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Satellite communication

Assignment - 1

1) State the expression for Look angles and derive the expressions for assimuth and elevation angle?

Look Angle determination:

* The look angles are the coordinates to which an earth station antenna must be pointed to communicate with a satellite.
* The azimuth and elevation angles, collectively called the look angles for the earth station (ES) to the satellite.
* Satellite look angle is angle which is helps the satellite to stay at a specific position in a given time. If anyone wants a service from satellite in a specific time, then user must know the look angle of satellite.

(i) Azimuth Angle (Az):

* The azimuth angle (Az) is the angle at which the earth station's disk is pointing at the horizon.
* The azimuth angle is an angle measured eastward from north direction in the local horizontal plane.

(ii) Elevation Angle (El):

* Elevation angle is the angle measured ⊥r to the horizontal plane to the line-of-sight to the satellite.
* The antenna bore-sight must be rotated to elevation angle to the satellite. Visibility requires +ve El otherwise it is below the horizon.

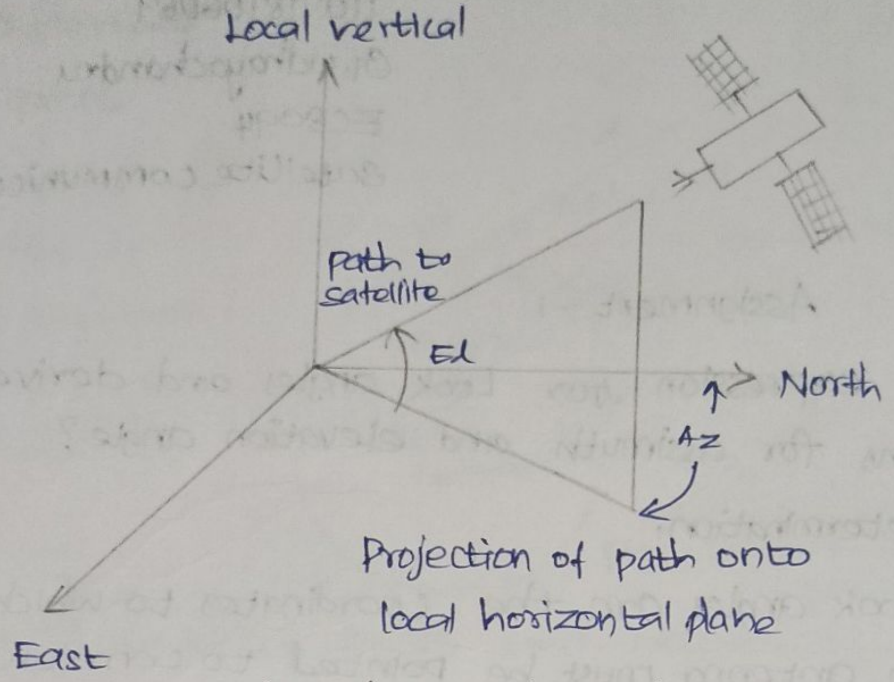


Fig1: Look angles : Az & El

Calculating the look angles:

steps in calculating look angles are as under:

* Need six orbital elements
* Calculate the orbit from these orbital elements.
* Define orbital plane.
* Locate satellite at time t with respect to the first point of Aries.
* Find location of the Greenwich Meridian relative to the first point of Aries.
* Use spherical trigonometry to find the position of the satellite relative to a point on the earth's surface.

Geometry for elevation calculation

Latitude: It is an angular distance, measured in degrees, North or south of the equator. L from -90 to +90 (or from 90S to 90N)

Longitude: It is an angular distance, measured in degrees from a given reference longitudinal line l from 0 to 360E (or 180W to 180E).

Satellite co-ordinates:

1) Sub-satellite point

   * Latitude L_s
   * Longitude l_s

2) Earth station Location:

