ORBITS AND BUS
Advanced Technology in Radio Communications

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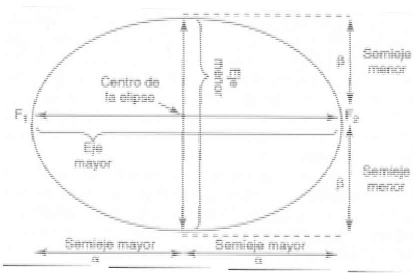
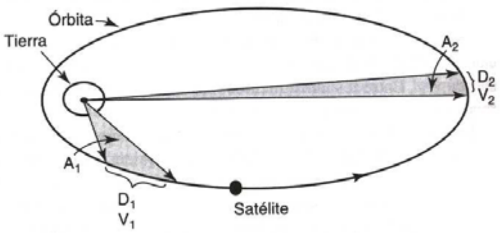
Orbits

- Orbital issues
- Classification of orbits
  - By synchronism (geo-synchronous and sun-synchronous)
  - By eccentricity (circular and elliptical)
  - By height (LEO, MEO and GEO)
- Comparison

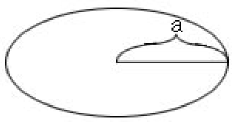
Orbital Issues

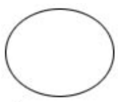
- Kepler's laws (18th century):
  - The orbit is an ellipse with the Sun in one of the two focus.
  - A line joining a planet and the Sun sweeps out equals areas during equal intervals of time.
  - The orbital period of a planet is directly proportional to the the semi-major axis of its orbit raising 3/2.



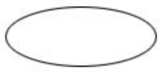


Orbital Issues

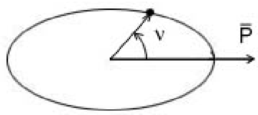


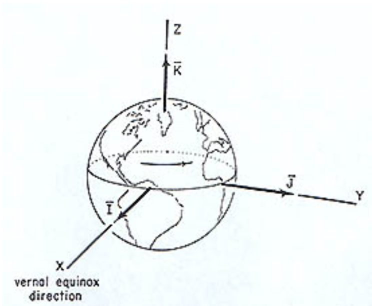


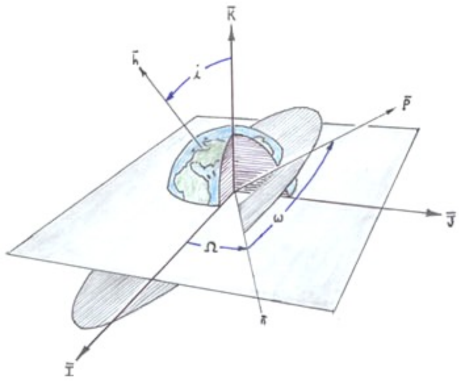
low eccen.
(0.1 - 0.2)



high eccentricity
(0.7 - 0.8)

