Satellite Communications

PRINCIPLE OF SATELLITE COMMUNICATION

Chapter One

Lecture 4

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The Elliptic Orbit

- All satellites around the Earth are in an elliptic orbit.
- A parabolic and hyperbolic orbit are non-periodic which represent escape orbits (the satellite in these orbits leaves the Earth).
- The parabolic orbit is the minimum energy escape orbit.

In the figure we can identify the following items:

Occupied focus location of the Earth or central attracting body

a = semi-major axis

r = radius from center of Earth to satellite

r_p = Earth perigee distance

r_a = Earth apogee distance

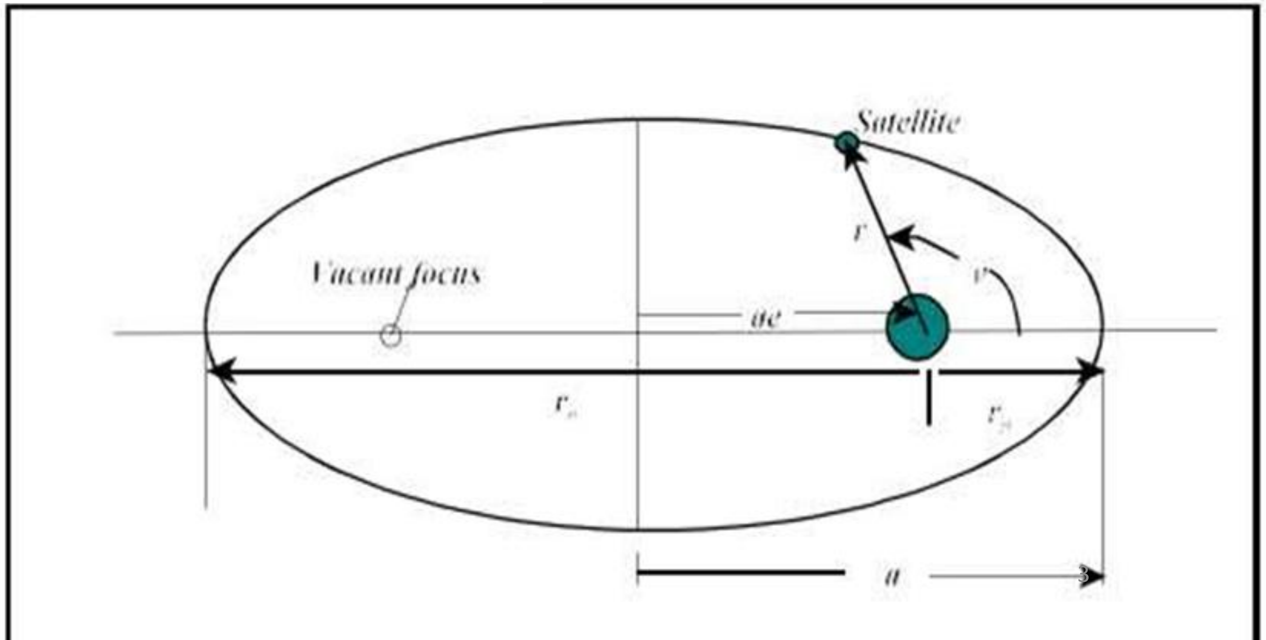
e = orbit eccentricity ($0<e<1$ for elliptic orbits, $e = 0$ is circular orbit)

Note that r is measured from the center of the Earth, hence we can note that:

$$r = R_e + h$$

where h = height ***above*** Earth's surface, R**e** = earth radius

Note: radius of the Earth must be added to the height to get the perigee and apogee radii.



The polar equation for the elliptic orbit

$$a = \frac{r_p + r_a}{2} \qquad \text{……………….(1)}$$

$$\left.\begin{aligned} r_a &= a(1+e) \\ r_p &= a(1-e) \end{aligned}\right\} \qquad \text{..…………………….(2)}$$

$$e = \frac{r_a - r_p}{r_a + r_p} \qquad \text{…………………..(3)}$$

Example

The international space station is in a “372 x 381 km orbit”, what is the eccentricity of the orbit?