   * Latitude L_e
   * Longitude l_e

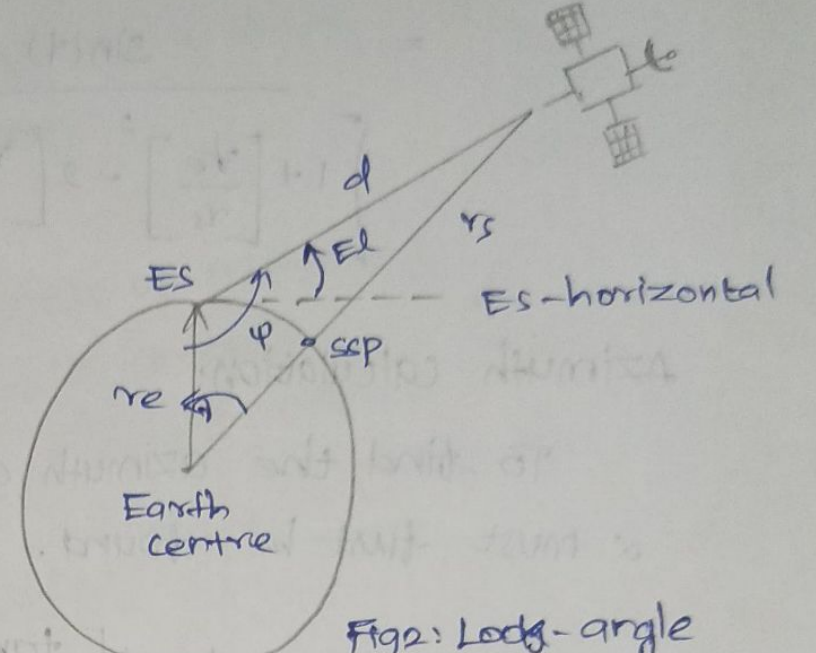


Fig2: Look-angle geometry.

Central Angle: (γ)

* γ is defined so that it is non-negative and by the law of cosines.

$$\cos(\gamma) = \cos(L_e) \times \cos(L_s) \cos(l_s - l_e) + \sin(L_e) \sin(L_s)$$

* The elevation above Earth station vertical is,

$$El = \varphi - 90^\circ$$

* The Magnitude of the vectors joining the centre of the earth, the satellite and the Earth station are related by the law of cosines:

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

* It is the communication path length d, along which path losses will be calculated.

Elevation calculation:

The Elevation calculation can be calculated from the coordinates of the subsatellite point (ssp), the coordinates of the earth station, the satellite orbital radius and earth radius, as follows,

By the sines law,

$$\frac{r_s}{\sin(\varphi)} = \frac{d}{\sin(\gamma)}$$

Which yields $\cos(El)$

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

Azimuth calculation:

To find the azimuth angle, an intermediate angle, α must first be found.

$$\alpha = \tan^{-1}\left[\frac{\tan|(l_s - l_e)|}{\sin(L_e)}\right]$$

case 1:

Earth station in the Northern hemisphere with,

(a) satellite to the SE of the Earth station

$Az = 180° - \alpha$

(b) satellite to the SW of the Earth station $Az = 180° + \alpha$

case 2:

Earth station in the southern hemisphere with,

(a) satellite to the NE of the Earth station : $Az = \alpha$

(b) satellite to the NW of the Earth station : $Az = 360° - \alpha$

2) With neat block diagram, explain the attitude & orbit control system present in the space segment?

Attitude control systems:

the role of attitude control usually consists of maintaining the mechanical axes in alignment with the local co-ordinate system to an accuracy defined by the amplitude of rotation about each of the axes.