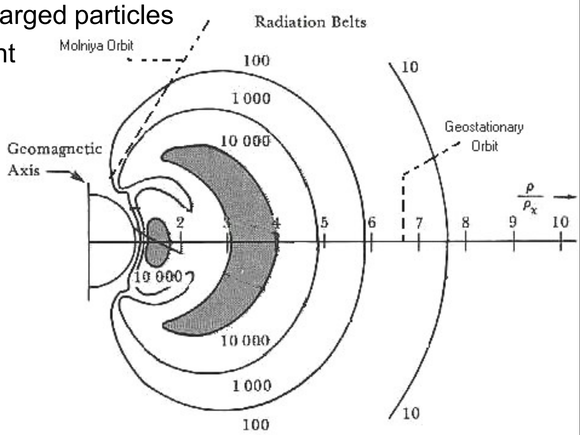






Orbital Issues

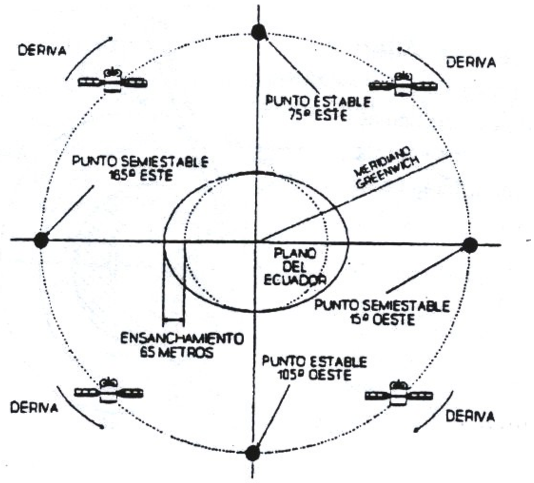
- Van Allen radiation belt
  - Magnetic field
  - Torus of energetic charged particles
  - It damages equipment
  - It protects low orbits
  - Molniya



Orbital Issues

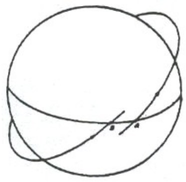
- Disturbing elements of the orbit
  - Gravity forces (Moon, Sun, planets).
  - Pressure forces of solar radiation
  - Atmospheric friction in low orbits
  - Terrestrial geometry
    - It is not spherical, it is flattened at the poles
    - It has not revolution symmetry
    - Earth three-dimensional model through series

GEO orbit drift



Orbital Issues

- Nodal regression $\Delta\Omega$: orbital plane change



$$k = J_2 R_E^2$$

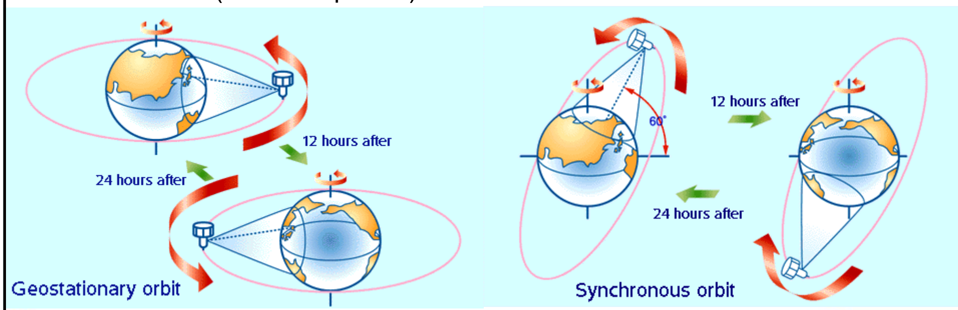
$$\Delta\Omega = -\frac{3\pi k}{a^2(1-e^2)^2}\cos(i)$$

- Apsidial rotation $\Delta\omega$: apogee rotation at the same plane

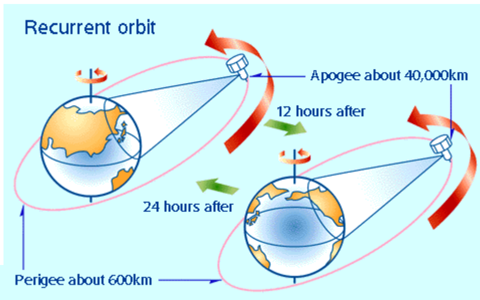
$$\Delta\omega = -\frac{3\pi k}{a^2(1-e^2)^2}(2-2{,}5sen^2(i))$$

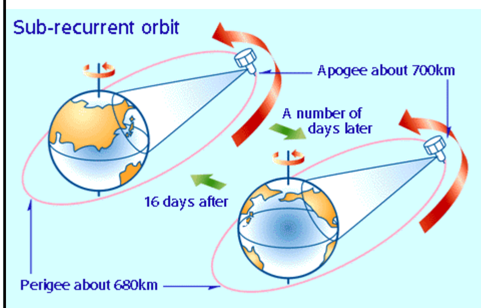
Types of orbits: Synchronous

- Geo-synchronous: Period is a submultiple of Earth rotation period.
  - Geostationary
  - Molniya (12 hours period)
  - Tundra (24 hours period)

