Satellite Communications

PRINCIPLE OF SATELLITE COMMUNICATION

Chapter One

Lecture 6

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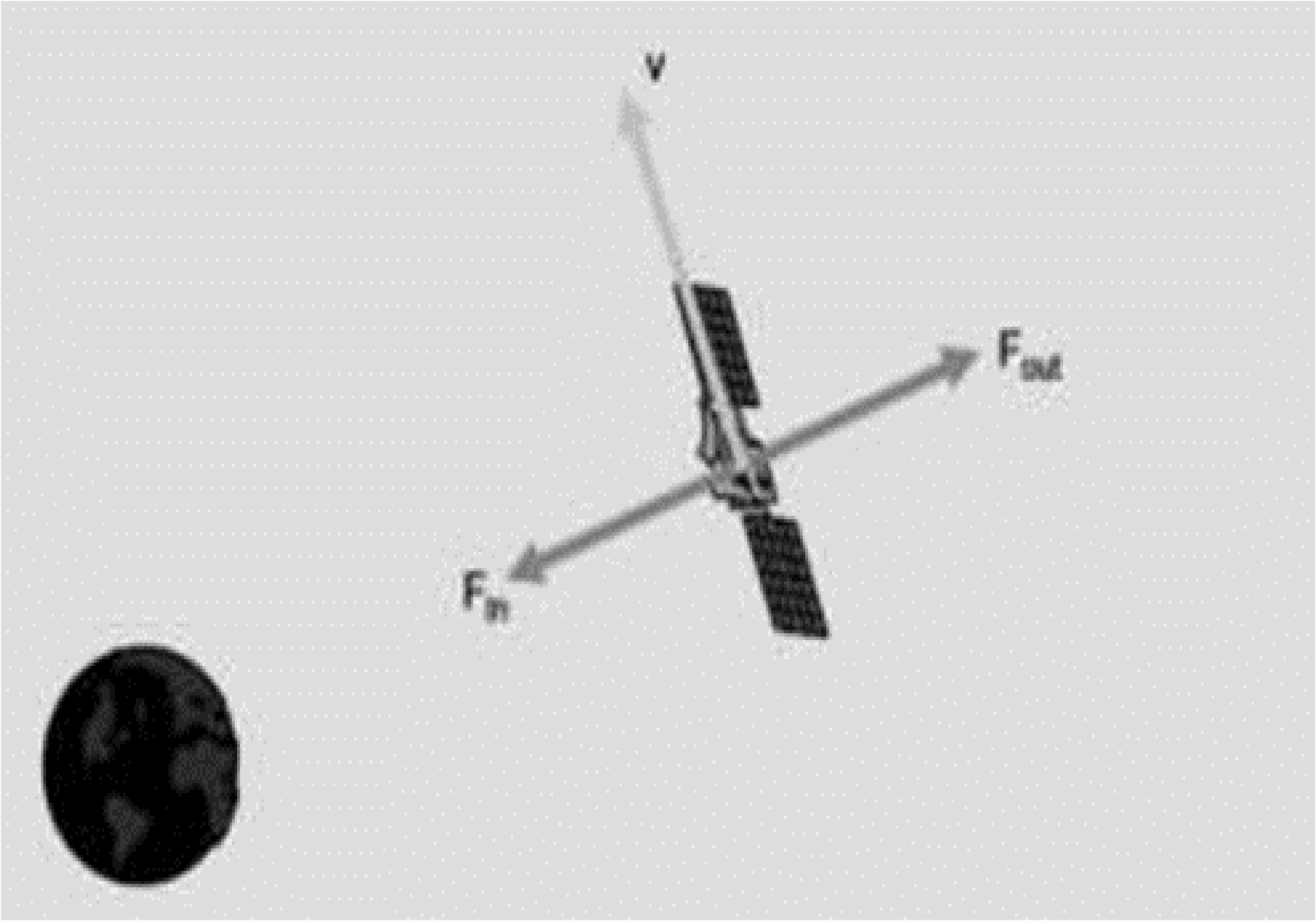
Orbital Velocity

Depending on the laws of motion first developed by Kepler and Newton.

