CEC352 - SATELLITE COMMUNICATION

L T P C
3 0 0 3

OBJECTIVES:

The student should be made to:

- Understand the basics of satellite orbits
- Understand the satellite segment and earth segment
- Analyze the various methods of satellite access
- Understand the applications of satellites
- Understand the basics of satellite Networks

UNIT I SATELLITE ORBITS 9

Kepler's Laws, Newton's Law, Orbital Parameters, Orbital Perturbations, Station Keeping, Geo Stationary and Non Geo-Stationary Orbits – Look Angle Determination - Limits of Visibility – Eclipse - Sub Satellite Point – Sun Transit Outage - Launching Procedures - Launch Vehicles and Propulsion.

UNIT II SPACE SEGMENT 9

Spacecraft Technology - Structure, Primary Power, Attitude and Orbit Control, Thermal Control and Propulsion, Communication Payload and Supporting Subsystems, Telemetry, Tracking and Command – Transponders - The Antenna Subsystem.

UNIT III SATELLITE LINK DESIGN 9

Basic Link Analysis, Interference Analysis, Rain Induced Attenuation and Interference, Ionospheric Characteristics, Link Design with and without Frequency Reuse.

UNIT IV SATELLITE ACCESS AND CODING METHODS 9

Modulation and Multiplexing: Voice, Data, Video, and Analog – Digital Transmission System, Digital Video Broadcast, Multiple Access: FDMA, TDMA, CDMA, DAMA Assignment Methods, Compression – Encryption, Coding Schemes.

UNIT V SATELLITE APPLICATIONS 9

INTELSAT Series, INSAT, VSAT, Mobile Satellite Services: GSM, GPS, INMARSAT, LEO, MEO, Satellite Navigational System. GPS Position Location Principles, Differential GPS, Direct Broadcast satellites (DBS/DTH).

TOTAL:45 PERIODS

OUTCOMES:

At the end of the course, the student would be able to:

- Analyze the satellite orbits
- Analyze the earth segment and space segment
- Analyze the satellite Link design
- Design various satellite applications

TEXT BOOKS:

1. Dennis Roddy, “Satellite Communication”, 4th Edition, Mc Graw Hill International, 2006.
2. Timothy,Pratt,Charles,W.Bostain,JeremyE.Allnutt,"SatelliteCommunication”,2ndEdition, Wiley Publications,2002

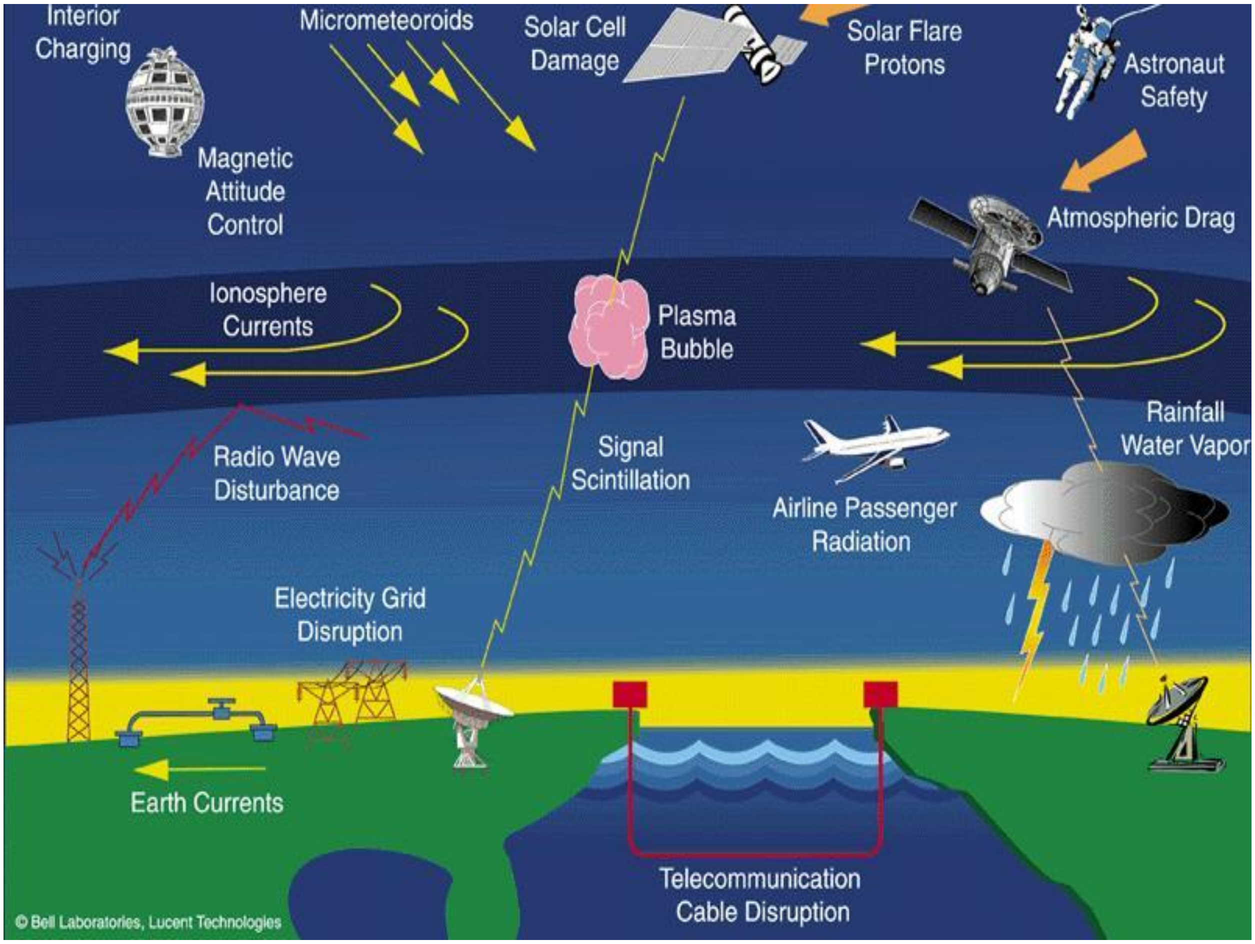
REFERENCES:

1. Wilbur L.Pritchard, Hendri G. Suyderhoud, Robert A. Nelson, “Satellite Communication Systems Engineering”, Prentice Hall/Pearson, 2007.
2. N.Agarwal, “Design of Geosynchronous Space Craft”, Prentice Hall, 1986.
3. Bruce R. Elbert, “The Satellite Communication Applications”, Hand Book, Artech House Bostan London, 1997.
4. Tri T. Ha, “Digital Satellite Communication”, II nd edition, 1990.
5. Emanuel Fthenakis, “Manual of Satellite Communications”, Mc Graw Hill Book Co.,1984.
6. Robert G. Winch, “Telecommunication Trans Mission Systems”, Mc Graw-Hill Book Co., 1983.
7. Brian Ackroyd, “World Satellite Communication and earth station Design”, BSP professional Books, 1990.
8. G.B.Bleazard, “Introducing Satellite communications“, NCC Publication, 1985.
9. M.Richharia, “Satellite Communication Systems-Design Principles”, Macmillan 2003.

UNIT I

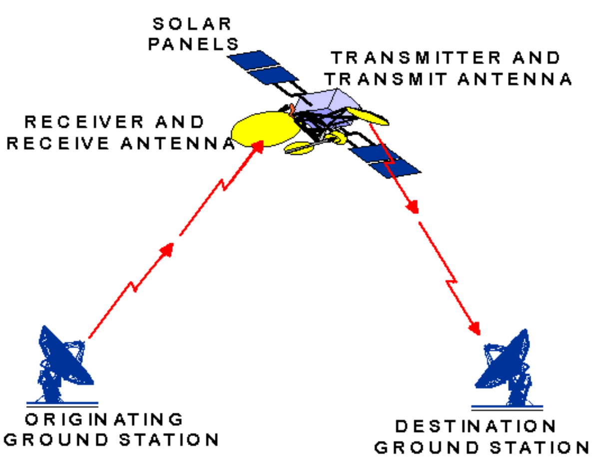
SATELLITE ORBITS

Kepler's Laws, Newton's Law, Orbital Parameters, Orbital Perturbations, Station Keeping, Geo Stationary and Non Geo-Stationary Orbits – Look Angle Determination - Limits of Visibility – Eclipse - Sub Satellite Point – Sun Transit Outage - Launching Procedures - Launch Vehicles and Propulsion.



Satellite

The word satellite originated from the Latin word "**Satellit**"- meaning an attendant, one who is constantly covering around & attending to a "master" or big man



- Earth Stations – antenna systems on earth
- Uplink – transmission from an earth station to a satellite
- Downlink – transmission from a satellite to an earth station
- Transponder – electronics in the satellite that convert uplink signals to downlink signals

First satellite launched into space: Sputnik (1957).

Motion of Space Objects

1473 -1543 Copernicus - Heliocentric (sun in the center) Orbit

1546 – 1601 Tycho Brahe
Before telescope followed the planets (acquired quality data)

1571 – 1630 Johannes Kepler
Discovered orbital path to be elliptical around focus point
Keplers 3 laws of planetary motion

1642 – 1727 Sir Isaac Newton
Physical Principals – Universal law of Gravitation

NEWTON'S LAWS

Newton's First law: Law of Inertia

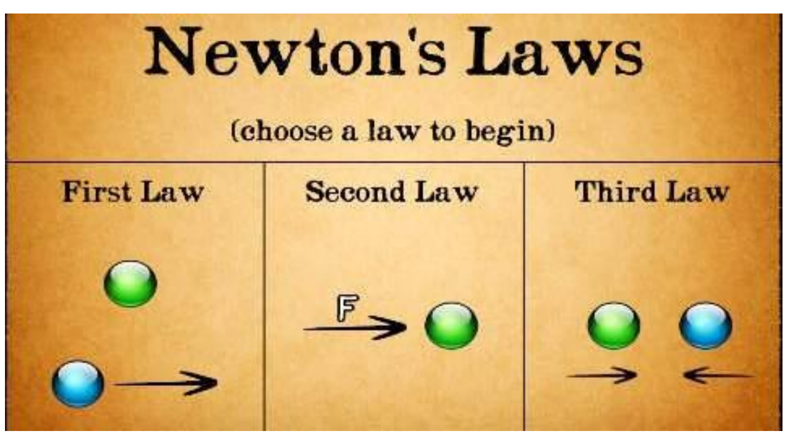
Everybody continues in a state of uniform motion unless it is compelled to change that state by a force imposed upon it.

Newton's Second law: Law of Momentum

Change in momentum is proportional to and in the direction of the force applied. Momentum equals mass x velocity. Change in momentum gives: F=ma.

Newton's Third law: Action – Reaction

For every action, there is an equal and opposite reaction. Hints at conservation of momentum



Origin of orbital mechanics

Kepler's laws:

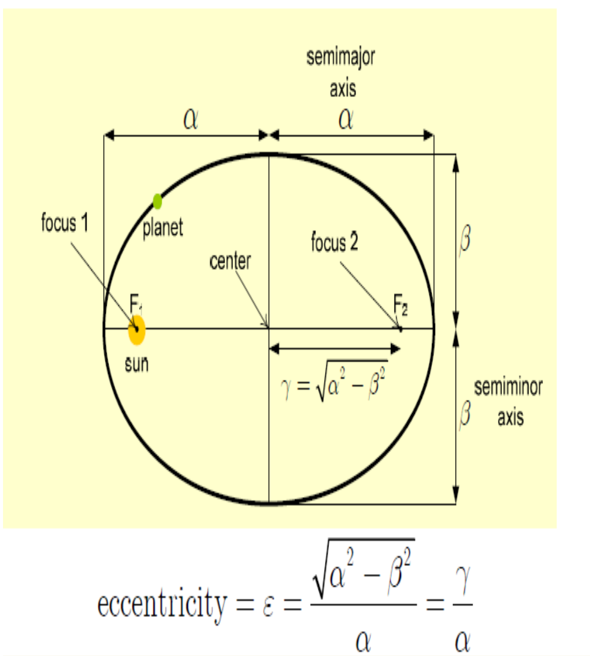
Kepler's laws apply quite generally to any two bodies in space which interact through gravitation. The more massive of the two bodies is referred to as the *primary,* the other, the *secondary* or *satellite.*

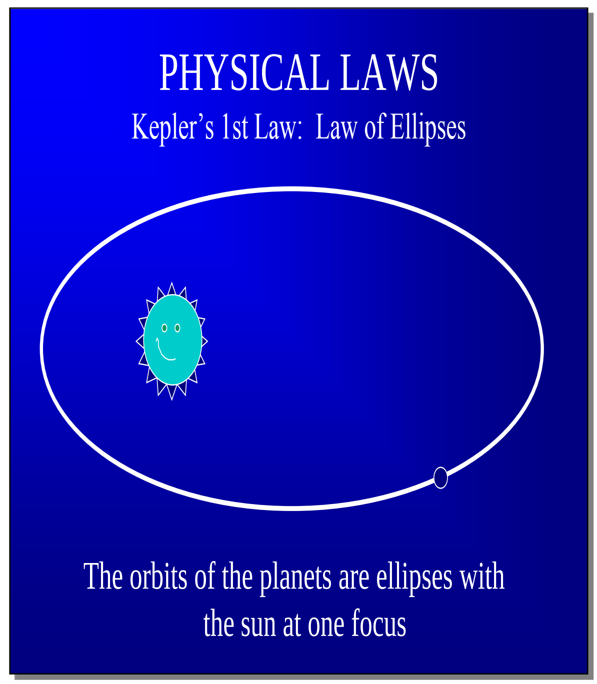
Keplers 3 (empirical) laws of Planetary Motion

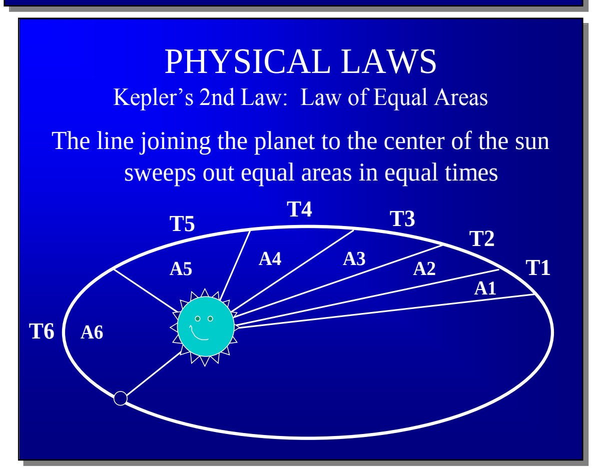
1. **Kepler's first law** states that, the path followed by a satellite around a primary is elliptical with the center of masses at one of the foci.

   (OR)

   "The orbital path of a planet takes the shape of an ellipse, with the Sun located at one of its focal points."







2. **Kepler's second law** states that, for equal time intervals, a satellite will sweep equal areas in its orbital plane.

   (OR)

   The line from the sun to a planet sweeps out equal areas in equal time intervals.

3. **Kepler's third law** states that, the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

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

Where,

T is the orbital period

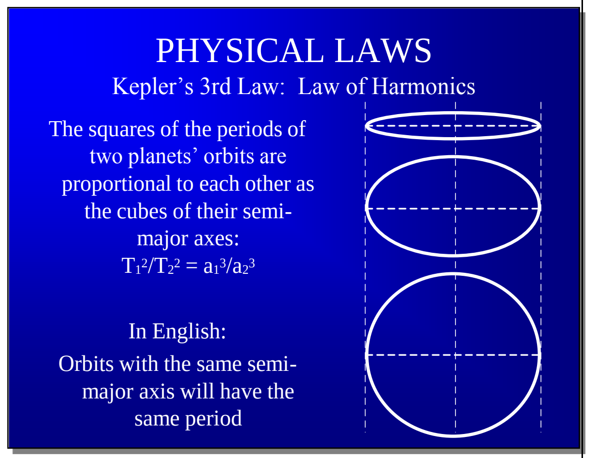
a is the semi major axis of the orbital ellipse

μ is the Kepler's constant = $3.986005*10^{14}$

(OR)

The ratio of the square of the planet's orbital period and the cube of the mean distance from the Sun is constant

$$\mathbf{(D_1/D_2)^3 = (P_1/P_2)^2}$$



Example:

Calculate the radius of a circular orbit for which the period is 1 day.

Solution There are 86,400 seconds in 1 day, and therefore the mean motion is

$$orbit\ period\ p = \frac{2\pi}{n}$$

$$\text{Mean motion of the satellite } n = \frac{2\pi}{86400}$$

$$n = 7.272 * 10^{-5} \text{ rad/s}$$

From Kepler's third law:

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

$$n = \left(\frac{\mu}{a^3}\right)^{\frac{1}{3}}$$

$$a = \left[\frac{3.986005*10^{14}}{(7.272*10^{-5})^2}\right]^{\frac{1}{3}} = 42{,}241 \text{ km}$$

Since the orbit is circular the semi major axis is also the radius.

Frequency Allocation and Regulatory Aspects

- Frequency band for satellite services are shared with terrestrial services.
- Satellite signal strength is constrained to avoid interference by it to others.
- Thus a large antenna and sensitive receiver are needed at the earth station.
- Frequency sharing techniques are important study area.
- Many satellites have to share a limited frequency band (and limited orbital arc) thus coordination in frequency and orbital location is important.
- Frequency allocations are done by international agreements.

Frequency Allocation for Satellite Communication

Band	Frequency Range	Total Bandwidth	General Applications
L	1 TO 2 GHz	1 GHz	Mobile Satellite Services (MSS)
S	2 TO 4 GHz	2 GHz	MSS, NASA, Deep Space Research
C	4 TO 8 GHz	4 GHz	Fixed Satellite Services (FSS)
X	8 TO 12.5 GHz	4.5 GHz	FSS Military, Terrestrial Explosion and Metrological Satellites
Ku	12.5 TO 18 GHz	5.5 GHz	FSS, Broadcast Satellite Services (BSS)
K	18 TO 26.5 GHz	8.5 GHz	BSS, FSS
Ka	26.5 TO 40 GHz	13.5 GHz	FSS

Regulatory Aspects:

Domestic: Example:

Federal Communication Commission (FCC)
National Telecommunication and Information Administration (NITA)
In Pakistan, PTA (Pakistan Telecommunication Authority)

International: Example: International Telecommunication Union (ITU)

- Formed in 1932 from the International Telegraph Union
- Consists of over 150 members nations

- World Administrative radio Conference (WARC)
- International Radio consultative committee (CCIR) consists of 13 group.
- World is divided into three regions:
  Region 1 – Europe, Africa, Soviet Union on Mongolia
  Region 2 – North and South America, Greenland
  Region 3 – Asia, Australia and South West Pacific

Frequency Bands Available for Satellite Communications

Band	Uplink (GHz)	Downlink (GHz)
C	6	4
Ku	14	12
Ka	30	20
X	8.2	7.5
S	40	20
Q	44	21
L	1.525 to 1.559	1.626 to 1.660

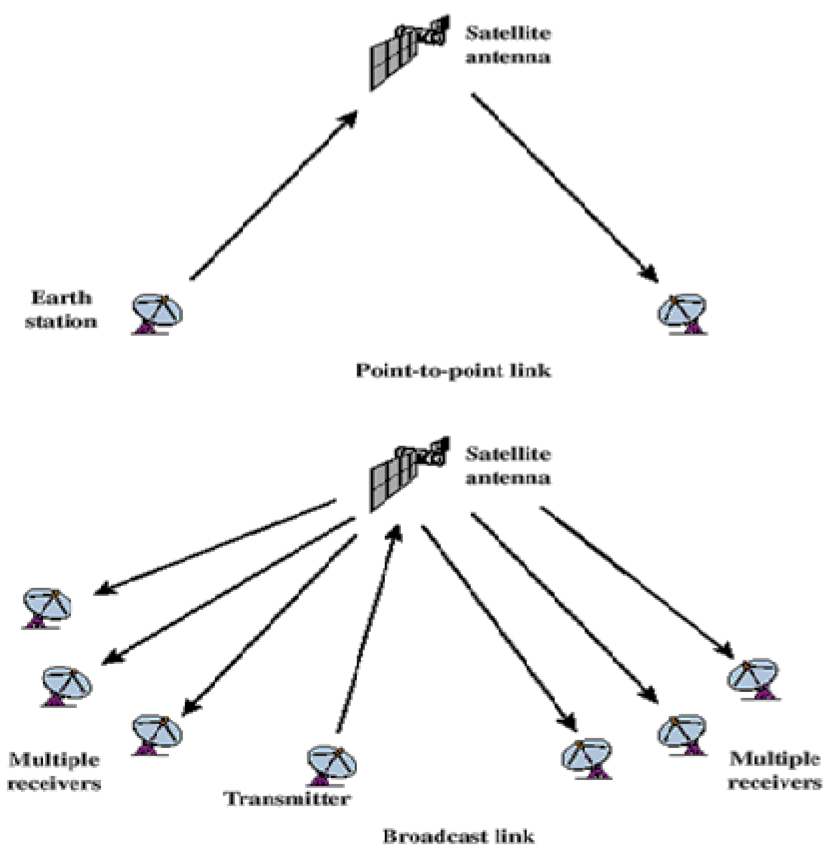
APPLICATIONS

1. Global Telecommunications : Land, Sea, Air
2. Broadcasting : Sound, TV, Multimedia, Cable TV, DTH, DTU, DBS, DVB
3. Navigation : Global Positioning System (GPS)
4. Remote Sensing – Earth Observation
5. Weather
6. Emergency Communication Services – Disasters
7. Mobile Communication Services
8. Corporate Communications – Virtual Private Network (VPN), VSAT Technology
9. Military Communications etc.,