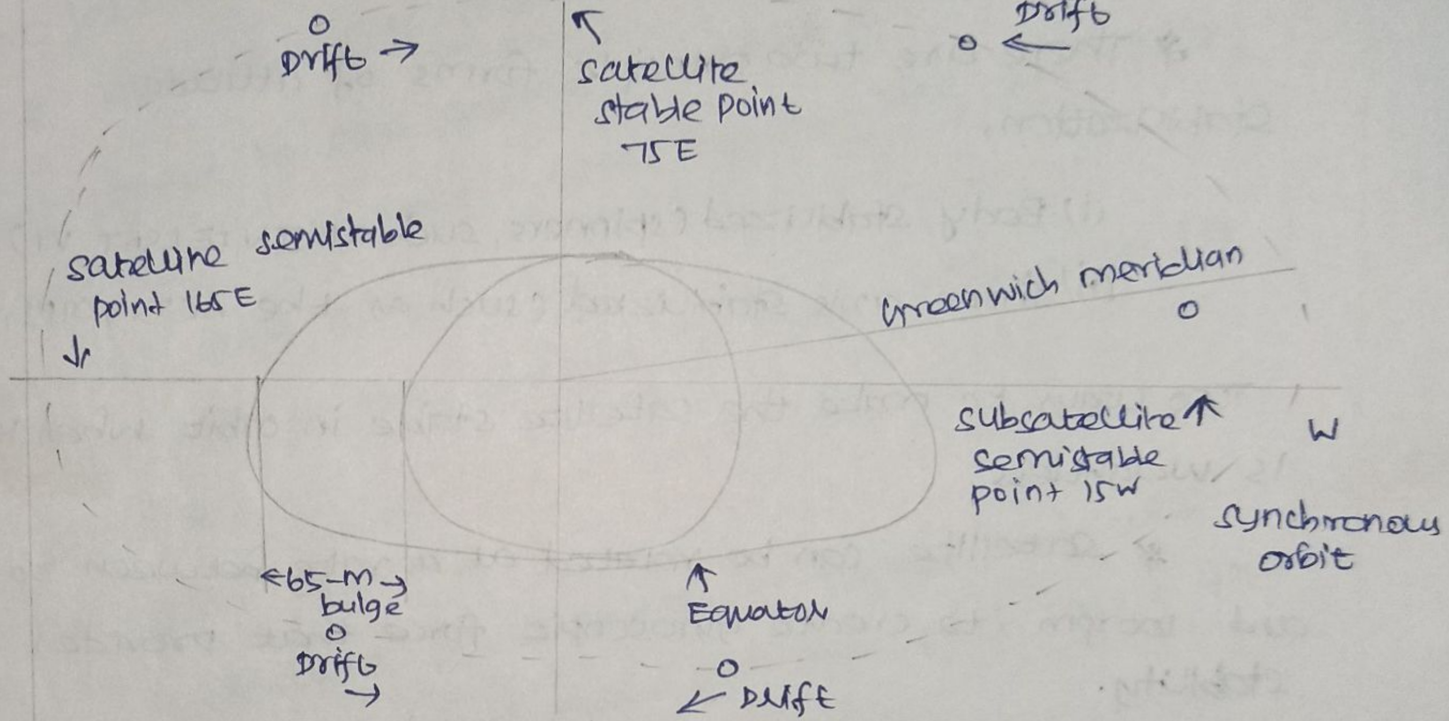


Fig1: Forces on a synchronous satellite

* The Typical ranges are ± 0.05° for roll axis ± 0.2° for yaw axis and ± 0.05° for pitch axis for a geostationary satellite.

For maintaining attitude control two functions are required:

(1) steering function:

It consists of causing the part of the satellite which must be oriented towards the earth to turn about the pitch axis in order to compensate for the apparent movement of earth with respect to the satellite.

Stabilization function:

Stabilization function involves compensating for the effects of attitude disturbing torques due to gravitational forces, solar radiation, pressure etc,

Fine postioning:

* satellite must be stabilized to prevent nutation move unsteadily.

* There are two principle forms of attitude stabilization,

(i) Body stabilized (spinners, such as INTELSAT VI)
(ii) Three axis stabilized (such as the ACTS, GPS, etc)

Two ways to make the satellite stable in orbit when it is weightless.

* Satellite can be rotated at a rate between 30 and 100rpm to create gyroscopic force that provides stability.

* Satellites can be stabilized by one or more momentum wheels, called 3-axis stabilized satellites.

Orbit Insertion & Maintenance - GEO

* Must control location in geo and position within constellation.

* Satellites need in-plane (E-W) and out of plane (N-S) maneuvers to maintain the correct orbit

* LEO systems less affected by sun and moon but may need more orbit-phasing control.

Two types of motors used on satellites:

1) Traditional bipropellant thrusters:

* Bipropellants used are Mono-methyl hydrazine & Nitrogen tetra oxide

* They are hypogolic, i.e., they ignite simultaneously on contact without any catalyst or heater

2) Arc jets or ion thrusters:

* High voltage is used to accelerate ions.

