PRESENTATION
ON

SATELLITE COMMUNICATIONS

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SATELLITE COMMUNICATIONS

UNIT-I
COMMUNICATION SATELLITE

SATELLITE COMMUNICATIONS

Overview of present and future trends of satellite communications introduction to satellite systems

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Need for satellite communications:

- Satellite communication is a wireless communication which covers very large area. In this introduction we will try to see why do you need it in such a difficult type of communication and then we will go back to history and cover a few terms in this process.
- There is a need of space communication; what is the need, it is a wireless communication; terrestrial microwave links are not suitable to meet a large cover large geographical area particularly for radio, television networking even cellular telephony large geographical area.
- The basic requirement is earth is not flat, earth surface is not flat and micro wave communication; it goes straight line just like light. So, therefore, if there are two towers, the second tower unless it is in the radio visibility it will be not able to receive the signal from the transmitting tower. So, therefore, only a short distance can be covered and you can see that our mobile towers can cover a smaller distance, radio and television earlier days the large towers some of you might have seen in big cities they cover only the city.

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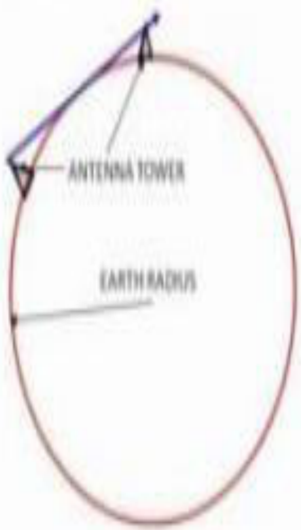
Need of space communications

Terrestrial microwave links are not suitable to meet the demand of large geographical coverage for Radio, Television networking and even cellular telephony.



Radio / TV Repeater towers are needed after every few kilometres.

How many towers required to cover Indian land mass ?

Assume,
Indian land area = 4×10^6 km^2
Mobile tower cover a radius of 1 Km
All towers are interconnected to provide all India coverage

Calculate number of mobile towers required to fully cover India.

Mobile tower coverage with 1 Km radius = $\pi(1)^2$ = 3.14 Km^2

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No. of towers required to cover India
= $(4 \times 10^6) / 3.14$ = 1.27 million

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Advantages of Satellite communications

- Broadcast to very large area
  - Cost effective as it can reach large number of customers
  - Communication to/from unreachable area
- Reliable solution to last mile problem
  - No need to get Govt. permission to dig the roads
- Quick set up time with bandwidth on demand
  - Use for Disaster and Defence
- Provide fairness of service as demanded
  - Diverse user network
- Long life (12 to 20 years)
  - Very Little maintenance

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Classification of Satellite Orbits

Circular or elliptical orbit
Circular with center at earth's center
Elliptical with one foci at earth's center Orbit around earth in different planes
Equatorial orbit above earth's equator
Polar orbit passes over both poles
Other orbits referred to as inclined orbits Altitude of satellites
Geostationary orbit (GEO)
Medium earth orbit (MEO)
Low earth orbit (LEO)

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Satellite Orbits are divided into 3 types

Equatorial

Inclined

Polar

Gravity depends on the mass of the earth, the mass of the satellite, and the distance between the center of the earth and the satellite.For a satellite traveling in a circle, the speed of the satellite and the radius of the circle determine the force (of gravity) needed to maintain the orbitThe radius of the orbit is also the distance from the center of the earth.

For each orbit the amount of gravity available is therefore fixed That in turn means that the speed at which the satellite travels is determined by the orbit From what we have deduced so far, there has to be an equation that relates the orbit and the speed of the satellite:

$$T = 2\pi \sqrt{\frac{r^3}{4 \cdot 10^{14}}}$$

R^3=mu/n^2

N=2pi/T

T is the time for one full revolution around the orbit, in seconds

r is the radius of the orbit, in meters, including the radius of the earth ($6.38 x 10^6$m).

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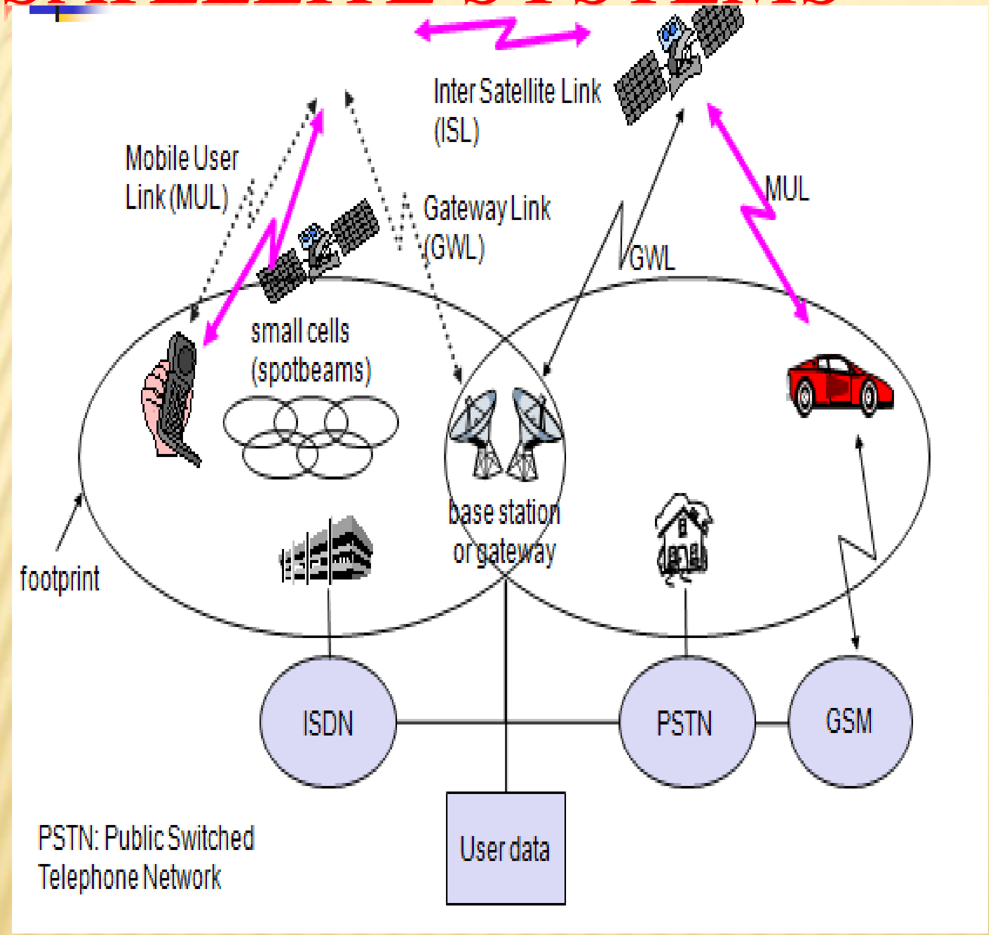
CLASSICAL SATELLITE SYSTEMS



Satellites in circular orbits

- attractive force $F_g = m\ g\ (R/r)^2$
- centrifugal force $F_c = m\ r\ \omega^2$
- m: mass of the satellite
- R: radius of the earth (R = 6370 km)
- r: distance to the center of the earth
- g: acceleration of gravity (g = 9.81 m/s²)
- ω: angular velocity (ω = 2π f, f: rotation frequency)

Stable orbit

- $F_g = F_c$

$$r = \sqrt[3]{\frac{gR^2}{(2\pi f)^2}}$$

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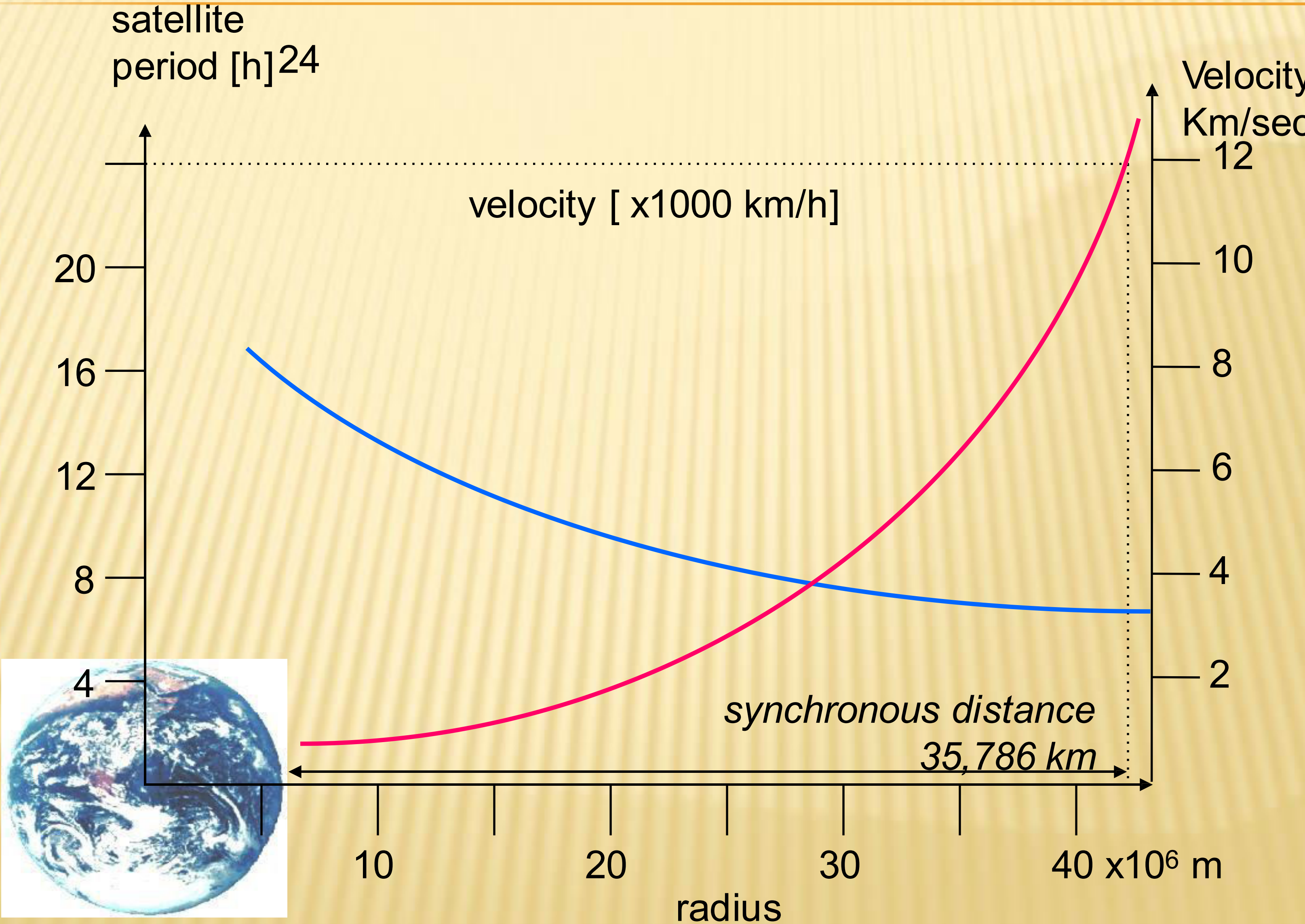

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- elliptical or circular orbits
- complete rotation time depends on distance satellite-earth
- inclination: angle between orbit and equator
- elevation: angle between satellite and horizon
- LOS (Line of Sight) to the satellite necessary for connection
  - high elevation needed, less absorption due to e.g. buildings
- Uplink: connection base station - satellite
- Downlink: connection satellite - base station
- typically separated frequencies for uplink and downlink
  - transponder used for sending/receiving and shifting of frequencies
  - transparent transponder: only shift of frequencies
  - regenerative transponder: additionally signal regeneration

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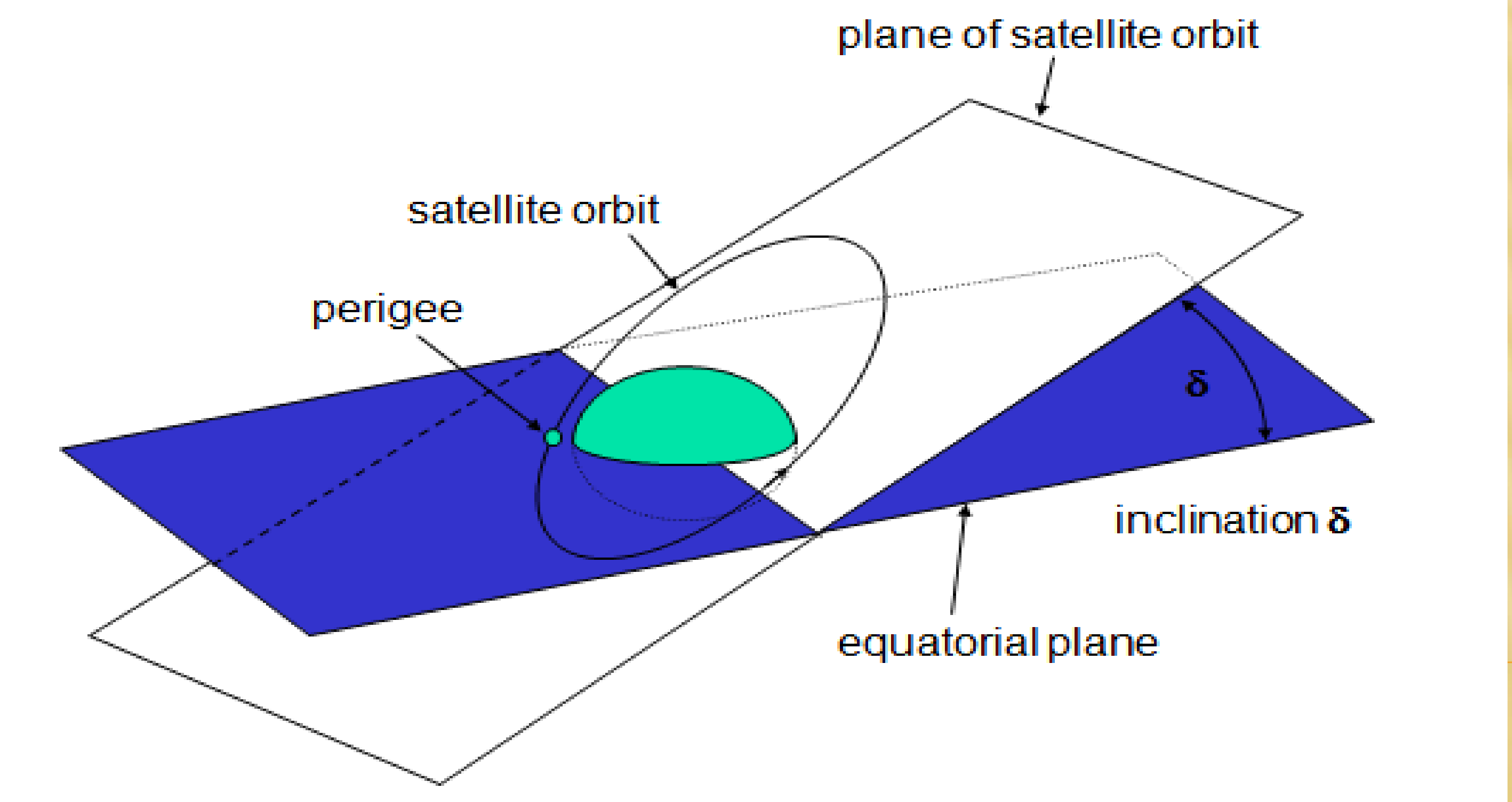
Inclination



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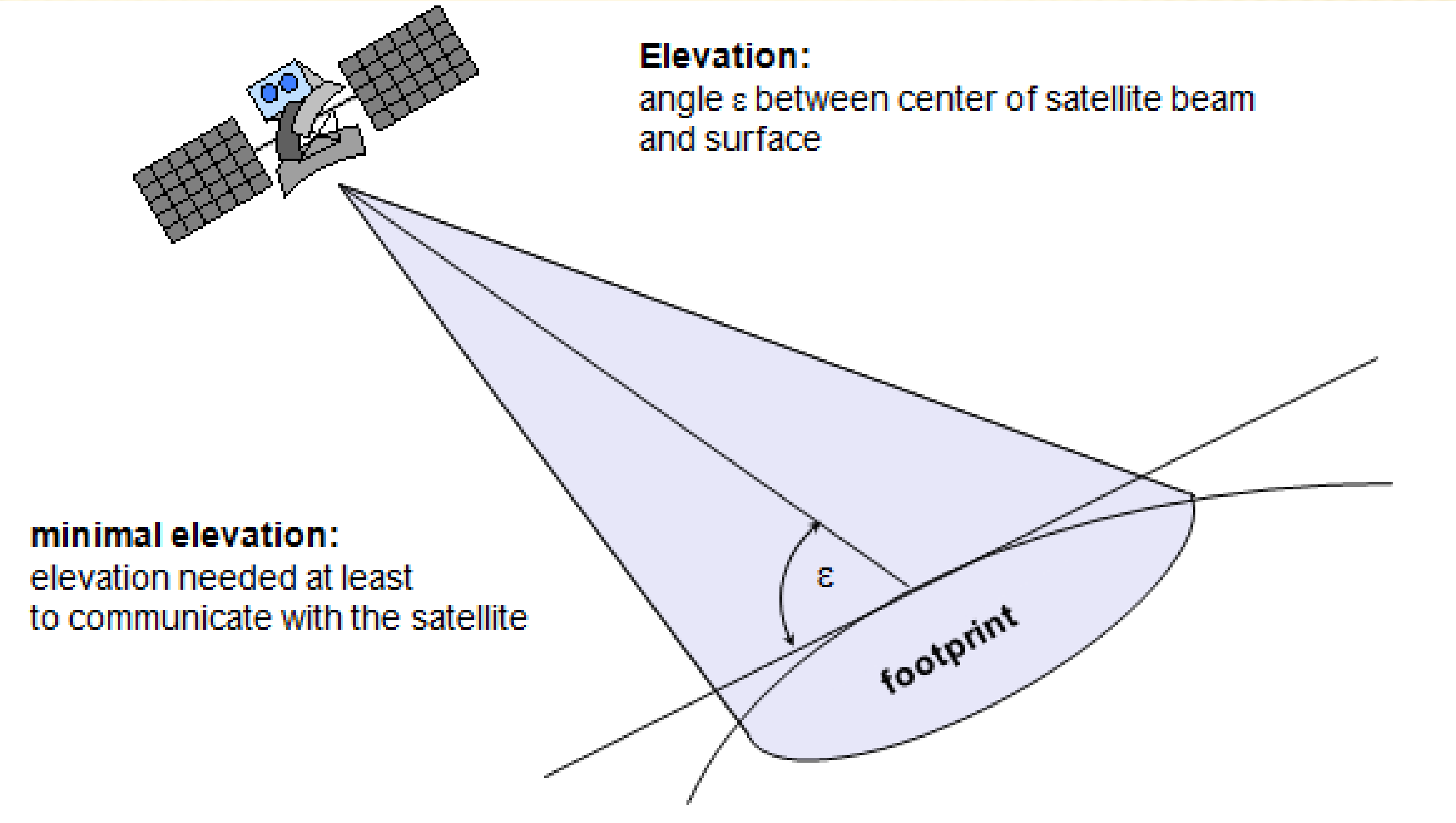
Elevation