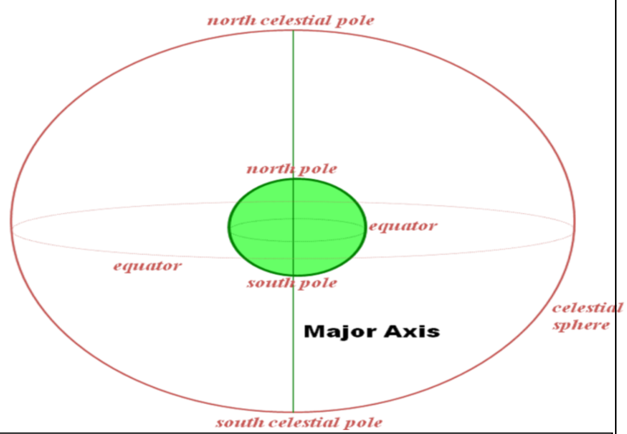
Different services of satellite systems

- **Fixed satellite services**
- **Broadcasting satellite services**
- **Mobile satellite services**
- **Navigational satellite services**
- **Meteorological satellite services.**

Satellite Communication Configurations



Satellite Orbits
An orbit is the path that a satellite follows as it revolves around Earth



Satellites orbits vary depending on:

1) Altitude 2) Inclination 3) Orbital Period

Three classes of Satellite orbits:

1) **Low Earth Orbit (LEO)**

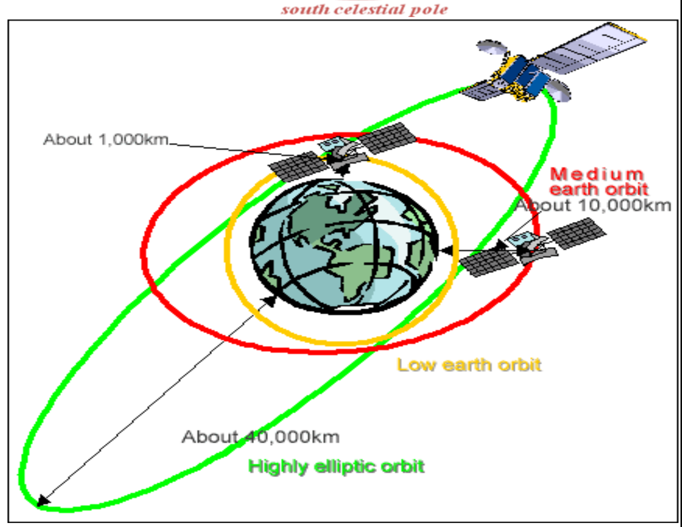
Up to 2,000km altitude
Remote sensing satellites, altimeter satellites

2) **Medium Earth Orbit (MEO)**

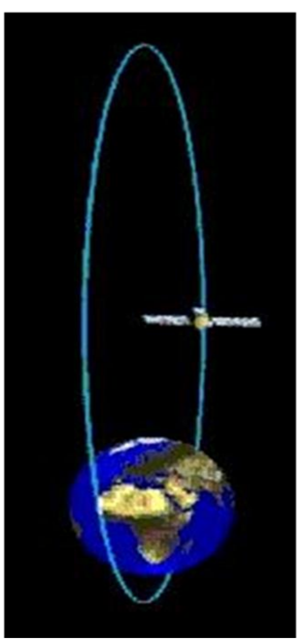
Altitudes between 5,000km – 20,000km
GPS satellites (12 hr periods – twice a day)

3) **Geostationary Earth Orbit (GEO)**

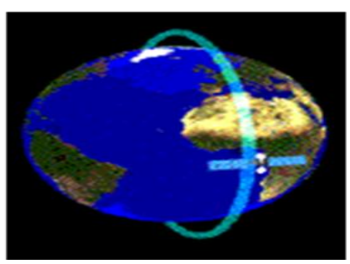
24hrs period appears fixed
Altitudes of 36,000km
Communication satellites



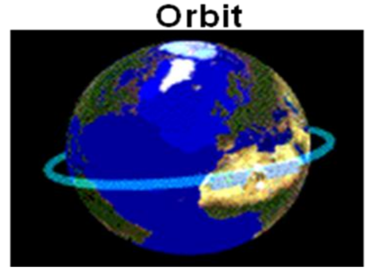
Molniya Orbit



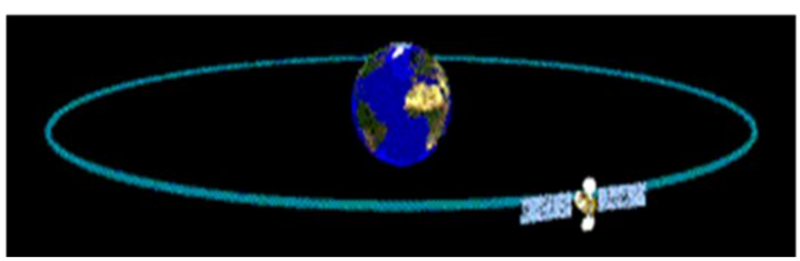
Polar Orbit



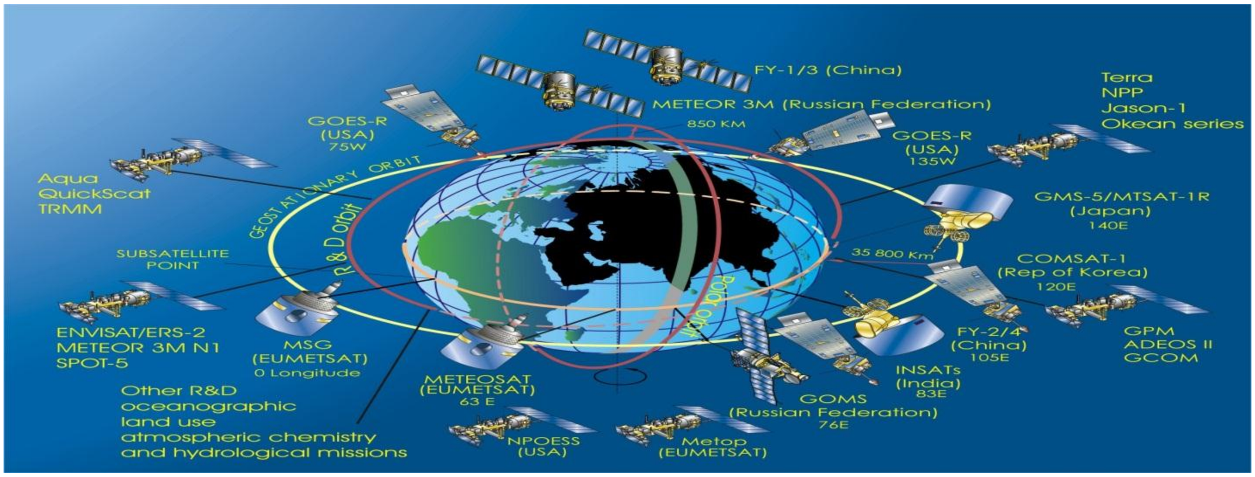
Low Earth Equatorial Orbit



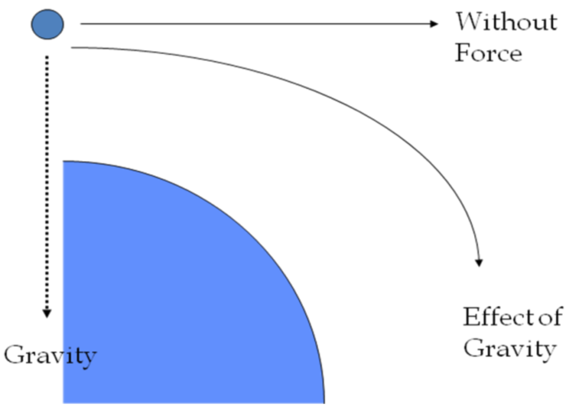
Geostationary Orbit



Motion of Space Objects



Orbital Mechanics



- 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 orbit

- The 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:

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

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 ($6.38\text{x}10^6$m).

Common Example

- "Height" of the orbit = 22,300 mile
- That is 36,000km = $3.6\text{x}10^7$m
- The radius of the orbit is $3.6\text{x}10^7$m + $6.38\text{x}10^6$m = $4.2\text{x}10^7$m

LEO Satellite Characteristics

- Circular/slightly elliptical orbit under 2000 km
- Orbit period ranges from 1.5 to 2 hours
- Diameter of coverage is about 8000 km
- Round-trip signal propagation delay less than 20 ms
- Maximum satellite visible time up to 20 min
- System must cope with large Doppler shifts
- Atmospheric drag results in orbital deterioration

MEO Satellite Characteristics

- Circular orbit at an altitude in the range of 5000 to 12,000 km
- Orbit period of 6 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 50 ms
- Maximum satellite visible time is a few hours

GEO Satellite Characteristics

- **Advantages of the GEO orbit**
  - No problem with frequency changes
  - Tracking of the satellite is simplified
  - High coverage area
- **Disadvantages of the GEO orbit**
  - Weak signal after traveling over 35,000 km
  - Polar regions are poorly served
  - Signal sending delay is substantial

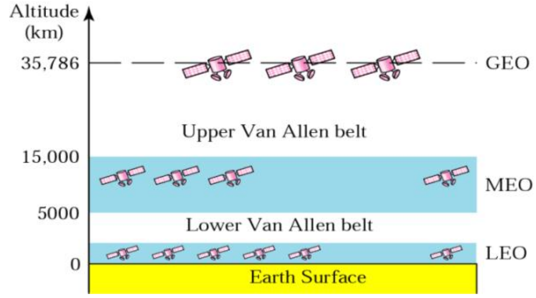
The Geosynchronous Orbit

- The answer is T = 86,000 sec (rounded)
- 86,000 sec = 1,433 min = 24hours (rounded)
- The satellite needs 1 day to complete an orbit
- Since the earth turns once per day, the satellite moves with the surface of the earth.

Comparison Chart

Features	GEO	MEO	LEO
Height (Km's)	36000	6000 - 12000	200 - 3000
Time per orbit (Hrs)	24	5 – 12	1.5
Speed (Km's / hr)	11000	19000	27000
Time Delay (ms)	250	80	10
Time in Site of Gateway	Always	2 – 4 hrs	< 15 min
Satellite for Global Coverage	3	10 – 12	50 - 70

Satellite orbit altitudes



Definitions & orbital parameters

Some of the important terms required in order to understand the orbital elements are given below:

1. **Sub Satellite Path:** This is the path traced out on the earth's surface directly below the satellite.

2. **Apogee:** The point farthest from the earth. (Apogee height -h_a)

3. **Perigee:** The point of closest approach to earth. (Perigee height -h_a)

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

5. **Ascending node:** The point where the orbit crosses the equatorial plane going from south to north.

6. **Descending node:** The point where the orbit crosses the equatorial plane going from north to south.

7. **Line of nodes:** The line joining the ascending and descending nodes through the center of the earth.

8. **Inclination**: The angle between orbital plane and the earth's equatorial plane. It is measured at the ascending node from equator to the orbit, going from east to north.

9. **Declination:** The angle of tilt is often referred to as the declination which must not be confused with the magnetic declination used in correcting compass readings.

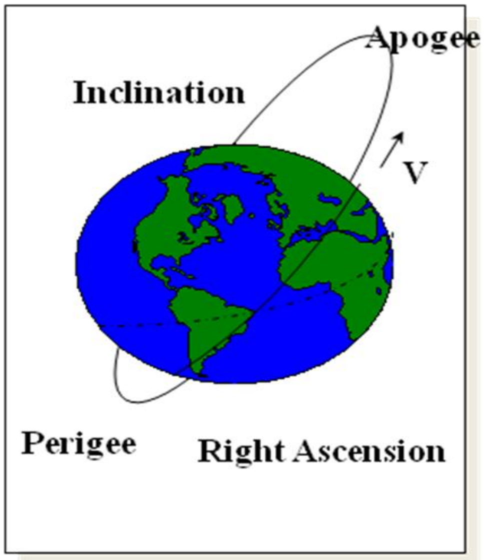
10. **Prograde orbit:** An orbit in which the satellite moves in the same direction as the earth's rotation (West to East). The prograde orbit is also known as the **direct orbit.** The inclination of a prograde orbit always lies between 0 and 90 degrees. Most satellites are launched in a prograde orbit because the earth's rotational velocity provides part of the orbital velocity with a consequent saving in launch energy.

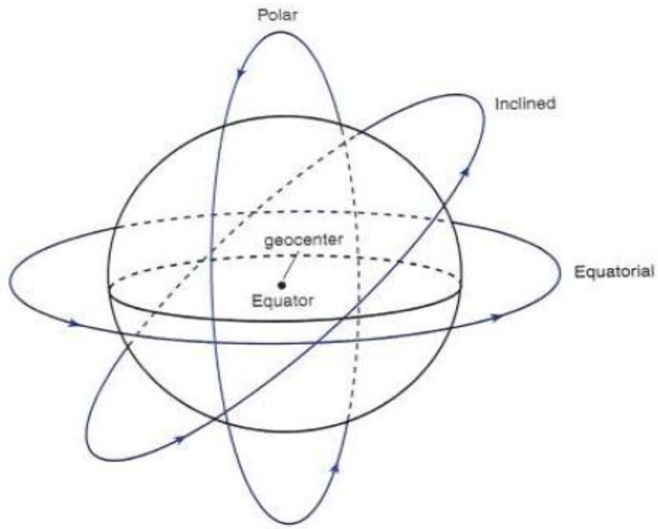
11. **Retrograde orbit:** An orbit in which the satellite moves in a direction of satellite motion.

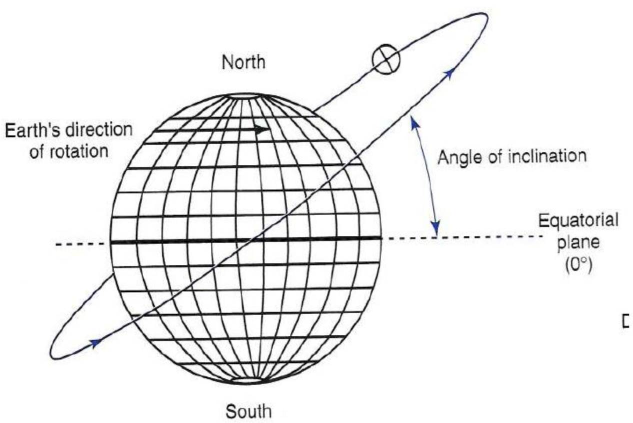
12. **Argument of perigee (w):** The angle from ascending node to perigee, measured in the orbital plane at the earth's center, in the direction of satellite motion.

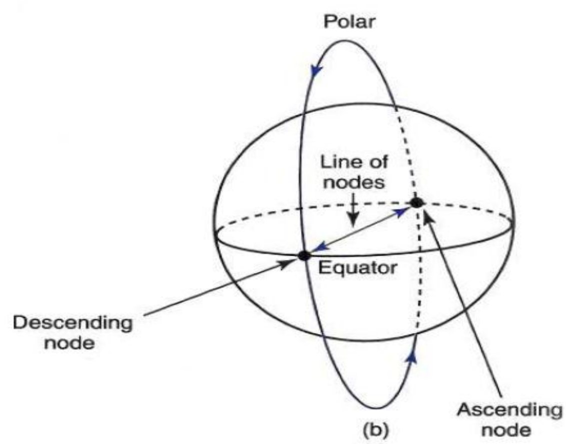
13. **Right ascension of the ascending node (Ω)** is the angle measured eastward in the equatorial plane from the line of Aries/ First point of Aries (♈) to the ascending node.

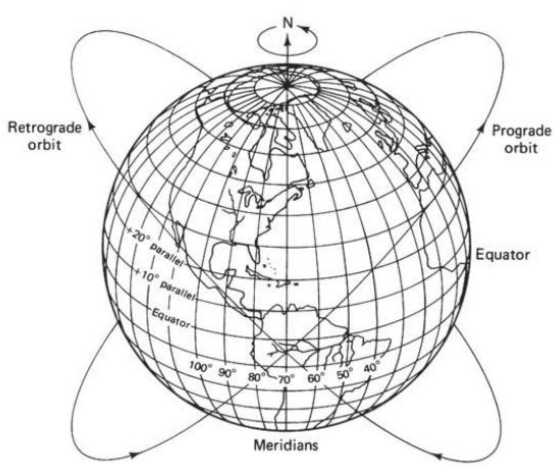
14. **Mean Anomaly** (δ_m) is an average value of the angular position of the satellite with reference to the perigee.
15. **True Anomaly** is the angle from perigee to the satellite position measured at the earth's centre.

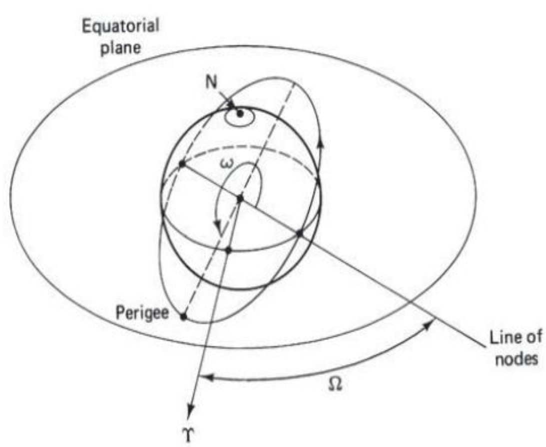

Apogee
Inclination
V
Perigee
Right Ascension


Polar
Inclined
geocenter
Equator
Equatorial


North
Earth's direction of rotation
Angle of inclination
Equatorial plane (0°)
South


Polar
Line of nodes
Equator
Descending node
Ascending node
(b)


N
Retrograde orbit
Prograde orbit
Equator
Meridians


Equatorial plane
N
ω
Perigee
Line of nodes
Ω
♈

Orbital Elements

Orbital elements are the six quantities required to determine the absolute coordinates of a satellite at time t. The orbital elements are:

1. **The semi major axis (a):** It represents half the length of the major axis of the elliptical orbit described by the satellite.

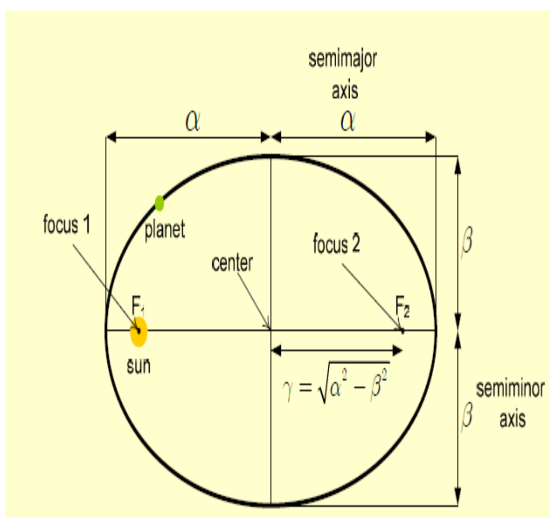
2. **The eccentricity (e):** Eccentricity of the ellipse.

3. **The mean anomaly (M):** Anomaly is the term for angle. Mean anomaly is the angle which describes the position of the satellite in its orbit relative to the perigee. At perigee, mean anomaly is zero. It increases to 180 degrees at apogee and back to perigee at 360 degrees.

4. **The argument of perigee:** It is the angle between the perigee points on the semi-major axis to the semi lotus rectum which joins the satellite to the centre of the earth.

5. **The inclination:** The angle that the orbital plane makes with the equatorial plane is called the inclination.

6. **The right ascension of the ascending node:** It is the angle between the vernal equinox line and the line of nodes measured in the equatorial plane.



$$\text{eccentricity} = \varepsilon = \frac{\sqrt{\alpha^2 - \beta^2}}{\alpha} = \frac{\gamma}{\alpha}$$

For an elliptical orbit, $0 < e < 1$. When $e = 0$, the orbit becomes circular.

Orbital Location:

The location of a geostationary satellite is referred to as its orbital location. International satellites are normally measured in terms of longitudinal degrees East (° E) from the Prime Meridian of 0°

Footprint

The geographic area of the Earth's surface over which a satellite can transmit to, or receive from, is called the satellite's "footprint."

Height of Apogee & Perigee:

The apogee & Perigee heights are often required. The length of the radius vectors at apogee and perigee can be obtained from the geometry of the eclipse.

$$r_a = a\,(1+e)$$

$$r_p = a\,(1-e)$$

Orbital perturbations

The orbit discussed so far is referred to as Keplerian orbit, is elliptical for the special case of an artificial satellite orbiting the earth. However, the Keplerian orbit is ideal in the sense that it assumes that the earth is a uniform spherical mass, and the only force acting is the centrifugal force, resulting from satellite motion balancing the gravitational pull of the earth.

In practice, other forces which can be significant are the gravitational forces of the sun and the moon, atmospheric drag and earth's oblate

The **gravitational pull of sun and moon** has negligible effect on low orbiting satellites, but they do affect satellites in the geo stationary orbit.

Atmospheric drag, on the other hand has negligible effect on geostationary satellites, but does affect low orbiting satellites below 1000 k.m.

Effect of a Non Spherical Earth

For a spherical earth of uniform mass, kepler's third law gives the nominal n_o as,

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

$$n_o = \sqrt{\frac{\mu}{a^3}}$$

The 'o' subscript is included to show for perfectly spherical earth of uniform mass.