The competing forces act on the satellite; gravity tends to pull the satellite in towards the earth, while its orbital velocity tends to pull the satellite away from the earth



Orbital Velocity

- The gravitational force keeps the satellite in orbit.
- gravitational force (Fin)
- angular velocity force (Fout)

satellite stable in orbit so the Fc(Fin) = Fg (Fout)

$$(mv^2/\mathrm{r}) = (GMm/\mathrm{r}^2)$$
$$(v^2/\mathrm{r}) = (GM/\mathrm{r}^2)$$

$$v = \sqrt{\frac{Gm_E}{r}}$$

v : satellite velocity for circular orbit in km/sec

Note: all other forces acting on the satellite, such as the gravity forces from the moon, sun, and other bodies, is neglected.

Example

Human-made satellites typically orbit at heights of 400 miles from the surface of the Earth (about 640 kilometers, or 6.4×10^5 meters). What's the speed of such a satellite? All you have to do is put in the numbers:

$$v = \sqrt{\frac{Gm_E}{r}} = \sqrt{\frac{\left(6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2\right)\left(5.98 \times 10^{24}\text{kg}\right)}{\left(6.38 \times 10^6\text{m}\right) + \left(6.40 \times 10^5\text{m}\right)}} \approx 7.54 \times 10^3\text{m/s}$$

This converts to about 16,800 miles per hour.

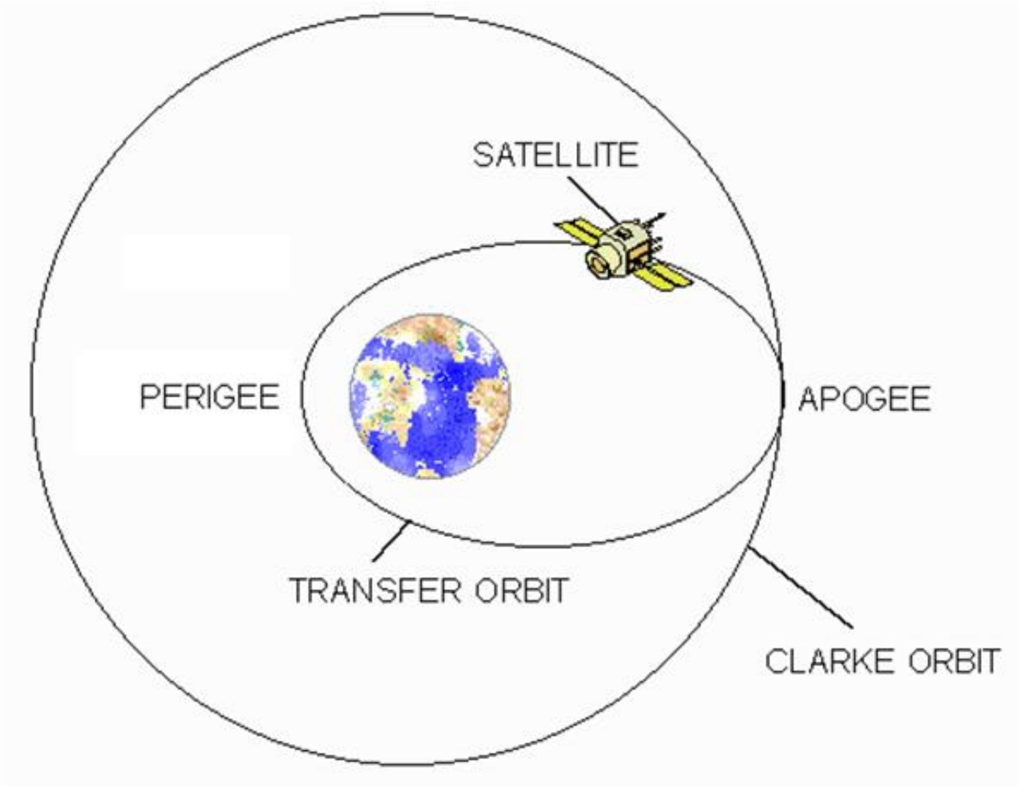
Launching Satellites into Orbit

Placing a satellite into geosynchronous orbit requires an enormous amount of energy. The launch process can be divided into two phases:

- Launch phase.
- Orbit injection phase.

The Launch Phase

During the launch phase, the launch vehicle places the satellite into the transfer orbit an elliptical orbit that has at its farthest point from earth (apogee) the geosynchronous elevation of 22,238 miles and at its nearest point (perigee) an elevation of usually not less than 100 miles.