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Orbits I

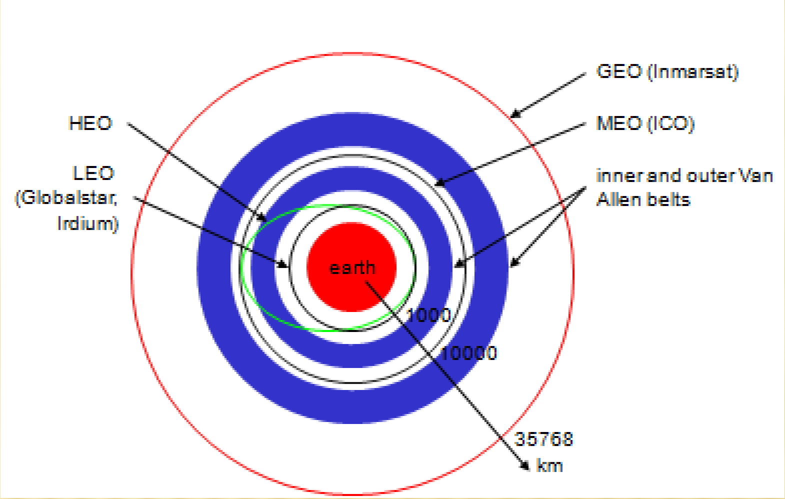
Four different types of satellite orbits can be identified depending on the shape and diameter of the orbit:

GEO: geostationary orbit, ca. 36000 km above earth surface

LEO (Low Earth Orbit): ca. 500 - 1500 km

MEO (Medium Earth Orbit) or ICO (Intermediate Circular Orbit): ca. 6000 - 20000 km

HEO (Highly Elliptical Orbit) elliptical



Orbits II

Van-Allen-Belts:
ionized particles
2000 - 6000 km and
15000 - 30000 km
above earth surface

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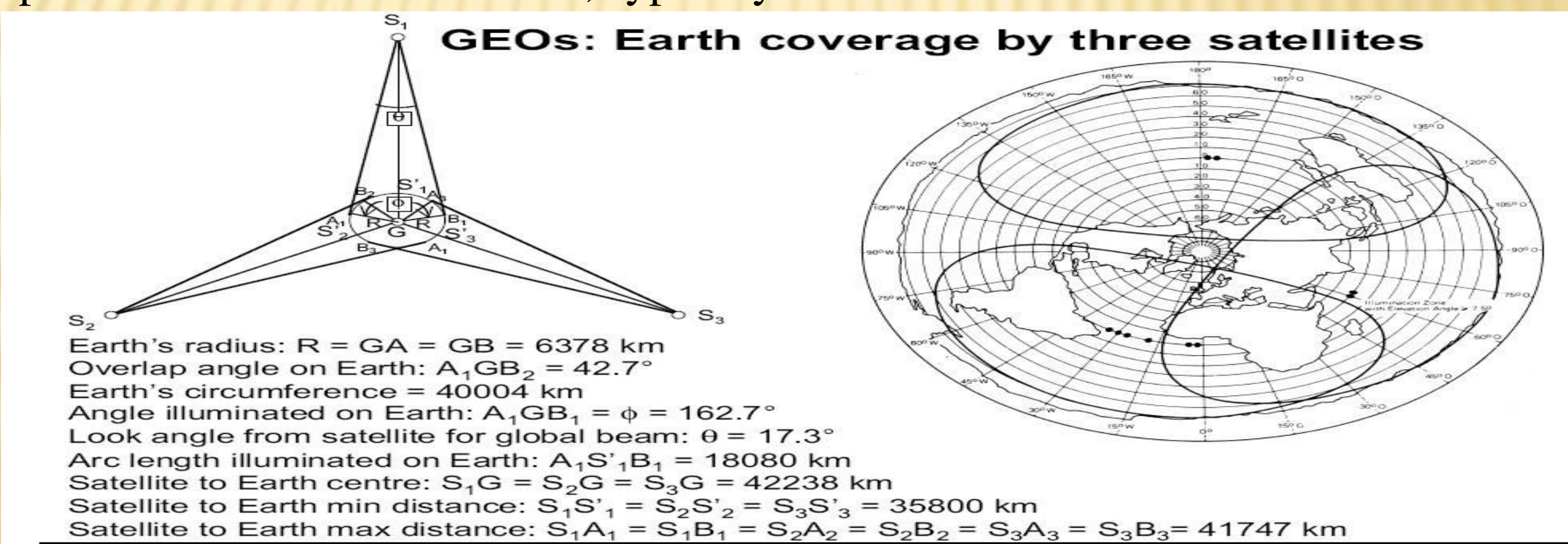
Geostationary satellites

Orbit 35,786 km distance to earth surface, orbit in equatorial plane (inclination 0°) complete rotation exactly one day, satellite is synchronous to earth rotation fix antenna positions, no adjusting necessary

satellites typically have a large footprint (up to 34% of earth surface!), therefore difficult to reuse frequencies bad elevations in areas with latitude above 60° due to fixed position above the equator high transmit power needed high latency due to long distance (ca. 275 ms) not useful for global coverage for small mobile phones and data transmission, typically used for radio and TV transmission



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LEO systems

Orbit ca. 500 - 1500 km above earth surface radio visibility of a satellite ca. 10 - 40 minutes global coverage possible

latency comparable with terrestrial long distance connections, ca. 5 - 10 ms smaller footprints, better frequency reuse but now handover necessary from one satellite to another many satellites necessary for global coverage more complex systems due to moving satellites

Examples:

Iridium (start 1998, 66 satellites)

Bankruptcy in 2000, deal with US DoD (free use, saving from ―deorbiting‖)

Globalstar (start 1999, 48 satellites)

Not many customers (2001: 44000), low stand-by times for mobiles

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MEO systems

- Orbit ca. 5000 - 12000 km above earth surface
- comparison with LEO systems:
- slower moving satellites
- less satellites needed
- simpler system design
- for many connections no hand-over needed
- higher latency, ca. 70 - 80 ms
- higher sending power needed
- special antennas for small footprints needed

- Example:
- ICO (Intermediate Circular Orbit, Inmarsat) start ca. 2000
  - Bankruptcy, planned joint ventures with Teledesic, Ellipso – cancelled again, start planned for 2003

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Table 2.4a Comparison of satellite orbits: operational considerations

	Geostationary orbit	Low Earth orbit	Medium Earth orbit	Highly elliptical orbit
Altitude	35 786 km	750–2000 km	10 000–20 000 km	Apogee: 40 000–50 000 km Perigee: 1000–20 000 km
Coverage	Ideally suited for continuous, regional coverage using a single satellite. Can also be used equally effectively for global coverage using a minimum of three satellites	Multi-satellite constellations of upwards of 30 satellites are required for global, continuous coverage. Single satellites can be used in store-and-forward mode for localised coverage but only appear for short periods of time	Multi-satellite constellations of between 10 and 20 satellites are required for global coverage	Three or four satellites are needed to provide continuous coverage to a region
Visibility	Mobile to satellite visibility decreases with increased latitude of the user. Poor visibility in built-up, urban regions	The use of satellite diversity, by which more than one satellite is visible at any given time, can be used to optimise the link. This can be achieved by either selecting the optimum link or combining the reception of two or more links. The higher the guaranteed minimum elevation angle to the user, the more satellites are needed in the constellation	Good to excellent global visibility, augmented by the use of satellite diversity techniques	Particularly designed to provide high guaranteed elevation angle to satellite for Northern and Southern temperate latitudes

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	Geostationary orbit	Low Earth orbit	Medium Earth orbit	Highly elliptical orbit
Network complexity	A relatively straightforward network architecture. Satellites appear stationary in the sky, no handover between satellites during a call	The dynamic nature of the satellite orbits introduces a level of complexity into the network. Handover between satellites during a call is required. A large number of gateways may be required to support the global network if inter-satellite link technology is not employed	The motion of the satellites around the Earth will necessitate the need to perform handover between satellites, although not as frequently as that of a LEO. Moreover, the larger coverage offered by a MEO in comparison to a LEO reduces the requirements on the supporting terrestrial network infrastructure	Handover between satellites will need to occur three or four times per day. Otherwise the network complexity is similar to that of a geostationary network
Technology	Has been used to provide mobile services for over two decades. The recent introduction of multi-spot-beam payloads, of the order of 200+ beams per satellite, with the associated on-board processing and routing capabilities represents the next significant technological advancement for this type of orbit	Introduced into service at the end of the last decade with a mixed response with respect to quality of service	Yet to be used for commercial mobile-satellite services. Some significant technological advances are required but not as significant as the LEO solution. The MEO orbit is used for the GPS and GLONASS navigation systems	Has been used to provide TV services to Russia for a number of years

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Overview of LEO/MEO systems

	Iridium	Globalstar	ICO	Teledesic
# satellites	66 + 6	48 + 4	10 + 2	288
altitude (km)	780	1414	10390	ca. 700
coverage	global	±70° latitude	global	global
min. elevation	8°	20°	20°	40°
frequencies [GHz (circa)]	1.6 MS 29.2 ↑ 19.5 ↓ 23.3 ISL	1.6 MS ↑ 2.5 MS ↓ 5.1 ↑ 6.9 ↓	2 MS ↑ 2.2 MS ↓ 5.2 ↑ 7 ↓	19 ↓ 28.8 ↑ 62 ISL
access method	FDMA/TDMA	CDMA	FDMA/TDMA	FDMA/TDMA
ISL	yes	no	no	yes
bit rate	2.4 kbit/s	9.6 kbit/s	4.8 kbit/s	64 Mbit/s ↓ 2/64 Mbit/s ↑
# channels	4000	2700	4500	2500
Lifetime [years]	5-8	7.5	12	10
cost estimation	4.4 B$	2.9 B$	4.5 B$	9 B$

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KEPLER'S FIRST LAW

The path followed by a satellite around the primary will be an ellipse.
An ellipse has two focal points shown as $F1$ and $F2$.
The center of mass of the two-body system, termed the *barycenter,* is always centered on one of the foci.
In our specific case, because of the enormous difference between the masses of the earth and the satellite, the center of mass coincides with the center of the earth, which is therefore always at one of the foci.
The semimajor axis of the ellipse is denoted by *a,* and the semiminor axis, by *b.* The eccentricity *e* is given by

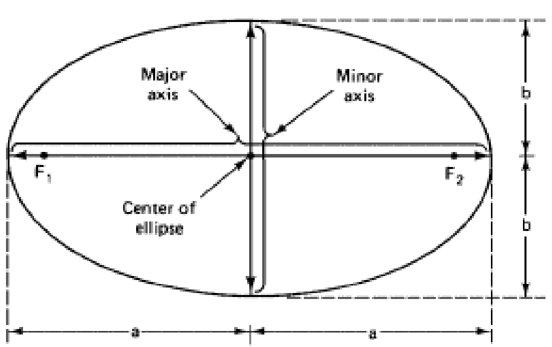

Figure 2.1 The foci F_1 and F_2, the semimajor axis a, and the semiminor axis b of an ellipse.

$$e = \frac{a - b}{a + b}$$

Kepler‘s Second Law

For equal time intervals, a satellite will sweep out equal areas in its orbital plane, focused at the barycenter.

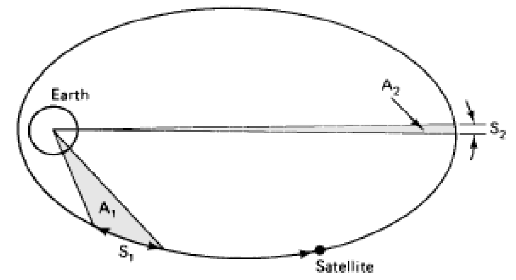

Figure 2.2 Kepler's second law. The areas A_1 and A_2 swept out in unit time are equal.

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.

The mean distance is equal to the semimajor axis *a*. For the satellites orbiting the earth, Kepler‘s third law can be written in the form

$$a^3 = \frac{\mu}{n^2}$$

where n is the mean motion of the satellite in radians per second and is the earth‘s geocentric gravitational constant. With a in meters, its value is

$$\mu = 3.986005 \times 10^{14}\ \mathrm{m^3/sec^2}$$

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GEO systemsA geosynchronous orbit is sometimes called a geostationary orbit. Satellites in geosynchronous orbits make one full trip around the Earth in the same amount of time it takes the Earth to make one full rotation. These satellites are always above the same location on Earth‘s surface. By positioning a satellite in one place at the same time, we are able to monitor Earth‘s weather and provide satellite television to homes – that‘s why satellite dishes are always pointed the same way in the sky.

Orbit	Description	Example
Low Earth Orbit (LEO)	High enough that it misses mountain peaks but doesn't gravitate back toward Earth	ISS, Hubble Space Telescope
Medium Earth Orbit (MEO)	Orbits between Low Earth orbits and Geosynchronous orbits	GPS' 24 satellites
Geosynchronous Orbit (GSO)	Always above one spot on Earth; great distance from Earth	Communication satellites
Polar Orbit	Travel north-south from pole to pole	Weather satellites
Elliptical – shape of some orbits	Orbital path is an ellipse (oval-shaped). Speed of the satellite increases when it is closer to the object it orbits.	GPS' 24 satellites

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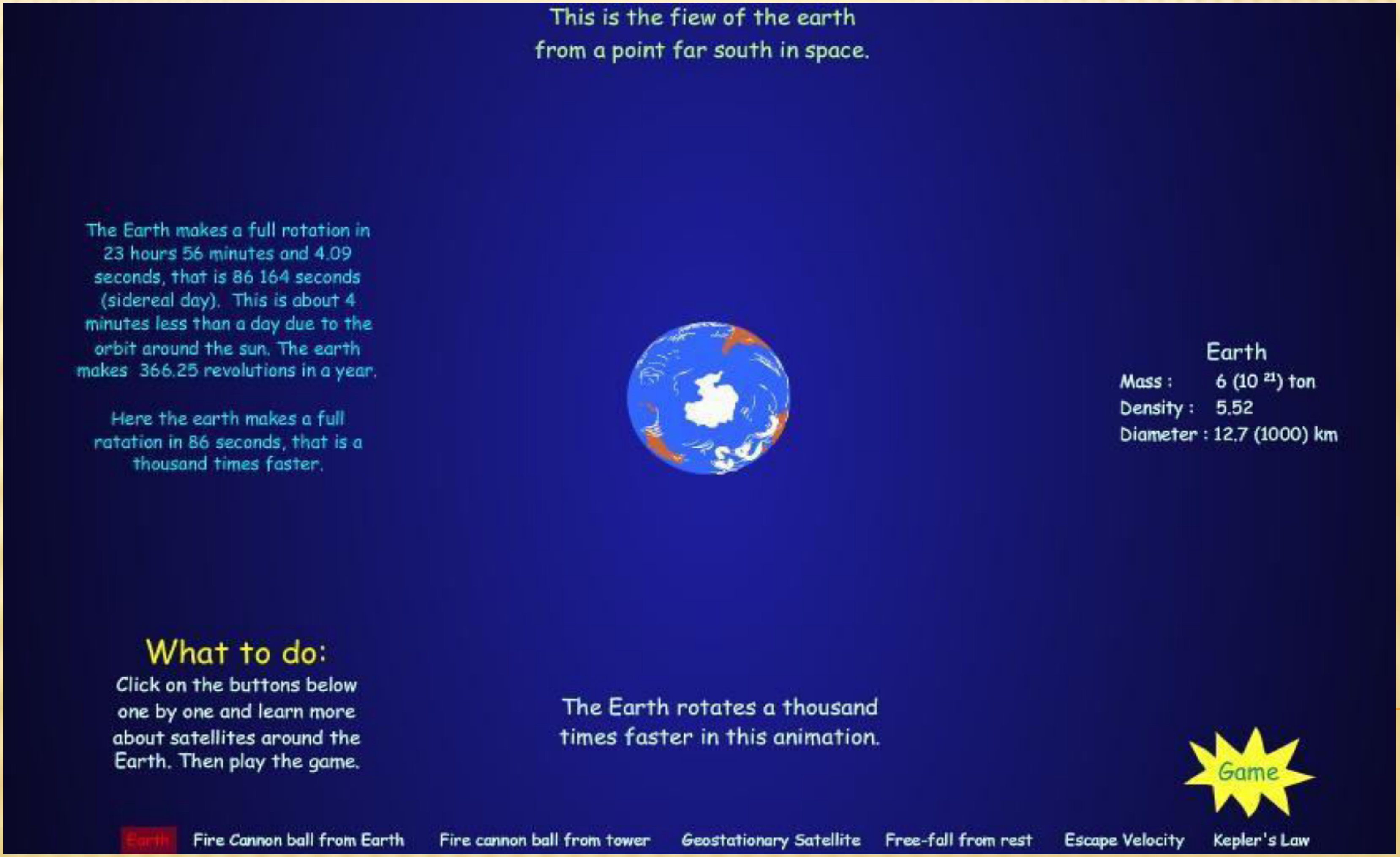
A simulation of a geosynchronous orbit.



ORBITAL MECHANICS

Apogee The point farthest from earth. Apogee height i shown as *ha* in Fig

Perigee The point of closest approach to earth. The perigee height is shown as *hp*

Line of apsides The line joining the perigee and apogee through the center of the earth.

Ascending node The point where the orbit crosses th equatorial plane going from south to north. **Descendin node** The point where the orbit crosses the equatorial plan going from north to south.

Line of nodes The line joining the ascending and descendin nodes through the center of the earth.

Inclination The angle between the orbital plane and the earth‘s equatorial plane. It is measured at the ascending node from the equator to the orbit, going from east to north. The inclination is shown as *i* in Fig.

Mean anomaly M gives an average value of the angular position of the satellite with reference to the perigee.

True anomaly is the angle from perigee to the satellite position, measured at the earth‘s center. This gives the true angular position of the satellite in the orbit as a function of time.

