The geostationary height (altitude above the earth's surface)

$$h_s = r_s - r_e$$

where, r_e = equatorial earth radius
= 6378 km

$$\Rightarrow h_s = (42164 - 6378) \text{ km}$$
$$= 35786 \text{ km}$$

$$\simeq 36000 \text{ km}$$

Conditions for satellites in Geostationary Orbits :-

1. Geosynchronous satellites must have a zero degree angle of inclination (i.e. Satellite Vehicle must be orbiting directly above earth's equatorial plane).

2. Satellite must be orbiting in the same direction as earth's rotation with the same angular velocity of one revolution per day.

3.

Geosynchronous Satellite Orbital Velocity →

The circumference (C) of a geosynchronous orbit is

$$C = 2\pi\,(42{,}164\ km)$$

Radius of orbit (r_s)

$$= 264\,790\ km$$

Velocity (v) of the Geosynchronous Satellite is

$$v = \text{Circumference} \,/\, \text{Time Period}$$

$$= \frac{264790}{24}\ \frac{km}{hr}$$

$$= 11{,}033\ km/hr$$

$$v = 6840\ mph \quad \text{(miles per hour)}$$

Round Trip time Delay of Geosynchronous Satellites :-

The round-trip propagation delay between a Satellite and an earth station directly below it is

$$t = \frac{d}{c}$$

d → 2×height of satellite above the sea level

c → Velocity of light

$$= 2 \times 35768\ km \,/\, 3 \times 10^5\ km/s$$

↳ (h)

$$= 238\ ms$$

Advantages of Geosynchronous Satellites :→

1. Geosynchronous satellites remain almost stationary in respect to a given earth station. Consequently, expensive tracking equipment is not required at the earth stations.

2. They are available to all earth stations within their shadow 100% of the time. The shadow of a satellite includes all the earth stations that have a line-of-sight path to it and lie within the radiation pattern of the satellite's antennas.

3. There is no need to switch from one geosynchronous satellite to another as they orbit overhead. Consequently, there are no transmission breaks due to switching times.

4. The effects of Doppler shift are negligible
Doppler shift - shift in the frequency and wavelength of an electromagnetic field by the relative motion.

Disadvantages of Geosynchronous Satellites :-
1. They require sophisticated and heavy propulsion devices on board to keep them in a fixed orbit.

2. High altitude geosynchronous satellites introduce much longer propagation delays. The round trip propagation delay between two earth stations through a geosynchronous satellite is between 500 ms and 600 ms.

3. They require higher transmit power and more

sensitive receivers because of the longer distances and greater path losses.

4. High-precision spacemanship is required to place a geosynchronous satellite into orbit and to keep it here.

Key Parameters for Geostationary Orbit (GSO) :-

1. Range of Satellite

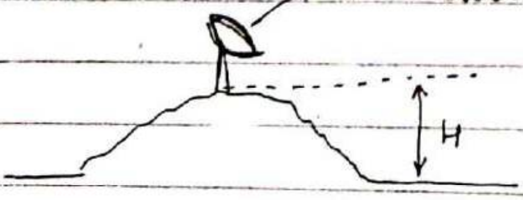
The determination of the range of the satellite from the earth station requires the radius of the earth at the earth station latitude and longitude, R. R (~~Range of the satellite~~) is given by

$$R = \sqrt{l^2 + z^2} \quad \text{———} \quad (1)$$

where l = radius of earth at the earth station longitude
z = radius of earth at the earth station latitude

$$l = \left\{ \frac{r_e}{\sqrt{1 - e_e^2 \left(\sin^2(L_e)\right)}} + H \right\} \cos(L_e) \quad \text{———} \quad (2)$$

where r_e = equatorial radius = 6378.14 km
H = earth station altitude above sea level
e_e = Eccentricity of the earth
= 0.08182

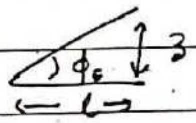


L_E = earth station latitude

$$z = \left\{ \frac{r_e (1 - e_e^2)}{\sqrt{1 - e_e^2 \sin^2(L_E)}} + H \right\} \sin(L_E) \quad \text{— (3)}$$

intermediate angle ϕ_E is given by

$$\phi_E = \tan^{-1}\left(\frac{z}{l}\right) \quad \text{— (4)}$$



Range d is then given by

$$d = \sqrt{R^2 + r_s^2 - 2 R r_s \cos\phi_E \cos B} \quad \text{— (5)}$$

Differential longitude (B) is defined as the difference between earth station and Satellite Longitudes

$$B = l_E - l_s \quad \text{— (6)}$$

where

l_E = earth station longitude (in Degree)

l_s = satellite longitude (in Degree)