Sol:

$$r_p = R_e + h_p = 6378.1363 + 372 - 6750.1363 \text{ km}$$

$$r_a = R_e + h_a = 6378.1363 + 381 = 6759.1363 \text{ km}$$

Then the eccentricity is given by:

$$e = \frac{r_a - r_p}{r_a + r_p} = \frac{6759.1363 - 6750.1363}{6759.1363 + 6750.1363} = 0.00067$$

Hence the international space station is in a near circular orbit.

In order to find the apogee and perigee height. The length of the radius vectors at apogee and perigee can be obtained from the geometry of the ellipse:

from equation (2) ,

ra: radius vector at apogee

rp : radius vector at perigee

e : Eccentricity

Then we can calculate h**a** and h**p** as :

$$h_a = r_a - R$$

$$h_p = r_p - R$$

Circular Orbits

- Circular orbit is a special type of elliptical orbit.
- The major and minor axis distances are equal or approximately equal in a circular orbit.
- The height above earth, instead of perigee and apogee, is used in describing a circular orbit.
- A satellite in a circular orbit at a height of approximately 36000 Km above the earth is in a synchronous orbit
- At this altitude the period of rotation of the satellite is 24 hours, the same as the rotation period of the earth. That means the orbit of the satellite is in sync with the rotational motion of the earth.
- Although inclined and polar synchronous orbits are possible, the term synchronous usually refers to asynchronous equatorial orbit