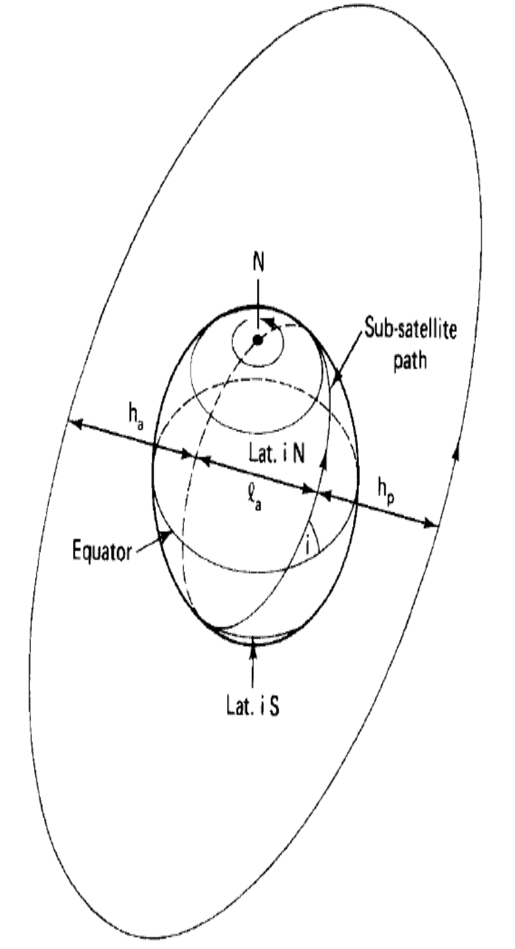


Figure 2.3 Apogee height h_a, perigee height h_p, and inclination i. l_a is the line of apsides.

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Prograde orbit An orbit in which the satellite moves in the same direction as the earth‘s rotation. The inclination of a prograde orbit always lies between 0 and 90°.

Retrograde orbit An orbit in which the satellite moves in a direction counter to the earth‘s rotation. The inclination of a retrograde orbit always lies between 90 and 180°.

Argument of perigee The angle from ascending node to perigee, measured in the orbital plane at the earth‘s center, in the direction of satellite motion.

Right ascension of the ascending node To define completely the position of the orbit in space, the position of the ascending node is specified. However, because the earth spins, while the orbital plane remains stationary the longitude of the ascending node is not fixed, and it cannot be used as an absolute reference. For the practical determination of an orbit, the longitude and time of crossing of the ascending node are frequently used. However, for an absolute measurement, a fixed reference in space is required. The reference chosen is the first point of Aries, otherwise known as the vernal, or spring, equinox. The vernal equinox occurs when the sun crosses the equator going from south to north, and an imaginary line drawn from this equatorial crossing through the center of the sun points to the first point of Aries (symbol). This is the line of Aries.

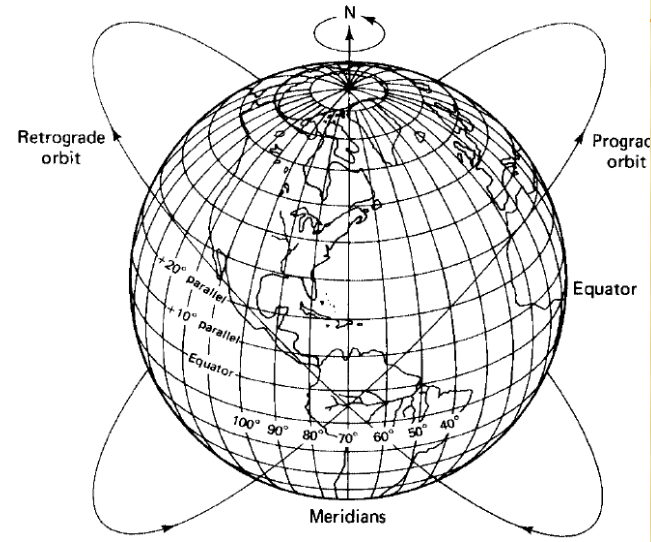

Figure 2.4 Prograde and retrograde orbits.

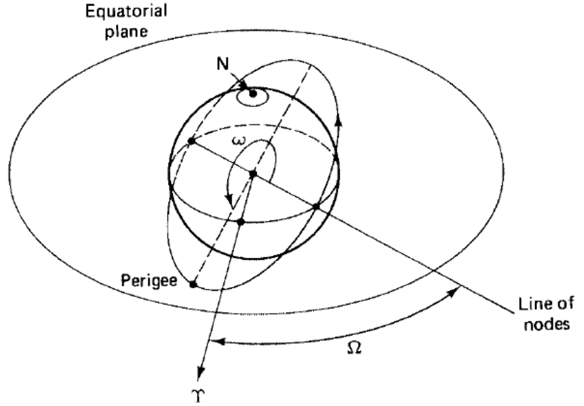

Figure 2.5 The argument of perigee ω and the right ascension of the ascending node Ω.

Six Orbital Elements

Earth-orbiting artificial satellites are defined by six orbital elements referred to as the *keplerian element set.*

The semimajor axis *a*.

The eccentricity *e*

give the shape of the ellipse.

A third, the mean anomaly *M*, gives the position of the satellite in its orbit at a reference time known as the *epoch*.

A fourth, the argument of perigee ω , gives the rotation of the orbit's perigee point relative to the orbit's line of nodes in the earth's equatorial plane.

The inclination *I*

The right ascension of the ascending node γ

Relate the orbital plane's position to the earth.

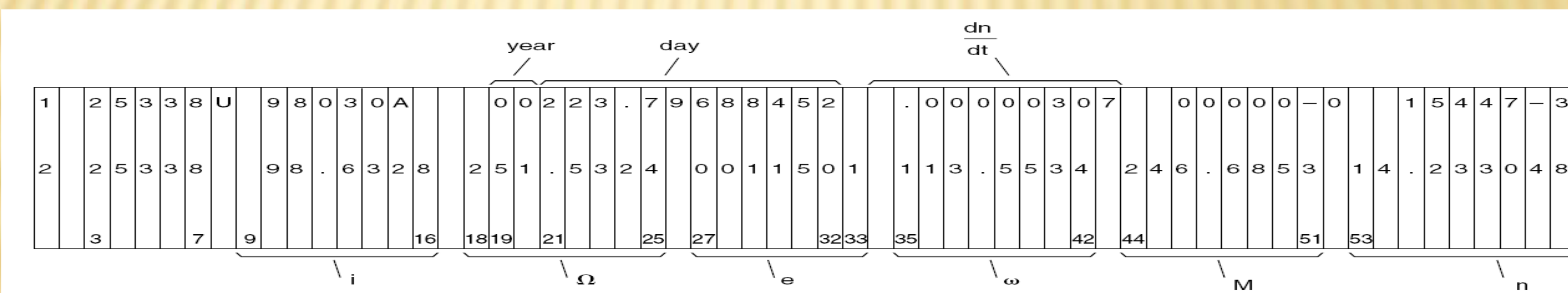

Figure 2.6 Two-line elements for NOAA-15.

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Line no.	Columns	Description
1	3–7	*Satellite number:* 25338
1	19–20	*Epoch year* (last two digits of the year): 00
1	21–32	*Epoch day* (day and fractional day of the year): 223.79688452 (this is discussed further in Sec. 2.9.2).
1	34–43	*First time derivative of the mean motion* (rev/day^2): 0.00000307
2	9–16	*Inclination* (degrees): 98.6328
2	18–25	*Right ascension of the ascending node* (degrees): 251.5324
2	27–33	*Eccentricity* (leading decimal point assumed): 0011501
2	35–42	*Argument of perigee* (degrees): 113.5534
2	44–51	*Mean anomaly* (degrees): 246.6853
2	53–63	*Mean motion* (rev/day): 14.23304826
2	64–68	*Revolution number at epoch* (rev/day): 11,663

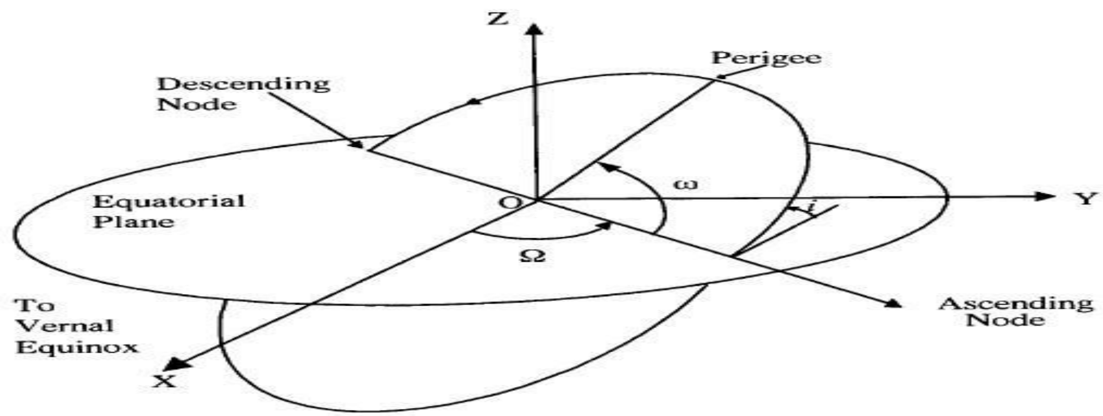

Figure 3.3 Satellite parameters in the geocentric-equatorial co-ordinate system.

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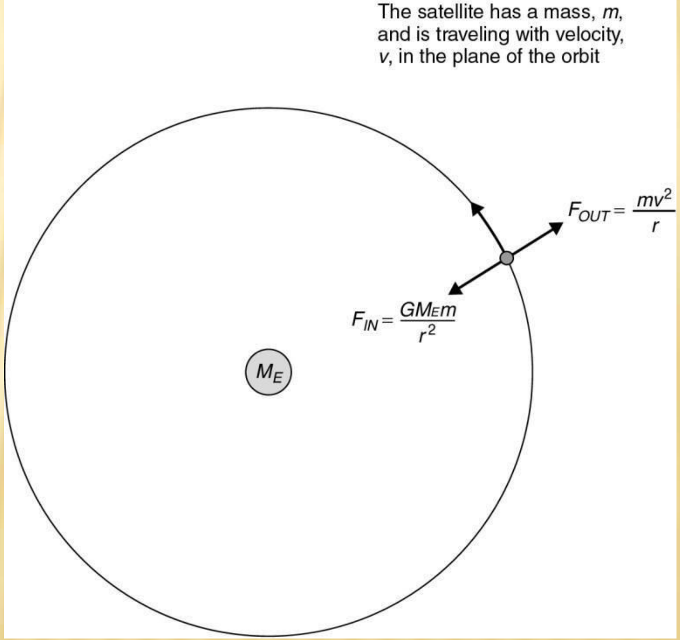
Forces acting on a satellite in a stable orbit around the earth

Gravitational force is inversely proportional to the square of the distance between the centers of gravity of the satellite and the planet the satellite is orbiting, in this case the earth. The gravitational force inward (F_{IN}, the centripetal force) is directed toward the center of gravity of the earth.

The kinetic energy of the satellite (F_{OUT}, the centrifugal force) is directed opposite to the gravitational force. Kinetic energy is proportional to the square of the velocity of the satellite. When these inward and outward forces are balanced, the satellite moves around the earth in a ―free fall‖ trajectory: the satellite‘s orbit.



Locating the satellite with respect to the earth:

A fixed rectangular coordinate system called the geocentric equatorial coordinate system whose origin is the center of the earth. The rotational axis of earth is the axis, which is through the geographic North Pole. The axis is from the center of the earth toward a fixed location in space called the first point of Aries. This coordinate system moves through space, it translates as the earth moves in its orbit around the sun, but it does not rotate as the earth rotates. The direction is always the same, whatever the earth‘s position around the sun and is in the direction of the first point of Aries. The plane contains the earth‘s equator and is called the equatorial plane.

Coverage angle & Slant range:

Communication with a satellite is possible if the earth station is in the footprint of the satellite. In other words, the earth-satellite link is established only when the earth station falls in the beam width of the satellite antenna. This would be a function of time and the satellite is to be tracked in case of a non-geostationary satellite. But for a geostationary satellite once the link is established, the link is available throughout the lifetime of the satellite without any tracking. To have the communication between the earth station-satellite-earth stations, both the antennas of the transmitting and receiving earth station are to be pointed towards the antenna of the spacecraft. With the help of look angle determination, this can be established. To locate the earth station in the footprint of the satellite, the information of slant range and coverage area/angle is required.

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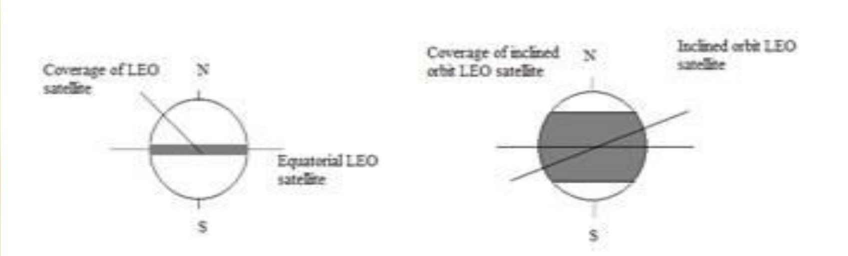
Inclined orbits:

Satellites that can no longer be maintained in a fully geostationary orbit, but are still used for communications services, are referred to as inclined orbit satellites, there are advantages and disadvantages to inclined orbits, depending on the mission goals and the data recovery requirements. The greater the inclination of the orbit is, the larger the surface area of the earth that the satellite will pass over at some time in its flight.

The inclined orbit will take the space craft at one time or another, over the earth‘s entire surface that lies approximately between the latitudes given by ± the orbital inclination. The superior coverage of the earth with an inclined orbit satellite is counter balanced by the disadvantage that the master control station (MCS) will not be able to communicate directly with the satellite on every orbit as with an equatorial orbit satellite.

A LEO satellite orbits the earth with a period of 90 to 100 min and for an inclined orbit satellite; the earth will have rotated the master control station out of the path of the satellite on the next pass over the same side of the earth.



Orbital perturbations due to earth's oblateness

Perturbations

Most of the studies for identifying potential relative motion orbits for flying formations have assumed a spherical Earth. The relative motion orbits identified from this assumption result primarily from small changes in the eccentricity and the inclination. This is satisfactory for identifying the potential relative motion orbits, but unsatisfactory for determining long term motion, fuel budgets and the best formations. Assuming that all satellites in the formation are nearly identical, the primary perturbation is the differential gravitational perturbation due to the Earth's oblateness. Since the differential gravity perturbations are a function of (a,e,i) the small changes in these elements result in different drift rates for each satellite and the negation of these drifts result in different fuel requirements for each satellite. Since some satellites running out of fuel before others will degrade the system performance it would be advantageous to have the satellites have equal fuel consumption. Satellites do not describe perfect elliptical orbits around its central body (this case is Earth).

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Effects of sun and moon:

Gravitational attractions by the sun and moon cause the orbital inclination of a geostationary satellite to change with time. If not countered by north-south station keeping, these forces would increase the orbital inclination from an initial 0° to 14.67° 26.6 years later. Since, no satellite has such a long lifetime, the problem is not acute.

Eclipse of GEO satellite:

A geostationary satellite utilizes solar energy to generate the required DC power to operate all the subsystems of the spacecraft. Solar energy is not available for a geostationary satellite when eclipse occurs. This occurs when the earth comes in between the sun and satellite in line and blocks the solar energy from reaching the solar panels of the satellite.

Sun transit outage:

The overall receiver noise will rise significantly to effect the communications when the sun passes through the beam of an earth station antenna. This effect is predictable and can cause outage for as much as 10 min a day for several days and for about 0.02% an average year. The receiving earth station has to wait until the sun moves out of the main lobe of the antenna. This occurs during the daytime, where the traffic is at its peak and forces the operator to hire some other alternative channels for uninterrupted communication link.

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UNIT-II
SPACE SEGMENT

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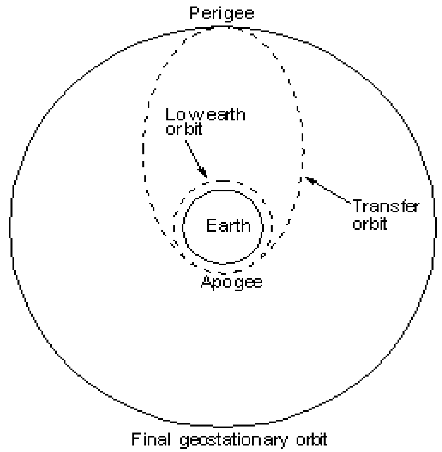
Placement of satellite into geostationary orbit:

There is a considerable amount of expertise and technology used to ensure that satellites enter their orbits in the most energy efficient ways possible. This ensures that the amount of fuel required is kept to a minimum; an important factor on its own because the fuel itself has to be transported until it is used. If too much fuel has to be used then this increases the size of the launch rocket and in turn this greatly increases the costs.

Many satellites are placed into geostationary orbit, and one common method of achieving this is based on the Hohmann transfer principle. This is the method use when the Shuttle launches satellites into orbit. Using this system the satellite is placed into a low earth orbit with an altitude of around 180 miles. Once in the correct position in this orbit rockets are fired to put the satellite into an elliptical orbit with the perigee at the low earth orbit and the apogee at the geostationary orbit as shown. When the satellite reaches the final altitude the rocket or booster is again fired to retain it in the geostationary orbit with the correct velocity.

Alternatively when launch vehicles like Ariane are used the satellite is launched directly into the elliptical transfer orbit. Again when the satellite is at the required altitude the rockets are fired to transfer it into the required orbit with the correct velocity.



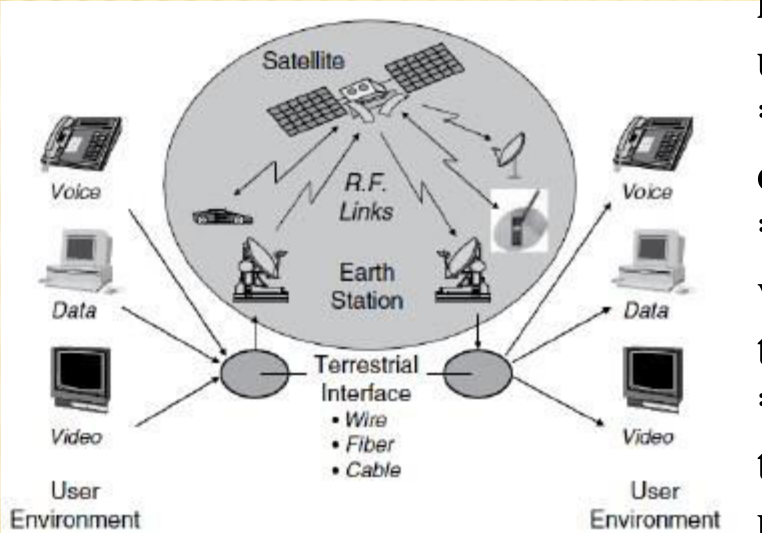
Use of a transfer orbit to place a satellite in geostationary orbit

SATELLITE COMMUNICATIONS

Satellite Subsystems

An operating communications satellite system consists of several elements or segments, ranging from an orbital configuration of space components to ground based components and network elements.