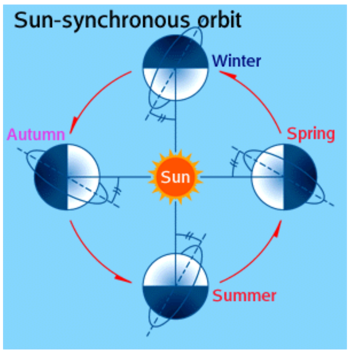


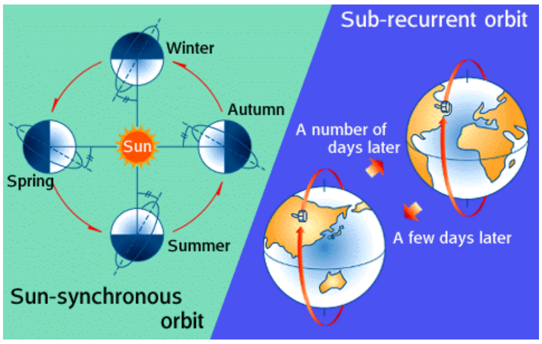
Types of orbits: Synchronous





Types of orbits: sun-synchronous





- Sun-synchronous: local solar time does not change over any given point.
- Under normal circumstances, orbit plane remains static.
- In sun-synchronous orbits, plane turns around and adapts to seasons.

Types of orbits

- Excentricity
  - Elliptical: Highly elliptical orbit (HEO)
  - Elliptical
  - Circular
- Orbit height
  - Geostationary Earth orbit (GEO)
  - Medium Earth orbit (MEO o ICO)
  - Low Earth orbit (LEO)

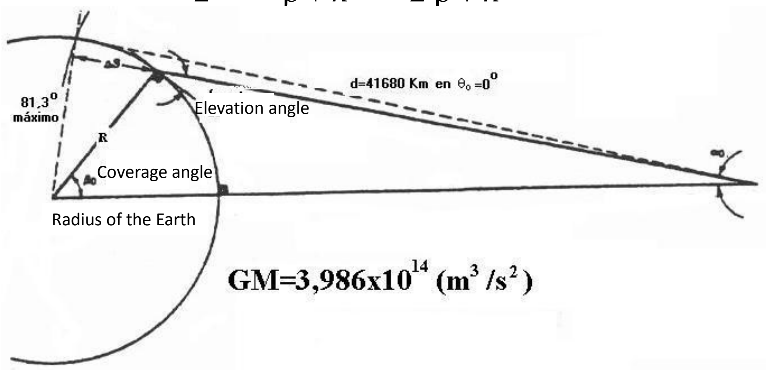
Orbits

- **GEO** Geostationary
- **HEO** Highly elliptical
  - Molniya has a perigee at a 593 km height and a apogee at a 39362 km height
  - Sloping is, usually, chosen from 63,4º to 116,6º
- **LEO** Circular, at least at a 1000 Km height
  - There can be polar orbits
  - Coverage to whole Earth requires from 60 to 90 satellites
- **ICO** intermediate circular orbit (**MEO**)
  - 14000 Km<radius<26000 Km if i=0º
  - Coverage to whole Earth requires from 8 to 12 satellites