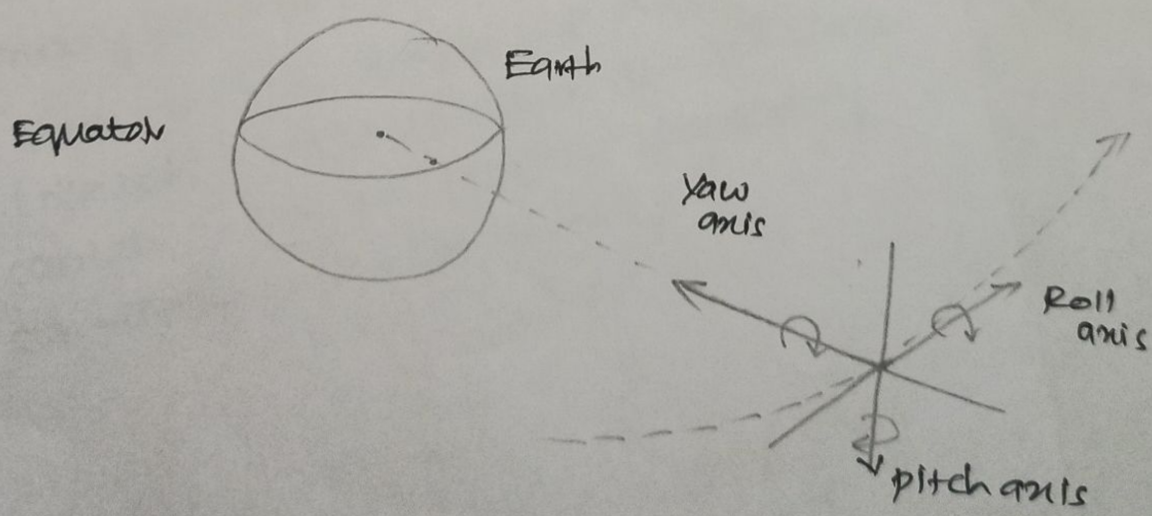
Fuel stored in GEO satellite is used for 2 purposes:

* Apogee Kick Motor that injects the satellites into its final orbit

* Maintain the satellite in that orbit over its lifetime.

Definition of axes:

Attitude of a satellite is represented with respect to three axes - Roll axis, pitch axis & yaw axis.



(i) Roll axis:

* The roll axis is the plane of orbit, perpendicular to the yaw axis and in the direction of the velocity.

* Roll axis rotates around the axis tangent to the orbital plane (N/S on the earth).

(ii) pitch axis:

* The pitch axis is perpendicular to both other axes and originated such that the co-ordinated system is regular.

* Attitude pitch axis moves around the axis perpendicular to the orbital plane (E/W on the earth).

(iii) Yaw axis:

* The yaw axis points in the direction of center of the earth.

* Yaw axis moves around the axis of the sub-satellite point.

3) Describe TTC- subsystem, with appropriate procedures?

TTC- subsystem:

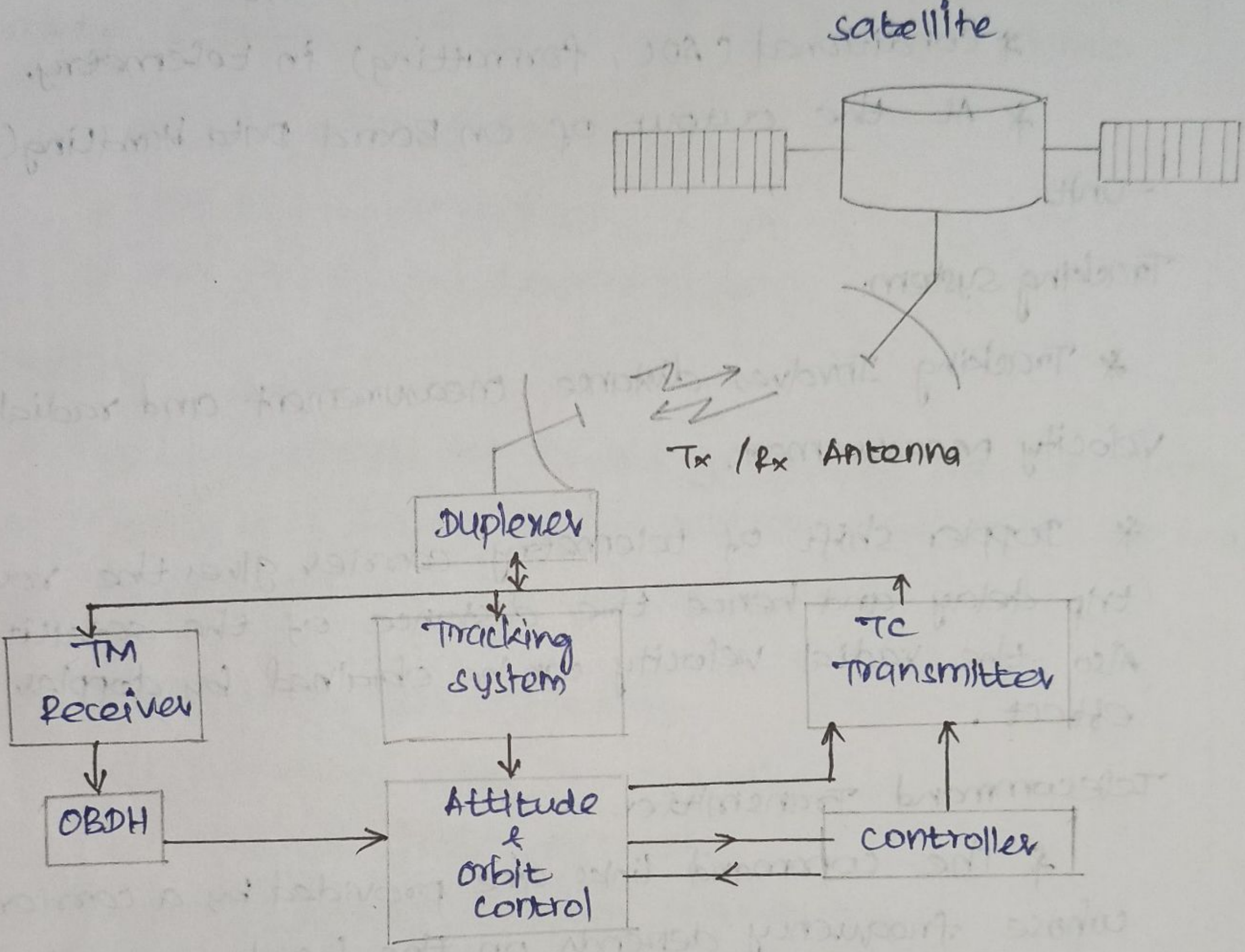


Fig1: TTC subsystem

Telemetry links & command links are low bit rate links typically few kbps. Nominal frequency band of communication payload can be used to handle TTC data.

TM receiver (Telemetry Receiver)

* The data from various sensors of different subsystems are collected by TM receivers by TM links. The TM links are carriers which are phase or frequency modulated by a sub-carrier at a 40.96 kHz.

the data can be obtained either,

* Directly from satellite equipment
* Conditioned (ADC, formatting) in telemetry.
* At the output of on Board Data Handling (OBDH) -unit.

Tracking system:

* Tracking Involves distance measurement and radial velocity measurement.

* Doppler shift of telemetry carrier gives the round trip delay and hence the distance of the satellite. Also the radial velocity can be obtained by doppler effect..

Telecommand Transmitter:

* The command links are provided by a carrier whose frequency depends on the band used and is phase or frequency modulated by a subcarrier at a 8 KHZ.

* The data commands to be transmitted are either regulating commands to adjust a parameter on board the satellite to a particular value. e.g: current of travelling wave tube or opening and closing of relay.

* commands can be executed immediately or stored in memory and executed on reception of a specific command.

on Board data Handling:

* Command processing: It covers decoding validation, acknowledgement and execution of command signals.

* Data storage and processing

* Data traffic Management

* Data timing and synchronization

Tracking:

* Regular estimation of orbital parameters are necessary to maintain a satellite in its assigned orbit and to provide look angle information to the earth station.

* Tracking involves following:-
  (i) Measuring range repeatedly
  (ii) Compute orbital elements
  (iii) Plan station-keeping maneuvers
  (iv) Communication with main control station & users

Command:

The command sub-system receives commands transmitted from the ground control centre, verifies reception and executes commands to perform various functions of the satellite during its operational mission such as,

(i) Satellite Transponder and beacon switching
(ii) Antenna pointing control
(iii) Switch matrix reconfiguration
(iv) controlling direction and speed of solar arrays drive
(v) Battery reconditioning.
(vi) Thrusters firing and switching heaters of the various -systems.

* The command system is used during launch to control the firing of the boost motor, deploy appendages such as solar panels and antenna reflectors and spin-up a spin-stabilized spacecraft body.

* The command procedure also involves multiple transmissions to the spacecraft, to assure the validity and correct reception of the command, before the execute instruction is transmitted.