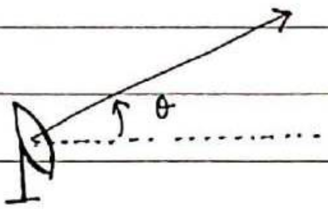
2. Elevation Angle to Satellite →

Elevation angle from the earth station to the satellite (θ) is

$$\theta = \cos^{-1}\left\{ \frac{r_e + h_{GSO}}{d} \sqrt{1 - \cos^2(B) \cos^2(L_E)} \right\} \quad \text{— (7)}$$

h_{GSO} = geostationary altitude = 35786 km

d = range in km



$\theta \rightarrow$ Elevation angle to satellite

Azimuth Angle to Satellite →

Intermediate angle A_i is given by

$$A_i = \sin^{-1}\left(\frac{\sin(|B|)}{\sin\beta}\right) \quad \text{——} (8)$$

where $|B|$ = Absolute value of the differential longitude

$$|B| = |l_E - l_s|$$

and $$\beta = \cos^{-1}\left[\cos(B)\cos(L_E)\right] \quad \text{——} (9)$$

The azimuth angle (ϕ_z) is determined from the intermediate angle (A_i) from one of the four possible conditions, based on the relative location of the earth station (ES) and sub satellite (SS) point on the earth's surface:-

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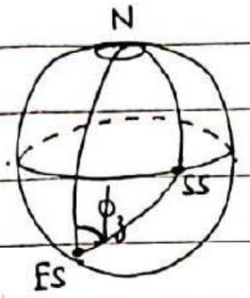
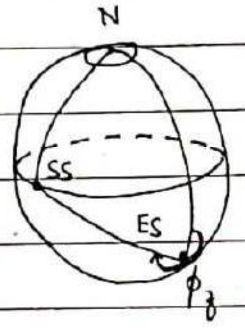


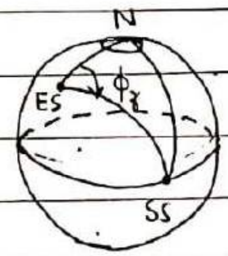
SS point is North East (NE) of ES

$\phi_z = A_i$



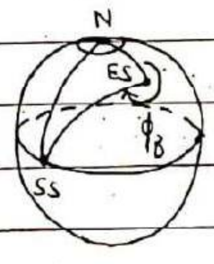
SS point is North West (NW) of ES

$\phi_z = 360 - A_i$



SS point is South East (SE) of ES

$\phi_z = 180 - A_i$



SS point is South West of ES

$\phi_z = 180 + A_i$

Frequency Band Designations → The frequency of operation is the major factor in the design and performance of a satellite communication link.

Wavelength of the free space path signal is the Principle that determines the interaction effects of the atmosphere, and the resulting link path degradation.

Methods of designation :-

1. Letter band frequency designation

In this there is division from 1 to 300 GHz into 8 bands with nominal frequency ranges :-

~~K- Band is further divided into Ku - band (K- lower) and KA - band (K - above).~~

Frequency (GHz)	Band	
1 – 2	L- Band	
2 – 4	S- Band	
4 – 8	C - Band	
8 – 12	X- Band	
12 – 18	Ku - Band	NATO K- Band
18 – 27	K- Band	NATO K- Band
27 – 40	KA - Band	NATO K- Band
40 – 300	Q - Band, V- Band, ...	

2. Frequency band designations by wavelength

In this, there is a division from 3Hz to 300 GHz into bands based on decade steps of nominal wavelength.

Frequency	Wavelength		
3 Hz	10^8 m		
30 kHz	10^4 m	→ VLF	Very low frequency
300 kHz	10^3 m	→ LF	Low Frequency
3 MHz	10^2 m	→ MF	Medium Frequency
30 MHz	10 m	→ HF	High Frequency
300 MHz	1 m	→ VHF	Very High Frequency
3 GHz	10 cm	→ UHF	Ultra high Frequency
30 GHz	1 cm	→ SHF	Super High Frequency
300 GHz	1 mm	→ EHF	Extremely High Frequency

Satellite Antenna Radiation Patterns: Footprints →

The geographical representation of a satellite antenna's radiation pattern is called a footprint or ~~f~~ footprint map.

Footprint of a satellite is the area on ~~ea~~ earth's surface that the satellite can receive from or transmit to.

Shape of the satellite's footprint depends on the satellite orbital path, hieght and the type of antenna used. The higher the satellite the more earth's surface it can cover.

A footprint map is constructed by drawing continuous lines between all points on a map with equal effective isotropic radiated power (EIRP)