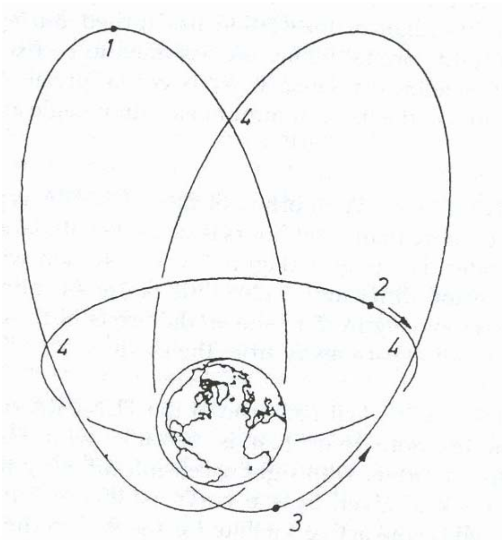
GEO orbit

- **Geo** Circular equatorial at a 35786 Km height

$$\frac{1}{2}v^2 - \frac{GM}{\rho + h} = -\frac{1}{2}\frac{GM}{\rho + h}$$



HEO



Daily curvature of the perigee argument is governed by:

$$\Delta\omega_{diario} = 4.98^\circ \left(\frac{R_E}{a}\right)^{\frac{7}{2}} \frac{5\cos^2 i - 1}{(1-\varepsilon^2)^2}$$

where:

R_E is terrestrial radius,

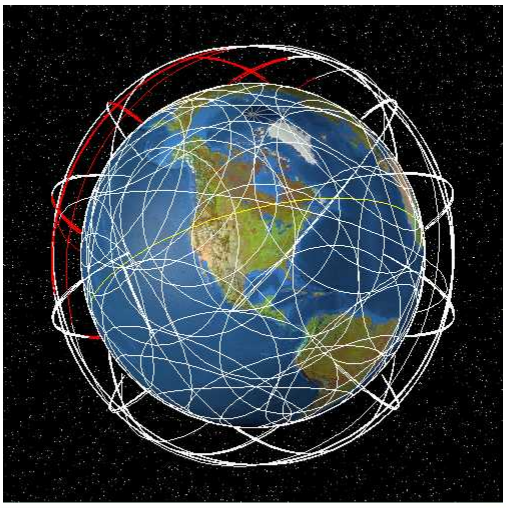
a is the semi-major axis length,

i is sloping,

and ε is total orbital eccentricity.

The equation is made equal zero with a 63,4 degrees sloping.

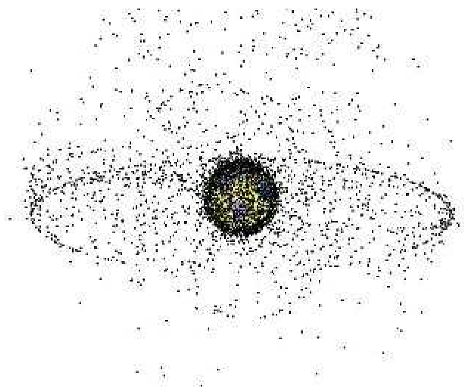
LEO



Environmental conditions

- Microgravity
- Solar influence
- galactic/cosmic rays
- Magnetosphere effects
- Atmosphere
- Ionosphere
- Micrometeorites / space debris
- Launch conditions: vibration, acoustics

Space debris



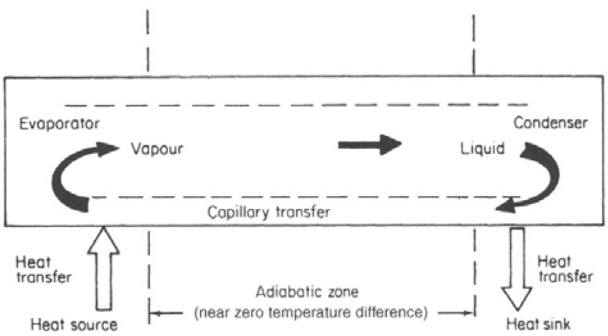
- 56 years in space
- 5000 launches
- 30000 objects > 10 cm
- Only 6% operatives
- -150000 obj. > 1 cm
- Only ≅0.1mm exceeds the natural spatial dust to human dust

BUS

- Structural subsystem
- Thermal control subsystem
- Power generation subsystem
- Orbit control and stabilization subsystem
- Propulsion subsystem
- Tracking, telemetry and command (TT&C)