However, earth is not perfectly spherical (**Oblate Spheroid**) taken into account and mean motion n is modified as,

$$n = n_o\left[1 + \frac{k_1(1 - 1.5\sin^2 i)}{a^2(1-e^2)^{1.5}}\right]$$

k1 is constant – 66,063.1704 km^2. The earth's oblateness has negligible effect on 'a' if a is known. The mean motion is readily calculated. The orbital period taking into account the earth's oblateness is **anamalistic period** (Perigee to Perigee)

The anamalistic period is,

$$p_A = \frac{2\pi}{n}$$

n – is radians/sec. If n is known quantity we can solve for

$$n - \sqrt{\frac{\mu}{a^3}}\left[1 + \frac{k_1(1 - 1.5\sin^2 i)}{a^2(1-e^2)^{1.5}}\right] = 0$$

The **oblateness of earth also produces two rotations** of the orbital plane is known as regression of nodes, is where the nodes appear to slide along the equator.

In effect, the line of nodes, which is in the equatorial plane, rotates about the center of the earth. Thus ʾΩ, the right ascension of the ascending node shifts its position.

If the orbit is prograde, the nodes slide westward, and if retrograde, they slide eastward. As seen from the ascending node, a satellite in prograde orbit moves eastward, and in a retrograde orbit, westward. **The nodes therefore move in a direction opposite to the direction of satellite motion, hence the term *regression of the nodes.***

The second effect is **rotation of apsides in the orbital plane**, described below. Both effects depend on the mean motion *n*, the semi major axis *a*, and the eccentricity *e*. These factors can be grouped into one factor *K* given by

$$k = \frac{nK_1}{a^2(1-e^2)^2}$$

K will have the same units as *n*. Thus, with *n* in rad/day, *K* will be in rad/day, and with *n* in degrees/day, *K* will be in degrees/day.

An approximate expression for the rate of change of _ with respect to time is

$$\frac{d'\Omega}{dt} = -k\cos i$$

Where *i* is the inclination. The rate of regression of the nodes will have the same units as *n*.

When the rate of change given by above Equation is negative, the regression is westward, and when the rate is positive, the regression is eastward. It will be seen, therefore that for eastward regression, *i* must be greater than 90^o, or the orbit must be retrograde. It is possible to choose values of *a*, *e*, and *i* such that the rate of rotation is 0.9856°/day eastward.

The other major effect produced by the equatorial bulge is a rotation of the line of apsides. This line rotates in the orbital plane, resulting in the argument of perigee changing with time. The rate of change is given by

$$\frac{d\omega}{dt} = k(2 - 2.5\sin^2 i)$$

Again, the units for the rate of rotation of the line of apsides will be the same as those for *n* (incorporated in *K*). When the inclination *i* is equal to 63.435°, the term within the parentheses is equal to zero, and hence no rotation takes place. Use is made of this fact in the orbit chosen for the Russian Molniya satellites

Denoting the epoch time by t_0, the right ascension of the ascending node by Ω_0, and the argument of perigee by w_0 at epoch gives the new values for Ω and *w* at time *t* as

$$\Omega = \Omega_0 + \frac{d\Omega}{dt}\,(t - t_0)$$

$$\omega = \omega_0 + \frac{d\omega}{dt}\,(t - t_0)$$

Keep in mind that the orbit is not a physical entity, and it is the forces resulting from an oblate earth, which act on the satellite to produce the changes in the orbital parameters. Thus, rather than follow a closed elliptical path in a fixed plane, the satellite drifts as a result of the regression of the nodes, and the latitude of the point of closest approach (the perigee) changes as a result of the rotation of the line of apsides.

With this in mind, it is permissible to visualize the satellite as following a closed elliptical orbit but with the orbit itself moving relative to the earth as a result of the changes in Ω and *w*. Thus, as stated earlier, the period *PA* is the time required to go around the orbital path from perigee to perigee, even though the perigee has moved relative to the earth.

***Equatorial Ellipticity*:** In addition to the equatorial bulge, the earth is not perfectly circular in the equatorial plane; it has a small eccentricity of the order of 10^{-5}. This is referred to as the *equatorial ellipticity*. The effect of the equatorial In addition to the equatorial bulge, the earth is not perfectly circular ellipticity is to set up a gravity gradient, which has a pronounced effect on satellites in geostationary orbit. Very briefly, a satellite in geostationary orbit ideally should remain fixed relative to the earth. The gravity gradient resulting from the equatorial Ellipticity causes the satellites in geostationary orbit to drift to one of two stable points, which coincide with the minor axis of the equatorial ellipse. These two points are separated by 180°on the equator and are at approximately **75° E** longitude and **105°W** longitude. Satellites in service are prevented from drifting to these points through station-keeping maneuvers. Because old, out-of-service satellites eventually do drift to these points, they are referred to as "**satellite graveyards**." It may be noted that the effect of equatorial ellipticity is negligible on most other satellite orbits.

Atmospheric drag: For near-earth satellites, **below about 1000 km**, the effects of atmospheric drag are significant. Because the drag is greatest at the perigee, the drag acts to reduce the velocity at this point, with the result that the satellite does not reach the same apogee height on successive revolutions. The result is that the semi major axis and the eccentricity are both reduced. Drag does not noticeably change the other orbital parameters, including perigee height. An approximate expression for the change of major axis is

$$a \cong a_0 \left[\frac{n_0}{n_0 + n'_0(t - t_0)}\right]^{\frac{2}{3}}$$

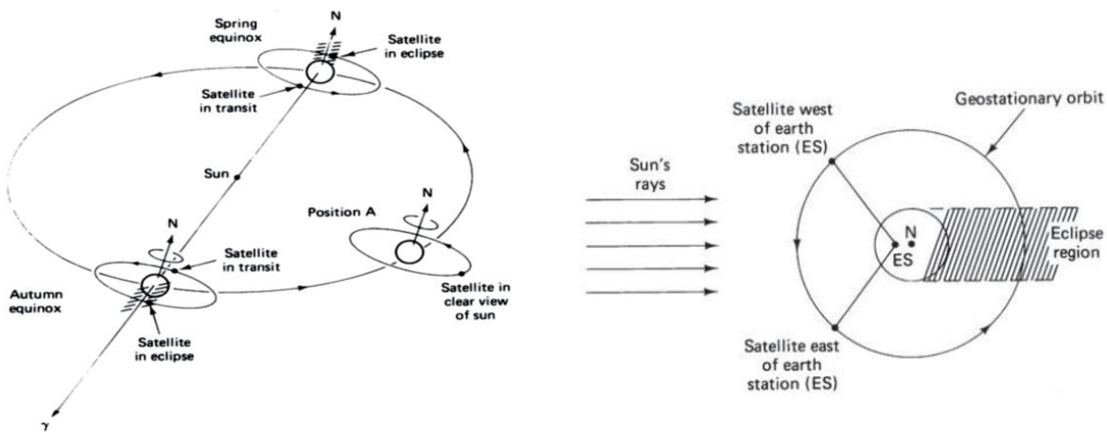
Where the "0" subscripts denote values at the reference time t_0, and n_0 is the first derivative of the mean motion. The mean anomaly is also changed, an approximate value for the change being:

$$\delta M = \frac{n'_0}{2}\,(t - t_0)^2$$

Earth Eclipse of Satellite

If the earth's equatorial plane coincided with the plane of the earth's orbit around the sun (the ecliptic plane), geostationary satellites would be eclipsed by the earth once each day. As it is, the equatorial plane is tilted at an angle of 23.4° to the ecliptic plane, and this keeps the satellite in full view of the sun for most days of the year, as illustrated by position *A* in Figure.

Around the spring and autumnal equinoxes, when the sun is crossing the equator, the satellite does pass into the earth's shadow at certain periods, these being periods of eclipse as illustrated in Figure. The spring equinox is the first day of spring, and the autumnal equinox is the first day of autumn.



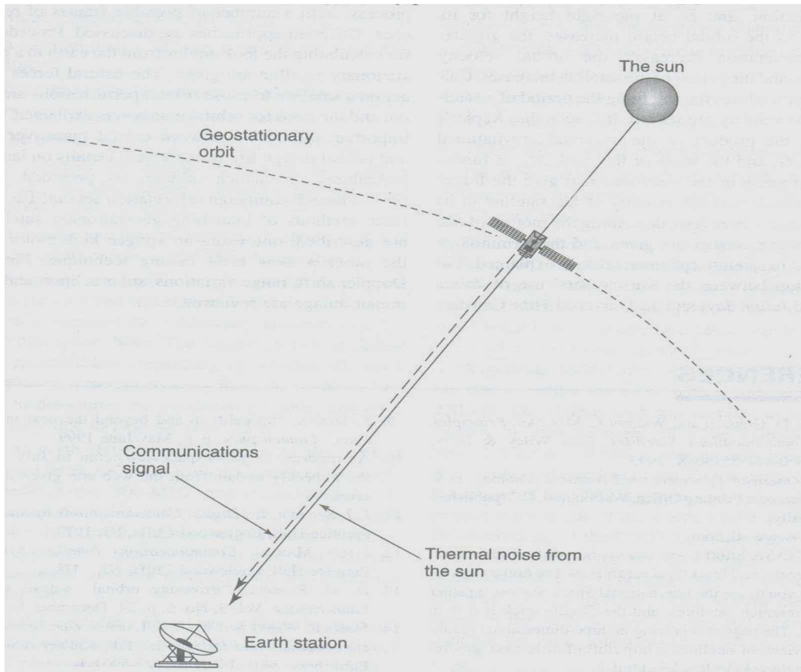
Eclipses begin 23 days before equinox and end 23 days after equinox. The eclipse lasts about 10 min at the beginning and end of the eclipse period and increases to a maximum duration of about 72 min at full eclipse (Spilker, 1977).

During an eclipse, the solar cells do not function, and operating power must be supplied from batteries. Where the satellite longitude is east of the earth station, the satellite enters eclipse during daylight (and early evening) hours for the earth station, as illustrated in Fig. This can be undesirable if the satellite has to operate on reduced battery power.

Where the satellite longitude is west of the earth station, eclipse does not occur until the earth station is in darkness, (or early morning) when usage is likely to be low. Thus satellite longitudes which are west, rather than east, of the earth station are more desirable.

Sun transit outage

During the equinox periods, the orbit of the satellite will also pass directly in front of the sun on the sunlit side of the earth. The sun is a hot microwave source with an equivalent temperature of about 6000 to 10000 K, depending on the time within the 11- year sunspot cycle, at the frequencies used by the communication satellites (4 to 50 GHz). The earth station will therefore receive not only the signal from the satellite but also the noise temperature transmitted by the sun. The added noise temperature will cause the fade margin of the receiver to be exceeded and an outage will occur. This is termed as Sun transit outage.



Sun transits occur when the sun crosses the earth's equatorial plane during the spring and fall equinoxes (late February or early March; September or October). At these times, the sun aligns directly behind the satellites for a few minutes each day. When the sun moves directly behind the satellite to your receive antenna, the satellite signal can be overwhelmed by the enormous amount of thermally generated radio frequency (RF) noise radiated by the sun. This can cause reception interference for a few minutes every day during this occurrence.

The time of occurrence depends both on the geographic location of the earth station and the location of the satellite. The sun may degrade the signal for several minutes depending on the antenna size and available link margin, although it is not unusual for the effect to go unnoticed.

The number of outages, outage duration and the time of outage depend on the radio emission activity of the sun, the movement of the earth with respect to the sun, the pointing and location of receive antenna, and characteristics of the communication system. Those characteristics, in turn, include the operating receive radio frequency, the receive antenna gain pattern, the clear sky operating carrier-to-noise ratio (C/N), the clear sky equivalent system noise temperature and the minimum acceptable C/N.

When the sun transits occur, the antenna noise temperature varies depending on the antenna size, the elevation angle, location and environment.

Computer generated predictions revealed that sun transits peak times of all days associated with an equinox for a given receive earth station do not differ from each other by more than a minute, and they do not vary much with respect to the year considered. The variations are less than one minute for at least the next decade. Thus for practical purposes, they can be considered the same and invariant with respect to the year they are considered.

Antenna Look Angles

The *look angles* for the ground station antenna are the azimuth and elevation angles required at the antenna so that it points directly at the satellite. The look angles were determined in the general case of an elliptical orbit, and there the angles had to change in order to track the satellite. With the geostationary orbit, the situation is much simpler because the satellite is stationary with respect to the earth. Although in general no tracking should be necessary, with the large earth stations used for commercial communications, the antenna beamwidth is very narrow, and a tracking mechanism is required

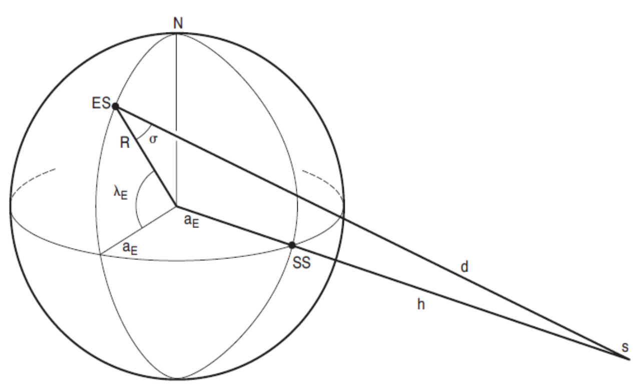
To compensate for the movement of the satellite about the nominal geostationary position. With the types of antennas used for home reception, the antenna beamwidth is quite broad, and no tracking is necessary. This allows the antenna to be fixed in position, as evidenced by the small antennas used for reception of satellite TV that can be seen fixed to the sides of homes.

The three pieces of information that are needed to determine the look angles for the geostationary orbit are

1. The earth-station latitude, denoted here by λ_E
2. The earth-station longitude, denoted here by Φ_E
3. The longitude of the subsatellite point, denoted here by Φ_{SS} (often this is just referred to as the satellite longitude)

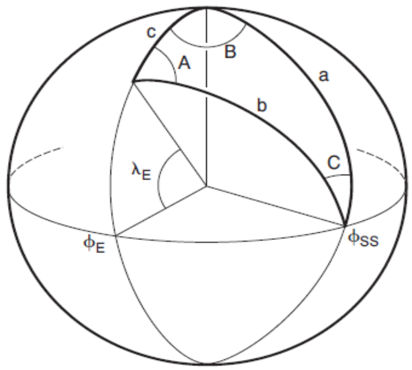
Latitudes north will be taken as positive angles, and latitudes south, as negative angles. Longitudes east of the Greenwich meridian will be taken as positive angles, and longitudes west, as negative angles. For example, if latitude of 40° S is specified, this will be taken as - 40°, and if a longitude of 35° W is specified, this will be taken as -35°.

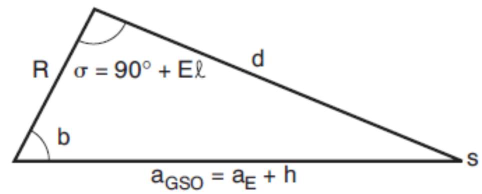
When calculating the look angles for *low-earth-orbit* (LEO) satellites, it was necessary to take into account the variation in earth's radius. With the geostationary orbit, this variation has negligible effect on the look angles, and the average radius of the earth will be used. Denoting this by *R*: *R* = 6371 km



The geometry involving these quantities is shown in above Figure. Here, ES denotes the position of the earth station, SS the sub satellite point, *S* the satellite, and *d* is the range from the earth station to the satellite. The angle *is* an angle to be determined.

There are two types of triangles involved in the geometry of above Figure, the spherical triangle and the plane triangle shown in heavy outline in below Figures.





Considering first the spherical triangle, the sides are all arcs of great circles, and these sides are defined by the angles subtended by them at the center of the earth. **Side *a*** is the angle between the radius to the North Pole and the radius to the subsatellite point, and it is seen that $a = 90°$. A spherical triangle in which one side is 90° is called a ***quadrantal triangle***. **Angle *b*** is the angle between the radius to the earth station and the radius to the subsatellite point. **Angle *c*** is the angle between the radius to the earth station and the radius to the north pole. From above Figure it is seen that $c = 90° - \lambda_E$.

There are six angles in all defining the spherical triangle. The three angles *A*, *B*, and *C* are the angles between the planes. **Angle *A*** is the angle between the plane containing *c* and the plane containing *b*. **Angle *B*** is the angle between the plane containing *c* and the plane containing *a*. From above figure $B = \Phi_E - \Phi_{SS}$. It will be shown shortly that the maximum value of *B* is 81.3°. **Angle *C*** is the angle between the plane containing *b* and the plane containing *a*. To summarize to this point, the information known about the spherical triangle is

$$\mathbf{a = 90°,\ c = 90° - \lambda_E}\ \textit{\textbf{and}}\ \mathbf{B = \Phi_E - \Phi_{SS}}$$

Note that when the earth station is west of the subsatellite point, *B* is negative, and when east, *B* is positive. When the earth-station latitude is north, *c* is less than 90°, and when south, *c* is greater than 90°. Special rules, known as ***Napier's rules***, are used to solve the spherical triangle, and these have been modified here to take into account the signed angles *B* and λ_E. Only the result will be stated here. Napier's rules gives angle *b* as

$$b = \arccos(\cos \boldsymbol{B} \cos \lambda_E)$$

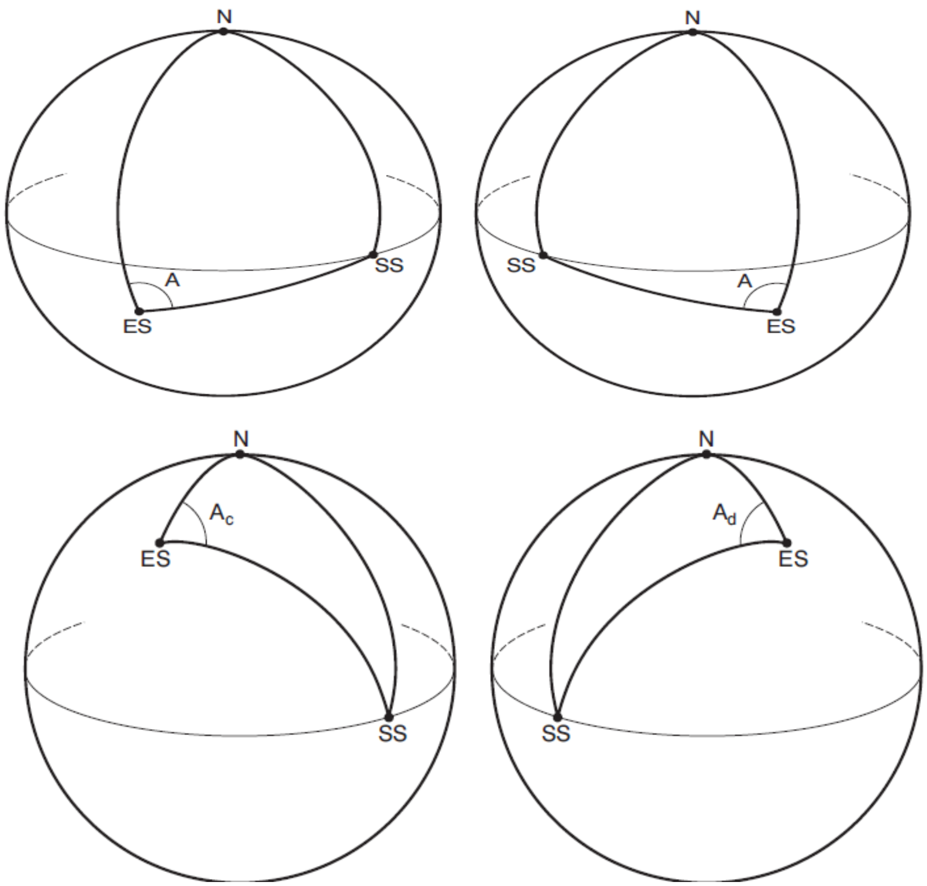
and angle *A* as

$$A = \arcsin\left(\frac{\sin|B|}{\sin b}\right)$$

Two values will satisfy the above Equation, *A* and 180°- *A*, and these must be determined by inspection. These are shown in below figures. Angle *A* is acute (less than 90°), and the azimuth angle is $Az = A$.

In second Figure, angle *A* is acute, and the azimuth is, by inspection, $Az = 360° - A$. In Third Figure, angle *Ac* is obtuse and is given by $Ac = 180° - A$, where *A* is the acute value obtained from angle A Equation. Again, by inspection, $Az = Ac - 180° - A$.

In Figure Four, angle *Ad* is obtuse and is given by 180°- *A*, where *A* is the acute value obtained from angle A Equation. By inspection, *Az* = 360° - *Ad* = 180° + *A*.



In all cases, *A* is the acute angle returned by angle A Equation. These conditions are summarized in below Table.

Angle	λ_E	B	A_z, Degrees
a	< 0	< 0	A
b	< 0	> 0	360° - A
c	> 0	< 0	180° - A
d	> 0	> 0	180° + A

Applying the cosine rule for plane triangles to the triangle Figure allows the **range *d*** to be found to a close approximation:

$$d = \sqrt{R^2 + a^2{}_{GSO} - 2Ra_{GSO}\cos b}$$

Applying the sine rule for plane triangles to the triangle Figure allows the **angle of elevation** to be found:

$$El = \arccos\left(\frac{a_{GSO}}{d}\sin b\right)$$

Example Problem:

A geostationary satellite is located at 90°W. Calculate the azimuth angle for an earth station antenna at latitude 35°N and longitude 100°W. And also find the range and antenna elevation angle.