The particular application of the satellite system, (for example fixed satellite service, mobile service, or broadcast service,) will determine the specific elements of the system.



The basic system consists of a satellite (or satellites) in space, relaying information between two or more users through ground terminals and the satellite.

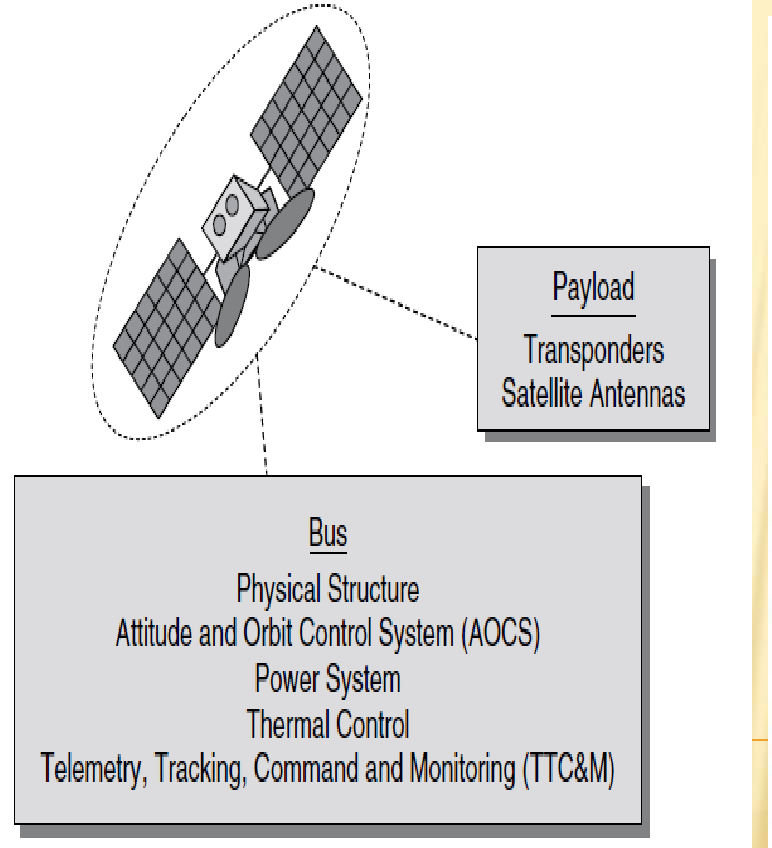
***The information relayed may be voice, data, video, or a combination of the three.**

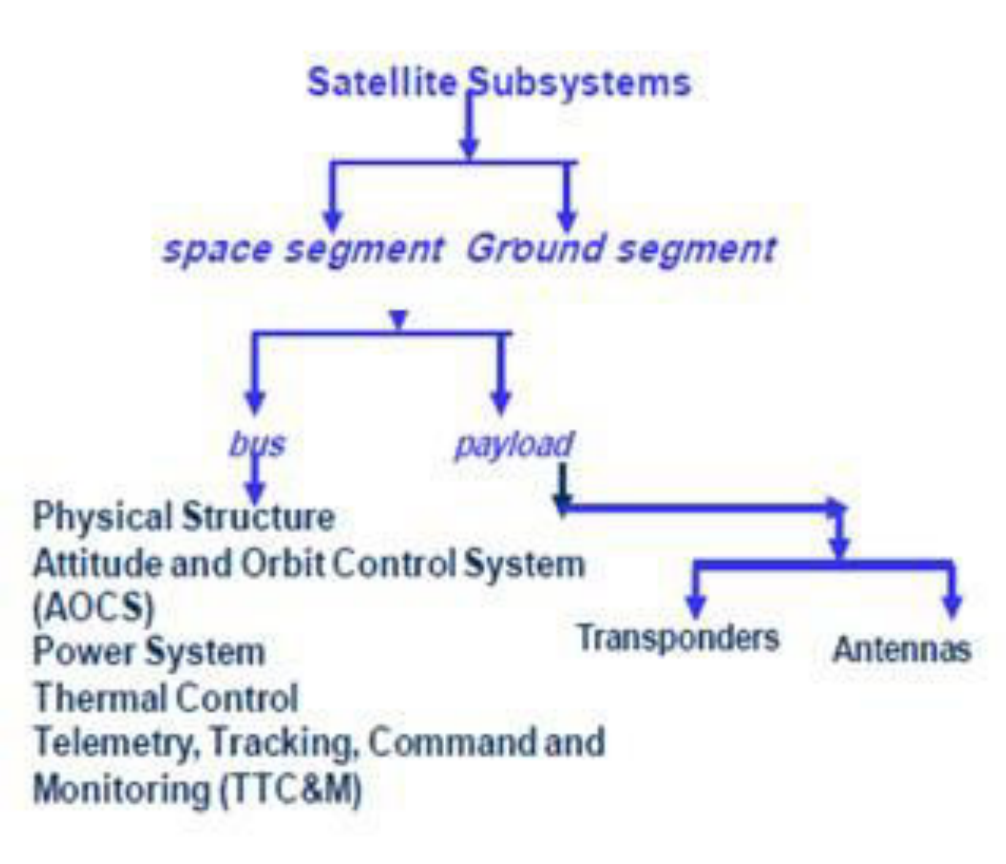
***The user information may require transmission via terrestrial means to connect with the ground terminal.**

*** The satellite is controlled from the ground through a satellite control facility, often called the master control center (MCC), which provides tracking, telemetry, command, and monitoring functions for the system**

SATELLITE COMMUNICATIONS

The space segment equipment carried aboard the satellite can be classified under two functional areas: the bus and the payload





SATELLITE COMMUNICATIONS

Bus :The bus refers to the basic satellite structure itself and the subsystems that support the satellite.The bus subsystems are:
* the physical structure,
* power subsystem,
* attitude and orbital control subsystem,
* thermal control subsystem,
*command and telemetry subsystem.

Payload : The payload on a satellite is the equipment that provides the service or services intended for the satellite.A communications satellite payload consists of:
*The communications equipment that provides the relay link between the up- and downlinks from the ground.
*The communications payload can be further divided into:
*The transponder
*The antenna subsystems

Satellite Bus

Physical Structure

The basic shape of the structure depends of the method of stabilization employed to keep the satellite stable and pointing in the desired direction, usually to keep the antennas properly oriented toward earth.

Physical Structure: Two methods are commonly employed:
*spin stabilization
*Three-axis or body stabilization.
Both methods are used for GSO satellite.

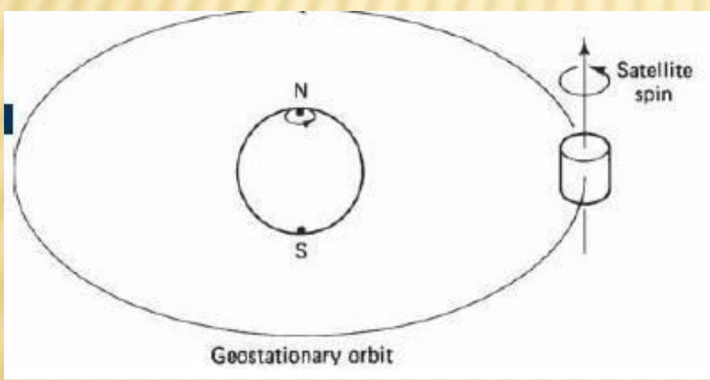
SATELLITE COMMUNICATIONS

Spin Stabilization

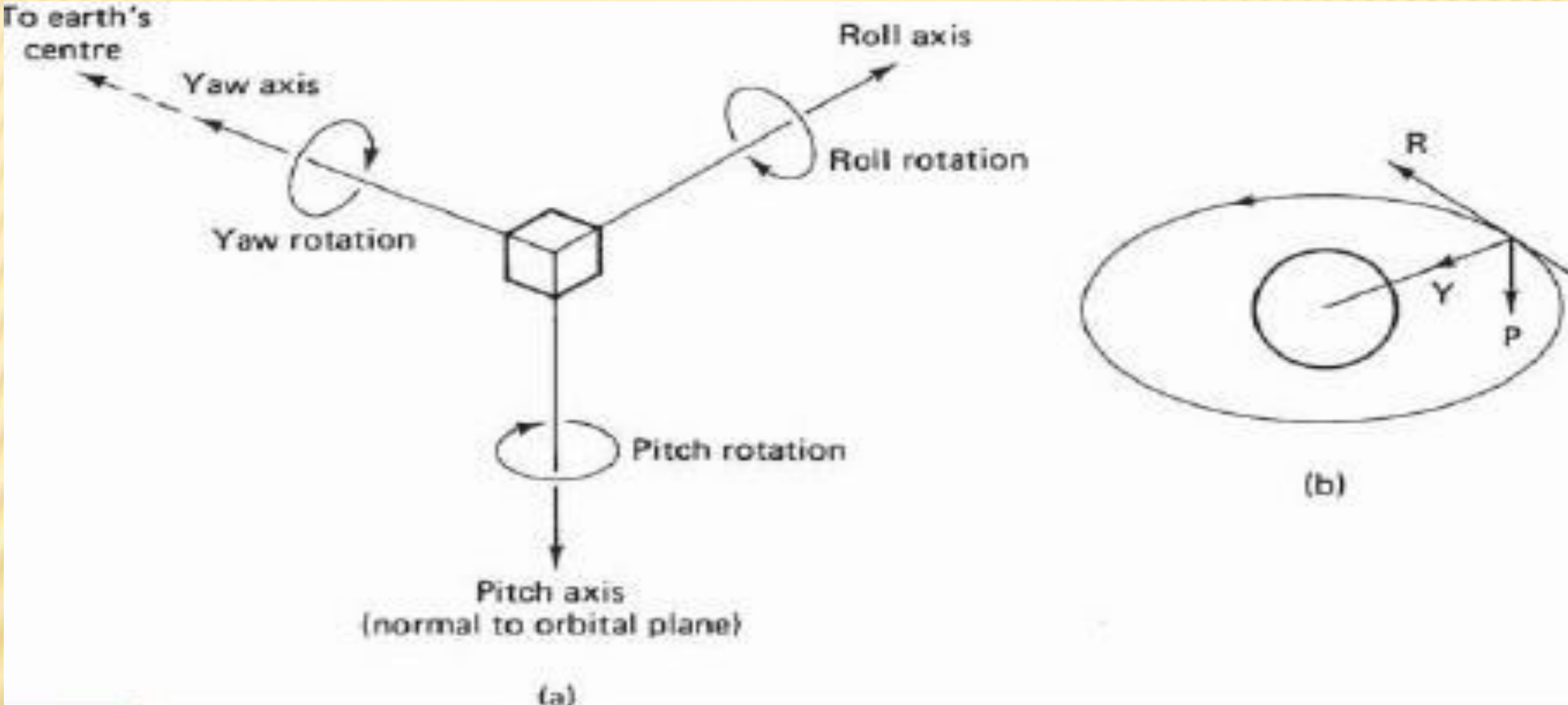
A spin stabilized satellite is usually cylindrical in shape, because the satellite is required to be mechanically balanced about an axis, so that it can be maintained in orbit by spinning on its axis. For GSO satellites, the spin axis is maintained parallel to
the spin axis of the earth, with spin rates in the range of 30 to 100 revolutions per minute

Three-axis Stabilization

A three-axis stabilized satellite is maintained in space with stabilizing elements for each of The three axes, referred to as roll,pitch, and yaw, in conformance with the definitions first used in the aircraft industry. The entire body of the spacecraft remains fixed in space, relative to the earth, which is why the three axis stabilized satellite is also referred to as a body-stabilized satellite.



SATELLITE COMMUNICATIONS



(*a*) Roll, pitch, and yaw axes. The yaw axis is directed toward the earth's center, the pitch axis is normal to the orbital plane, and the roll axis is perpendicular to the other two.

(*b*) RPY axes for the geostationary orbit. Here, the roll axis is tangential to the orbit and lies along the satellite velocity vector.

SATELLITE COMMUNICATIONS

Power Subsystem

The electrical power for operating equipment on a communications satellite is obtained primarily from solar cells. *The radiation on a satellite from the sun has an intensity averaging about 1.4 kW/m2. *Solar cells operate at an efficiency of 20–25% at beginning of life (BOL), and can degrade to 5–10% at end of life (EOL), usually considered to be 15 years .All satellite and spacecraft must also carry storage batteries to provide power during launch and during eclipse periods when sun blockage occurs.

A power conditioning unit is also included in the power subsystem, for the control of battery charging and for power regulation and monitoring.

Attitude Control

Attitude control is necessary so that the antennas, are pointed correctly towards earth

Several forces can interact to affect the attitude of the spacecraft:

*Gravitational forces from the sun, moon, and planets;

*Solar pressures acting on the spacecraft body, antennas or solar panels;

*Earth‘s magnetic field

The attitude of a satellite refers to its orientation in space with respect to earth

Orbital control

It is often called station keeping, is the process required to maintain a satellite in its proper orbit location.

*GSO satellites will undergo forces that would cause the satellite to drift in the east-west (longitude) and north-south (latitude) directions, *Orbital control is usually maintained with the same thruster system as is attitude control

Thermal Control

- Several techniques are employed to provide thermal control in a satellite.
- Thermal blankets and thermal shields are placed at critical locations to provide insulation. Radiation mirrors are placed around electronic subsystems, particularly for spin-stabilized satellites, to protect critical equipment.
- The satellite thermal control system is designed to control the large thermal gradients generate in the satellite
- Heat pumps are used to relocate heat from power devices such as traveling wave power amplifiers to outer walls or heat sinks to provide a more effective thermal path for heat to escape.
- Thermal heaters may also be used to maintain adequate temperature conditions for some components, such as propulsion( ) دفع lines or thrusters,

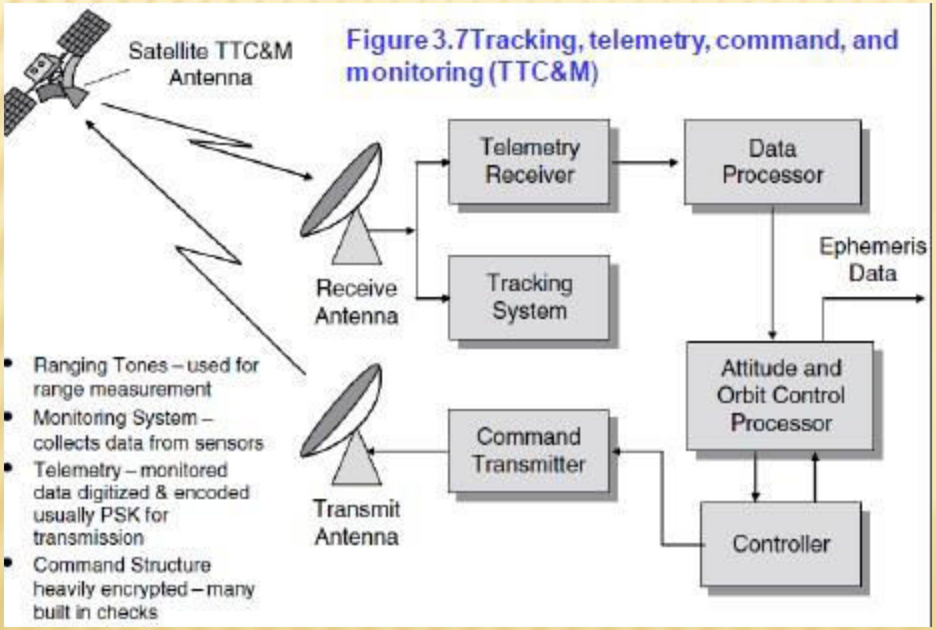
SATELLITE COMMUNICATIONS

Tracking, Telemetry, Command, and Monitoring

The tracking, telemetry, command, and monitoring (TTC&M) subsystem provides essential spacecraft management and control functions to keep the satellite operating safely in orbit.

The TTC&M links between the spacecraft and the ground are usually separate from the communications system links.

TTC&M links may operate in the same frequency bands or in other bands



shows the typical TTC&M functional elements for the satellite and ground facility for a communications satellite application

SATELLITE COMMUNICATIONS

The satellite TTC&M subsystems comprise
***The antenna**
***Command receiver**
***Tracking and telemetry transmitter**
***Tracking sensors**

The elements on the ground include the TTC&M antenna, telemetry receiver, command transmitter, tracking subsystem, and associated processing and analysis functions.

Satellite control and monitoring is accomplished through monitors and keyboard

INTERFACE
Telemetry data are received from the other subsystems of the spacecraft, such as the payload, power, attitude control, and thermal control.
Command data are relayed from the command receiver to other subsystems to control such parameters as antenna pointing, transponder modes of operation, battery and solar cell changes, etc

SATELLITE COMMUNICATIONS

1Tracking: refers to the determination of the current orbit, position, and movement of the spacecraft. The tracking function is accomplished by a number of techniques, usually involving satellite beacon signals, which are received at the satellite TTC&M earth station
The Doppler shift of the beacon (or the telemetry carrier) is monitored to determine the rate at which the range is changing (the range rate). Angular measurements from one or more earth terminals can be used to determine spacecraft location. The range can be determined by observing the time delay of a pulse or sequence of pulses transmitted from the satellite. . Acceleration and velocity sensors on the satellite can be used to monitor orbital location and changes in orbital location.
2Telemetry:Its function involves the collection of data from sensors on-board the spacecraft and the relay of this information to the ground. The telemetered data include following parameters -Voltage and current conditions in the power subsystem, -Temperature of critical subsystems, -Status of switches and relays in the communications and antenna subsystems, -Fuel tank pressures, and attitude control sensor status.
3Command: is the complementary function to telemetry. The command system relays specific control and operations information from the ground to the spacecraft. Parameters involved in typical command links include changes and corrections in attitude control and orbital control; antenna pointing and control; transponder mode of operation; battery voltage control.
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. Security is an important factor in the command system for a communications satellite.