Thermal subsystem

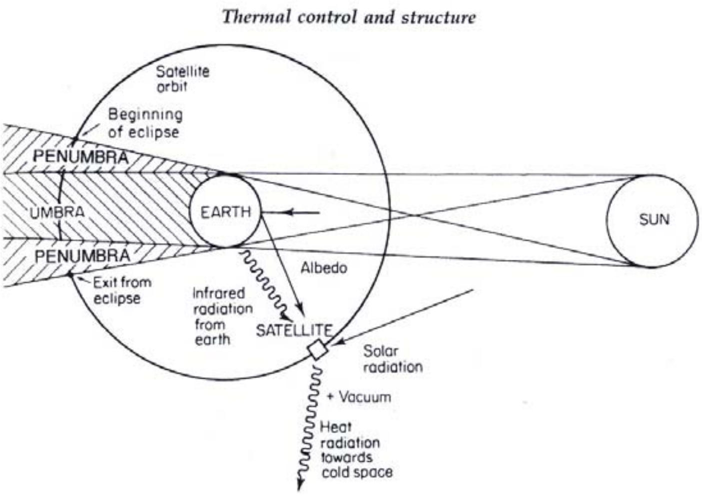
- Passive systems
  - isolators, conductives
- Active systems
  - Cool and Heat sink, cool and heat transfer



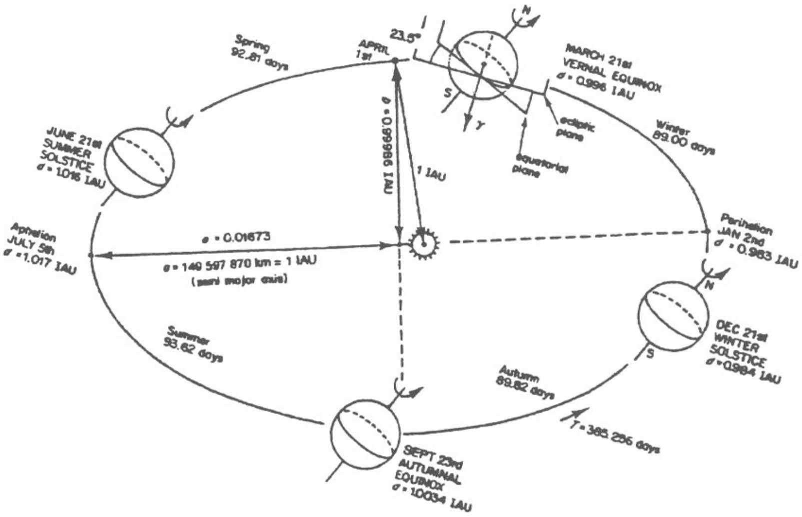
Power: generation

- Si or AsGa solar panels
- Deterioration by e^- and p^+ particles bombing
- It is oversized
- It is affected by eclipses due to the Earth