Solution the given quantities are

Φ_{SS} = - 90° (West) **,** λ_E = 35° (North), Φ_E = - 100° (West)

$$B = \Phi_E - \Phi_{SS} = -100 + 90 = -10°$$

angle *b* as

$$b = \arccos(\cos \boldsymbol{B} \cos \lambda_E) = 36.23°$$

and angle *A* as

$$A = \arcsin\left(\frac{\sin|B|}{\sin b}\right) = 17.1°$$

azimuth is, by inspection, $\lambda_E > 0$ *and* $B < 0$, *therefore*

$$Az = 180° - A = 162.9°$$

range *d*

$$d = \sqrt{R^2 + a^2{}_{GSO} - 2Ra_{GSO} \cos b}$$

R- Earth radius = 6371 or 6378

$a_{GSO} - GEO\ Stationary\ Radius = 42164$

d = 37215 km

Angle of elevation

$$El = \arccos\left(\frac{a_{GSO}}{d} \sin b\right) = 48°$$

The Polar Mount Antenna

Where the home antenna has to be steerable, expense usually precludes the use of separate azimuth and elevation actuators. Instead, a single actuator is used which moves the antenna in a circular arc. This is known as a *polar mount antenna.*

$$\textit{Angle of tilt: } \delta = 90° - \mathrm{El}_0 - \lambda_E \textit{ and } b = \lambda_E$$

$$El = \arccos\left(\frac{a_{GSO}}{d} \sin \lambda_E\right)$$

Example:

Determine the angle of tilt required for a polar mount used with an earth station at latitude 49° north. Assume a spherical earth of mean radius 6371 km, and ignore earth-station altitude

range *d*

$$d = \sqrt{R^2 + a^2{}_{GSO} - 2Ra_{GSO}\cos b} = 38287 \text{ km}$$

Angle of elevation

$$El = \arccos\left(\frac{a_{GSO}}{d}\sin\lambda_E\right) = 33.8°$$

Angle of tilt:

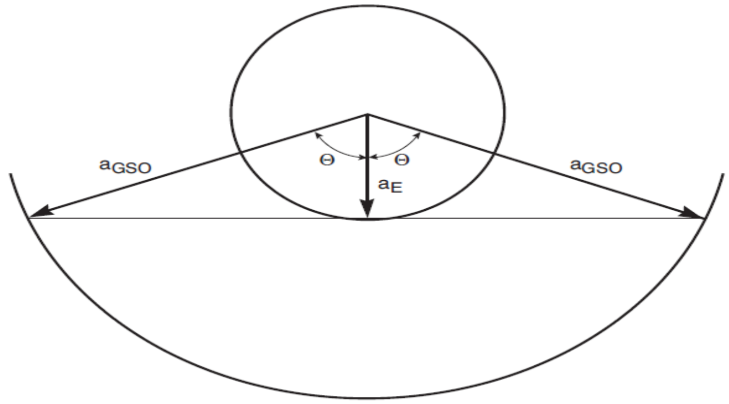
$$\delta = 90° - \text{El}_0 - \lambda_E = 7°$$

Limits of Visibility

There will be east and west limits on the geostationary arc visible from any given earth station. **The limits will be set by the geographic coordinates of the earth station and the antenna elevation.** The lowest elevation in theory is zero, when the antenna is pointing along the horizontal. A quick estimate of the longitudinal limits can be made by considering an earth station at the equator, with the antenna pointing either west or east along the horizontal, as shown in Figure. The limiting angle is given by

$$\theta = \arccos\frac{a_E}{a_{GSO}}$$

$$\theta = \arccos\frac{6378}{42164} = 81.3°$$



Thus, for this situation, an earth station could see satellites over a geostationary arc bounded by $\pm$ 81.3° about the earth-station longitude.

In practice, to avoid reception of excessive noise from the earth, some finite minimum value of elevation is used, which will be denoted here by El_{min}. A typical value is 5°. The limits of visibility will also depend on the earth-station latitude. As in Figure, let S represent the angle **subtended** at the satellite when the angle $\boldsymbol{\sigma_{min} = 90° - El_{min}}$. Applying the sine rule gives

$$S = \arcsin\left(\frac{R}{a_{GSO}} \sin \sigma_{\min}\right)$$

A sufficiently accurate estimate is obtained by assuming a spherical earth of mean radius 6371 km as was done previously. Once angle S is known, angle b is found from

$$b = 180 - \sigma_{\min} - S$$

$$B = \arccos\left(\frac{\cos b}{\cos \lambda_E}\right)$$

Example:

Determine the limits of visibility for an earth station situated at mean sea level, at latitude 48.42° north, and longitude 89.26 degrees west. Assume a minimum angle of elevation of 5°.

Given Data:

$$\lambda_E = 48.42°, \Phi E = -89.26°, El\min = 5°$$

R- Earth radius = 6371 or 6378
$a_{GSO} - GEO\ Stationary\ Radius = 42164$

$$\sigma_{min} = 90° - El_{min} = 95°$$

$$S = \arcsin\left(\frac{R}{a_{GSO}} \sin \sigma_{\min}\right) = 8.66°$$

$$b = 180 - \sigma_{\min} - S = 76.34°$$

$$B = \arccos\left(\frac{\cos b}{\cos \lambda_E}\right) = 69.15°$$

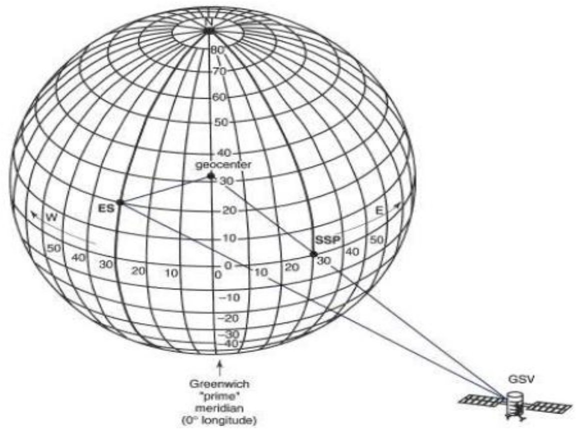
The satellite limit east of the earth station is at

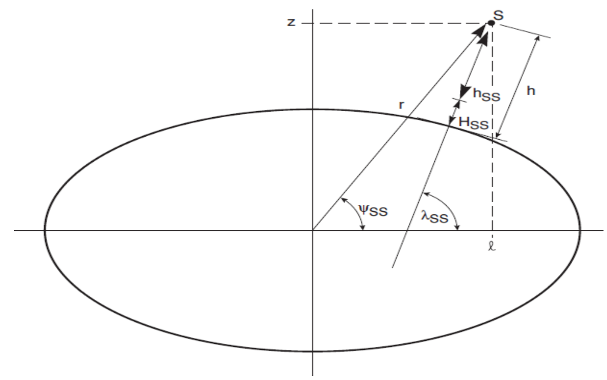
$$\Phi E + B \approx -20°$$

and west of the earth station at

$$\Phi E - B \approx -158°$$

Sub Satellite Point





The point on the earth vertically under the satellite is referred to as the *subsatellite point.* The latitude and longitude of the subsatellite point and the height of the satellite above the subsatellite point can be determined from knowledge of the radius vector **r**. The above Figure shows the meridian plane which cuts the subsatellite point. The height of the terrain above the reference ellipsoid at the subsatellite point is denoted by HSS, and the height of the satellite above this, by hSS. Thus the total height of the satellite above the reference ellipsoid is

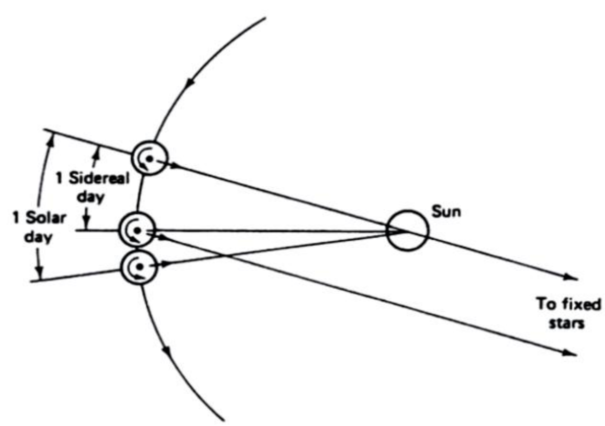
$$h = H_{ss} + h_{ss}$$

Sidereal Time:

1. Sidereal time is the time measured relative to the fixed stars.
2. Sidereal day is defined as one complete rotation of the earth relative to the fixed star.

1 mean solar day = 1.0027379093 mean sidereal days
= 24 ^{h} 3^{m} 56^{s} .55536 sidereal time
= 86,636.55536 mean sidereal seconds.

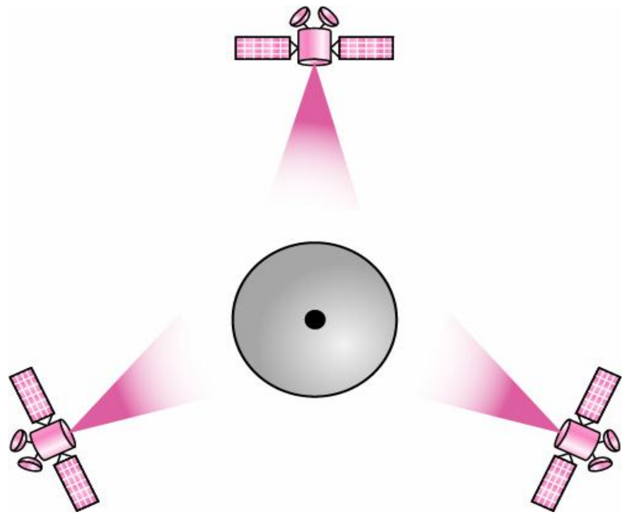
1 mean sidereal day = 0.9972695664 mean solar days
= 23^{h} 56 ^{m} 04^{s} .09054 mean solar time
= 86,164.09054 mean solar seconds.



Geostationary Orbit

1. A satellite in a geostationary orbit appears to be stationary with respect to the earth.
2. Three conditions are required for an orbit to be stationary.
    - The satellite must travel eastward at the same rotational speed as the earth.
    - The orbit must be circular.
    - The inclination of the orbit must be 0.
3. The radius of the geostationary orbit=42164km.

Satellites in geosynchronous orbit



Uses of Geostationary Orbits

Geostationary orbits are primarily used for two functions:

- Weather monitoring
- Telecommunications & Broadcasting
    - Commercial growth is focused on:
        - DTH TV (Direct To Home: Sky TV)
        - Phone, Fax, Video, Data services
        - Mobile Communications
        - VSAT & USAT
        - Digital Radio

How to File for a Geo Position

- Only Allocated to National Governments
- Go to National Government
    - Request Orbital Position (s)
        - US Companies (Non Governmental Entities) work through FCC
        - UK through UK Radiocommunications Agency
- Prepare ITU Paperwork
- File & Coordinate
    - First Come, First Served = Priority!

Characteristics of Geostationary (GEO) Orbit Systems

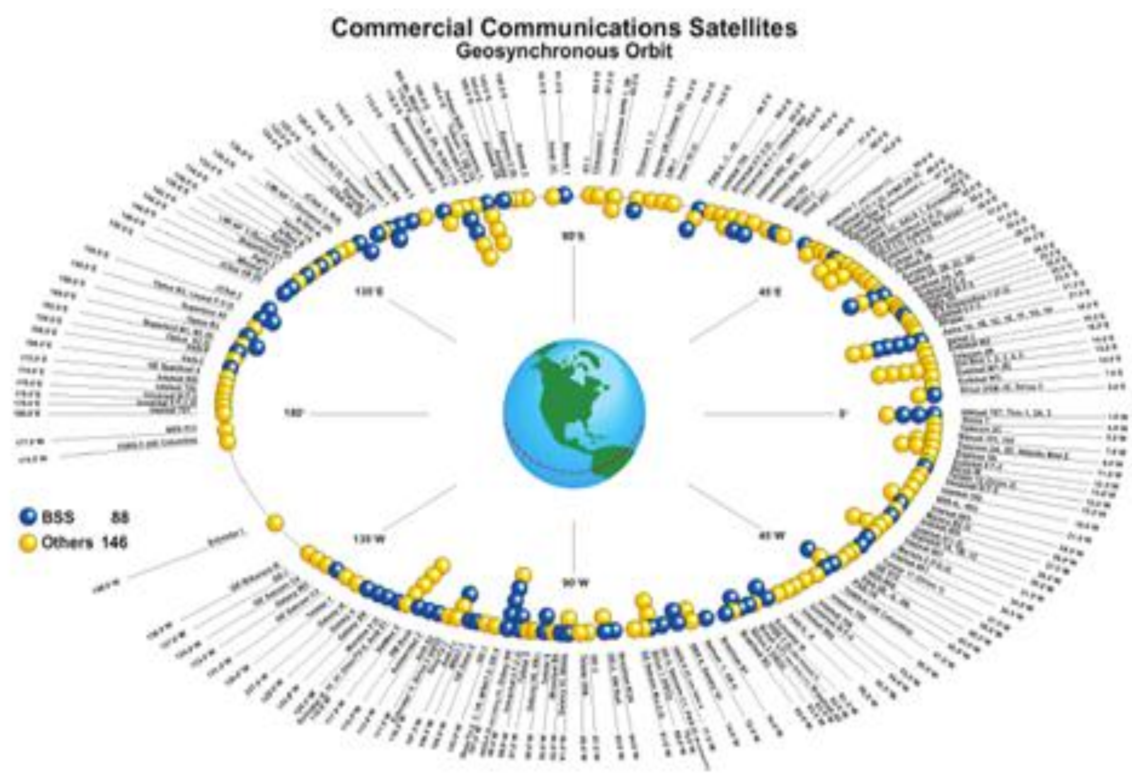
- User terminals do not have to track the satellite
- Only a few satellites can provide global coverage
- Maximum life-time (15 years or more)
- Above Van Allen Belt Radiation
- Often the lowest cost system and simplest in terms of tracking and high speed switching

Features	GEO
Height (Km's)	36000
Time per orbit (Hrs)	24
Speed (Km's / hr)	11000
Time Delay (ms)	250
Time in Site of Gateway	Always
Satellite for Global Coverage	3

Challenges of Geostationary (GEO) Orbit

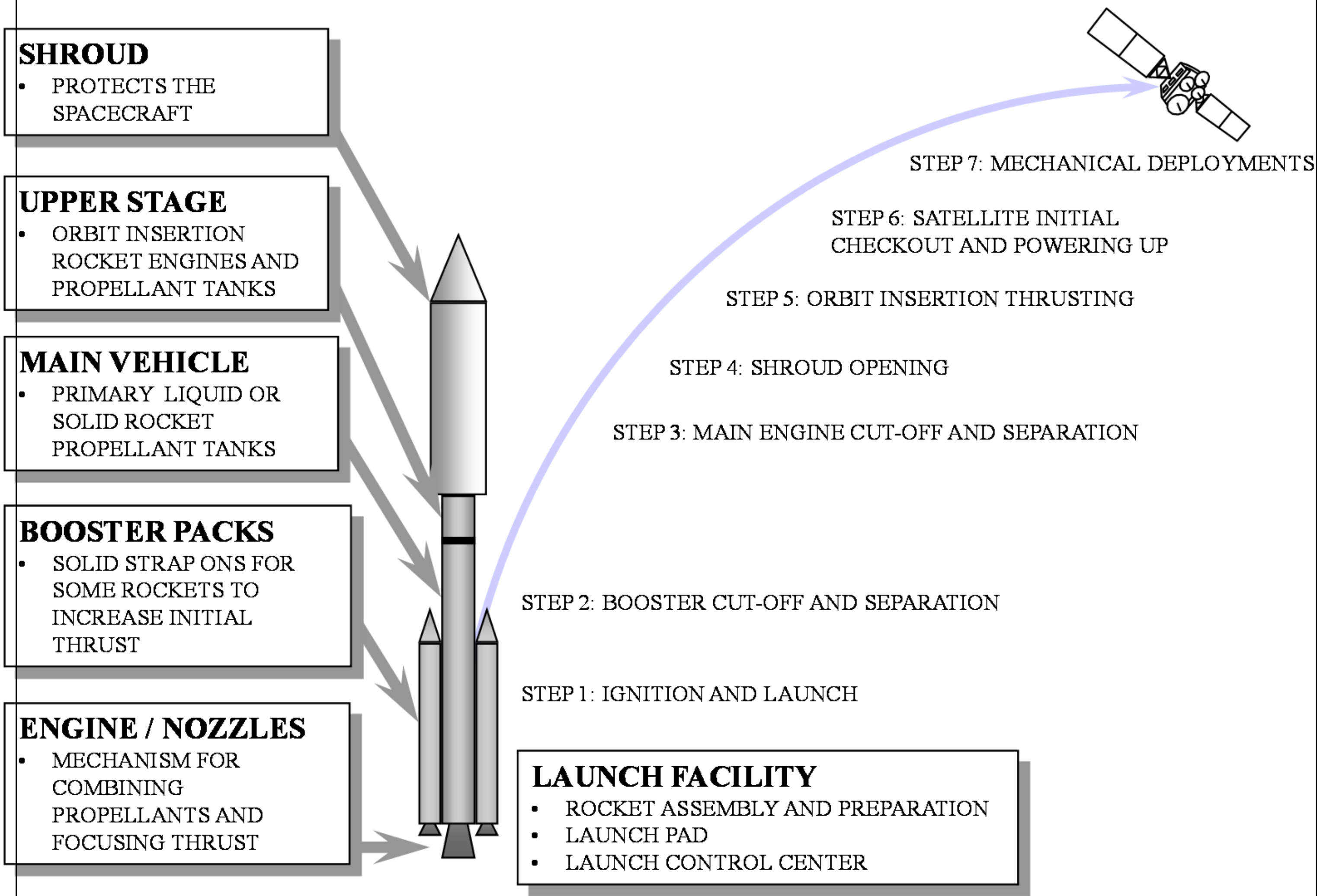
- Transmission latency or delay of 250 millisecond to complete up/down link
- Satellite antennas must be of larger aperture size to concentrate power and to create narrower beams for frequency reuse
- Poor look angle elevations at higher latitudes

Geostationary Orbit Today



LAUNCH SYSTEM CONCEPTS

Satellites may be *directly injected* into low-altitude orbits, up to about 200 km altitude, from a



launch vehicle. Launch vehicles may be classified as *expendable* or *reusable*.

In addition shuttle was designed with the capability to retrieve satellite in low orbit. The shuttle consists of a reusable orbiter which injects satellites to a LEO and re-enters the atmosphere, landing as an aircraft. The orbitter itself is launched vertically with the help of two recoverable solid rocket boosters. An expendable liquid hydrogen/ liquid oxygen tank furnishes propellant to the three main engines. This tank is the only part of the shuttle that is not reused.

The shuttle can only launch satellite in LEO and therefore additional propulsion is necessary to inject a satellite into the GEO. The heavy lift capability of the shuttle is effectively used for carrying shuttle upper stages for the extra propulsion. Various types of upper stage have been developed. These may be categorized as perigee stages and Integrated stages.

Typical of the expendable launchers are the U.S. Atlas-Centaur and Delta rockets and the European Space Agency Ariane rocket. Japan, China, and Russia all have their own expendable launch vehicles, and one may expect to see competition for commercial launches among the countries which have these facilities. Until the tragic mishap with the Space Shuttle in 1986, this was to be the primary transportation system for the United States. As a reusable launch vehicle, the shuttle, also referred to as the *Space Transportation System* (STS), was planned to eventually replace expendable launch vehicles for the United States (Mahon and Wild, 1984).

Three methods of launching a satellite: (1) Using apogee kick motor
(2) Using spacecraft thrusters
(3) Direct insertion to GEO

Using spacecraft thrusters

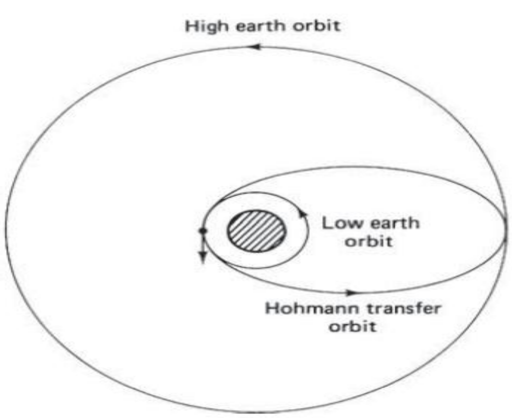
This method is employed since apogee kick motor imparts a vigorous acceleration. Spacecraft thrusters are used to raise the orbit from GTO to GEO over a number of turns. There are two thrusters on a satellite, one for more powerful orbit raising maneuvers and the other for on-orbit maneuvers.

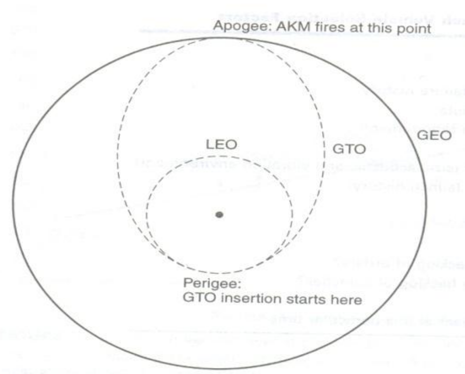
Direct insertion to GEO

Here the final stages of the rocket are used to place the satellite directly into GEO rather than the satellite using its own propulsion system to go from GTO to GEO.