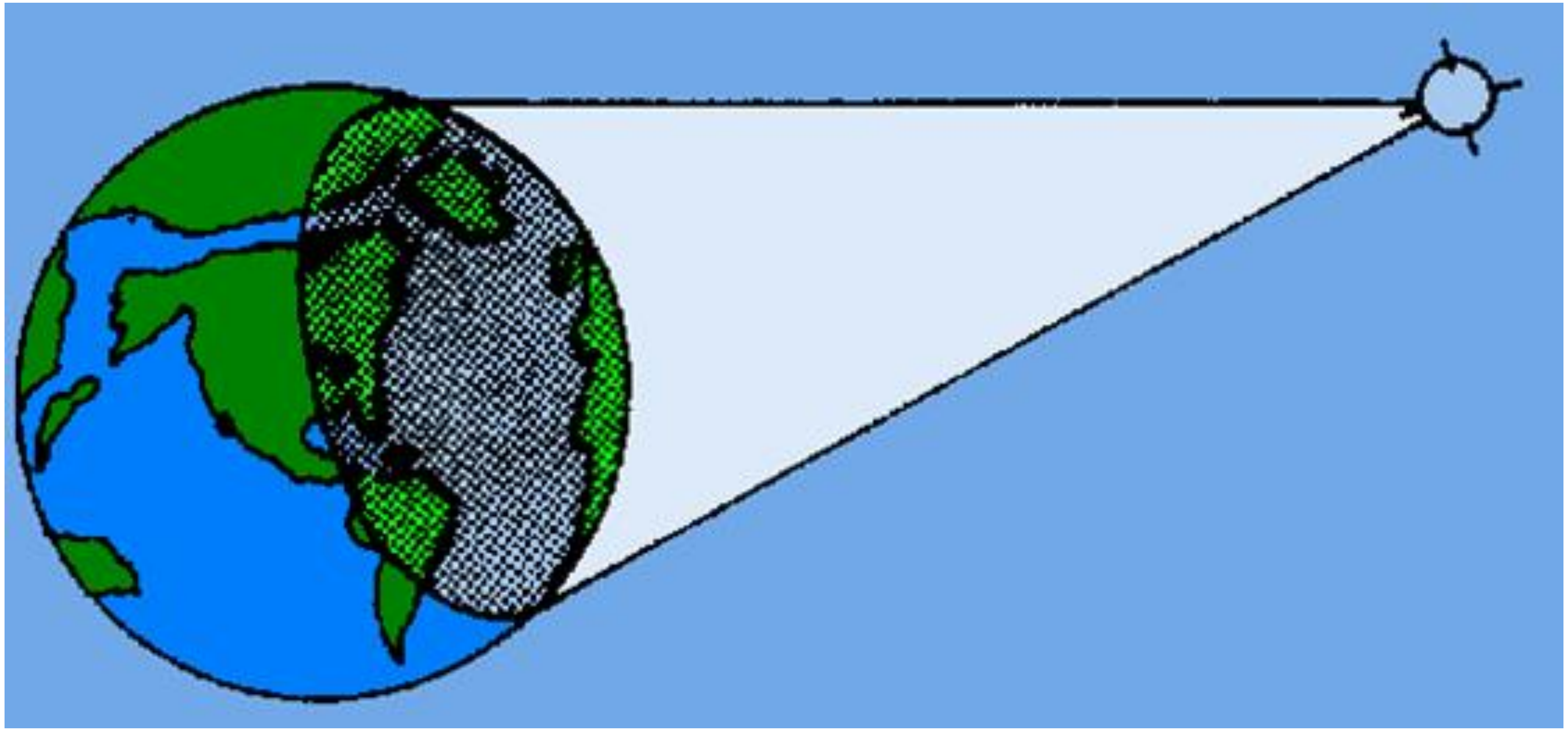


Figure 1-8 - Illumination from a synchronous satellite.

Three of these satellites can provide coverage over most of the earth

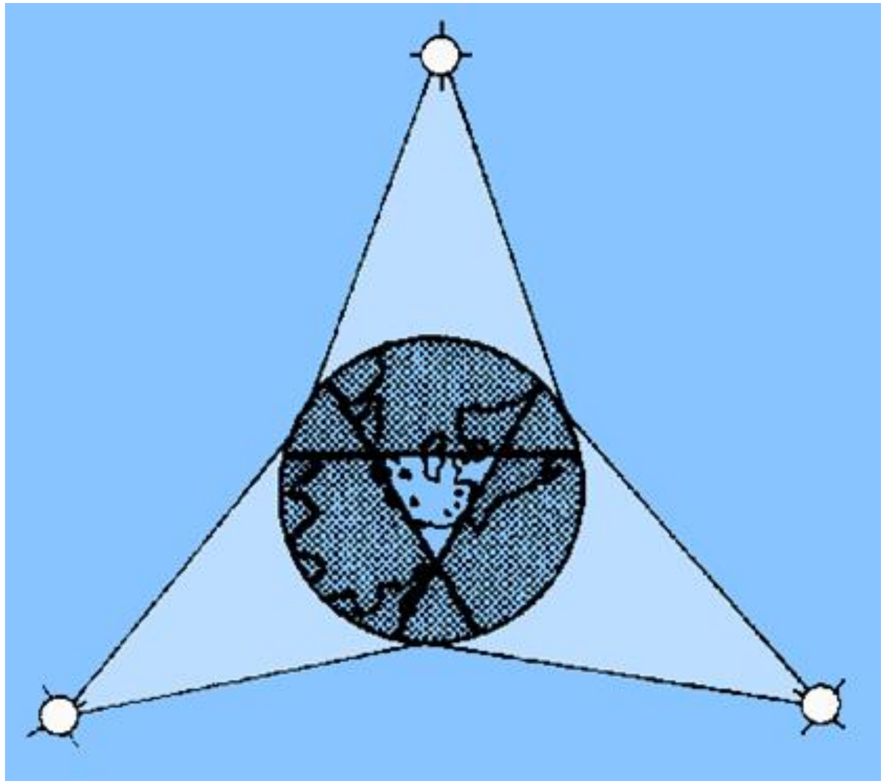


Figure 1-9. - Worldwide synchronous satellite system viewed from above the North Pole