Generation & Thermal control



Seasons of the year

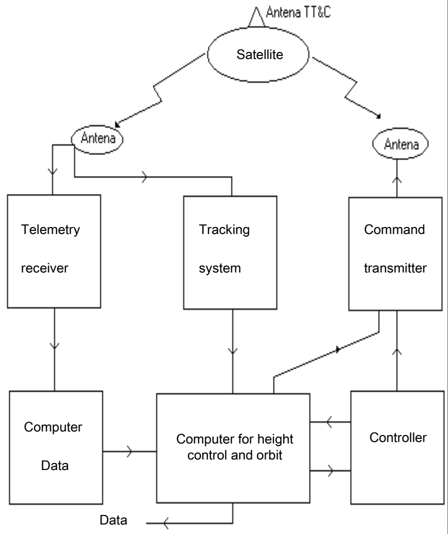


Power: conditioning and storage

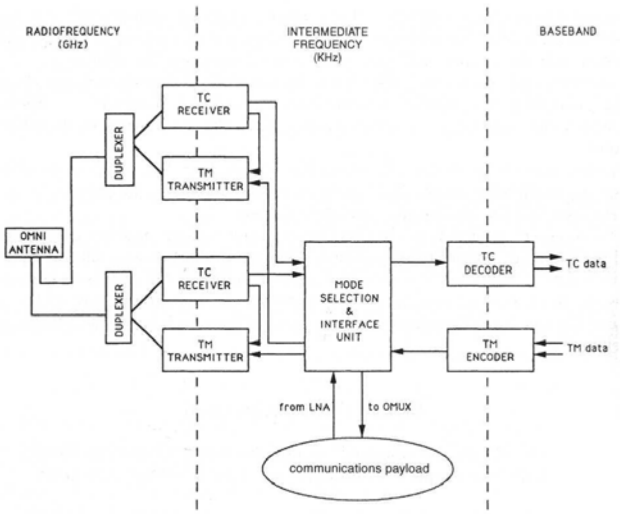
- Power generation depends on temperature
- Regulated or not regulated power Bus
- Ni-Cd battery (15% of total weight)
- There are discharge of the batteries in eclipses

TT&C (Tracking, Telemetry and command

- Shared antenna
  - Low directivity
  - Low bandwidth (PSK, FSK)
  - S and C bands (500-200 b/s)
- Tracking
  - Downlink direction
  - Radio beacon
  - Information of sensors with telemetry
- Telemetry
  - Downlink direction
  - It sends information from satellite
- Commanding
  - Uplink direction
  - It sends commands to satellite



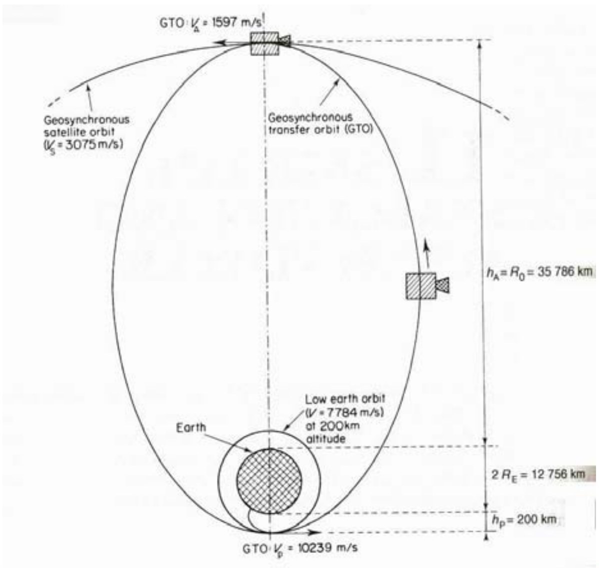
Bus: TT&C Telemetry



Bus: TT&C command

- It requires to duplicate commands in order to execute the functions
- To send orders and maneuvers unauthorized
- High channel and orders protection

Satellite deployment



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[2] W. Tomasi "Sistemas de Comunicaciones Electrónicas" Prentice Hall, México, 2003.

[3] "Antena de Telecomunicación" número 151, COITT, marzo 2003.

[4] www.esa.int

[5] www.upv.es/satelite

Appendix: Azimuth and elevation

1. Satellite concepts.
2. Orbits.
3. Low orbit sattelites.
4. Geostationary sattelites.

Appendix: Azimuth and elevation

1. Satellite concepts.

-It works in Microwave Frequency bands (4-8 GHz).

-Nowadays, 10 GHz (TV)

-GPS (Global Positioning System):

Satellite signals application is able to detect a radio link position on terrestrial surface

Appendix: Azimuth and elevation

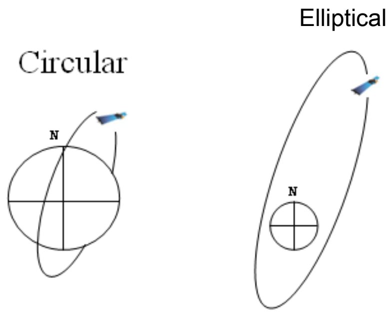
2. Orbits.