Where an orbital altitude greater than about 200 km is required, it is not economical in terms of launch vehicle power to perform direct injection, and the satellite must be placed into transfer orbit between the initial LEO and the final high-altitude orbit.

In most cases, the transfer orbit is selected to minimize the energy required for transfer, and such an orbit is known as a *Hohmann transfer* orbit. The time required for transfer is longer for this orbit than all other possible transfer obits. Assume for the moment that all orbits are in the same plane and that transfer is required between two circular orbits, as illustrated in Figure. The Hohmann elliptical orbit is seen to be tangent to the low altitude orbit at perigee and to the high-altitude orbit at apogee. At the perigee, in the case of rocket launch, the rocket injects the satellite with the required thrust into the transfer orbit. With the Space Transportation System (STS), the satellite must carry a perigee kick motor which imparts the required thrust at perigee. At apogee, the *apogee kick motor* (AKM) changes the velocity of the satellite to place it into a circular orbit in the same plane. As shown in Figure, it takes 1 to 2 months for the satellite to be fully operational.





The total energy, U of a satellite, for a two body system, is given by

$$U = \frac{1}{2}\,mv^2 - \frac{GmM}{r}$$

Where m and v are the mass and velocity of the satellite respectively, and r is the distance from geocenter, G is the gravitational constant and M the mass of the earth. To achieve a geostationary orbit, the launch vechicle must be able to impart a velocity of 3070m/s at the GEO orbit height about 42165 km from the earth. In an equipotential field, the maximum velocity increment, Δv, which a launch vehicle of total mass m_0 can impact may be given as

$$\Delta v = v_g\, ln\left(\frac{1}{1-\frac{m_f}{m_0}}\right)$$

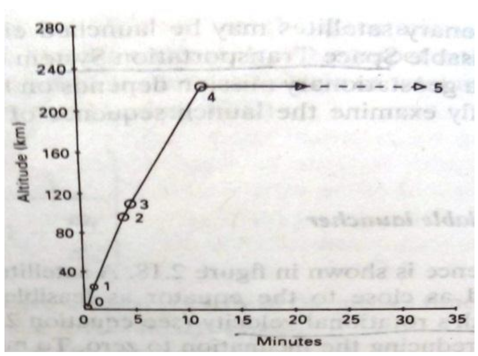
v_g = effective exhaust velocity of the gas, m_f = mass of the expanded fuel

In order to maximize Δv the ratio $\frac{m_f}{m_0}$ should be maximized. Therefore it is usual to launch satrllites by means of multiple stage rockets, each stage being jettisoned after imparting a given thrust. As m_o is progressively reduced, succeeding stages of rockets need to impact progressively lower thrust to achieve the desired orbit. The final velocity of the spacecraft is the sum of the velocity increments of all the stages.

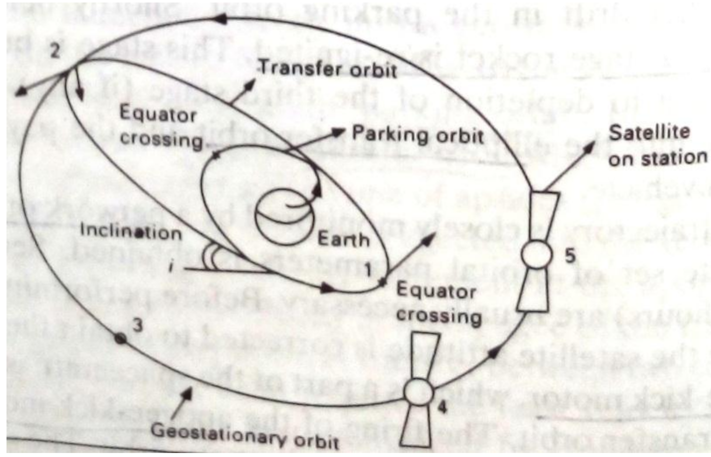
Orbital inclination is determined by the latitude of the launch station and is given by

$$\cos(i) = \sin(\in_1)\cos(\theta_1)$$

Where i – inclination, $\in_1 - azimuth\ of\ launch,\ \theta_1 - latitude\ of\ launch\ site.$



Event Number	Event
0	Vertical lift off
1	Guidance system begins tilting rocket towards east
2	First stage drop off
3	Second stage ignition
4	Horizontal insertion into parking orbit 185 to 250 km
5	Second and third stages fired at equator to acquire transfer orbit



Event Number	Event
1	Velocity increment to acquire transfer orbit, satellite spun for stabilization, attitude maneuvers done before apogee kick motor firing
2	Apogee kick motor fired to give necessary velocity increment, orbit ciculaized and inclination reduced to near zero
3	Satellite despun
4	Three axis stabilization acquired
5	Minor orbit errors in orbit tested and position satellite on station

Throughout the launch and acquisition phases, a network of ground stations, spread across the earth, is required to perform the ***tracking, telemetry, and command*** **(TT&C)** functions. Velocity changes in the same plane change the geometry of the orbit but not its inclination. In order to change the inclination, a velocity change is required normal to the orbital plane. Changes in inclination can be made at either one of the nodes, without affecting the other orbital parameters. Since energy must be expended to make any orbital changes, a geostationary satellite should be launched initially with as low an orbital inclination as possible. It will be shown shortly that the smallest inclination obtainable at initial launch is equal to the latitude of the launch site. Thus the farther away from the equator a launch site is, the less useful it is, since the satellite has to carry extra fuel to effect a change in inclination. Russia does not have launch sites south of 45°N, which makes the launching of geostationary satellites a much more expensive operation for Russia than for other countries which have launch sites closer to the equator.

Prograde (direct) orbits have an easterly component of velocity, so prograde launches gain from the earth's rotational velocity. For a given launcher size, a significantly larger payload can be launched in an easterly direction than is possible with a retrograde (westerly) launch. In particular, easterly launches are used for the initial launch into the geostationary orbit. The relationship between inclination, latitude, and azimuth may be seen as follows [this analysis is based on that given in Bate et al. (1971)].

Launch Window: before the launch of a satellite is necessary to ensure that the launch time falls within a "launch window". This guarantees that the position of a satellite in respect of the sun is favorable thus ensuring adequate power supply and thermal control throughout the mission.

Further, the launch must be so timed that the satellite is that the satellite is visible to the control station during all the critical maneuvers. This set of conditions limits the launch time to certain specified intervals, designed the launch window.

Propellant types:

- Chemical propulsion
- Solid propulsion

Consideration of chemical propulsion

Chamber Condition:

- Mass Balance
- Enthalpy Balance (Conversion of energy)
- Pressure Balance (Daltons Law)
- Chemical Equilibirium (Minimization of Gibbs Formula)

Rocket Performance:

- Equation of state (Ideal Gas law)
- Continuity Equation (Conversion of mass)
- Conversion of momentum
- Conversion of energy (First law of thermodynamics)
- Isotropic Expansion (Second law of thermodynamics)

Launch Vehicles

Arian:

- Arian Space – European consortium with European space agency and french space agency
- Initiated in 1973, launch took place in 1979.
- Payload capacity of 1850 kg
- Ariane 2 & Ariane 3 has initiated in 1980
- Ariane 2 has a 2175 kg capacity into GTO (Geo Transfer orbit) & Ariane 3 has 2700 kg capacity.

ATLAS:

- The atlas launch system is the product of the general dynamics space system division
- Atlas I, II & II A
- Payload capacity of 2500 kg

DELTA:

- Delta I & II
- Managed by McDonnell Douglay for NASA
- Launched in 1960
- 2 stage mission & 3 stage mission

M- I & M – II:

- Launch vechicle of the national space development agency & Japan
- M-I has 3 stages, consisting of two liquid propellant stages and a composite solid propellant 3 stage.
- Operational in 1988
- M – II has 2 stage liquid oxygen & liquid hydrogen rocket augmented by two solid

Orbit	M-I	M-II
GTO	1100	400
LEO 30 degree, 300 km	2900	9200
Sun synchronous, 700 km	1400	5000
Lunar or planetary	1400	2500

Long March:

- Developed by china initiated in 1956
- Long march 1,2,3,4 & 2E vehicles
- Since 1970, launches have placed more than 30 satellite into orbits
- E the most powerful in current production has a payload capability of 93000 kg into LEO and 3370 kg into GTO.

PROTON:

- In Russia proton was developed between 1961 & 1965
- The proton has a capability of 20000 kg into LEO, 5500 kg into GTO, 2800 kg into sun synchronous orbit.

SLV/ GSLV/ PSLV – ASSIGNMENT

UNIT II

SPACE SEGMENT

Spacecraft Technology - Structure, Primary Power, Attitude and Orbit Control, Thermal Control and Propulsion, Communication Payload and Supporting Subsystems, Telemetry, Tracking and Command – Transponders - The Antenna Subsystem.

Introduction

A satellite communications system can be broadly divided into two segments—a ground segment and a space segment.

The space segment will obviously include the satellites, but it also includes the ground facilities needed to keep the satellites operational, these being referred to as the *tracking, telemetry, and command* (TT&C) facilities. In many networks it is common practice to employ a ground station solely for the purpose of TT&C.

The equipment carried aboard the satellite also can be classified according to function. The *payload* refers to the equipment used to provide the service for which the satellite has been launched. The *bus* refers not only to the vehicle which carries the payload but also to the various subsystems which provide the power, attitude control, orbital control, thermal control, and command and telemetry functions required to service the payload.

In a communications satellite, the equipment which provides the connecting link between the satellite's transmit and receive antennas is referred to as the *transponder*. The transponder forms one of the main sections of the payload, the other being the antenna subsystems.

SPACE CRAFT CONFIGURATION

- ✓ The spacecraft provides a platform on which the communications equipment can function and maintains this platform in the chosen orbit.
- ✓ The design of the spacecraft is a complicated exercise involving just about every branch of engineering and physics.
- ✓ The interrelations among the requirements for communication performance, the need to provide a begin environment for the communication equipment, and the problems of launching into the desired orbit constitute the subject of space systems engineering.

SPACECRAFT DESING

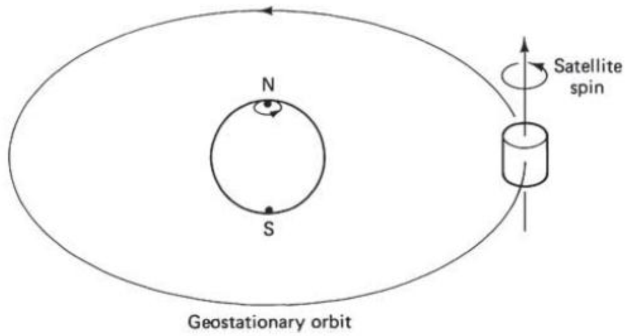
- ✓ **Methods of stabilization:** The principal characteristic of a communication satellite is its method of stabilization.
- ✓ The method adopted depends on both tangible factors, such as the type of orbit and the specification of the payload, and intangibles, such as design philosophy and compatibility with existing satellites within the system.
- ✓ Methods of stabilization may be divided into two categories: ***passive and active.***

Passive methods: Include gravity-gradient stabilization and magnetic damping, which are methods that have been used on some small, low-earth-orbiting spacecraft.

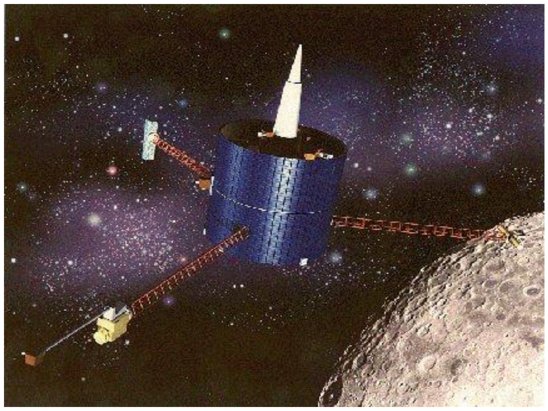
Active methods: Include spin stabilization and three axis stabilization. These are the only two viable alternatives for geostationary satellites.

Spinning satellite stabilization:

- ✓ Spin stabilization may be achieved with cylindrical satellites.
- ✓ The satellite is constructed so that it is mechanically balanced about one particular axis and is then set spinning around this axis.
- ✓ For geostationary satellites, the spin axis is adjusted to be parallel to the N-S axis of the earth, as illustrated in Figure, Spin rate is typically in the range of 50 to 100 rev/min.



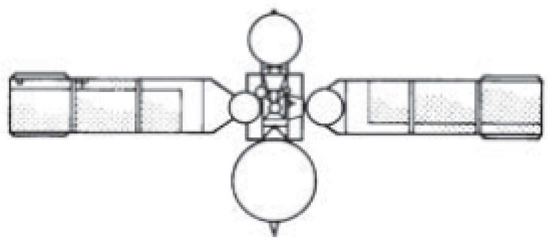
- ✓ Spin is initiated during the launch phase by means of small gas jets.
- ✓ In the absence of disturbance torques, the spinning satellite would maintain its correct attitude relative to the earth.
- ✓ Disturbance torques are generated in a number of ways, both external and internal to the satellite. Solar radiation, gravitational gradients, and meteorite impacts are all examples of external forces which can give rise to disturbance torques.
- ✓ Motor-bearing friction and the movement of satellite elements such as the antennas also can give rise to disturbance torques.
- ✓ The overall effect is that the spin rate will decrease, and the direction of the angular spin axis will change.
- ✓ Impulse-type thrusters, or jets, can be used to increase the spin rate again and to shift the axis back to its correct N-S orientation.
- ✓ ***Nutation,*** which is a form of wobbling, can occur as a result of the disturbance torques and/or from misalignment or unbalance of the control jets. This nutation must be damped out by means of energy absorbers known as ***nutation dampers***.
- ✓ Certain dual-spin spacecraft obtain spin stabilization from a spinning flywheel rather than by spinning the satellite itself.
- ✓ These flywheels are termed ***momentum wheels***, and their average momentum is referred to as ***momentum bias.***
- ✓ Reaction wheels, described in the next section, operate at zero momentum bias.
- ✓ In the Intelsat series of satellites, the INTELSAT-VI series spacecraft are spin-stabilized, all the others being 3-axis stabilized (body stabilized) through the use of momentum wheels.



Spin and Three-Axis Stabilization

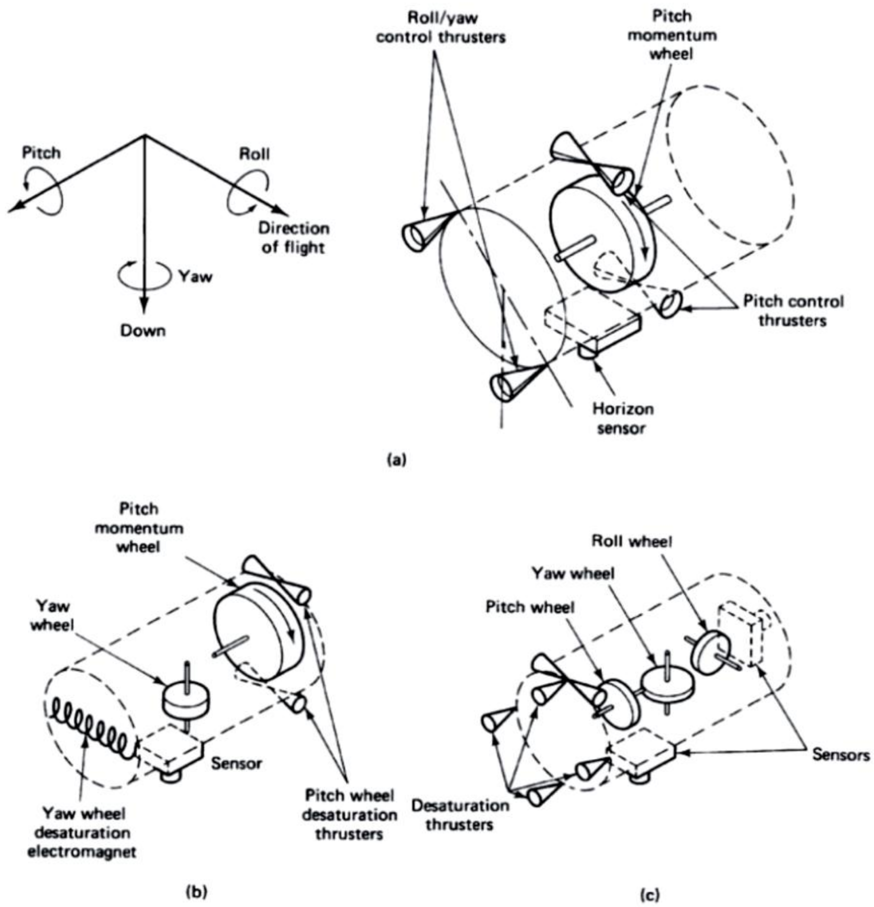
Momentum wheel stabilization

- ✓ In the previous section the gyroscopic effect of a spinning satellite was shown to provide stability for the satellite attitude.
- ✓ Stability also can be achieved by utilizing the gyroscopic effect of a spinning flywheel, and this approach is used in satellites with cube-like bodies (the INTELSAT V type satellites shown in Figure). These are known as ***body-stabilized*** **satellites.**



- ✓ The complete unit, termed a momentum wheel, consists of a flywheel, the bearing assembly, the casing, and an electric drive motor with associated electronic control circuitry.
- ✓ The flywheel is attached to the rotor, which consists of a permanent magnet providing the magnetic field for motor action.
- ✓ The stator of the motor is attached to the body of the satellite. Thus the motor provides the coupling between the flywheel and the satellite structure.
- ✓ Speed and torque control of the motor is exercised through the currents fed to the stator.
- ✓ The housing for the momentum wheel is evacuated to protect the wheel from adverse environmental effects, and the bearings have controlled lubrication that lasts over the lifetime of the satellite.
- ✓ TELDIX manufactures momentum wheels ranging in size from 20, 26, 35, 50 to 60 cm in diameter that is used in a wide variety of satellites.
- ✓ The term momentum wheel is usually reserved for wheels that operate at nonzero momentum.

- ✓ This is termed a momentum bias. Such as wheel provides passive stabilization for the yaw and roll axes when the axis of rotation of the wheel lies along the pitch axis, as shown in Figure (a) , Control about the pitch axis is achieved by changing the speed of the wheel.



Alternative momentum wheel stabilization systems:
(a) one-wheel, (*b*) twowheel, (*c*) three-wheel.

- ✓ When the momentum wheel is operated with zero momentum bias, its generally referred as a *reaction wheel.* Reaction wheels are used in three-axis stabilized systems. Here, as the name suggests, each axis is stabilized by a reaction wheel, as shown in Figure (c).
- ✓ Reaction wheels can also be combined with a momentum wheel to provide the control needed.
- ✓ Random and cyclic disturbance torques tends to produce zero momentum on average.
- ✓ However, there will always be some disturbance torques that causes a cumulative increase in wheel momentum, and eventually at some point the wheel *saturates.* In effect, it reaches its maximum allowable angular velocity and can no longer take in any more momentum.
- ✓ Mass expulsion devices are then used to unload the wheel, that is, remove momentum from it (in the same way brake removes energy from a moving vehicle0. Of course, operation of the mass expulsion devices consumes part of the satellite's fuel supply.

COMMUNICATION PAYLOAD AND SUPPORTING SUBSYSTEMS

- ✓ The typical satellite consists of the communications payload and the network of supporting subsystems, or bus. The supporting subsystems include
  - Structure
  - Primary power
  - Thermal control
  - Telemetry, tracking and command
  - Attitude control
  - Propulsion

- ✓ Table is a simple chart listing these systems, their purposes and the principal parameters that characterize them quantitatively.