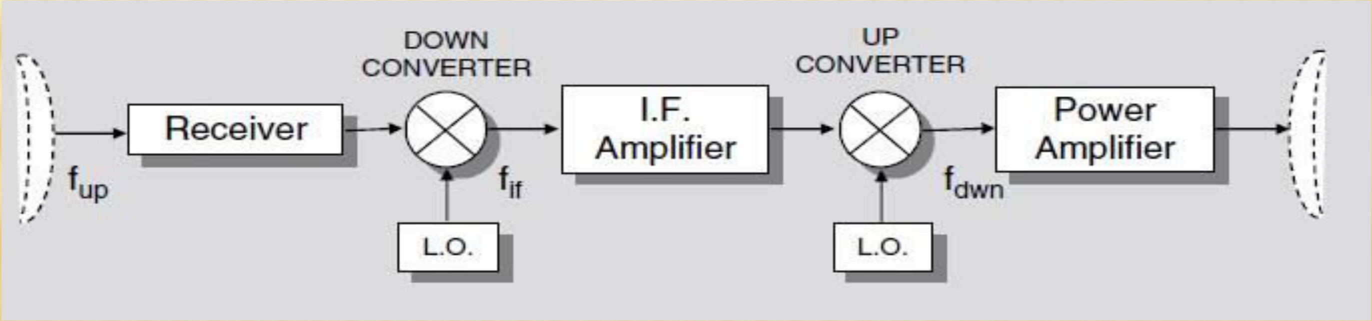
SATELLITE COMMUNICATIONS

Satellite Payload

Transponder The transponder is the series of components that provides the communications channel, or link, between the uplink signal received at the uplink antenna, and the downlink signal transmitted by the downlink antenna The key elements of the payload portion of the space segment, is the transponder and antenna subsystems. There two types of transponder:

1. The frequency translation transponder
2. The on-board processing transponder

1. Frequency Translation Transponder: The frequency translation transponder, also referred to as a non-regenerative repeater, or bent pipe, *It receives the uplink signal and, after amplification, retransmits it with only a translation in carrier frequency, Frequency Translation Transponder, also called Repeater Non-Regenerative Satellite _Bent Pipe‘ .Uplinks and downlinks are codependent From the Fig. its clear that uplink radio frequency, fup, is converted to an intermediate lower frequency, fif , amplified, and then converted back up to the downlink RF frequency, fdwn, for transmission to earth,Frequency translation transponders are used for in both GSO and NGSO orbits,The uplinks and downlinks are codependent, meaning that any degradation introduced on the uplink will be transferred to the downlink, affecting the total communications link



SATELLITE COMMUNICATIONS

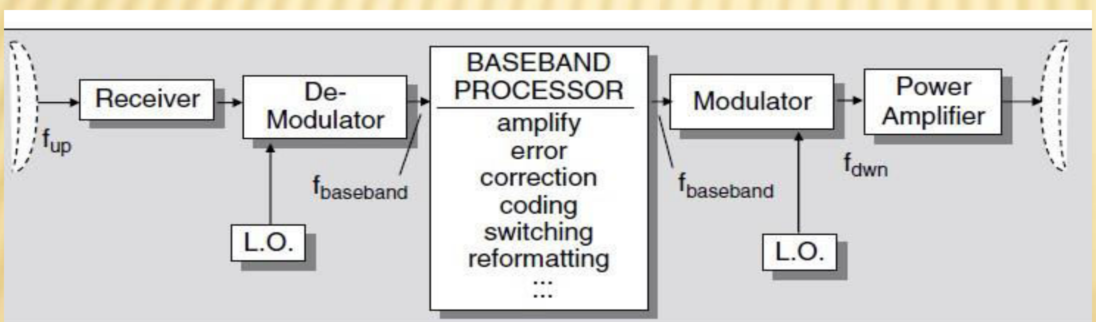
On-board Processing Transponder: The on-board processing transponder, called a regenerative repeater demod/ remod transponder, or smart satellite. *The uplink signal at fup is demodulated to baseband, f base band . *The baseband signal is available for processing on-board, including reformatting and error-correction. The baseband information is then remodulated to the downlink carrier at fdwn, after final amplification, transmitted to the ground.

*The demodulation/remodulation process removes uplink noise and interference from the downlink,

while allowing additional on-board processing to be accomplished.

*Thus the uplinks and downlinks are independent with

respect to evaluation of overall link performance, unlike the frequency translation transponder



- On-Board Processing Transponder, also called
  - Regenerative Repeater
  - Demod/Remod Transponder
  - 'Smart Satellite'
- First generation systems:
  - ACTS, MILSTAR, IRIDIUM, …
- Uplinks and downlinks are independent

SATELLITE COMMUNICATIONS

Antennas

The antenna systems on the spacecraft are used for transmitting and receiving the RF signals that comprise the space links of the communications channels

The most important parameters that define the performance of an antenna are:

- ❑ Antenna gain,
- ❑ Antenna beam width,
- ❑ Antenna side lobes

Most satellite communications applications require an antenna to be highly directional

- ❑ High gain,
- ❑ narrow beam width
- ❑ negligibly small side lobes

The common types of antennas used in satellite systems are

- ❑ The linear dipole
- ❑ The horn antenna
- ❑ The parabolic reflector
- ❑ The array antenna

SATELLITE COMMUNICATION

Satellite frequency bands and allocations:

Frequency Band	Frequency Range(GHz)	Bandwidth(GHz)	Applications
L band	1-2	1	MSS
S band	2-4	2	MSS
C band	4-8	4	FSS
X band	8-12.5	4.5	meteorological satellite and FSS military
Ku band	12.5-18	5.5	FSS,BSS
K band	18-26.5	8.5	FSS,BSS
Ka band	26.5-40	13.5	FSS

Satellite applications include FSS, BSS and MSS. FSS stands for Fixed Service Satellite, BSS stands for Broadcast Service Satellite and MSS stands for Mobile Service Satellite.

SATELLITE COMMUNICATIONS

Satellite Link Design

Satellite Link Design

- Low earth orbit (LEO) & medium earth orbit (MEO) satellite systems are closer and produces stronger signals but earth terminals need omni directional antennas
- The design of any satellite communication is based on
  - Meeting of minimum C/N ratio for a specific percentage of time
  - Carrying the maximum revenue earning traffic at minimum cost

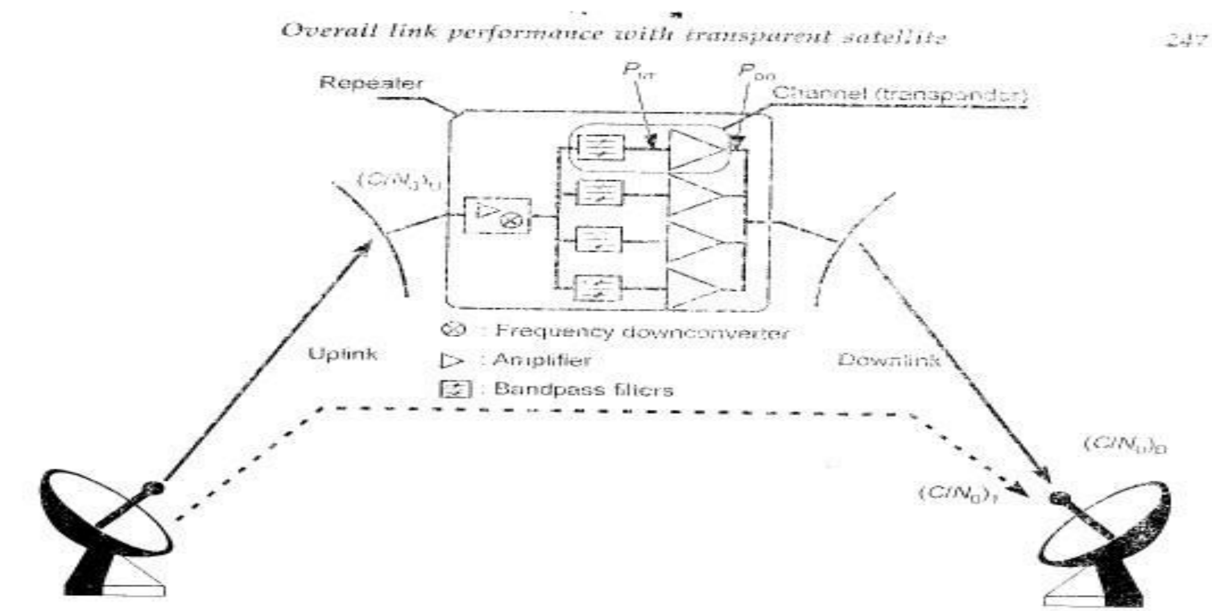


Figure 5.32 Overall station-to-station link for a transparent satellite: see page for notation

SATELLITE COMMUNICATIONS

Link Budgets

- C/N ratio calculation is simplified by the use of link budgets
- Evaluation the received power and noise power in radio link
- The link budget must be calculated for individual transponder and for each link
- When a bent pipe transponder is used the uplink and down link C/N rations must be combined to give an overall C/N

Satellite Link Design – Downlink received Power

- The calculation of carrier to noise ratio in a satellite link is based on equations for received signal power Pr and receiver noise power:

  Pr = EIRP + Gr – Lp – La – Lta – Lra dBW,

  Where:

  EIRP = 10log1o (PtGt)

  Gr = 10log10 $(4\pi Ae / \lambda^2)$dB

  PathLoss LP = 10log10 $[(4 \pi Ae / \lambda) 2]$ = 20log1o $(4\pi R/ \lambda)$dB

  La = Attenuation in the atmosphere

  Lta = Losses assosiated with transmitting antenna

  Lra = Losses associated with receiving antenna

SATELLITE COMMUNICATIONS

Satellite Link Design – Downlink Noise Power

- A receiving terminal with a system noise temperature
  TsK and a noise bandwidth Bn Hz has a noise power Pn referred to the output terminals of the antenna where
  Pn = kTsBn watts
- The receiving system noise power is usually written in decibel units as:
  N = k + Ts + Bn dBW,
  where:

k is Boltzmann's constant)-228.6 Dbw/K/Hz)

Ts is the system noise temperature in DBK

Bn is the noise Bandwidth of the receiver in dBHz

Satellite Link Design – Uplink

- Uplink design is easier than the down link in many cases
  - Earth station could use higher power transmitters
- Earth station transmitter power is set by the power level required at the input to the transporter, either
  - A specific flux density is required at the satellite
  - A specific power level is required at the input to the transporter
- Analysis of the uplink requires calculation of the power level at the input to the transponder so that uplink C/N ratio can be found
- With small-diameter earth stations, a higher power earth station transmitter is required to achieve a similar satellite EIRP.
  - Interference to other satellites rises due to wider beam of small antenna
- Uplink power control can be used to against uplink rain attenuation

SATELLITE COMMUNICATIONS

Propagation Effects & their Impact

Propagation Effects & their Impact

- Many phenomena causes lead signal loss on through the earths atmosphere:
  - Atmospheric Absorption (gaseous effects)
  - Cloud Attenuation (aerosolic and ice particles
  - Tropospheric Scintillation (refractive effects)
  - Faraday Rotation (an ionospheric effect)
  - Ionospheric Scintillation (a second ionospheric effect)
  - Rain attenuation
  - Rain and Ice Crystal Depolarization
- The rain attenuation is the most important for frequencies above 10 GHz
  - Rain models are used to estimate the amount of degradation (or fading) of the signal when passing through rain.

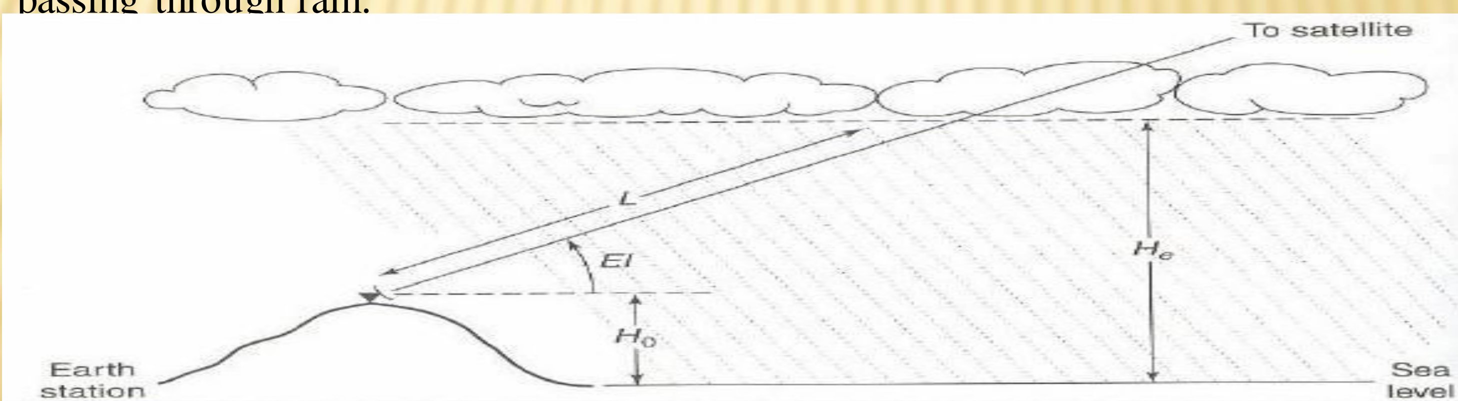


Figure 3. Geometry of satellite path through rain [1]

SATELLITE COMMUNICATIONS

System noise temperature ,C/N and G/T ratio Thermal noise in its pre amplifier

- Pn=ktsb
- System noise temperature is also called effective input noise temperature of the receiver
- It is defined as the noise temperature of a noise source located at the input of a noise source located at the input of a noiseless receiver which will produce then same contribution to the receiver output same contribution to the receiver output noise

As the internal noise of the actual system itself

Ts is located at the input to the receiver.

- RF amplifier
- IF amplifier
- Demodulator
- Over all gain at the receiver G
- Narrowest bandwidth is B
- Noise power at the demodulator input is

$$P_n = KT_S BG$$

SATELLITE COMMUNICATIONS

Pr is the signal power at the input of the RF section of the receiver

signal power at the demodulator input will be PrG

$$\frac{C}{N} = \frac{P_r G}{K T_S B G} = \frac{P_r}{K T_s B}$$

$$P_n = G_{If} K T_{If} B + G_{If} G_m K T_m B + G_{If} G_m G_{RF} K B (T_{RF} + T_{in})$$

$$P_n = G_{If} G_M G_{Rf} \left[\frac{K T_{If} B}{G_{If} G_m} + \frac{K T_m B}{G_{Rf}} + K B (T_{RF} + T_{in}) \right]$$

SATELLITE COMMUNICATIONS

$$P_n = G_{If} G_M G_{Rf} KB \left[T_{Rf} + T_{in} + \frac{T_{if}}{G_m G_{Rf}} + \frac{T_m}{G_{RF}} \right]$$

$$P_n = G_{If} G_M G_{Rf} KBT_s$$

from above equation

$$\mathrm{KT_s}B = KB \left[T_{Rf} + T_{in} + \frac{T_{if}}{G_m G_{Rf}} + \frac{T_m}{G_{RF}} \right]$$

$$T_s = \left[T_{Rf} + T_{in} + \frac{T_{if}}{G_m G_{Rf}} + \frac{T_m}{G_{RF}} \right]$$

SATELLITE COMMUNICATIONS

- G/T ratio is 40.7 db k^{-1} at 4 GHz and 5^0 elevation
- Gr varies with frequency f^2
- Ts depends upon the sky noise temperature

$$\frac{C}{N} = \frac{P_T G_T G_R \left(\frac{\lambda}{4\pi d} \right)^2}{K T_S B L_A}$$

$$N_0 = \frac{N}{B}$$

EIRP

$$\left(\frac{C}{N} \right)_{dBHz} = 10 \log P_T G_T - 20 Log \left(\frac{4\pi d}{\lambda} \right) + 10 \log \frac{G_R}{T_S} - 10 Log L_A - 10 Log K$$

Gr/Ts -- ratio is called figure of merit

SATELLITE COMMUNICATIONS

Atmospheric and ionospheric effect on link design

- Absorption
- refraction
- Diffusion(diffraction)
- Rotation of polarization of plane

depend on path length more pronounced at small elevation angles

Absorption and diffusion--- lower layers

---- increase in noise power at receiving antenna

Atmospheric and ionospheric effect on link design –cont-

- Upper layer of atmosphere cause refraction and depolarization
- De polarization is produced when radio waves traverse through the ionosphere layer.
- Below 10 GHz atmospheric attenuation is of no importance
- atmosphere has a small effect on the link quality at frequency between 2GHz and 10 GHz for higher elevation angles

SATELLITE COMMUNICATIONS

Atmospheric and ionospheric effect on link design – contt---

- Rain attenuation
- Frequency, rainfall rate, diameter and distribution of rain drops

$$A_{rain} = \gamma_r L_e$$

- γ_r specific rain attenuation
- L_e effective path length

Few decibels at very heavy rainfall

SATELLITE COMMUNICATIONS

UNIT-III

PROPAGATION EFFECT AND MULTIPLE ACCESS

SATELLITE COMMUNICATIONS

Multiple Access System

Applications employ multiple-access systems to allow two or more Earth stations to simultaneously share the resources of the same transponder or frequency channel. These include the three familiar methods: FDMA, TDMA, and CDMA.

1.Another multiple access system called space division multiple access (SDMA) has been suggested in the past. In practice, SDMA is not really a multiple access method but rather a technique to reuse frequency spectrum through multiple spot beams on the satellite.

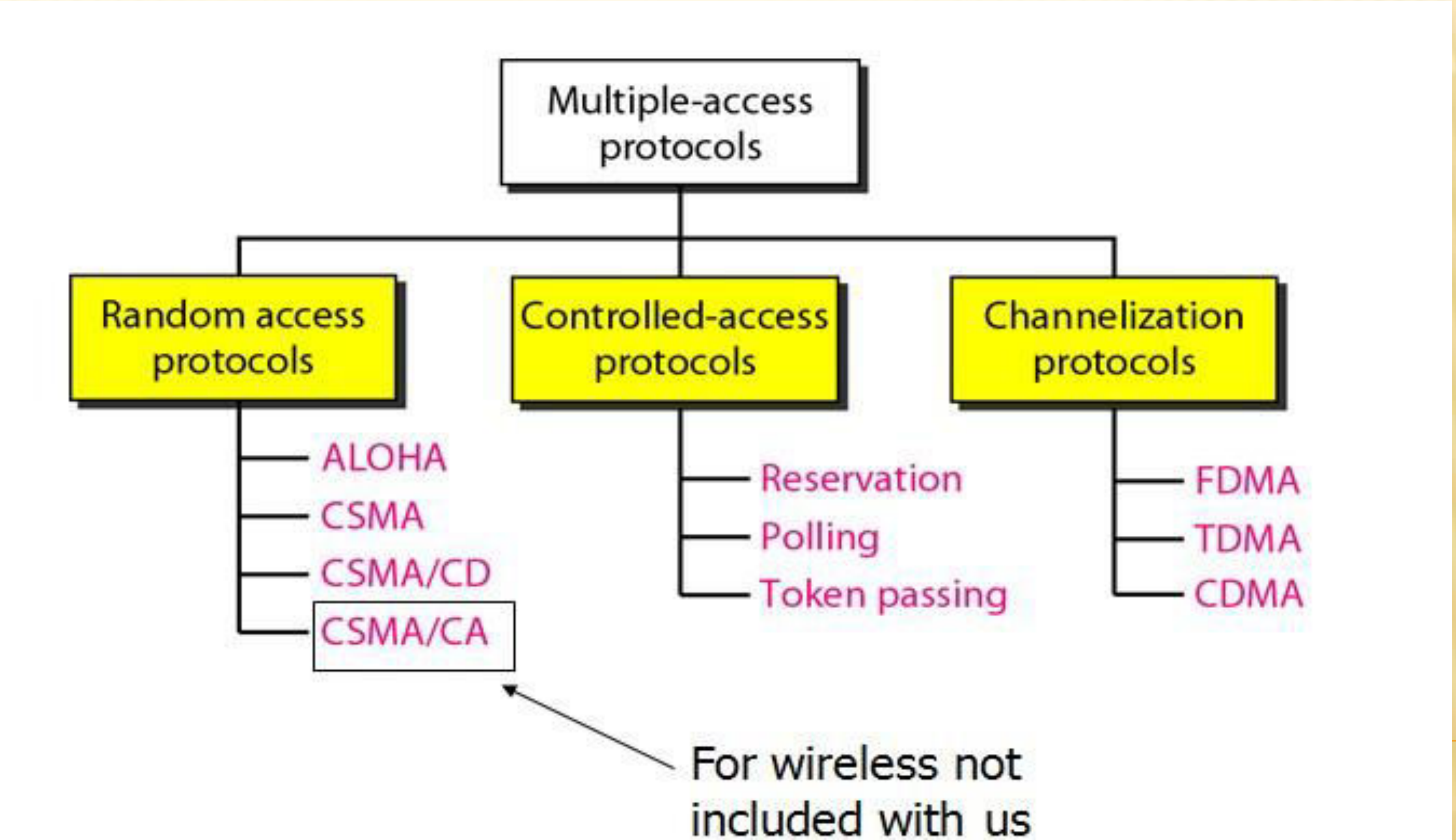
2.Because every satellite provides some form of frequency reuse (cross-polarization being included), SDMA is an inherent feature in all applications.