Orbit : Geometric figure that describes the movement of a satellite around the Earth.

There are 2 types:

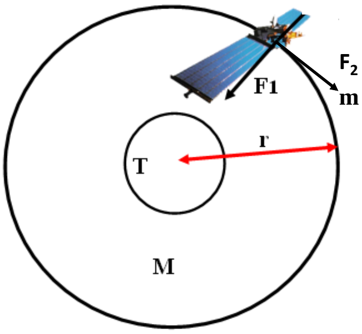
Circular

Elliptical



Appendix: Azimuth and elevation

2. Orbits.



r = a + h

a: terrestrial radius (6378 Km).

h: orbit radius on terrestrial surface.

F1= centripetal force. F2= centrifugal force

$$F_1 = G\frac{M \cdot m}{r^2} \qquad F_2 = \frac{m \cdot V^2}{r}$$

$$G = 6.668 \cdot 10^{-11}\, m^3/r \qquad M = 5.98 \cdot 10^{24}\, Kg$$

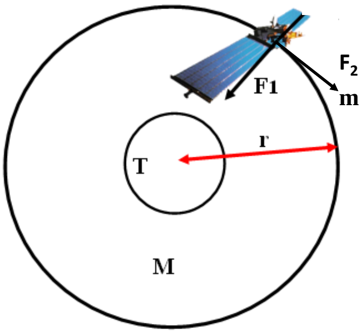
stable r → F_1=F_2 → $V = \sqrt{\frac{G \cdot M}{r}}$

τ : orbital periods of satellites

$$\tau(s) = \frac{2\pi \cdot r(km)}{v} = 0.0099527 \cdot r^{3/2}$$

Appendix: Azimuth and elevation

2. Orbits.



Example:

Sattelite in orbit h=1500Km → LEO

¿Laps/Day?

r=a+h

a=6378 km

τ (6959 s): Satellite time needed in a lap around the world.

$$T(Sec/Day) = 24(h) \cdot 60(m) \cdot 60(s) = 86400s$$

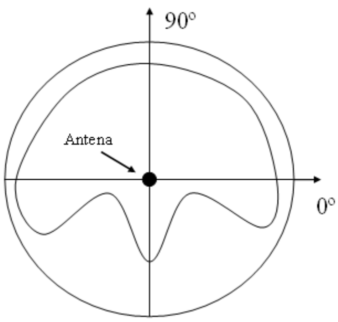
$$N = \frac{T}{\tau} = 12.41\, laps/day$$

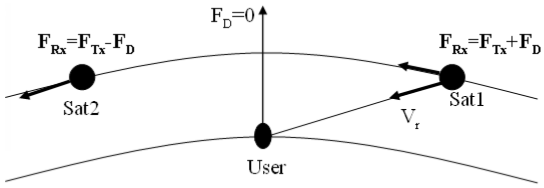
Appendix: Azimuth and elevation

3. Low orbit satellites.

Doppler effect

When the transmitter or the receiver of an electromagnetic or acoustic signal is separated from a variable distance, the received frequency is different to the transmitted frenquency .





$$F_D = \frac{V_r \cdot F_{TX}}{C}$$

V_r : radial velocity in satellite-user direction.

Lesson 4. Orbits and bus

Appendix: Azimuth and elevation

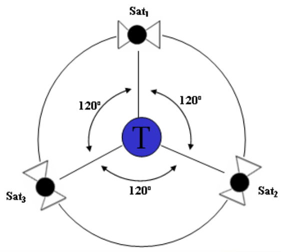
4. Geostationary satellites.