System	***Function***	***Principal Quantitative Characteristics***
Communication Transponders Antennas	Receive, amplify, process and retransmit signals; capture and radiate signals	Transmitter power, bandwidth, G/T, beamwidth, orientation, gain, signal-carrier saturated flux density.
Structure	Support spacecraft under launch and orbital environment	Resonant frequencies, structural strengths
Primary power	Supply electrical power to spacecraft	Beginning of life (BOL) power, end of life (EOL) power; solstice and equinox powers, eclipse operation
Thermal control	Maintain suitable temperature ranges for all subsystems during life, operating and non-operating, in and out of eclipse	Spacecraft mean temperature range and temperature ranges for all critical components
Telemetry, tracking, and command (TT & C)	Monitor spacecraft status, orbital parameters, and control spacecraft operation	Position and velocity measuring accuracy, number of telemetered points, number of commands
Attitude control	Keeps antennas pointed at correct earth locations and solar cells pointed at the sun	Role, pitch, and yaw tolerances.
Propulsion	Maintain orbital position, major attitude control corrections, orbital changes, and initial orbit deployment	Specific impulse, thrust, propellant mass
Complete spacecraft	Provide satisfactory communications operations in desired orbit	Mass, primary power, design lifetime, reliability, communications performance; number of channels and types of signals

STRUCTURE

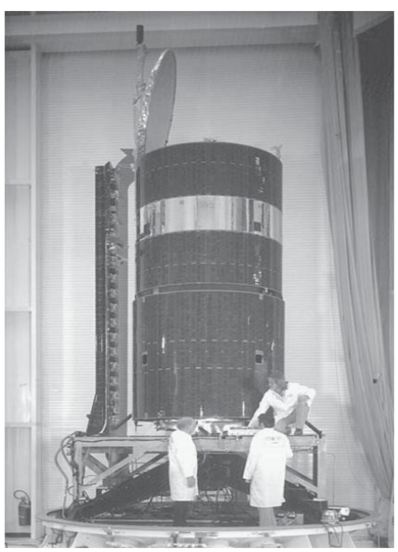
- ✓ The structure to hold the spacecraft together must be designed to withstand a variety of loads.
- ✓ During launch and transfer, there are accelerations, vibration and aerodynamic loads, centrifugal stresses, operating thrusts, and separation shocks.
- ✓ A wide variety of materials and techniques has been used for spacecraft structures. Mostly derivative from aeronautical practice, and Table lists some common structural materials

Table - Common Structural Materials

Aluminium
Magnesium
Stainless steel
Invar
Titanium
Graphite-reinforced phenolic (GFRP)
Fiber-glass epoxy
Beryllium

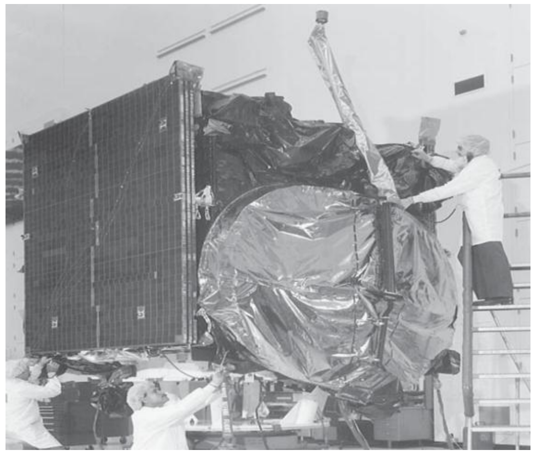
THE POWER SUPPLY

- ✓ The primary electrical power for operating the electronic equipment is obtained form solar cells.
- ✓ Individual cells can generate only small amounts of power, and there force, arrays of cells in series-parallel connection are required.
- ✓ Figure shows the solar cell panels for the HS 376

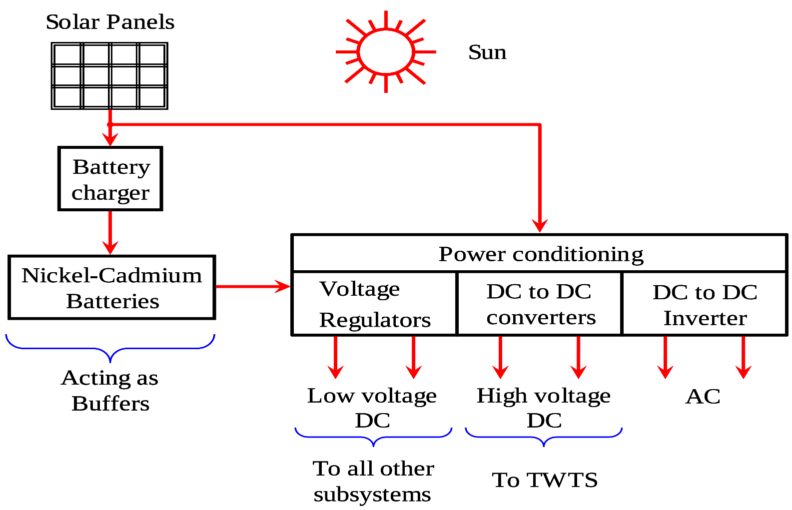


- ✓ During the launch sequence, the outer cylinder is telescoped over the inner one, to reduce the overall length.
- ✓ Only the outer panel generates electrical power during this phase.

- ✓ In geostationary orbit the telescoped panel is fully extended so that both are exposed to sunlight. At the beginning of life, the panels produce 940 W dc powers, which may drop to 760 W at the end of 10 years. During eclipse, power is provided by tow **nickel-cadmium (Ni-Cd)** long-life batteries, which will deliver 830 W. At the end of life, battery recharge time is less than 16h.
- ✓ Higher power can be achieved with solar panels arranged in the form of rectangular ***solar sails.*** Solar sails must be folded during the launch phase and extended when in geostationary orbit. Figure shows the HS 601. As shown, the solar sails are folded up on each side, and when fully extended, they stretch to 67 ft (20.42m) from tip to tip.



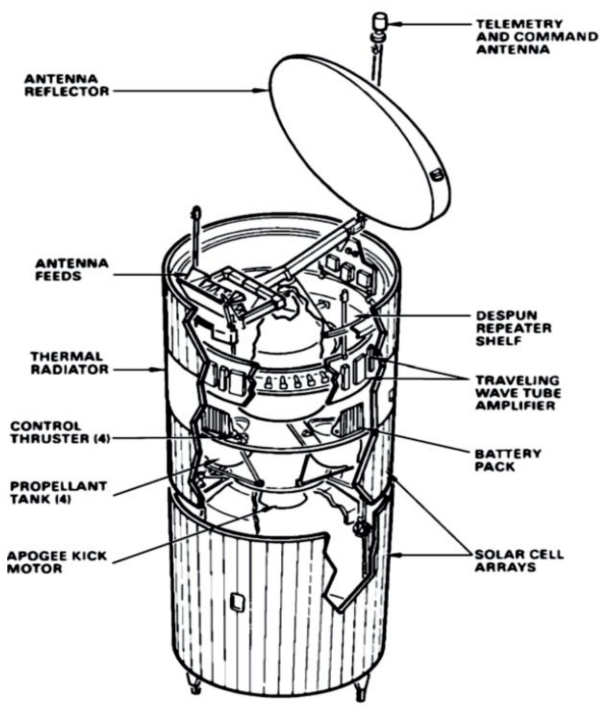
- ✓ The full complement of solar cells is exposed to the sunlight, and the sails are arranged to rotate to track the sun, so they are capable of greater power output than cylindrical arrays having a comparable number of cells.
- ✓ The HS 601 can be designed to provide dc power from 2 to 6 kW.
- ✓ In comparing the power capacity of cylindrical and solar-sail satellites, the cross-over point is estimated to be about 2 kW, where the solar-sail type is more economical than the cylindrical type.



Basic satellite primary power system

THERMAL CONTROL

- ✓ Satellites are subject to large thermal gradients, receiving the sun's radiation on one side while the other side faces into space.
- ✓ In addition, thermal radiation from the earth and the earth's ***albedo***, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationary satellites.
- ✓ Equipment in the satellite also generates heat which has to be removed.
- ✓ The most import consideration is that the satellite's equipment should operate as nearly as possible in a stable temperature environment. Various steps are taken to achieve this.
- ✓ Thermal blankets and shields may be used to provide insulation.
- ✓ Radiation mirrors are often used to remove heat from the communications payload.
- ✓ The mirrored thermal radiator for the HS376 satellite can be seen in Figure. These mirrored drums surround the communications equipment shelves in each case and provide good radiation paths for the generated heat to escape into the surrounding space.

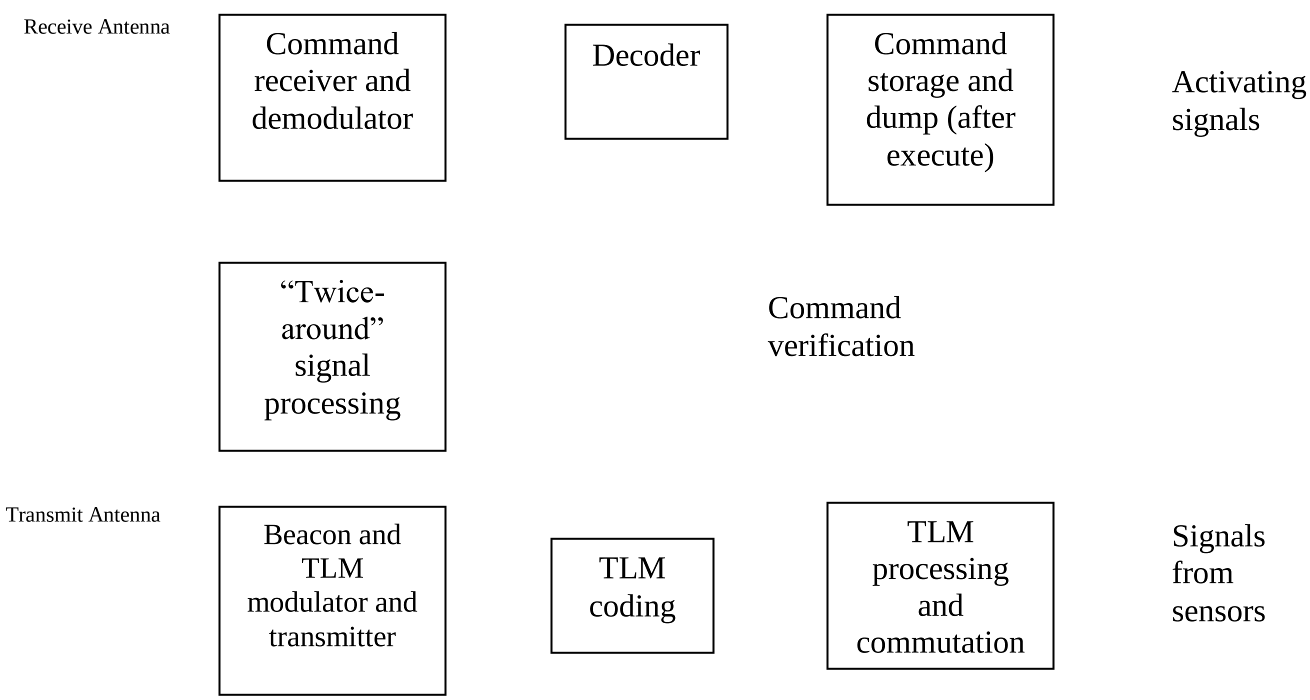


- ✓ One advantage of spinning satellites compared with body-stabilized is that the spinning body provides an averaging of the temperature extremes experienced from solar flux and the cold back, ground of deep space.
- ✓ In order to maintain constant temperature conditions, heaters may be switched on (usually on command from ground) to make up from the heat reduction which occurs when transponders are switched off.

TELEMETRY, TRACKING AND COMMAND (TT & C)

- ✓ The three related functions, telemetry, tracking (including range measurements) and command, are usually grouped into one subsystem called telemetry, tracking and command (TT&C) or alternatively *telemetry, tracking, command and ranging (TTC & R)*. All three are essentially communications functions.
- ✓ Thus the computations of link performance. Signal-to-noise rations, error rats and other communications parameters are identical in principle to those for telephone, TV and data.
- ✓ VHF and S-band links, in common use for all three services. A simplified block diagram of a spacecraft TT&C system is shown in Figure.

Generalized spacecraft TT&C system



Telemetry

- ✓ The satellite condition must be known on the ground at all times. Its usual to choose some hundreds of points around the spacecraft and measure such quantities as
  - Voltage
  - Currents
  - Temperatures
  - Pressures
  - The status of switches and solenoids
- ✓ Sensors for these quantities are provided together with analog-to-digital (A-D) converters and their outputs are sampled in a commutation system. PCM, TDM and PSK are usual telemetry transmission modes. FM analog telemetry is still used occasionally

Tracking

- ✓ Beacon transmitters are usually provided on the spacecraft for tracking during launch and operations.
- ✓ This transmitter can also carry telemetry signals and range signal turnaround and command verifications.
- ✓ Angular measurements are done by conventional terrestrial methods using large antennas and monopulse or conical scanning systems developed years ago for radar.
- ✓ Ranging is done by one of two methods. A standard technique is to phase modulate the uplink or command carrier with pairs of low –frequency tones, detect these signals on board, and remodulate the telemetry carrier on the downlink.
- ✓ The earth station compares the transmitted and received phases to calculate the range.
- ✓ By using the tones in pairs. It's possible to resolve the range ambiguities otherwise present.
- ✓ Another method is to transmit pulsed signals on the uplink and retransmit them on the downlink, measuring the range by time difference in the usual radar manner. \

Command

- ✓ A wide variety of such systems has been developed and the choice depends on the number of commands, the rest of the TT&C, and the security required.
- ✓ Digital systems and low-frequency tones are both used.
- ✓ Most command systems take a similar sequence of operations to protect against unauthorized or take commands and errors the sequence is :
    - An enabling signal is transmitted to permit command system operation.
    - The specific command is sent and stored.
    - The command is verified by transmitting to the earth the telemetry link
    - An execute signal is transmitted and the command is carried out.
- ✓ Commands are necessary for many functions during manual operation, specifically,
    - Transponder switching,
    - Station keeping
    - Attitude changes
    - Gain control
    - Redundancy control

During launch there may be others, for example,

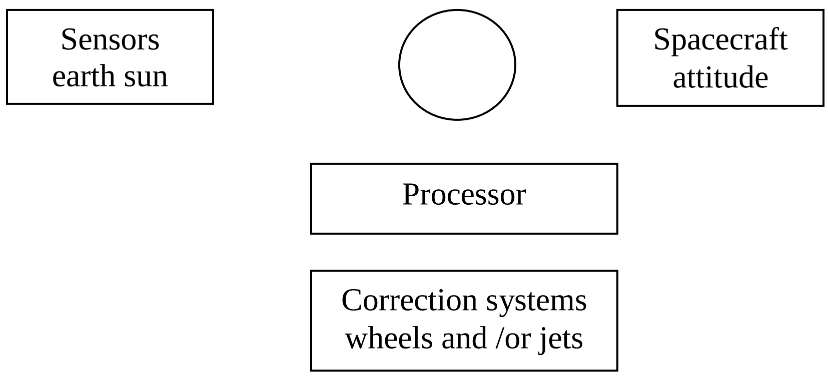
- Separation commands
- Antenna and solar panel deployment
- Apogee motor firing

ATTITUDE CONTROL

- ✓ The attitude control subsystem must accomplish two things
- ✓ First, it must keep the antennas pointed in the proper direction (that is, toward the region to be communicated with) on the surface of the earth or perhaps another satellite,
- ✓ Second, it must keep the solar array pointed toward the sun.

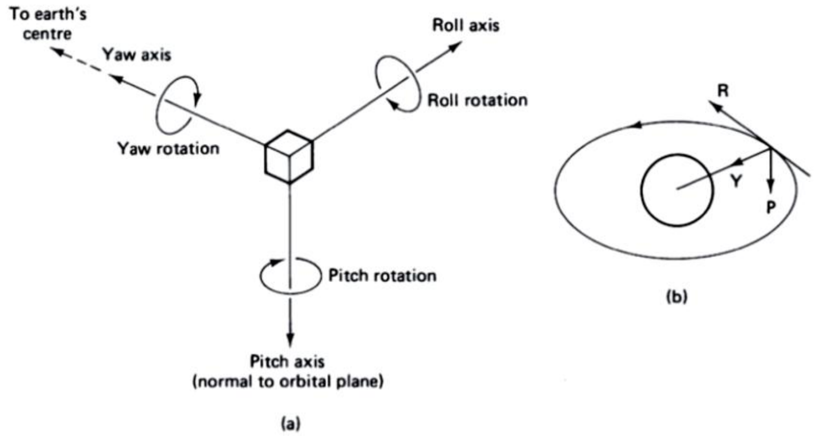
Note that both functions require a double action on the part of the attitude-control system.

- ✓ It must pitch the satellite 15^0 per hour to maintain earth pointing.
- ✓ At the same time, it must correct for attitude changes resulting from orbital disturbances and from upsetting torques generated when making station keeping maneuvers.



Basic attitude-control subsystem.

- ✓ It's important to emphasize that all attitude-control systems function in accordance with the block diagram of figure. Any perturbation in the attitude or position or the satellite is detected by sensors and compared to a reference, and an error signal is derived that is used to command corrections.
- ✓ The correction s are achieved either by varying the speeds of spinning momentum wheels or by thrusters, or by some combination.
- ✓ All attitude control systems require sensors. It is the resolution of these sensors that limits the ultimate pointing accuracy of the spacecraft. Sensors can be optical (either in the visible or infrared regions of the spectrum), or they can be radio-frequency sensors to work in conjunction with ground-based transmitter.
- ✓ All active attitude control systems, whether they use single inertial wheels multiple wheels, or despun platforms, require thrusters to correct large errors.
- ✓ This is sometimes referred to as *dumping momentum* since the use of a jet to expel propellant changes the total angular momentum of the spacecraft itself. (a) Spin-stabilized controls (b) Three axis active control, (c) momentum bias control and (d) Dual spin control are the four principal kinds of active attitude control systems.



(*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.

The three axes which define a satellite's attitude are its *roll*, *pitch*, and *yaw* (RPY) axes. These are shown relative to the earth in Figure. All three axes pass through the center of gravity of the satellite. For an equatorial orbit, movement of the satellite about the roll axis moves the antenna footprint north and south; movement about the pitch axis moves the footprint east and west; and movement about the yaw axis rotates the antenna footprint.

Earth Station Technology:

The earth segment of a satellite communications system consists of the transmit and receive earth stations. The simplest of these are the home *TV receive-only* (TVRO) systems, and the most complex are the terminal stations used for international communications networks. Also included in the earth segment are those stations which are on ships at sea, and commercial and military land and aeronautical mobile stations.

As mentioned in earth stations that are used for logistic sup- port of satellites, such as providing the *telemetry, tracking, and command* (TT&C) functions, are considered as part of the space segment.

Terrestrial Interface:

Earth station is a vital element in any satellite communication network. 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. But it is fundamentally governed by its Location which are listed below,

- In land
- On a ship at sea
- Onboard aircraft

The factors are

- Type of services
- Frequency bands used
- Function of the transmitter
- Function of the receiver
- Antenna characteristics

Transmitter and Receiver

Any earth station consists of four major subsystems

- Transmitter
- Receiver
- Antenna
- Tracking equipment

Two other important subsystems are

- Terrestrial interface equipment
- Power supply

The earth station depends on the following parameters

- Transmitter power
- Choice of frequency
- Gain of antenna
- Antenna efficiency
- Antenna pointing accuracy
- Noise temperature

The functional elements of a basic digital earth station are shown in the below figure

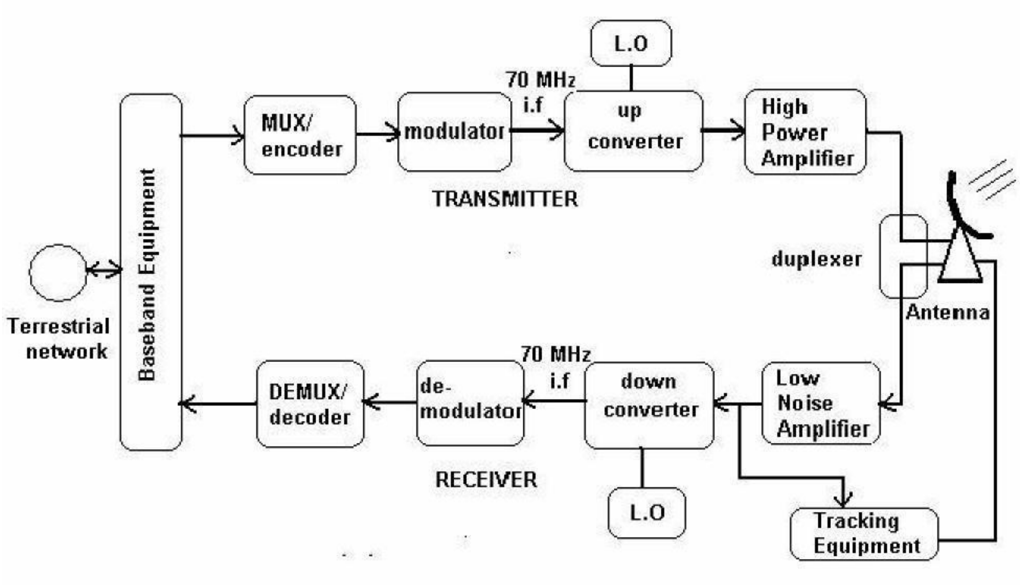


Figure Transmitter- Receiver

Digital information in the form of binary digits from terrestrial networks enters earth station and is then processed (filtered, multiplexed, formatted etc.) by the base band equipment.

The encoder performs error correction coding to reduce the error rate, by introducing extra digits into digital stream generated by the base band equipment. The extra digits carry information.

In satellite communication, I.F carrier frequency is chosen at 70 MHz for communication using a 36 MHz transponder bandwidth and at 140 MHz for a transponder bandwidth of 54 or 72 MHz.

On the receive side, the earth station antenna receives the low-level modulated R.F carrier in the downlink frequency spectrum.

The low noise amplifier (LNA) is used to amplify the weak received signals and improve the signal to Noise ratio (SNR). The error rate requirements can be met more easily.

R.F is to be reconverted to I.F at 70 or 140 MHz because it is easier design a demodulation to work at these frequencies than 4 or 12 GHz.

The demodulator estimate which of the possible symbols was transmitted based on observation of the received if carrier.

The decoder performs a function opposite that of the encoder. Because the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and recover information-bearing digits.

The information stream is fed to the base-band equipment for processing for delivery to the terrestrial network.

The tracking equipment tracks the satellite and align the beam towards it to facilitate communication.

Earth Station 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

1. Satellite acquisition
2. Automatic tracking
3. Manual tracking
4. Program tracking.

Antenna Systems:

The antenna system consist of

- Feed System
- Antenna Reflector
- Mount
- 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:

- Axi-Symmetric Configuration
- Asymmetric Configuration
- Axi-Symmetric Configuration

In an axi-symmetric configuration the antenna axes are symmetrical with respect to the reflector, which results in a relatively simple mechanical structure and antenna mount.