TDMA and FDMA require a degree of coordination among users:

- ❑FDMA users cannot transmit on the same frequency and
- ❑TDMA users can transmit on the same frequency but not at the same time.
- ❑Capacity in either case can be calculated based on the total bandwidth and power available within the transponder or slice of a transponder.
- ❑CDMA is unique in that multiple users transmit on the same frequency at the same time (and in the same beam or polarization).
- ❑This is allowed because the transmissions use a different code either in terms of high-speed spreading sequence or frequency hopping sequence.

SATELLITE COMMUNICATIONS

Taxonomy of multiple-access protocols



SATELLITE COMMUNICATIONS

The capacity of a CDMA network is not unlimited, however, because at some point the channel becomes overloaded by self-interference from the multiple users who occupy it.

❖Furthermore, power level control is critical because a given CDMA carrier that is elevated in power will raise the noise level for all others carriers by a like amount.

❖Multiple access is always required in networks that involve two-way communications among multiple Earth stations.

❖The selection of the particular method depends heavily on the specific communication requirements, the types of Earth stations employed, and the experience base of the provider of the technology.

❖All three methods are now used for digital communications because this is the basis of a majority of satellite networks.

❖The digital form of a signal is easier to transmit and is less susceptible to the degrading effects of the noise, distortion from amplifiers and filters, and interference.

❖Once in digital form, the information can be compressed to reduce the bit rate, and FEC is usually provided to reduce the required carrier power even further.

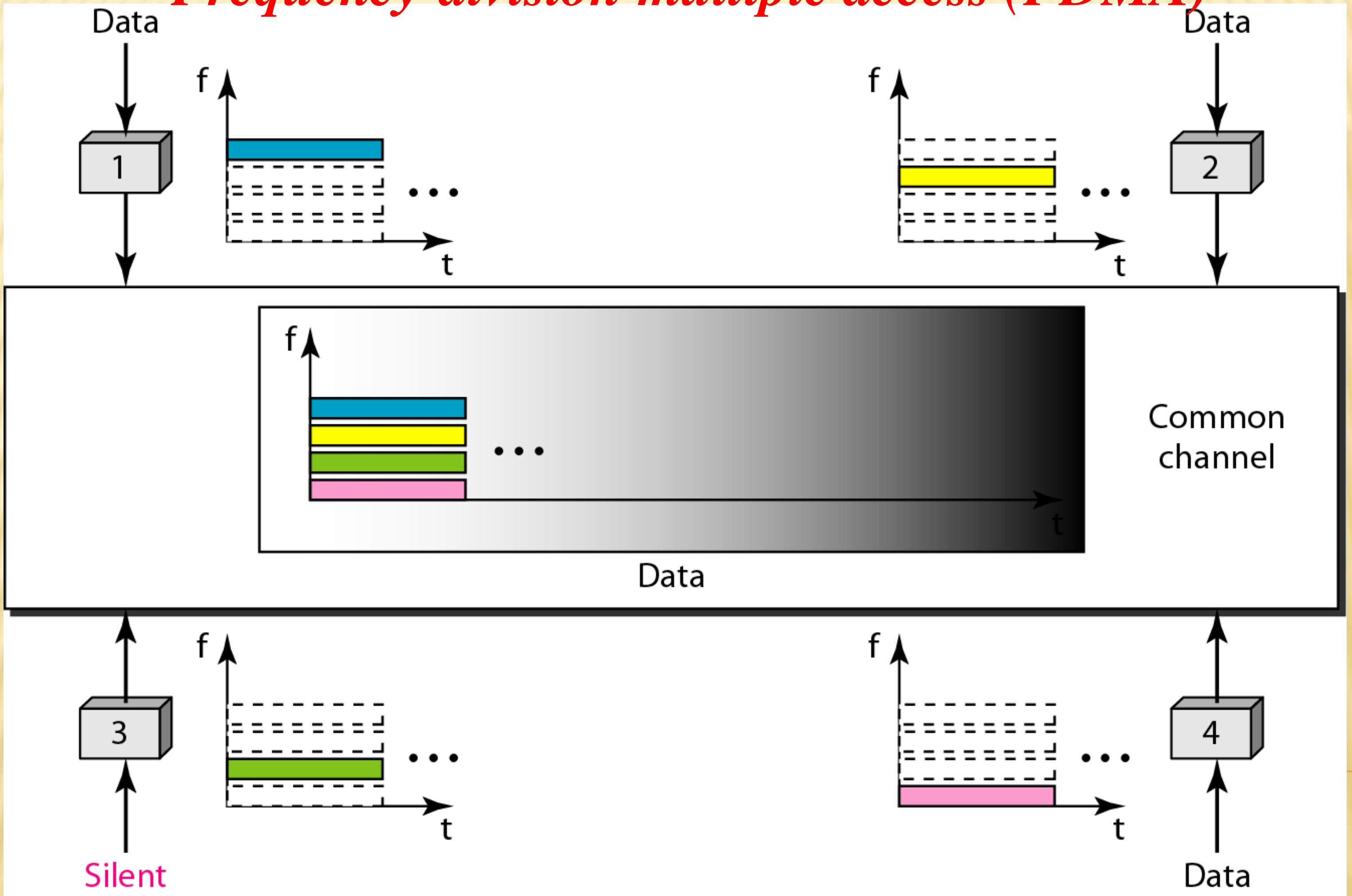
❖The specific details of multiple access, modulation, and coding are often preselected as part of the application system and the equipment available on a commercial off-the-shelf (COTS) basis.

❖The only significant analog application at this time is the transmission of cable TV and broadcast TV.

❖These networks are undergoing a slow conversion to digital as well, which may in fact be complete within a few years.

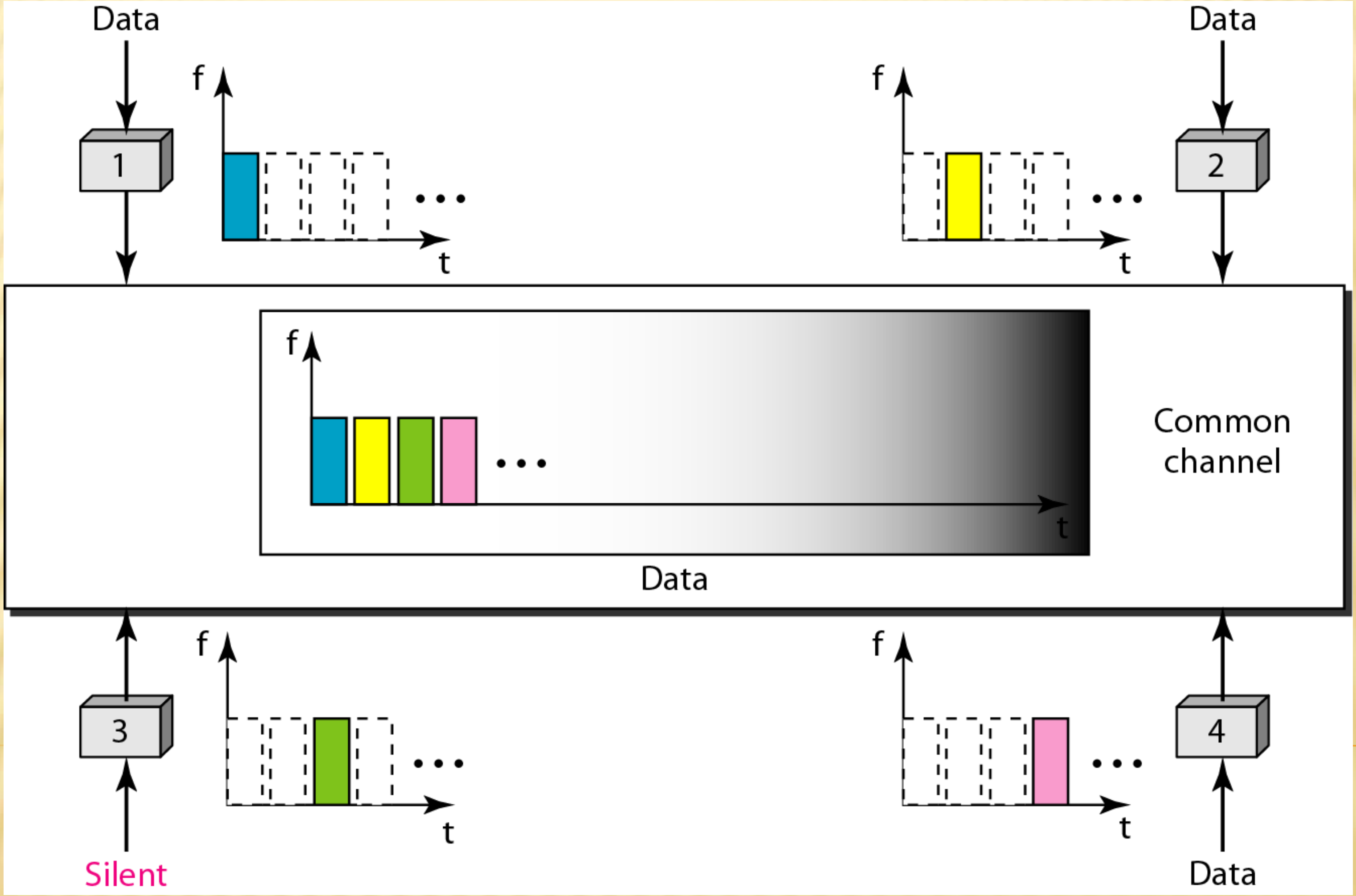
SATELLITE COMMUNICATIONS

Frequency-division multiple access (FDMA)



SATELLITE COMMUNICATIONS

Time-division multiple access (TDMA)



Time Division Multiple Access and ALOHA

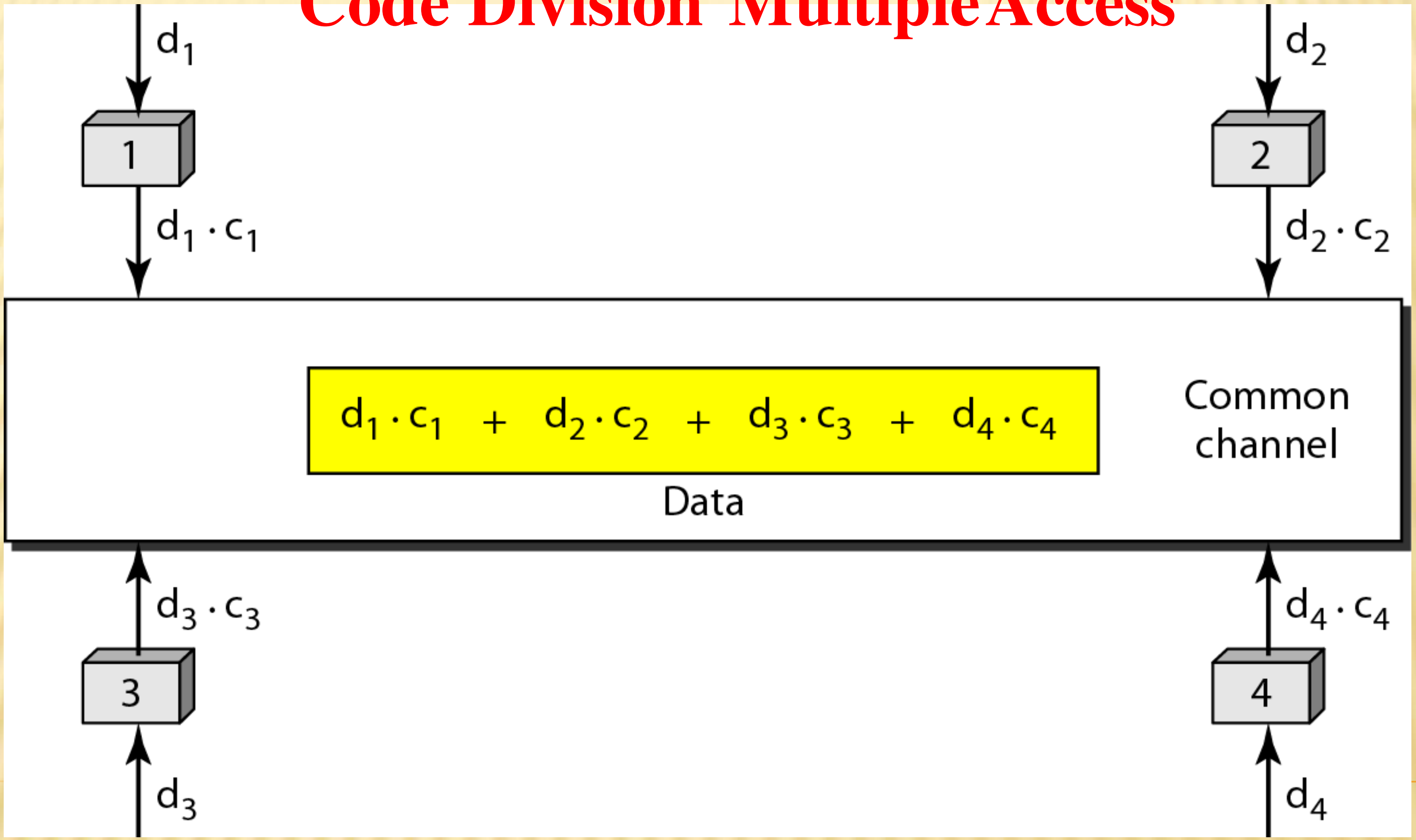
TDMA is a truly digital technology, requiring that all information be converted into bit streams or data packets before transmission to the satellite. (An analog form of TDMA is technically feasible but never reached the market due to the rapid acceptance of the digital form.) Contrary to most other communication technologies, TDMA started out as a high-speed system for large Earth stations. Systems that provided a total throughput of 60 to 250 Mbps were developed and fielded over the past 25 years. However, it is the low-rate TDMA systems, operating at less than 10 Mbps, which provide the foundation of most VSAT networks. Lower speed means that less power and bandwidth need to be acquired (e.g., a fraction of a transponder will suffice) with the following benefits:

The uplink power from small terminals is reduced, saving on the cost of transmitters. The network capacity and quantity of equipment can grow incrementally, as demand grows. TDMA signals are restricted to assigned time slots and therefore must be transmitted in bursts. The time frame is periodic, allowing stations to transfer a continuous stream of information on average. Reference timing for start-of-frame is needed to synchronize the network and provide control and coordination information. This can be provided either as an initial burst transmitted by a reference Earth station, or on a continuous basis from a central hub. The Earth station equipment takes one or more continuous streams of data, stores them in a buffer memory, and then transfers the output toward the satellite in a burst at a higher compression speed.

At the receiving Earth station, bursts from Earth stations are received in sequence, selected for recovery if addressed for this station, and then spread back out in time in an output expansion buffer. It is vital that all bursts be synchronized to prevent overlap at the satellite; this is accomplished either with the synchronization burst (as shown) or externally using a separate carrier. Individual time slots may be pre-assigned to particular stations or provided as a reservation, with both actions under control by a master station. For traffic that requires consistent or constant timing (e.g., voice and TV), the time slots repeat at a constant rate.

SATELLITE COMMUNICATIONS

Code Division Multiple Access



SATELLITE COMMUNICATIONS

Code Division Multiple Access

CDMA, also called spread spectrum communication, differs from FDMA and TDMA because it allows users to literally transmit on top of each other. This feature has allowed CDMA to gain attention in commercial satellite communication. It was originally developed for use in military satellite communication where its inherent anti-jam and security features are highly desirable. CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems. It has not been proven that CDMA is universally superior as this depends on the specific requirements. For example, an effective CDMA system requires contiguous bandwidth equal to at least the spread bandwidth. Two forms of CDMA are applied in practice:

(1) direct sequence spread spectrum (DSSS) and

(2) frequency hopping spread spectrum (FHSS).

FHSS has been used by the Omni Tracs and Eutel-Tracs mobile messaging systems for more than 10 years now, and only recently has it been applied in the consumer‘s commercial world in the form of the Bluetooth wireless LAN standard. However, most CDMA applications over commercial satellites employ DSSS (as do the cellular networks developed by Qualcomm).Consider the following summary of the features of spread spectrum technology (whether DSSS or FHSS):Simplified multiple access: no requirement for coordination among users; Selective addressing capability if each station has a unique chip code sequence—provides authentication.

SATELLITE COMMUNICATIONS

A typical CDMA receiver must carry out the following functions in order to acquire the signal, maintain
synchronization, and reliably recover the data:
Synchronization with the incoming code through the technique of correlation detection;
De-spreading of the carrier;
Tracking the spreading signal to maintain synchronization; Demodulation of the basic data stream;

Timing and bit detection;
Forward error correction to reduce the effective error rate;
The first three functions are needed to extract the signal from the clutter of noise and other signals.
The processes of demodulation, bit timing and detection, and FEC are standard for a digital receiver, regardless of the multiple access method.
The bottom line in multiple access is that there is no single system that provides a universal answer. FDMA, TDMA, and CDMA will each continue to have a place in building the applications of the future. They can all be applied to digital communications and satellite links. When a specific application is considered, it is recommended to perform the comparison to make the most intelligent selection.