There are satellites that have two conditions:

- Geosynchronous: it moves with the same velocity than Earth.
- Orbital plane, is in equatorial plane (Earth axis coincides with satellite axis).

$$\tau = 0.0099527 \cdot r^{3/2} = 86164.1 \Rightarrow r = 42162Km$$
$$r = a + h \Rightarrow h = r - a \Rightarrow h = 42162 - 6378 = 35784Km$$

In order to give satellite coverage all around the world we need 3 geostationary satellites.



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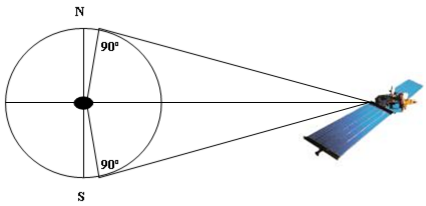
Appendix: Azimuth and elevation

4. Geostationary satellite.



Do not give coverage in poles.→ Solution : low orbit satellites.

Global coverage antenna $D=\frac{4\pi}{\Omega_{eq}}=\frac{4\pi}{(\theta_{-3dB})^2}\Rightarrow \theta_{-3dB}=8.7^{\circ}\Rightarrow D=21dB$

Appendix: Azimuth and elevation

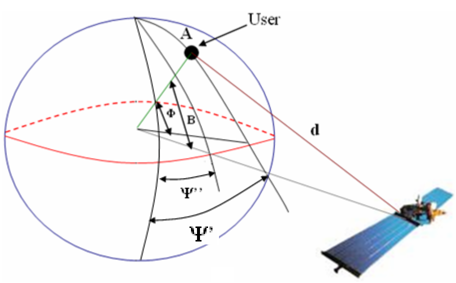
4. Geostationary satellites.

<u>Distance and positioning.</u>

$$d=h\cdot\sqrt{1+\frac{(1-\cos B)(2\cdot a^2+2\cdot a\cdot h)}{h}}$$

$$d=35783\sqrt{1+0.42\cdot(1-\cos B)}$$

$$\cos B=\cos\phi\cdot\cos(\psi'-\psi'')$$



Φ Ξ user latitude.

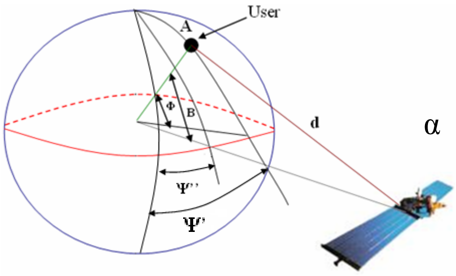
Ψ' Ξ user longitude.

Ψ'' Ξ satellite longitude.

Appendix: Azimuth and elevation

4. Geostationary satellites.

<u>Distance and positioning.</u>



Azimuth(α):

$$\alpha' \Rightarrow tg(\alpha') = \frac{tg(\psi' - \psi'')}{sen(\Phi)}$$

$$\alpha \begin{cases} \alpha' + 180^{\circ} \text{ (North hemisphere)} \\ \alpha' \end{cases}$$

Elevation(θ):

$$tg\ \theta = \frac{\cos B - a/(a+h)}{senB} = \frac{\cos B - 0.151269}{SenB}$$

Appendix: Azimuth and elevation

4. Geostationary satellites.

<u>Distance and positioning.</u>

Example:

- Satellite: Longitude 24° W → Ψ''= -24°
- User: Longitude 2° W → Ψ'=-2°, Latitude 53° N → Φ=53°
- Cos B = 0.558 → B = 56.1°

$$d = 35783 \cdot \sqrt{1 + 0.42 \cdot (1 - \cos B)} = 38963.11\, Km$$

- <u>Azimuth:</u>

$$tg(\alpha') = \frac{tg(\psi' - \psi'')}{sen\Phi} = \frac{tg((-2^{\circ}) - (-24^{\circ}))}{sen(53^{\circ})} = 0.505$$ → α' =26.83° → α =α'+180° =206.83°

- <u>Elevation:</u>

$$tg\,\theta = \frac{\cos B - 0.151269}{senB} = 0.49$$ →θ=26.11°