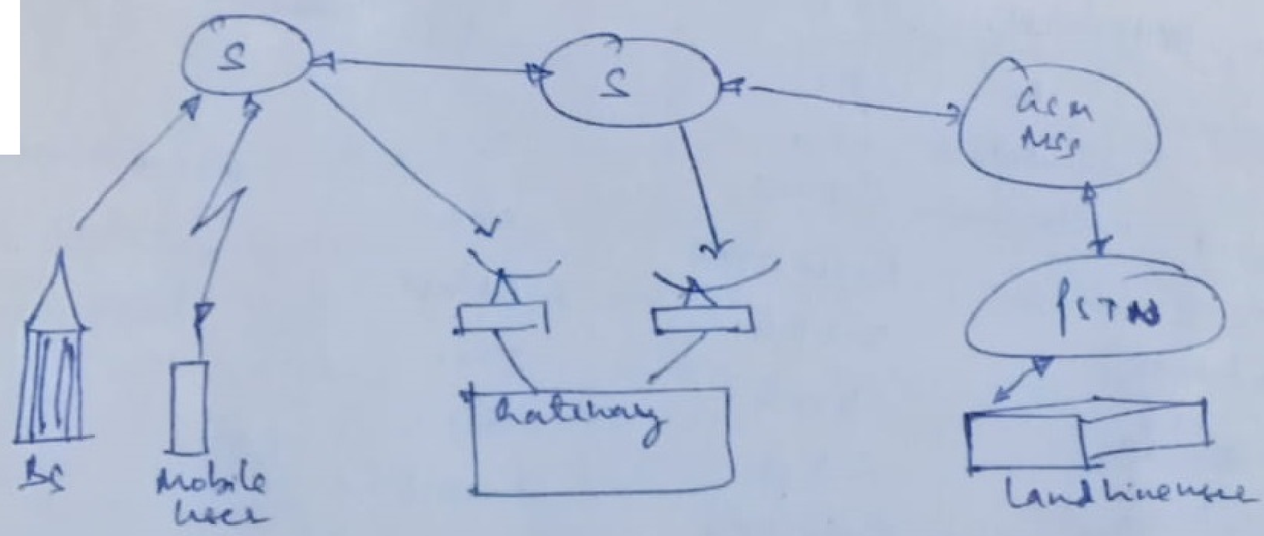
* AMPS & GSM do not provide support for global roaming but sat will be backbone
* Satellites with small foot prints can be connected thro RF interline connectivity. Then sat can be linked to gateways
* In case of LEO sat. direct connectivity from mobile stations possible.



* Sat-Syst with gateways & terrestrial n/w route data from one mobile to another. Sat handles individual lines or relay it to other sat (ISL - Inter sat link), which in turn can connect to the mobile
* Home location, visitor location, Satellite mobility register (SAMR) are important in linking. SAMR keep track of mobile & sat.
* Satellite hand over is important in LEO for mobile users
* In cellular comm hand over is important when mobile user moves from one cell to another. Hence Inter-sat handoff, Gateway handoff, Terrestrial n/w handoff, BS handoffs
- f range from 12 to 60 GHz is used

Unit 2-22

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Parameter	Iridium	Global Star	ICO (Intermediate circular orbit sat)
1) No of sats	72	52	12
2) Altitude km	780	1414	10,390
3) coverage	global	±70° lattitude	global
4) freq (GHz) UL	29.2	6.9	7.0
DL	19.5	5.1	5.2
Intersatellite	23.3		
Mobile station	1.6 MS	2.5	2
5) Access methods	FDMA/TDMA	CDMA	FDMA/TDMA
6) Bitrate	2.4 kbps	9.6 kbps	4.8 kbps
7) No of ch	4000	2700	4500
8) Lifetime	5-8	7.5	12
9) Services	data/voice	data/voice	

Other satellites in LEO and for mobile applns

	1) Aries ECCO	2) Ellipsat	3) Teledesic	4) Orbcom	5) Star systems	6) Vitasat
No of sats	10	12-24	288	26-36	24	2
orbital inclination	Equatorial	63°	82°	47° polar	50.6°	88°
mobile freq TX	L/S band	1.61 to 1.627 GHz	24/30 GHz			
links RX	—"—	2.483 to 2.5 GHz	20/30 —"—			
service	voice/data	voice/data	Internet	page	paging	paging

DBS : Direct Broadcast Sat Television

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"Concept of using sats to provide direct trn into home" they support Audio, TV & Internet services

* They use KU band, UL - 17.3 to 17.8 GHz, DL - 12.2 to 12.7 GHz } Higher power sats
  UL - 14 to 14.5 GHz, DL 11.7 to 12.2 GHz } low — " —
* total b.w 500 MHz, 32 Transponders each of b.w 24 MHz. of 3 MHz guard band is used then b.w is 27 MHz.
* Freq reuse, RHCP (Right hand circular polzn) LHCP (Left — " —) are used
* Digitized signals using QPSK & compression methods are used.
* In HDTV, 16 bits / pixel gives a colour depth of $2^{16} = 65536$ colours Pixels / frame 1920 x 1080, refresh rate 25 to 30 frames/sec, bit rate 995 Mbps.