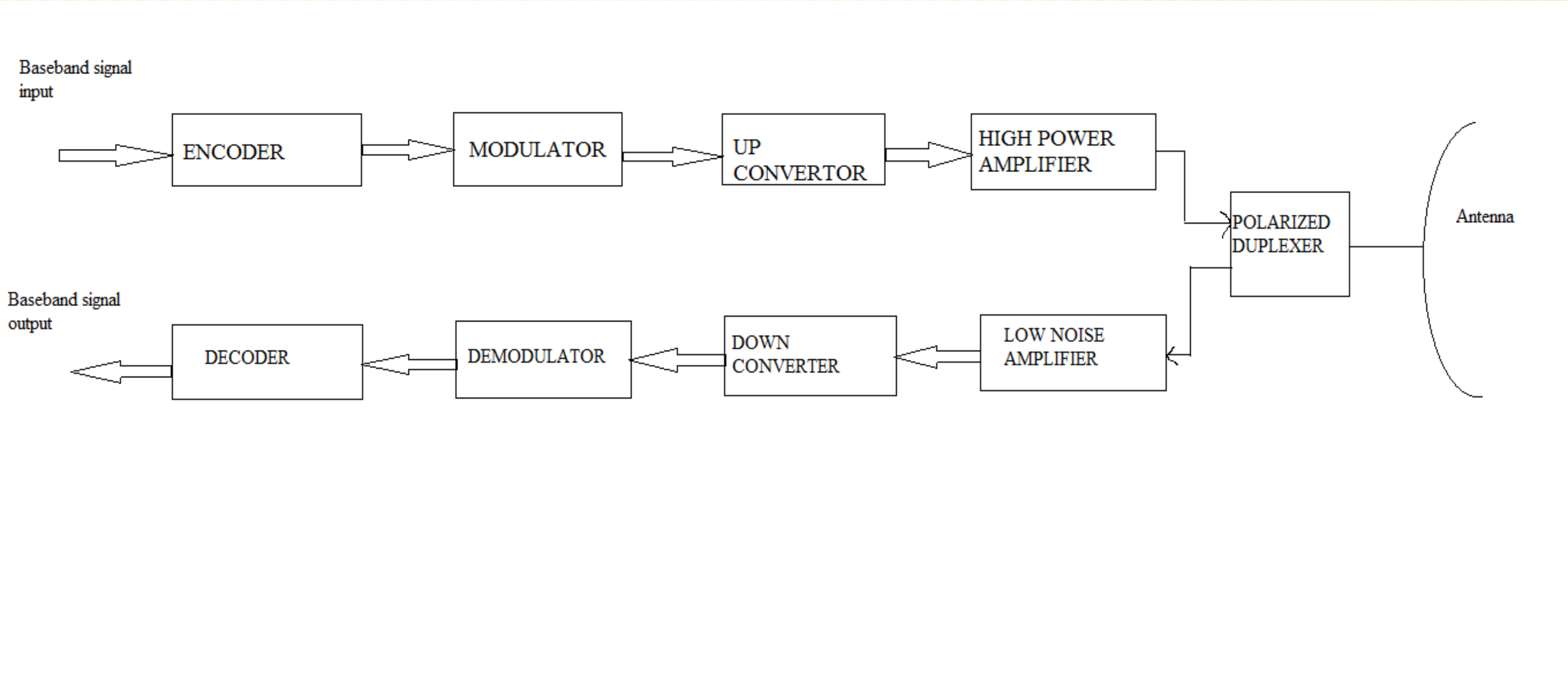
UNIT-IV
EARTH STATION

EARTH STATION

- The base band signal from the terrestrial network enters the earth station at the transmitter after having processed (buffered, multiplexed, formatted, etc.,) by the base band equipment.
- After the encoder and modulator have acted upon the base band signal, it is converted to the uplink frequency.
- Then it is amplified and directed to the appropriate polarization port of the antenna feed.
- The signal received from the satellite is amplified in an LNA first and is then down converted from the down link frequency.
- It is then demodulated and decoded and then the original base band signal is obtained.

EARTH STATION

- Critical components will often be installed redundantly with automatic switch over in the event of failure so that uninterrupted operation is maintained. The isolation of low noise receiver from the high power transmitter is of much concern in the design considerations of earth station



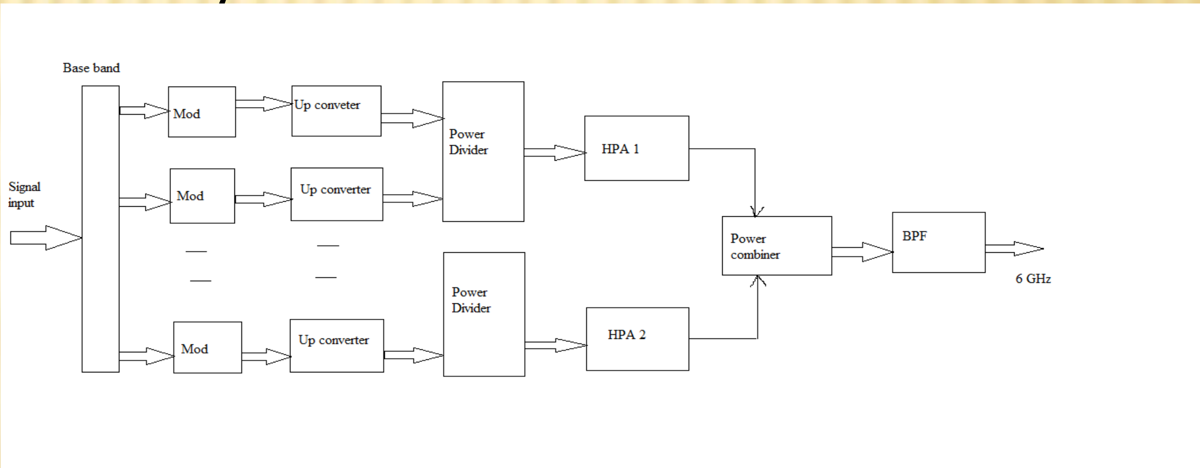
TRANSMITTERS

- Here the signal to be transmitted is converted to the uplink frequency, with proper encoding and modulation.
- It is then amplified and directed to the appropriate polarization port of the antenna feed.
- In a large earth station there will be many transmitters as well as receivers multiplexed together into one antenna to provide channelize communication through satellite transponders.
- Transmitters are very much expensive part of the earth station because of the tight specifications on out of band

  emission, frequency stability and power control that are necessary to avoid interference with other channels and satellites.
- Further as transmitters are not manufactured in large scale so there cost is high.

TRANSMITTERS

- The cost increases with the increase in transmitted power which may vary from tens to thousands of watts.
- Since earth stations require the transmission of microwave power, they use high power amplifiers (HPAs) such as travelling tubes and multi cavity klystrons.
- In fact compared to klystrons, TWTAs allow high power over a wide bandwidth. These tubes require quite a good amount of cooling that is provided by water circulation using a close refrigeration system.



RECEIVER

- Receiver of an earth station employs mainly low noise amplifier (LNA), down converter, demodulator, decoder and base band signal treatment equipments.
- In fact in the receive chain of the earth station the weak signals from the satellite are accepted by the same feed that carries the transmitter output.
- These two signals which differ in power by several orders of magnitude or kept separate in the frequency domain as they are assigned to the uplink and down link bands, and in addition by means of orthogonal polarization, diplexers are used to enhance the separation in the frequency domain.

ANTENNAS

- The antenna systems consist of
- 1.Feed System
- 2.Antenna Reflector
- 3.Mount
- 4.Antenna tracking System.

Feed System: The feed along with the reflector is the radiating/receiving element of electromagnetic waves.

- The reciprocity property of the feed element makes the earth station antenna system suitable for transmission and reception of electromagnetic waves.

The way the waves coming in and going out is called feed configuration Earth Station feed systems most commonly used in satellite communication are:

- i)Axi-Symmetric Configuration
- ii)Asymmetric Configuration

ANTENNA REFLECTOR

- Mostly parabolic reflectors are used as the main antenna for the earth stations because of the high gain available from the reflector and the ability of focusing a parallel beam into a point at the focus where the feed, i.e., the receiving/radiating element is located .
- For large antenna system more than one reflector surfaces may be used in as in the cassegrain antenna system. Earth stations are also classified on the basis of services for example:
- 1. Two way TV, Telephony and data
- 2. Two way TV
- 3. TV receive only and two way telephony and data
- 4. Two way data

ANTENNA REFLECTOR

For mechanical design of parabolic reflector the following parameters are required to be considered:

- Size of the reflector
- Focal Length /diameter ratio
- RMS error of main and sub reflector
- Pointing and tracking accuracies
- Speed and acceleration
- Type of mount
- Coverage Requirement

ANTENNA TRACKING SYSTEM

- Tracking is essential when the satellite drift, as seen by an earth station antenna is a significant fraction of an earth station's antenna beam width.
- An earth station's tracking system is required to perform some of the functions such as
- i)Satellite acquisition
- ii)Automatic tracking
- iii)Manual tracking
- iv)Program tracking.

ANTENNA TRACKING SYSTEM

- Recent Tracking Techniques: There have been some interesting recent developments in auto-track techniques which can potentially provide high accuracies at a low cost. In one proposed technique the sequential lobbing technique has been implemented by using rapid electronic switching of as single beam which effectively approximates simultaneous lobbing.

TERRESTRIAL INTERFACE

- The function of an earth station is to receive information from or transmit information to, the satellite network in the most cost-effective and reliable manner while retaining the desired signal quality.
- The design of earth station configuration depends upon many factors and its location.
- Location are listed below,

1. In land
2. on a ship at sea
3. Onboard aircraft

- The factors are

1. Type of services
2. Frequency bands
3. Function of the transmitter
4. Function of the receiver
5. Antenna characteristics.

POWER TEST METHODS

Noise power ratio (NPR):

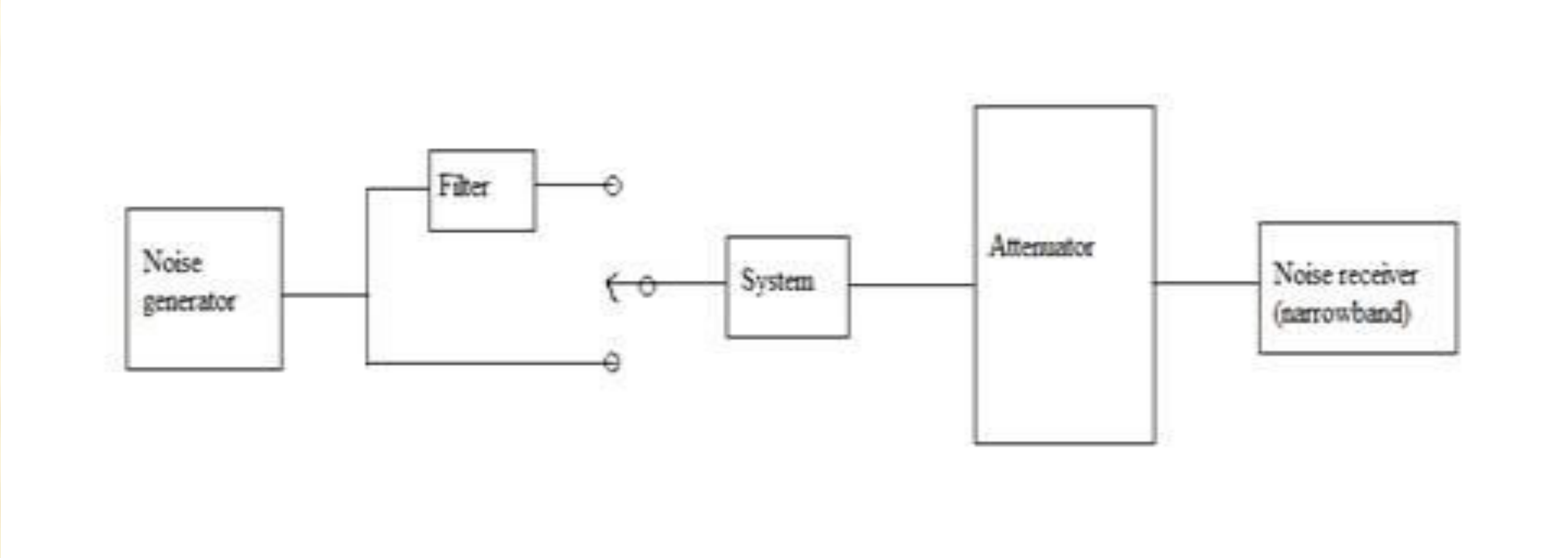
- Noise power ratio (NPR), the traditional measure of inter modulation noise for FDM systems in the communication field.
- The principle of NPR measurement involves loading the entire base band spectrum, save for the one voice- frequency channel slot, with noise, simulating in total the loading of the system by actual voice traffic in all but that channel.
- Noise appearing in the unloaded slot is manifestation of inter modulation.
- The ratio of that noise power to the per- channel loading noise power is the NPR.

THE SYSTEM CAN BE BETWEEN ANY TWO POINTS OF INTEREST THE NOISE GENERATOR BAND IS LIMITED BY FILTERS TO THE BASE BAND, AND THE NOISE GENERATOR LEVEL IS SET TO SIMULATE FULL LOAD ACCORDING TO THE CCIR FORMULAS

P = -15 + 10 LOG N DBMO, N ≥ 240

P = -1 + 4 log N dBmO, N < 240

$$BWR = 10 \log \frac{base\ band\ total\ bandwidth}{signal\ channel\ bandwidth}$$



$$NLR = 10 \log \frac{base\ band\ noise\ test\ power}{test-tone\ power\ per\ channel}$$ = dBmO of loading calculation.

THE MEASUREMENT OF G/T:

- antenna gain, and as the antennas get larger, this characteristic is not so easy to get.
- The gain of smaller antennas, say less than 7 or 8m, can be found from pattern measurements on a range or by comparison to gain standard, but these measures are cumbersome and may be impartial for larger antennas.
- Large earth stations, with antenna sizes up from 10m, can sometimes use a carefully calibrated satellite signal to measure.

- In effect, is calculated from the link equation, knowing the other variables. This method is often used with intermediate sized antennas (from 5 to 15m).
- An engineer's method has been developed for the measurement of for large antennas using the known radio noise characteristics of stellar sources, usually called radio stars.
- These characteristics, particularly S, the flux density of the source in.Hz, have been accurately measured by radio astronomers.

LOWER ORBIT CONSIDERATIONS

- In order that a satellite can be used for communications purposes the ground station must be able to follow it in order to receive its signal, and transmit back to it.
- Communications will naturally only be possible when it is visible, and dependent upon the orbit it may only be visible for a short period of time.
- To ensure that communication is possible for the maximum amount of time there are a number of options that can be employed:
- The first is to use an elliptical orbit where the apogee is above the planned Earth station so that the satellite remains visible for the maximum amount of time.

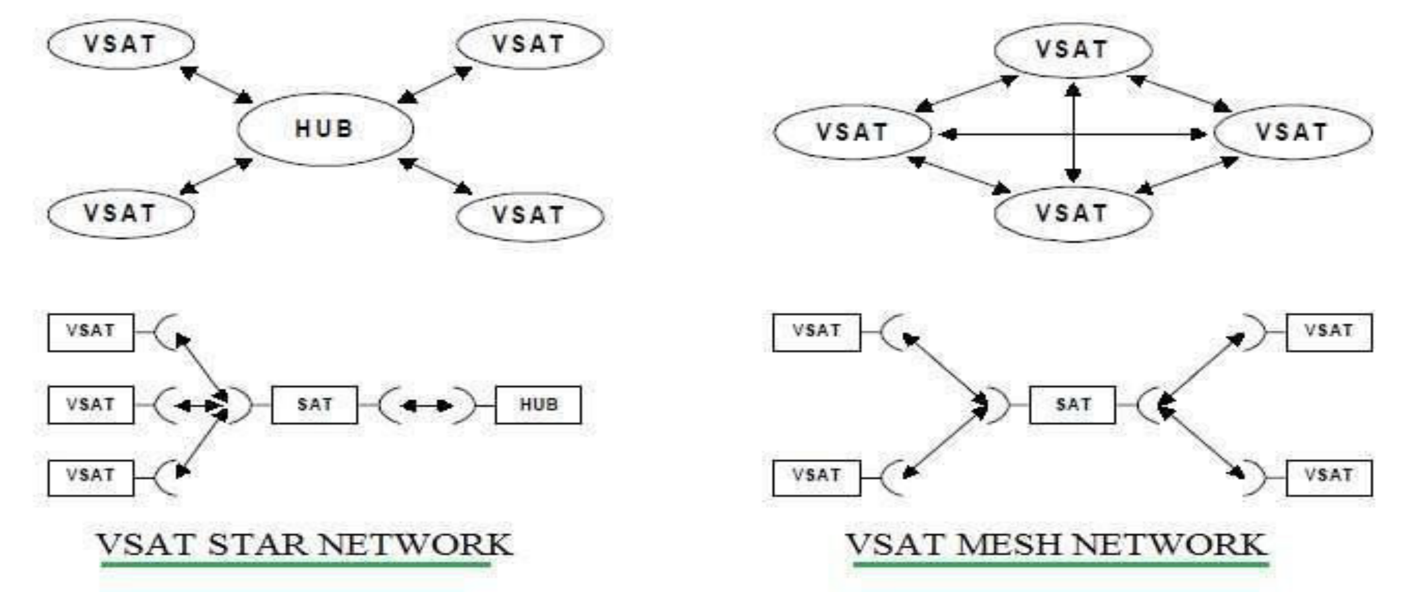
- Another option is to launch a number of satellites with the same orbit so that when one disappears from view, and communications are lost, another one appears.
- Generally three satellites are required to maintain almost uninterrupted communication.
- However the handover from one satellite to the next introduces additional complexity into the system, as well as having a requirement for at least three satellites.

VSAT (VERY SMALL APERTURE TERMINAL) SYSTEMS

- VSAT (Very Small Aperture Terminal) describes a small terminal that can be used for two-way communications via satellite.
- VSAT networks offer value-added satellite-based services capable of supporting the Internet, data, video, LAN, voice/fax communications, and can provide powerful private and public network communication solutions.
- They are becoming increasingly popular, as VSATs are a single, flexible communications platform that can be installed quickly and cost efficiently to provide telecoms solutions for consumers, governments and corporations.