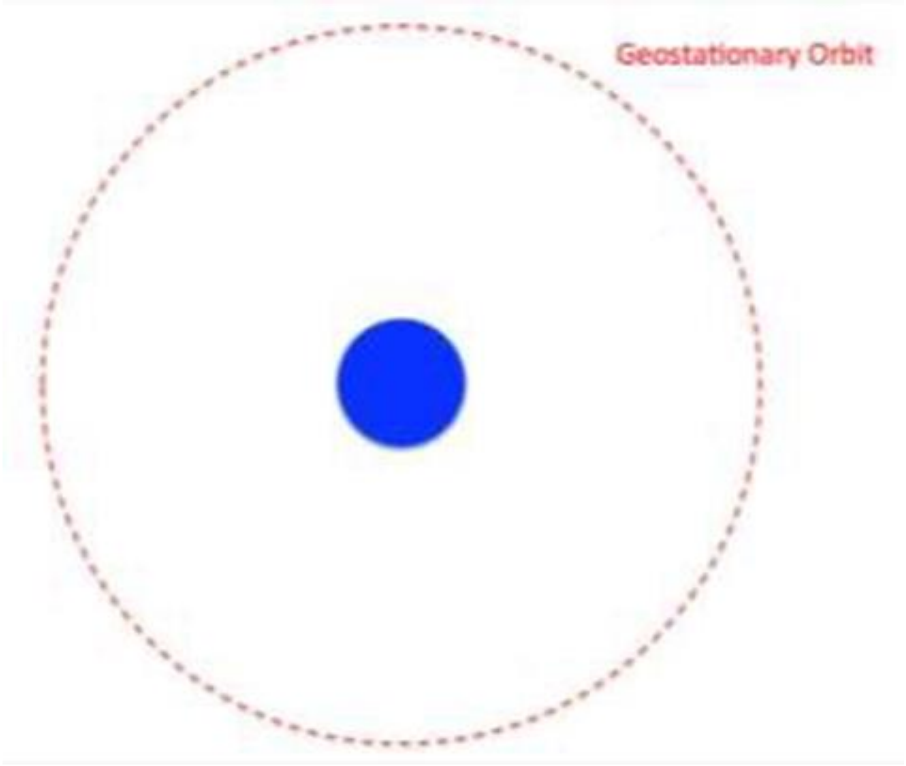
The Orbit Injection Phase

The energy required to move the satellite from the elliptical transfer orbit into the geosynchronous orbit is supplied by the satellite’s apogee kick motor (AKM). This is known as the orbit injection phase.

The Orbit Injection Phase

A geostationary orbit is an orbit in which a spacecraft can appear to hover over a fixed point on Earth. That is particularly useful for communication or observation satellites.

A geosynchronous orbit is an orbit in which a spacecraft will pass over the same point, once per day.



The Orbit Injection Phase

If we want our the spacecraft appears to hover over a fixed point on Earth:

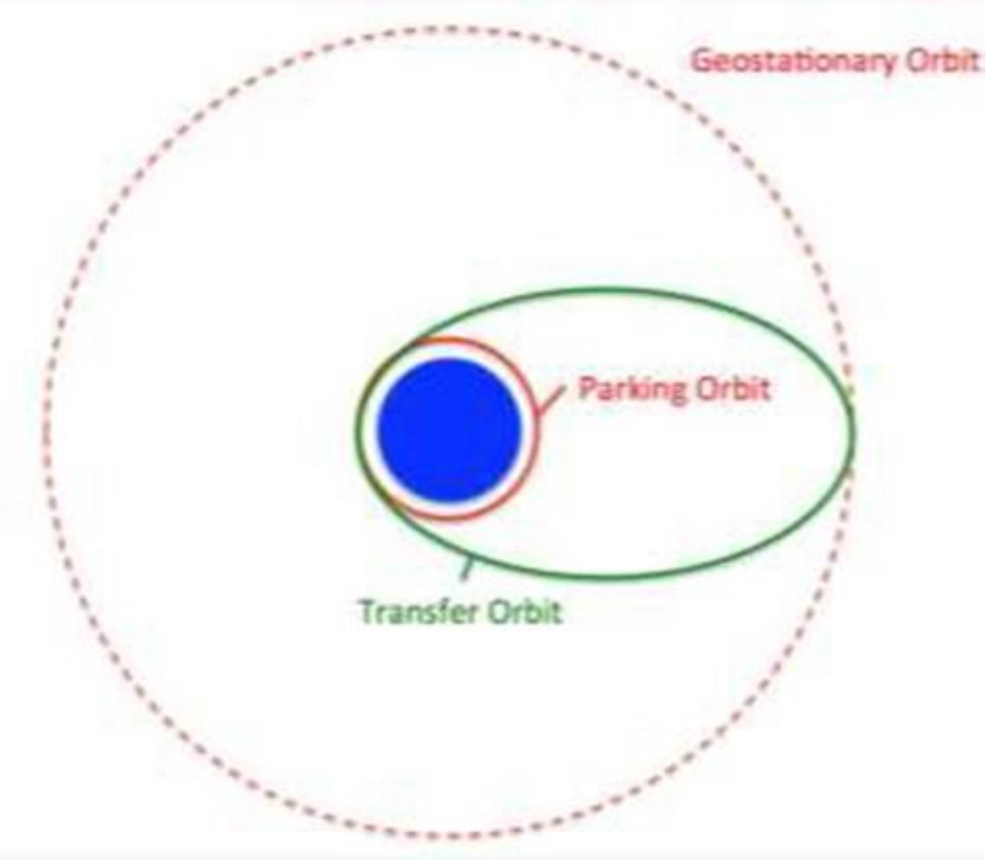
1. The orbit must be equatorial (inclination of 0 degrees).
2. The angular velocity must match that of the surface of the Earth. That turns out to be around 35,900 km (22,300 miles).