Primary Feed:

In primary, feed is located at the focal point of the parabolic reflector. Many dishes use only a single bounce, with incoming waves reflecting off the dish surface to the focus in front of the dish, where the antenna is located. when the dish is used to transmit ,the transmitting antenna at the focus beams waves toward the dish, bouncing them off to space. This is the simplest arrangement.

Cassegrain :

Many dishes have the waves make more than one bounce .This is generally called as folded systems. The advantage is that the whole dish and feed system is more compact. There are several folded configurations, but all have at least one secondary reflector also called a sub reflector, located out in front of the dish to redirect the waves.

A common dual reflector antenna called Cassegrain has a convex sub reflector positioned in front of the main dish, closer to the dish than the focus. This sub reflector bounces back the waves back toward a feed located on the main dish’s center, sometimes behind a hole at the center of the main dish. Sometimes there are even more sub reflectors behind the dish to direct the waves to the fed for convenience or compactness.

Gregorian

This system has a concave secondary reflector located just beyond the primary focus. This also bounces the waves back toward the dish.

Asymmetric Configuration

Offset or Off-axis feed

The performance of tan axi- symmetric configuration is affected by the blockage of the aperture by the feed and the sub reflector assembly. The result is a reduction in the antenna efficiency and an increase in the side lobe levels. The asymmetric configuration can remove this limitation.. This is achieved by off-setting the mounting arrangement of the feed so that it does not obstruct the main beam.As a result ,the efficiency and side lobe level performance are improved

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:

- Two way TV ,Telephony and data
- Two way TV
- TV receive only and two way telephony and data
- Two way data

From the classifications it is obvious that the technology of earth station will vary considerably on the performance and the service requirements of earth station 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

Wind Speed

The size of the reflector depends on transmit and receive gain requirement and beamwidth of the antenna. Gain is directly proportional to the antenna diameter whereas the beamwidth is inversely proportional to the antenna diameter .for high inclination angle of the satellite, the tracking of the earth station becomes necessary when the beamwidth is too narrow.

The gain of the antenna is given by Gain= (η4ΠAeff)/ λ2
Where Aeff is the aperture Λ is wave length
H is efficiency of antenna system

For a parabolic antenna with circular aperture diameter D, the gain of the antenna is :

Gain= (η4Π/ λ2) (ΠD2/4) = η (ΠD/ λ)2

The overall efficiency of the antenna is the net product of various factors such as

1. Cross Polarization
2. Spill over
3. Diffraction
4. Blockage
5. Surface accuracy
6. Phase error
7. Illumination

In the design of feed ,the ratio of focal length F to the diameter of the reflector D of the antenna system control the maximum angle subtended by the reflector surface on the focal point. Larger the F/D ratio larger is the aperture illumination efficiency and lower the cross polarization.

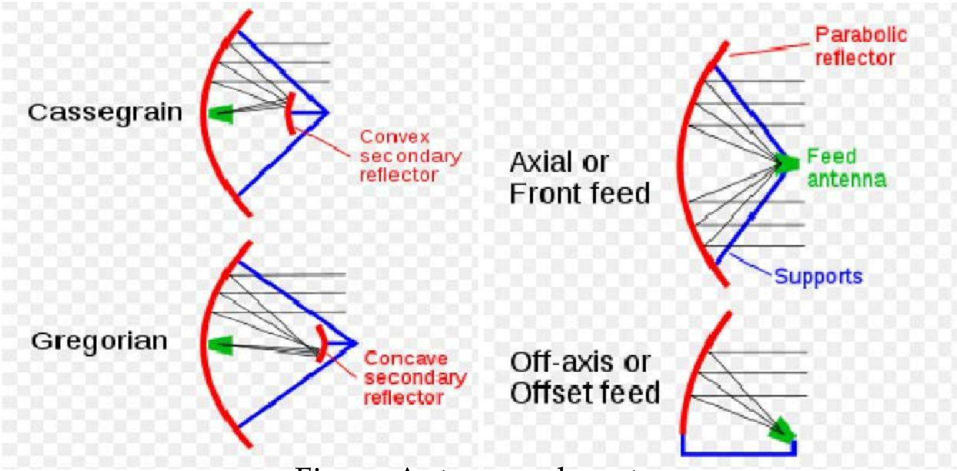


Figure Antenna sub systems

ANTENNA MOUNT:

Type of antenna mount is determined mainly by the coverage requirement and tracking requirements of the antenna systems. Different types of mounts used for earth station antenna are:

The Azimuth –elevation mount:

This mount consists of a primary vertical axis. Rotation around this axis controls the azimuth angle. The horizontal axis is mounted over the primary axis, providing the elevation angle control.

The X-Y mount:

It consists of a horizontal primary axis (X- axis) and a secondary axis (Y-axis) and at right angles to it. Movement around these axes provides necessary steering.

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

- Satellite acquisition
- Automatic tracking
- Manual tracking
- Program tracking.

Recent Tracking Techniques:

There have been some interesting recent developments in auto-track techniques which can potentially provide high accuracies at a low cost.

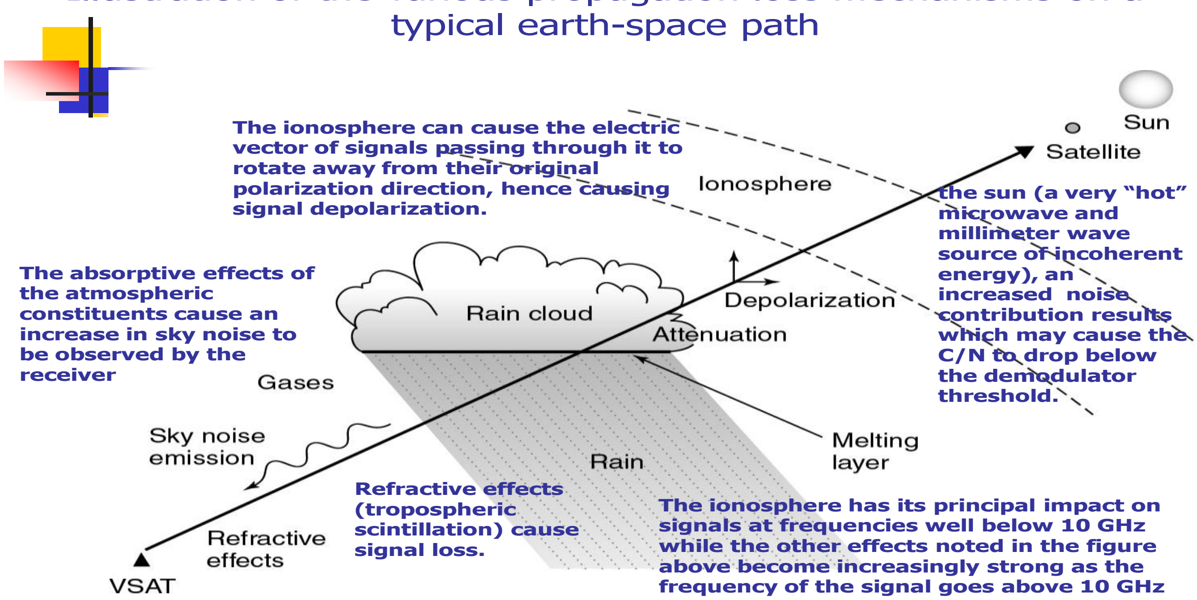
In one proposed technique the sequential lobing technique has been I implemented by using rapid electronic switching of a s single beam which effectively approximates simultaneous lobbing

UNIT III

SATELLITE LINK DESIGN

Basic Link Analysis, Interference Analysis, Rain Induced Attenuation and Interference, Ionospheric Characteristics, Link Design with and without Frequency Reuse.

Illustration of the various propagation loss mechanisms on a typical earth-space path



Signal Transmission Link-Power Budget Formula

Link-power budget calculations take into account all the gains and losses from the transmitter, through the medium to the receiver in a telecommunication system. Also taken into the account are the attenuation of the transmitted signal due to propagation and the loss or gain due to the antenna.

The decibel equation for the received power is:

$$[P_R] = [EIRP] + [G_R] - [LOSSES]$$

Where:

$[P_R]$ = received power in dBW
[EIRP] = equivalent isotropic radiated power in dBW
$[G_R]$ = receiver antenna gain in dB
[LOSSES] = total link loss in Db

dBW = 10 $\log_{10}$ (P/(1 W)), where P is an arbitrary power in watts, is a unit for the measurement of the strength of a signal relative to one watt.

Link Budget parameters

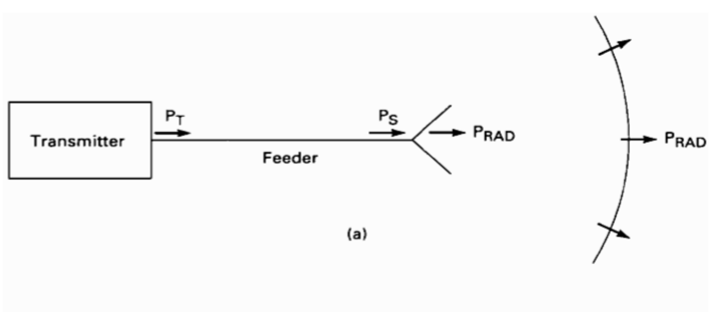
- EIRP
- Free space path loss
- System noise temperature
- Figure of merit for receiving system
- Carrier to thermal noise ratio
- Carrier to noise density ratio
- Carrier to noise ratio
- Transmitter power at the antenna
- Antenna gain compared to isotropic radiator

Signal Transmission Equivalent Isotropic Radiated Power

- An isotropic radiator is one that radiates equally in all directions.
- The power amplifier in the transmitter is shown as generating P_T watts.
- A feeder connects this to the antenna, and the net power reaching the antenna will be P_T minus the losses in the feeder cable, i.e. P_S.
- The power will be further reduced by losses in the antenna such that the power radiated will be P_{RAD} (< P_T).

$$P_t = P_{out} / L_t \qquad EIRP = P_t G_t$$

$$Maximum\ flux\ density\ \varphi_m = \frac{Gp_s}{4\pi r^2}$$



Antenna Gain

We need directive antennas to get power to go in wanted direction. Define Gain of antenna as increase in power in a given direction compared to isotropic antenna.

$$G(\theta) = \frac{P(\theta)}{P_0 / 4\pi}$$

- P (θ) is variation of power with angle.
- G (θ) is gain at the direction θ.
- P_0 is total power transmitted.
- sphere = *4p* solid radians

Signal Transmission Link-Power Budget Formula Variables

Link-Power Budget Formula for the received power [P_R]:

[P_R] = [EIRP] + [G_R] - [LOSSES]

The equivalent isotropic radiated power [EIRP] is:

[EIRP] = [P_S] + [G] dBW, where:

[P_S] is the transmit power in dBW, [G] is the transmitting antenna gain in dB, and **[G_R]** is the receiver antenna gain in dB.

[LOSSES] = [FSL] + [RFL] + [AML] + [AA] + [PL],

where:

[FSL] = free-space spreading loss in dB = P_T/P_R (in watts)
[RFL] = receiver feeder loss in dB
[AML] = antenna misalignment loss in dB
[AA] = atmospheric absorption loss in dB
[PL] = polarization mismatch loss in dB

The major source of loss in any ground-satellite link is the free-space spreading loss. Other effects need to be accounted for in the transmission equation:

L_a = Losses due to attenuation in atmosphere
L_{ta} = Losses associated with transmitting antenna
L_{ra} = Losses associates with receiving antenna
L_{pol} = Losses due to polarization mismatch
L_{other} = (any other known loss - as much detail as available)
Lr = additional Losses at receiver (after receiving antenna)

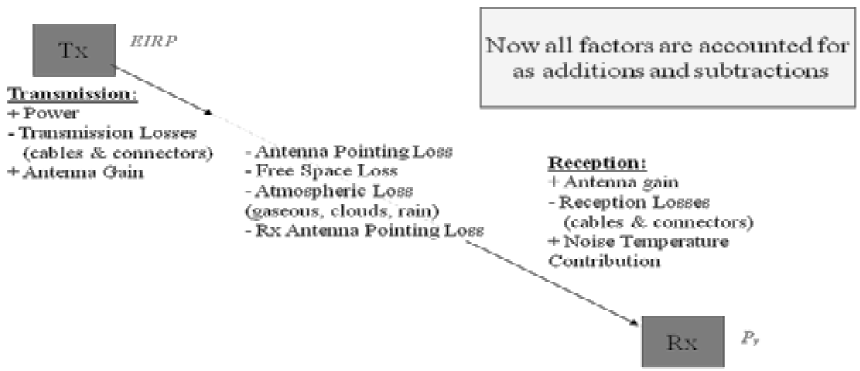
$$P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

Some intermediate variables were also defined before:

$P_t = P_{out} / L_t$, $EIRP = P_t G_t$

$$P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r} = \frac{EIRP \text{ x } G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r} = \frac{P_{out} G_t G_r}{L_t L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

Where: P_t = Power into antenna, L_t = Loss between power source and antenna
$EIRP$ = Effective isotropic radiated power



Translating to dBs

The transmission formula can be written in dB as:

$$P_r = EIRP - L_{ta} - L_p - L_a - L_{pol} - L_{ra} - L_{other} + G_r - L_r$$

The calculation of received signal based on transmitted power and all losses and gains involved until the receiver is called “Link Power Budget”, or “Link Budget”. The received power Pr is commonly referred to as “**Carrier Power**”, ***C.***

Why we need to calculate Link Power Budget

- System performance tied to operation thresholds
- Operation thresholds C_{min} tell the minimum power that should be received at the demodulator in order for communications to work properly
- Operational threshold depend on
  - Modulation scheme being used
  - Desired communication quality
  - Coding Gain
  - Additional overheads
  - Channel Bandwidth
  - Thermal Noise Power
- We need to calculate the link budget in order to verify if we are “closing the link”
  P_r>=C_{min} → Link Closed, **P_r<C_{min} → Link not Closed**
- Usually we obtain the “ Link Margin”, which tells how tight we are closing the link
  Margin=P_r-C_{min}
- Equivalently **Margin> 0 → Link Closed, Margin<0 → Link not closed**

PERFORMANCE IMPAIRMENT

SYSTEM NOISE

- ✓ The receiver power in a satellite link is very small, on the order of Pico watts. This by itself would be no problem because amplification could be used to bring the signal strength up to an acceptable level. However, electrical noise is always present at the input, and unless the signal is significantly greater than the noise, amplification will be of no help because it will amplify signal and noise to the same extent. In fact, the situation will be worsened by the noise added by the amplifier.

- ✓ The major source of electrical noise in equipment is that which arises from the random thermal motion of electrons in various resistive and active devices in the receiver. Thermal noise is also generated in the lossy components of antennas, and thermal-like noise is picked up by the antennas as radiation. The available noise power from a thermal noise source is given by

$$P_N = K\,T_N\,B_N$$

- ✓ Here, T_N is known as the equivalent noise temperature, B_N is the equivalent noise bandwidth and k=1.38*10^{-23} J/K is Boltzmann's constant. With the temperature in kelvins and bandwidth in hertz, the noise power will be in watts.

- ✓ The noise power bandwidth is always wider than the - 3dB bandwidth determined from the amplitude-frequency response curve, and a useful rule of thumb is that the noise bandwidth is equal to 1.12 times the -3dB bandwidth, or $B_N = 1.12 * 3dB$. The bandwidths here are in hertz (or a multiple such as MHz).

- ✓ The noise power per unit bandwidth is termed the *noise power spectral density*. Denoting this by N_0

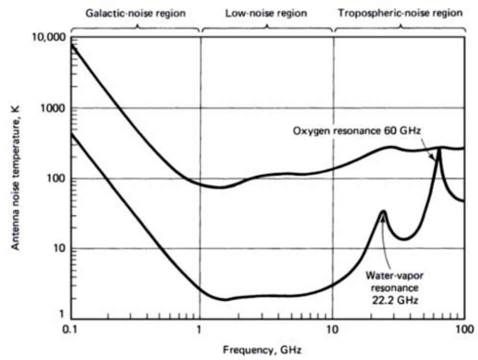
$$N_o = \frac{P_N}{B_N} = K\,T_N$$

- ✓ In addition to these thermal noise sources, intermodulation distortion in high-power amplifiers can result in signal products which appear as noise and in fact is referred to as *intermodulation noise*.

ANTENNA NOISE

- ✓ Antennas operating in the receiving mode introduce noise into the satellite circuit. Noise therefore will be introduced by the satellite receive antenna and the ground station receive antenna. Although the physical origins of the noise in either case are similar, the magnitudes of the effects differ significantly.
- ✓ The antenna noise can be broadly classified into two groups *noise originating from antenna losses* and *sky noise*.

SKY NOISE: Is a term used to describe the microwave radiation which is present throughout the universe and which appears to originate from matter in any form at finite temperatures. Such radiation in fact covers a wider spectrum than just the microwave spectrum.



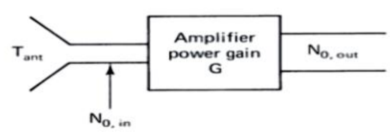
The equivalent noise temperature of the sky, as seen by an earth-station antenna, is shown in Figure. The lower graph is for the antenna pointing directly overhead, while the upper graph is for the antenna pointing just above the horizon. The increased noise in the latter case results from the thermal radiation of the earth, and this in fact sets a lower limit of about 5° at C band and 10° at Ku band on the elevation angle which may be used with ground-based antennas.

The graphs show that at the low-frequency end of the spectrum, the noise decreases with increasing frequency. Where the antenna is zenith pointing, the noise temperature falls to about 3 K at frequencies between about 1 and 10 GHz. This represents the residual background radiation in the universe. Above about 10 GHz, two peaks in temperature are observed, resulting from resonant losses in the earth's atmosphere.

Rainfall introduces attenuation, and therefore, it degrades transmissions in two ways: It attenuates the signal, and it introduces noise. The detrimental effects of rain are much worse at Ku-band frequencies than at C band, and the downlink rain-fade margin, must also allow for the increased noise generated.

AMPLIFIER NOISE TEMPERATURE

- ✓ Consider first the noise representation of the antenna and the *low noise amplifier (LNA)*. The available power gain of the amplifier is denoted as G, and the noise power output, as Pno.



- ✓ For the moment we will work with the noise power per unit bandwidth, The input noise energy coming from the antenna is

$$N_{0,ant} = kT_{ant}$$

- ✓ The output noise energy $N_{0,out}$ will be $GN_{0,ant}$ plus the contribution made by the amplifier. Now all the amplifier noise, wherever it occurs in the amplifier, may be referred to the input in terms of an equivalent input noise temperature for the amplifier Te. This allows the output noise to be written as

$$N_{0,out} = Gk\,(T_{ant} + T_e)$$

The total noise referred to the input is simply N0, out/G, or

$$N_{0,in} = k\,(T_{ant} + T_e)$$

Te can be obtained by measurement, a typical value being in the range 35 to 100 K. Typical values for T_{ant} are given in Antenna noise

NOISE FACTOR

- ✓ An alternative way of representing amplifier noise is by means of its *noise factor*, F. In defining the noise factor of an amplifier, the source is taken to be at *room temperature*, denoted by T_0, usually taken as 290K. The input noise from such a source is kT0, and the output noise from the amplifier is

$$N_{0,out} = FGkT_0$$

- ✓ Here, G is the available power gain of the amplifier as before, and F is its noise factor.
- ✓ A simple relationship between noise temperature and noise factor can be derived. Let Te be the noise temperature of the amplifier, and let the source be at room temperature as required by the definition of F. This means that $T_{ant} = T_0$.
- ✓ Since the same noise output must be available whatever the representation, it follow that

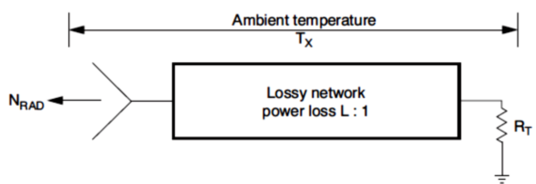
$$Gk\,(T_0 + T_e) = FGkT_0 \qquad \text{or} \qquad \mathbf{T_e = (F - 1)\,T_0}$$

- ✓ This shows the direct equivalence between noise factor and noise temperature. In a practical satellite receiving system, noise temperature is specified for low-noise amplifiers and converters, while noise factor is specified for the main receiver unit. The ***noise figure*** is simply *F* expressed in decibels:

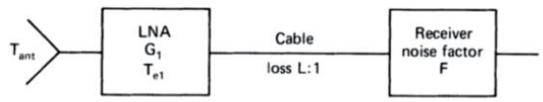
$$\boldsymbol{Noise\ Figure = [F] = 10\log F}$$

Noise temperature of absorptive networks

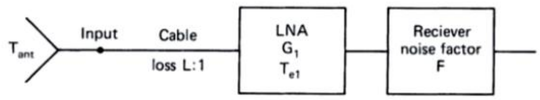
- ✓ An *absorptive network* is one which contains resistive elements. These introduce losses by absorbing energy from the signal and converting it is to heat. Resistive attenuators, transmission lines and waveguides are all examples of absorptive networks, and even rainfall, which absorbs energy from radio signals passing through it, can be considered a form of absorptive network. Because an absorptive network contains resistance, it generates thermal noise.