Kepler's Law

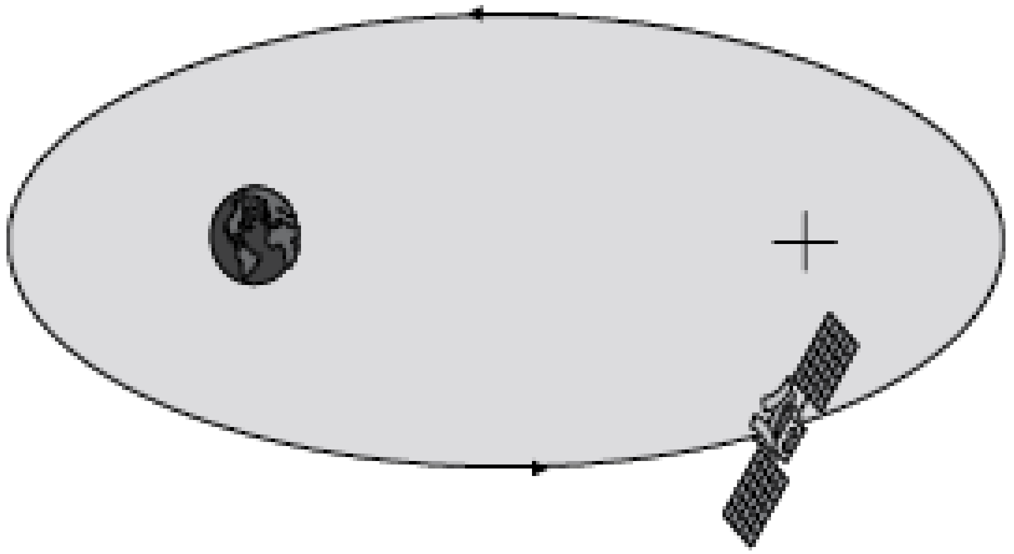
- Johann Kepler determined three laws characterizing orbital motion which can be proven mathematically using Newton's law of gravitation.

- laws apply directly to satellite orbital motion, thus the laws are from the point of view of an Earth-orbiting satellite.

Kepler's Law

- **Kepler's First Law:**

Satellite orbits are elliptical Paths with the Earth at one focus of the ellipse

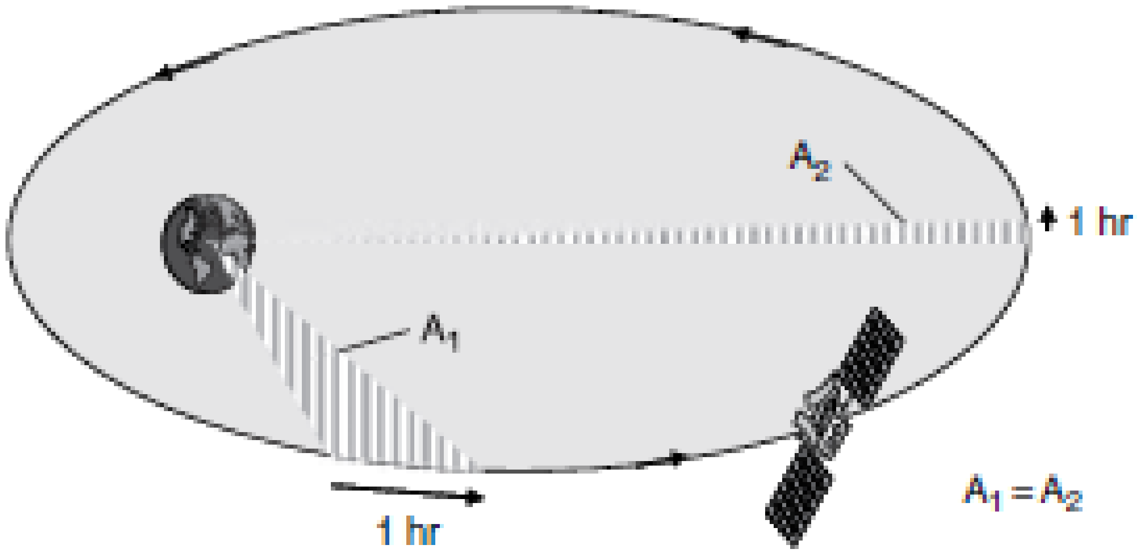


Kepler's Law

• **Kepler's Second Law:**

for equal time intervals, the satellite sweeps out equal areas in the orbital plane.

Note that the satellite orbital velocity is not constant; the satellite is moving much faster at locations near the earth, and slows down as it approaches apogee



Kepler's Law

- **Kepler's Third Law:**

The square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

$$T^2 = [\frac{4\pi^2}{\mu}]a^3$$

T : orbital period in sec.

a : distance between the two bodies in km

μ: Kepler’s Constant =3.986004×10^5 km^3/s^2.

If the orbit is circular, then a = r

$$r = [\frac{\mu}{4\pi\verb|^|2})]^{\frac{1}{3}} \; T^{\frac{2}{3}}$$