VSAT - Very small Aperture Terminal

This is N/W used for long distance low density voice & data commn.

Applns : * used by supermarket shops, stockmarkets, ATM Machines, broadband DTH, Internet access from ships, Hotel & internet cafes connectivity, Travel agents booking system, Insurance offices, ATC, Job centers, Customs & tax offices, VoIP, phone connectivity, environmental monitoring etc

Link concepts: Link is nothing but EM wave connection between Sat & ES. There are two parts namely UL & DL.

EM waves in the link undergoes following losses

1. path loss (α_p)
2. Losses in atmosphere / troposphere (α_a) - This includes scattering & absorption due to rainfall / fog / snow etc.
3. losses in ionosphere (α_i) - faraday rotation
4. losses in the antenna system (α_{ant})
5. Additional losses in the link (α_l)

we consider only the path loss, because it is the major loss.

path loss (α_p)

* If P_t is the transmitted power over the slant range d_s with an antenna having gain G_t, then power density at the sat ant is $P_r = \frac{P_t G_t}{4\pi d_s^2}$ watts/m² —(1)

where $P_t G_t$ = EIRP = Effective Isotropically radiated power

* having an ant $G_t = \frac{A_{eff}}{A_{iso}} = \frac{\text{Effective aperture of ant}}{\text{— " — an isotropic ant}}$

For an isotropic radiator $G_t = 1$ & also $A_{iso} = \lambda^2/4\pi$ ∴

$$G_t = \frac{4\pi A_{eff}}{\lambda^2} \quad \therefore \ A_{eff} = \frac{\lambda^2}{4\pi} \quad -(2)$$

* For isotropic ant at ES & sat, the power received by sat with effective aperture A_{eff} is

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

But path loss for isotropic ant $\alpha_p = \frac{P_t}{P_r} = \left(\frac{4\pi d_s}{\lambda}\right)^2$ But $\lambda = \frac{c}{f}$

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$\therefore L_p = \left(\frac{4\pi f d_s}{c}\right)^2$, In log scale

$10\log L_p = 10\log \frac{P_t}{P_r} = 20\log\frac{4\pi}{c} + 20\log f + 20\log d_s$

But $c = 3\times10^5$ km/sec, if f in GHz & d_s in km

$\therefore \boxed{[L_p]_{dB} = 92.4 + 20\log f + 20\log d_s}$ for isotropic ant. at ES.

* During the times we use directive ants at ES with gain G_t

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

* If Gr will the gain of Sub ant then power received is

$P_r = P_r' G_r = \frac{P_t G_t G_r \frac{\lambda^2}{4\pi}}{4\pi d_s^2}$

$\therefore L_p$ for directional ant $= \frac{P_t G_t}{P_r} = \left(\frac{4\pi d_s f}{c}\right)^2 \cdot \frac{1}{G_r}$

$\therefore L_{p\,dB} = 20\log\frac{4\pi}{c} + 20\log d_s + 20\log f - 10\log G_r$

$= 92.4 + $ ——"——

i.e proportional to sq of freq & dist, & inversely ∝ to gain

* If D mouth diag of dish ant ~~ [illegible]~~ then

$G_t = \eta_a\left[\frac{\pi D f}{c}\right]^2$; $.65 < \eta_a < .75$

$G_{t\,dB} = 10\log\eta_a + 20\log\frac{\pi}{c} + 20\log D + 20\log f$ (D → mts, f → GHz)

$= 10\log\eta_a + 20.4 + $ ——"——

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eg:- At 5.62 GHz, feed dish ant 6 m, power Tx 8 kW, Slant range 39920 km, $\eta_a = 0.7$. Find EIRP, Rx power at ant, Path loss

<u>Soln</u>:- $L_{P_{dB}} = 92.4 + 20\log 5.62 + 20\log 39920$

$= 199.26\,dB$.

$\therefore [P_t]_{dB} = 10\log 8000 = 39.03\,dBW$

$\therefore P_{r_{dB}} = [EIRP]_{dB} - L_{P_{dB}}$

$G_{t_{dB}} = 20.4 + 20\log 5.62 + 20\log 6 + 10\log 0.7$

$= 49.4\,dB$.

$\therefore [EIRP]_{dB} = [P_t]_{dB} + [G_t]_{dB} = 88.43\,dB$.

$[P_r]_{dB} = -110.83\,dBW = 8.26\,pW$

$$\begin{array}{r} 199.26 \\ 88.43 \\ \hline 110.83 \end{array}$$