Two challenges need to solve:

1. Need to get to that high altitude.
2. Need to change our inclination.

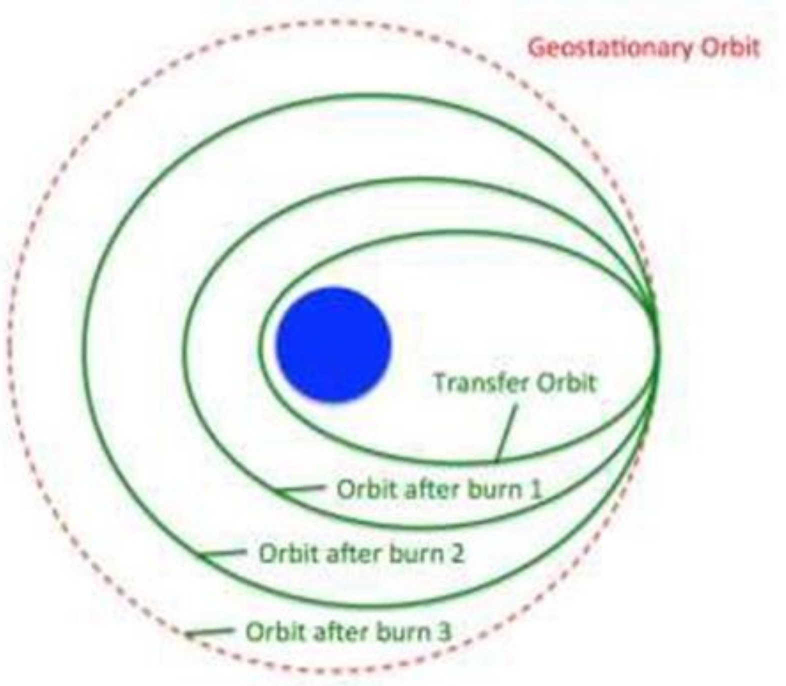
The Orbit Injection Phase

The rocket often takes the spacecraft to a **parking orbit** at an altitude of 180-200 km , this called the **parking orbit** ,it is often used to test vehicle systems before committing to further action.



The Orbit Injection Phase

The Geostationary Transfer Orbit (GTO) is a highly elliptical orbit with a perigee of 180-200 km above the Earth's surface and an apogee of around 35,900 km.



The Orbit Injection Phase

- The spacecraft has an engine that is called the **Apogee Kick Motor (AKM).** That motor is fired at apogee to circularize the orbit.

- **AKM** is used three times. Each of these burns has two objectives:

1) increase the perigee of the orbit.

2) decrease the inclination of the orbit.

Sidereal Time Vs Solar Time

- **Sidereal Time**: is a time scale that is based on the Earth's rate of rotation measured relative to the fixed stars.

  Sidereal day = 23h 56 m 04.09053 s

- **Solar Time:** is a reckoning of the passage of time based on the Sun's position in the sky. Solar day = 24 h

- Satellite orbits coordinates are specified in sidereal time rather than in solar time.
- Solar time, which forms the basis of all global time standards.
- The earth rotates once per sidereal day of The earth rotates once per sidereal day of 23 h 56 min 4.09s. Use 23 h 56 min 4.09s.

Footprint

- The area on Earth that the satellite can reach with its antennas is called the satellite 'footprint'.
- A satellite's footprint refers to the area over which the satellite operates: the intersection of a satellite antenna transmission pattern and the surface of the Earth.