VSAT NETWORK ARCHITECTURES

- Any telecommunication services there are three basic implementations services: one-way, split-two-way (referred to as split-IP sometimes, when referring to internet traffic) and two-way implementation. Further division of two-way implementation is star and mesh network architectures.
- There are two Architectures:



STAR

- In Star network architecture, all traffic is routed via the main hub station.
- If a VSAT want to communicate with another VSAT, they have to go through the hub station.
- This makes double hop link via the satellite. Star is the most common VSAT configuration of the TDM/TDMA.
- These have a high bit rate outbound carrier (Time Division Multiplexed) from the hub to the remote earth stations, and one or more low or medium bit rate (Time Division Multiple Access) inbound carriers.
- In a typical VSAT network, remote users have a number of personal computers or dumb terminals

MESH

- Meshed VSAT networks provide a way to set up a switched point to point data network that can have the capability for high data rates of up to 2Mb/s.
- Links are set up directly between remote terminals usually on a call by call basis. These networks are usually configured to operate without a large central earth station and carry a mix of data traffic and telephony traffic or only data traffic.
- These networks generally will have a network control station, which controls the allocation of resources across the network.
- This control centre is only involved in the signaling for the call setup/teardown and in monitoring the operation of the network.

ACCESS CONTROL

- In general, multiple access schemes suitable for use in VSAT networks are packet-oriented.
- Loosely speaking, they may be classified into two broad categories; namely, contention or random access schemes and reservation schemes.
- The main contention schemes, suitable for use in VSAT systems, are based on the ALOHA concept, of which there are three variations; namely,
- Pure ALOHA,
- Slotted ALOHA
- Reservation ALOHA

MULTIPLE ACCESS SELECTION

- One satellite can simultaneously support thousands of Pico terminal accesses.
- This means that the number of users in a Pico terminal network can be a multiple of this, resulting in a communication network with an enormous size.
- To control such a number of terminals, the multiple access schemes for Pico terminals may be a combination of frequency division multiple access (FDMA) and code division multiple access (CDMA).
- The CDMA spread-spectrum technique normally used for satellite communications is direct sequence spread spectrum.

- The use of spread spectrum techniques in Pico terminal networks has several advantages.
- It is advantageous as multiple access schemes, because (asynchronous) SSMA does not need network control and synchronization.
- A second advantage is the inherent interference protection of the system. This is important for Pico terminals which will be more or less sensitive to interference from unwanted directions due to their small antennas.
- A third advantage is that Pico terminals can transmit with low power densities giving less interference problems.
- Finally SSMA gives some kind of message privacy through the encryption with a code word

NGSO CONSTELLATION DESIGN: ORBITS

- NGSOs are classified in the following three types as per the inclinations of the orbital plane
  - Polar Orbit
  - Equatorial Orbit
  - Inclined Orbit
- In polar orbit the satellite moves from pole to pole and the inclination is equal to 90 degrees.
- In equatorial orbit the orbital plane lies in the equatorial plane of the earth and the inclination is zero or very small.
- All orbits other than polar orbit and equatorial orbit are called inclined orbit. A satellite orbit with inclination of less than 90 degrees is called a pro grade orbit.

- The satellite in pro grade orbit moves in the same direction as the rotation of the earth on its axis.
- Satellite orbit with inclination of more than 90 degrees is called retrograde orbit when the satellite moves in a direction opposite to the rotational motion of the earth.
- Orbits of almost all communication satellites are pro grade orbits, as it takes less propellant to achieve the final velocit of the satellite in pro grade orbit by taking yAdvantage of the earth's rotational speed.

COVERAGE

- The designer of a satellite system has few degrees of freedom in designing a pay load to provide optimum coverage.
- This occurs in some missions where a shared space craft has to accommodate a no. of payloads.
- A GEO can be selected or a constellation of NGSO satellites can be designed to provide the necessary coverage overlap between successive satellites.
- The determination of coverage area, while initially an exercise in simple geometry, is eventually heavily influenced by the available technology both on the ground and in space, and other aspects such as the radiation environment.
- First consider the geometrical aspects of determining an optimum coverage. The elevation angle to the satellite is θ. using the sine rule:

$$[r_s / sin(90 + \theta)] = [d / sin(\gamma)]$$

This yield to

$$cos(\theta) = [r_s sin(\gamma)] / d$$

FREQUENCY BANDS

- Low earth orbit satellite systems providing data and voice service to mobile users tend to use the lowest available RF frequency.
- The EIRP required by the satellite transponder to establish a given C/N ratio in the mobile receiver is proportional to the square of the RF frequency of the downlink.
- The power that must be transmitted by a mobile transmitter is also proportional to RF frequency squared when the mobile uses an Omni directional antenna.
- Since the cost of satellites increases as the EIRP of the transponders increases, a lower RF frequency yields a lower cost system.
- This is one reason why L-band is allocated for mobile satellite services.

DELAY AND THROUGHPUT

- Delay in a communications link is not normally a problem unless the interactions between the users are very rapid – a few milli seconds apart in response time.
- Long delays, such as those associated with manned missions to the moon. For most commercial satellite links that are over long distances, particularly those with satellites in geostationary orbit, the main problem was not delay, but echo.
- A mismatched transmission line will always have a reflected signal. If the mismatch is large, a strong echo will return.
- Over a GEO satellite link, the echo arrives back in the telephone head set about half a second after the speaker has spoken, and usually while the speaker is still speaking.

NGSO (NON GEOSTATIONARY ORBIT) CONSTELLATION DESIGN

Constellation design:

- Basic formation
- Station keeping
- Collision avoidance

Constellation: set of satellites distributed over space intended to work together to achieve a common objective. Satellites that are in close proximity are called clusters or formations.

Principal factors to be defined during constellation design		
Factor	**Effect**	**Selection criteria**
NO. Of satellites	Principal cost & coverage driver	Minimize number consistent with meeting other criteria.
Constellation pattern	Determines coverage Vs latitude	Select for best coverage
Minimum elevation angle	Principal determinant of single satellite coverage	Minimum value consistent with constellation pattern
Altitude	Coverage, environment launch and transfer cost	System level trade of cost Vs performance
NO. Of orbit planes	Determines coverage plateaus, growth and degradation	Minimize consistent with coverage needs.
Collision avoidance parameters	Key to preventing constellation destruction	Maximize the inter satellite distances at plane crossings

UNIT V
SATELLITE PACKET COMMUNICATION

MESSAGE TRANSMISSION BY FDMA

- With Frequency Division Multiple Access (FDMA) the entire available frequency channel is divided into bands and each band serves a single station.
- Every station is therefore equipped with a transmitter for a given frequency band, and a receiver for each band.
- To evaluate the performance of the FDMA protocol, we assume that the entire channel can sustain a rate of R bits/sec which is equally divided among M stations i.e. R/M bits/sec for each.
- The individual bands do not overlap as such there is no interference among transmitting stations. This allows for viewing the system as M mutually independent queues.
- If the packet length is a random variable P, then the service $T = {}^{MP}/_{R}$ time afforded to every packet is the random variable.

M/G/I QUEUE

- Consider a queuing system, in which arrivals occur according to a Poisson process with parameter and in which x is the service rendered to the customers, is distributed according to a distribution B (t).
- In such a queuing system, an outside observer sees the number of customers in the system as equal to that seen by an arriving customer, which equals that seen by a departing customer.
- The following holds for an M/G/I queuing system:

•D = x + W = x +

Where:

$$\frac{\lambda x^2}{2(1-p)}$$

- D= Average delay time; p = λx= Load factor; W= Queuing time.

- Therefore, for an FDMA system, considering a typical user that generates packets according to a Poisson process with rate λ packets/sec and its buffering capabilities are not limited, the time required for the transmission of a packet.
- Each node can therefore be viewed as an M/G/1 queue since each packet size is not constant. Thus, using the known system delay time formula for M/G/1 queuing systems we get that the expected delay of a packet is:
- $D = T + \frac{\lambda T^2}{2(1-\lambda T)}$
- And the delay distribution is given by,

$$D^* = X^*(s)\frac{s(1-p)}{s-\lambda+\lambda X^*(S)}$$

- Where (S) is the Laplace transform of the transmission time

MESSAGE TRANSMISSION BY TDMA

- In the time division multiple access (TDMA) scheme the entire time frame is divided into time slots, pre-assigned to the different stations.
- Centralized control is absent in a contention-based system, as such when a node needs to transmit data, it contends for control of the transmission medium.
- The major advantage of contention techniques is simplicity, as they are easily implementable in individual nodes. The contention techniques are efficient under light to moderate network load, but performance rapidly degrades with increase in load level.
- Message transmission by TDMA can be done using the ALOHA protocol, packet reservation and tree algorithm.

PACKET RESERVATION

- Dynamic channel allocation protocols are designed to overcome the drawback faced by static conflict-free protocols, which involves (inefficient) under utilization of the shared channel, especially when the system is lightly loaded or when the loads of different users are asymmetric.
- The static and fixed assignment in these protocols, cause the channel (or part of it) to be idle even though some users have data to transmit.

TREE ALGORITHM

- This is a collision resolution protocol (CRP). As opposed to the instability of the ALOHA protocol, the efforts of CRP are concentrated on resolving collisions as soon as they occur.
- Here, the fixed-length packets involved in collision participate in a systematic partitioning procedure for collision resolution, during which time new messages are not allowed to access the channel.
- The stability of the system is ensured provided that the arrival rate of new packets to the system is lower than its collision resolution rate.
- The tree-type protocols have excellent channel capacity capabilities, but are vulnerable to deadlocks due to incorrect channel observation

Examples of improved binary-tree protocols are

- 1. The Modified binary-tree protocol: Its operation requires ternary feedback, i.e., the users have to be able to distinguish between idle and successful slots.
- 2. The Epoch Mechanism: Its operation models the system in such a way that the CRI starts with the transmission of exactly one packet (yields a throughput of 1) by determining when packets are transmitted for the first time.
- 3. The Clipped binary-tree protocol: This improved on the Epoch mechanism by adopting the rule that whenever a collision is followed by two successive successful transmissions, the packets that arrived in.

ERROR CONTROL FOR DIGITAL SATELLITE LINKS:
ERROR CONTROL CODING:

- The primary function of an error control encoder-decoder pair is to enhance the reliability of message
- An error control code can also ease the design process of a digital transmission system in multiple ways such as the following:

a) the transmission power requirement of a digital transmission scheme can be reduced by the use of an error control codec.

b) Even the size of a transmitting or receiving antenna can be reduced by the use of an error control codec while maintaining the same level of end-to-end performance.

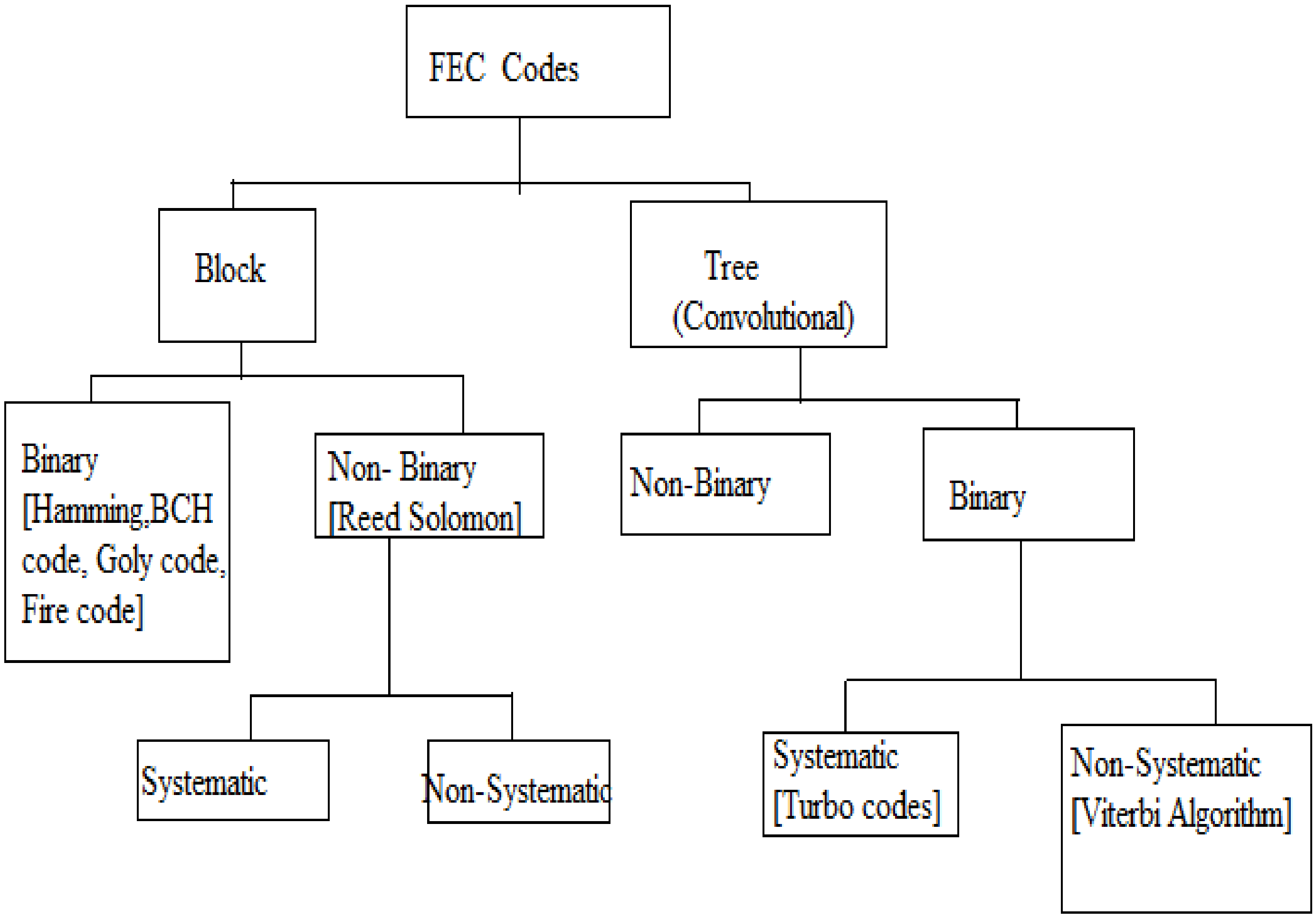
c) Access of more users to same radio frequency in a multi-access communication system can be ensured by the use of error control technique.

The major categories of activities on error control coding can broadly be identified as the following:

a) to find codes with good structural properties and good asymptotic error performance,

b) to devise efficient encoding and decoding strategies for the codes and

c) to explore the applicability of good coding schemes in various digital transmission and storage systems and to evaluate their performance.


FEC Codes
Block
Tree
(Convolutional)
Binary
[Hamming,BCH
code, Goly code,
Fire code]
Non- Binary
[Reed Solomon]
Non-Binary
Binary
Systematic
Non-Systematic
Systematic
[Turbo codes]
Non-Systematic
[Viterbi Algorithm]

BLOCK CODES

The encoder of a block code operates on a group of bits at a time. A group or ‘block’ of ‘k’ information bits (or symbols) are coded using some procedure to generate a larger block of ‘n’ bits (or symbols). Such a block code is referred as an (n, k) code.

Convolution codes:

- Convolutional codes, which are used in a variety of systems including today’s popular wireless standards (such as 802.11) and in satellite communications.
- Convolutional codes are beautiful because they are intuitive, one can understand them in many different ways, and there is a way to decode them so as to recover the mathematically most likely message from among the set of all possible transmitted messages.

IMPLEMENTATION OF ERROR DETECTION ON SATELLITE LINKS

- The following three basic techniques can be used, which are based on the type of the link used for retransmission request:
- In a one way simplex link, the ACK and NAK signal must travel on the same path as the data, so the transmitter must stop transmission after each block and wait for the receiver to send back a NAK or ACK before it retransmits the last data block or sends the next one.
- The data rate is very slow and thus useful for links in which data are generated slowly.
- In a stop and wait system, the transmitting end sends a block data and waits for the acknowledgement to arrive on the return channel. Though the implementation is simple but the amount of delay is the same as the simplex case.

- In a continuous transmission system using the go- back – N technique, data are sent in the form of a block continuously and held in a buffer at the receiver of the end of the link.
- When the data block arrives, it is checked for error and the appropriate ACK or NAK is send back to the transmitting end with block number specified.
- When a NAK (N) is received, the transmit end goes back to block N and retransmits all subsequent blocks.

DATA RELAY COMMUNICATION SATELLITES

- Data Relay Satellite System (DRSS) is primarily meant for providing continuous/real time communication of Low-Earth-Orbit (LEO) satellites/human space mission to the ground station.
- A data relay satellite in the Geo-stationary Orbit (GEO) can see a low altitude spacecraft for approximately half an orbit.
- Two such relay satellites, spaced apart in GEO, could theoretically provide continuous contact for any spacecraft in LEO.

ARCHITECTURE OF A GENERIC DRSS SATELLITE

a) DRSS Space Segment:

The DRSS space segment primarily consists of high altitude satellite system of GEO or Molniya class, defined in a modular way providing several payloads satisfying the data relay service requirements at different orbital positions with on-board state-of-the-art technologies.

b) DRSS Ground Segment:

DRSS Network Control Centre, whose task will include managing and operating the end to end data relay links and to provide data relay customer interface for mission request, mission planning, scheduling and mission execution.

c) DRSS User Segment:

The users of DRSS services can be broadly categorized as Institutional users (e.g. Space agency), Commercial users (e.g. Other Launcher/Satellite Agencies).

SATELLITE MOBILE SERVICES

- Mobile satellite service (MSS) is the term used to describe telecommunication services delivered to or from the mobile users by using the satellites.
- MSS can be used in remote areas lacking wired networks.
- Limitations of MSS are availability of line of sight requirement
  and emerging technologies.
- The basic Mobile satellite service (MSS) System comprises of these three segments:

➢ SPACE SEGMENT

➢ USER SEGMENT

➢ CONTROL SEGMENT

- **Space segment:** Space segment is equipped with satellite pay-load equipment. The Pay load is used to enable the ability of the satellite for users in space communication.
- **User segment:** The user segment consists of equipment that transmits and receives the signals from the satellite.
- **Control segment:** The control segment controls the satellite and operations of all internet connections to maintain the bandwidth and adjust power supply and antennas.

The mobile satellite services are classified into the following five types:

- Maritime mobile satellite service (MMSS).
- Land mobile satellite service (LMSS):
- Aeronautical mobile satellite service (AMSS):
- Personal mobiles satellite service (PMSS):
- Broadcast mobile satellite service (BCMSS):

APPLICATIONS OF SATELLITES

- Satellites that are launched in to the orbit by using the rockets are called man-made satellites or artificial satellites.
- Artificial satellites revolve around the earth because of the gravitational force of attraction between the earth and satellites.
- Unlike the natural satellites (moon), artificial satellites are used in various applications.

The various applications of artificial satellites include:

1. Weather Forecasting
2. Navigation
3. Astronomy
4. Satellite phone
5. Satellite television
6. Military satellite
7. Satellite Internet
8. Satellite Radio.