Overall system noise temperature



(a)



- ✓ Figure shows a typical receiving system, Applying the results of the previous sections yields, for the system nose temperature referred to the input,

$$TS = \text{Tant} + \text{Te1} + \frac{(L-1)T0}{G1} + \frac{L(F-1)T0}{G1}$$

<u>Carrier to Noise Ratio/ Carrier to noise density ratio / Carrier to thermal noise ratio</u>

Carrier to Noise Ratio: A measure of the performance of a satellite link is the ratio of carrier power to noise power at the receiver input, and link-budget calculations are often concerned with determining this ration. Conventionally, the ration is denoted by C/N (or CNR), which is equivalent to P_R/P_N. In terms of decibels,

$$\left[\frac{\mathbf{C}}{\mathbf{N_0}}\right] = [\boldsymbol{P_R}] - [\boldsymbol{P_N}]$$

$$\left[\frac{C}{N_0}\right] = [\text{EIRP}] + [\text{GR}] - [\text{LOSSES}] - [\text{K}] - [T_S] - [B_N]$$

$[C/N_0]$	- Carrier to Noise Ratio
EIRP	- Equivalent Isotropic Radiated Power
K	- Temperature – 228.6 dB J/K (since k= 1.38 x 10^{-23} J/K)
T_N	- Equivalent noise temperature
B_N	- Noise bandwidth
$[G_R/T_s]$	- The G/T ratio is a key parameter is specifying the receiving system performance. The antenna gain G_R and the system noise temperature T_S

- ✓ This equation is correct for either the uplink or downlink, with the caution that the operating values of EIRP and G/T must be used. When modified by atmospheric and other incidental losses, it is applicable to any line-of-sight communication link, either terrestrial or in space.

$$\left[\frac{\mathbf{G}}{\mathbf{T}}\right] = [\boldsymbol{G_R}] - [\boldsymbol{T_S}]$$

$$\left[\frac{C}{N_0}\right] = [\text{EIRP}] + \left[\frac{G}{T}\right] - [\text{LOSSES}] - [\text{K}] - [B_N]$$

The ratio of carrier power to noise power density P_R/N_0 may be the quantity actually required.

$$P_N = K\,T_N\,B_N = N_0 B_N$$

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_0 B_N}\right]$$

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_0}\right] - [B_N]$$

$$\left[\frac{\mathbf{C}}{\mathbf{N_0}}\right] = \left[\frac{\mathbf{C}}{\boldsymbol{N}}\right] + [\boldsymbol{B_N}]$$

$$\left[\frac{\mathbf{C}}{\mathbf{N_0}}\right] = [\mathbf{EIRP}] + \left[\frac{\mathbf{G}}{\mathbf{T}}\right] - [\mathbf{LOSSES}] - [\mathbf{K}]$$

$\left[\frac{C}{N}\right]$ Carrier to Noise power in receiving bandwidth (dB):

Allows simple calculation of margin if:

- ✓ Receiver bandwidth is known
- ✓ Required C/N is known for desired signal type.

$\left[\frac{C}{N_0}\right]$ Carrier to Noise power Density (dB Hz):

Allows simple calculation of allowable receiving bandwidth if:

- ✓ Required C/N is known for desired signal type.
- ✓ Critical for calculations involving carrier recovery loop performance calculations.

$\left[\frac{G}{T}\right]$ Receiving Antenna Gain / System Temperature:

- ✓ Also called as system figure of merit
- ✓ Easily describes the sensitivity of a receive system
- ✓ [G/T] degrades for most systems when rain loss increases; this is caused by the increase in the sky noise component. This is in addition to the loss of received power flux density.
- ✓ Most system require C/N>10dB. Usually C > N+10 dB. and T[k] = T[^{o}C] + 27.

SATELLITE UP LINK/ DOWN LINK

UPLINK AND INPUT BACKOFF

- ✓ The uplink of a satellite circuit is the one in which the earth station is transmitting the signal and the satellite is receiving it.

$$\left[\frac{C}{N_0}\right]_U = [\mathrm{EIRP}]_U + \left[\frac{G}{T}\right]_U - [\mathrm{LOSSES}]_U - [\mathrm{K}]$$

- ✓ The uplink is often handled by introducing an intermediate parameter, ψ, the flux density required to produce the maximum or saturated transponder output, P_T, for a single carrier. It is a satellite parameter and its use conveniently separates the required satellite level from the rest of the link.

- ✓ **Travelling Wave Tube Amplifier (TWTA)** in a satellite transponder exhibits power output saturation the flux density required at the receiving antenna to produce saturation of the TWTA is termed as the **Saturation Flux Density**.
- ✓ SFD is a specified quantity in link budget calculation & knowing it, one can calculate the required EIRP at the earth station

$$\varphi_m = \frac{EIRP\ (earth\ station)}{4\pi r^2}$$

In decibel $[\varphi_m] = [EIRP] + 10\log\frac{1}{4\pi r^2}$

But we have free space loss

$$-[FSL] = 10\log\frac{\lambda^2}{4\pi} + 10\log\frac{1}{4\pi r^2}$$

$$-[FSL] - 10\log\frac{\lambda^2}{4\pi} = 10\log\frac{1}{4\pi r^2}$$

Substitute this in above equation gives,

$$[\varphi_m] = [EIRP] - [FSL] - 10\log\frac{\lambda^2}{4\pi}$$

The $\frac{\lambda^2}{4\pi}$ term has dimensions of area, and in fact, it is the effective area of an isotropic antenna.

$$[A_O] = 10\log\frac{\lambda^2}{4\pi}$$

$$[EIRP] = [\varphi_m] + [FSL] + [A_O]$$

Above equation was derived on the basis that the only loss present was the spreading loss, denoted by [FSL]. But, the other propagation losses are the atmospheric absorption loss, the polarization mismatch loss, and the antenna misalignment loss.

$$[EIRP] = [\varphi_m] + [FSL] + [A_O] + [AA] + [PL] + [AML]$$

In terms of the total losses given by

$$[EIRP] = [\varphi_m] + [A_O] + [LOSSES] - [RFL]$$

This is for clear-sky conditions and gives the *minimum* value of [EIRP] which the earth station must provide to produce a given flux density at the satellite. Normally, the saturation flux density will be specified. With saturation values denoted by the subscript *S*.

$$[EIRP]_U = [\varphi_S] + [A_O] + [LOSSES]_U - [RFL]$$

Input back off

As numbers of carriers are present simultaneously in a TWTA, the operating point must be backed off to a linear portion of the transfer characteristic to reduce the effects of intermodulation distortion. Such multiple carrier operation occurs with *frequency division multiple access* (FDMA).

The point to be made here is that *backoff* (B_O) must be allowed for in the link budget calculations. Suppose that the saturation flux density for single-carrier operation is known. Input BO will be specified for multiple-carrier operation, referred to the single-carrier saturation level.

The earth-station EIRP will have to be reduced by the specified BO, resulting in an uplink value of

$$[EIRP]_U = [EIRP_S]_U - [B_O]_i$$

Input BO is normally achieved through reduction of the [EIRP] of the earth stations actually accessing the transponder

$$\left[\frac{\mathrm{C}}{\mathrm{N_0}}\right]_U = [\varphi_S] + [A_O] - [B_O]_i + \left[\frac{\mathrm{G}}{\mathrm{T}}\right]_U - [\mathrm{K}] - [RFL]$$

DOWNLINK AND OUTPUT BACKOFF

The downlink of a satellite circuit is the one in which the satellite is transmitting the signal and the earth station is receiving it. Uplink equation can be applied to the downlink, but subscript *D* will be used to denote specifically that the downlink is being considered.

$$\left[\frac{\mathrm{C}}{\mathrm{N_0}}\right]_D = [\mathrm{EIRP}]_D + \left[\frac{\mathrm{G}}{\mathrm{T}}\right]_D - [\mathrm{LOSSES}]_D - [\mathrm{K}]$$

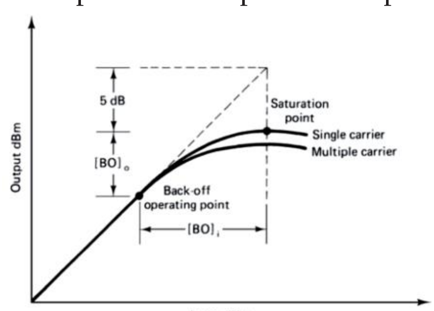
In above Equation, the values to be used are the satellite EIRP, the earth station receiver feeder losses, and the earth-station receiver *G*/*T*. The free space and other losses are calculated for the downlink frequency.

The resulting carrier-to-noise density ratio given by above equation is that which appears at the detector of the earth station receiver. Where the carrier-to-noise ratio is the specified quantity rather than carrier-to-noise density ratio, is used. This becomes, on assuming that the signal bandwidth *B* is equal to the noise bandwidth B_N:

$$\left[\frac{\mathrm{C}}{N}\right]_D = [\mathrm{EIRP}]_D + \left[\frac{\mathrm{G}}{\mathrm{T}}\right]_D - [\mathrm{LOSSES}]_D - [\mathrm{K}] - [B]$$

Output back off

Where input B_O is employed, a corresponding output B_O must be allowed for in the satellite EIRP. A rule of thumb, frequently used, is to take the output B_O as the point on the curve which is 5 dB below the extrapolated linear portion, as shown in Figure. Since the linear portion gives a 1:1 change in decibels, the relationship between input and output B_O is **$[B_O]_0 = [B_O]_i - 5$ dB.**



If the satellite EIRP for saturation conditions is specified as $[EIRP_S]_D$, then

$$[EIRP]_D = [EIRP_S]_D - [B_O]_0$$

and [C/N] Equation becomes

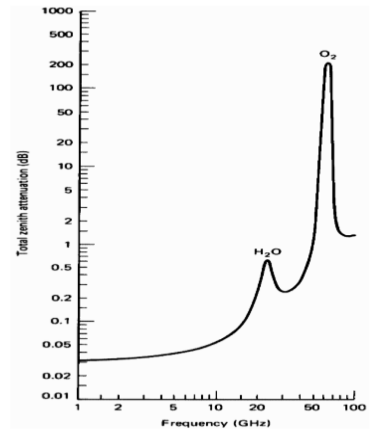
$$\left[\frac{\mathrm{C}}{\mathrm{N_0}}\right]_D = [\mathrm{EIRP}]_D - [\mathrm{B}_o]_D + \left[\frac{\mathrm{G}}{\mathrm{T}}\right]_D - [\mathrm{LOSSES}]_D - [\mathrm{K}]$$

Propagation factors: Atmospheric Losses

Different types of atmospheric losses can perturb radio wave transmission in satellite systems:

- Atmospheric absorption;
- Atmospheric attenuation;
- Traveling ionospheric disturbances.

Radio Propagation: **Atmospheric Absorption**



- Energy absorption by atmospheric gases, which varies with the frequency of the radio waves.

Two absorption peaks are observed:

- 22.3 GHz from resonance absorption in water vapour (H_2O)
- 60 GHz from resonance absorption in oxygen (O_2)

Radio Propagation: **Atmospheric Attenuation**

Rain is the main cause of atmospheric attenuation (hail, ice and snow have little effect on attenuation because of their low water content).

Total attenuation from rain can be determined by:

$$A = \alpha L \text{ [dB]}$$

Where α [dB/km] is called the specific attenuation
L [km] is the effective path length of the signal through the rain; note that this differs from the geometric path length due to fluctuations in the rain density.

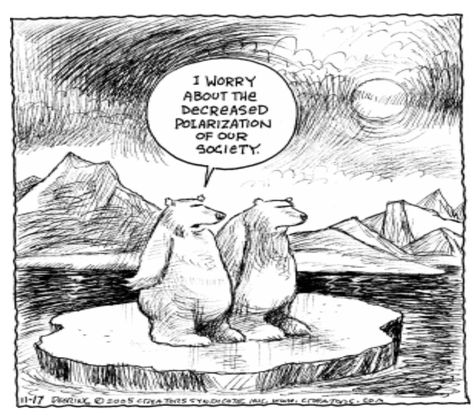
Radio Propagation: **Traveling Ionospheric Disturbances**

Traveling ionospheric disturbances are clouds of electrons in the ionosphere that provoke radio signal fluctuations which can only be determined on a statistical basis.

The disturbances of major concern are:

- Scintillation;
- Polarisation rotation.

Scintillations are variations in the amplitude, phase, polarisation, or angle of arrival of radio waves, caused by irregularities in the ionosphere which change over time. The main effect of scintillations is fading of the signal.



Signal Polarisation: **What is Polarisation?**

Polarisation is the property of electromagnetic waves that describes the direction of the transverse electric field. Since electromagnetic waves consist of an electric and a magnetic field vibrating at right angles to each other it is necessary to adopt a convention to determine the polarisation of the signal. Conventionally, the magnetic field is ignored and the plane of the electric field is used.

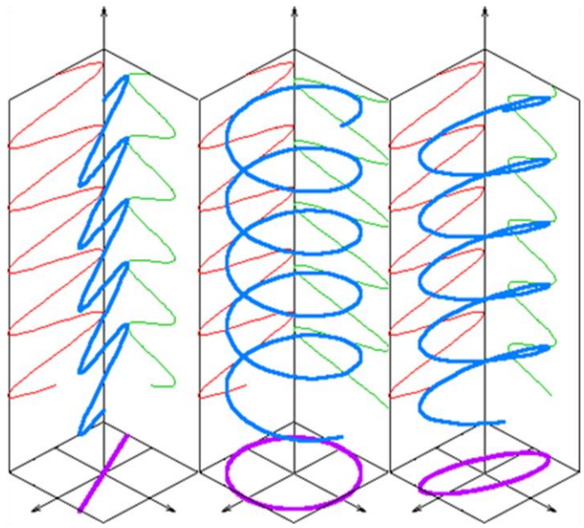
Signal Polarisation: **Types of Polarisation**

Linear Polarisation (horizontal or vertical):

- The two orthogonal components of the electric field are in phase;
- The direction of the line in the plane depends on the relative amplitudes of the two components.

Circular Polarisation:
The two components are exactly 90º out of phase and have exactly the same amplitude.

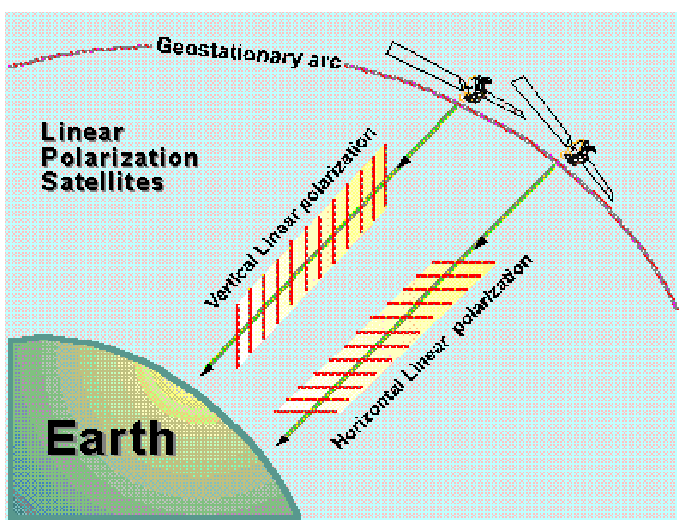
Elliptical Polarisation:
All other cases.



Linear Polarisation Circular Polarisation Elliptical Polarisation

Signal Polarisation: **Satellite Communications**

Alternating vertical and horizontal polarisation is widely used on satellite communications to reduce interference between programs on the same frequency band transmitted from adjacent satellites (one uses vertical, the next horizontal, and so on), allowing for reduced angular separation between the satellites.

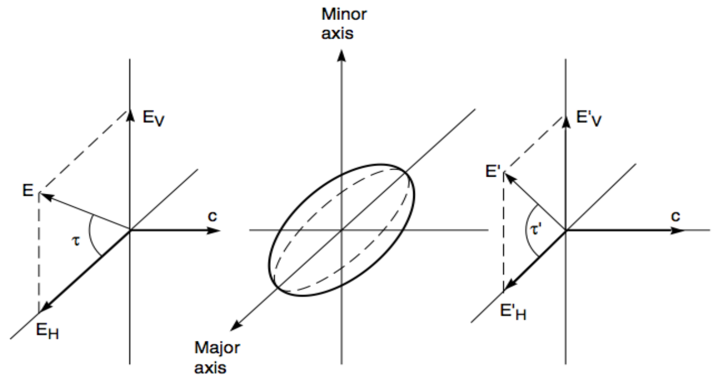


Signal Polarisation: **Depolarisation**

Rain depolarisation:

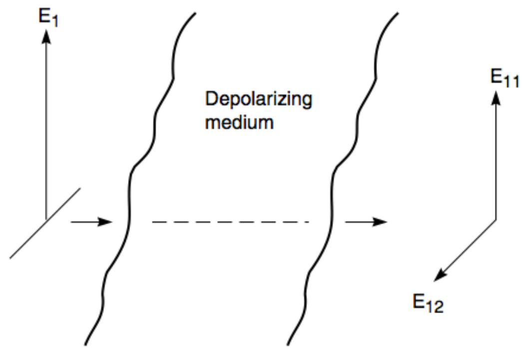
Since raindrops are not perfectly spherical, as a polarised wave crosses a raindrop, one component of the wave will encounter less water than the other component.

There will be a difference in the attenuation and phase shift experienced by each of the electric field components, resulting in the depolarisation of the wave.



Polarisation vector relative to the major and minor axes of a raindrop.

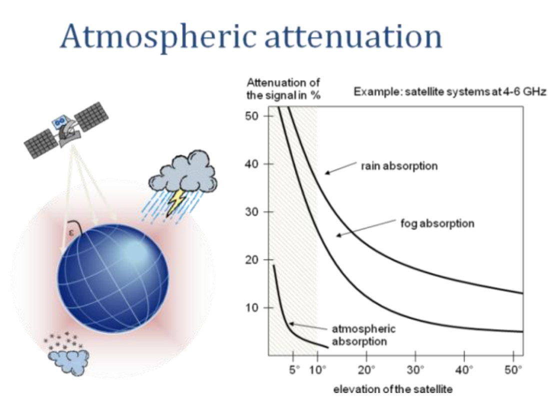
Signal Polarisation: **Cross-Polarisation Discrimination**



Depolarisation can cause interference where orthogonal polarisation is used to provide isolation between signals, as in the case of frequency reuse.

The most widely used measure to quantify the effects of polarisation interference is called Cross-Polarisation Discrimination (XPD):

$$\textbf{XPD} = \textbf{20 log} (E_{11}/E_{12})$$



To counter depolarising effects circular polarising is sometimes used.

Alternatively, if linear polarisation is to be used, polarisation tracking equipment may be installed at the antenna.

EFFECTS OF RAIN

In the C band and, more especially, the Ku band, rainfall is the most significant cause of signal fading. Rainfall results in attenuation of radio waves by scattering and by absorption of energy from the wave.

Rain attenuation increases with increasing frequency and is worse in the Ku band compared with the C band.

This produces a depolarization of the wave; in effect, the wave becomes elliptically polarized. This is true for both linear and circular polarizations, and the effect seems to be much worse for circular polarization (Freeman, 1981).

The $C/N0$ ratio for the downlink alone, not counting the PNU contribution, is PR/PND, and the combined $C/N0$ ratio at the ground receiver is

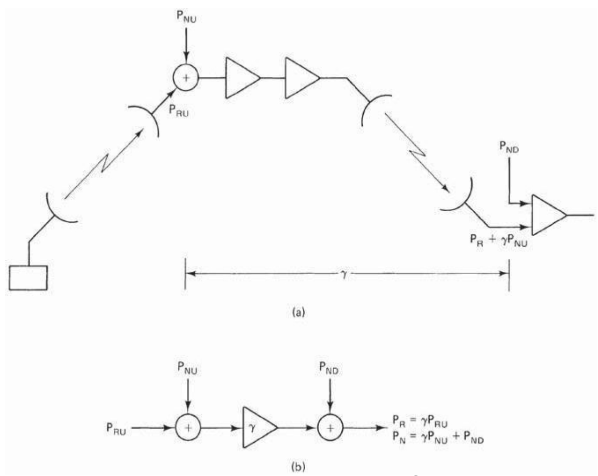


Figure (*a*) Combined uplink and downlink; (*b*) power flow diagram

The reason for this reciprocal of the sum of the reciprocals method is that a single signal power is being transferred through the system, while the various noise powers, which are present are additive. Similar reasoning applies to the carrier-to-noise ratio, C/N.

INTER MODULATION AND INTERFERENCE

Intermodulation interference is the undesired combining of several signals in a nonlinear device, producing new, unwanted frequencies, which can cause interference in adjacent receivers located at repeater sites.Not all interference is a result of intermodulation distortion. It can come from co-channel interference, atmospheric conditions as well as man-made noise generated by medical, welding and heating equipment.

Most intermodulation occurs in a transmitter's nonlinear power amplifier (PA). The next most common mixing point is in the front end of a receiver. Usually it occurs in the unprotected first mixer of older model radios or in some cases an overdriven RF front-end amp.
Intermodulation can also be produced in rusty or corroded tower joints, guy wires, turnbuckles and anchor rods or any nearby metallic object, which can act as a nonlinear "mixer/rectifier" device.

Test Equipment Measurements on G/T, C/No, EIRP:

Measurement of G/T of small antennas is easily and simply measured using the spectrum analyser method. For antennas with a diameter of less than 4.5 meters it is not normally necessary to point off from the satellite.

A step in frequency would be required into one of the satellite transponder guard bands.

However antennas with a G/T sufficiently large to enable the station to see the transponder noise floor either a step in frequency into one of the satellite transponder guard bands and/or in azimuth movement would be required.

The test signal can be provided from an SES WORLD SKIES beacon.

Procedure:

- Set up the test equipment as shown below. Allow half an hour to warm up, and then calibrate in accordance with the manufacturer's procedures

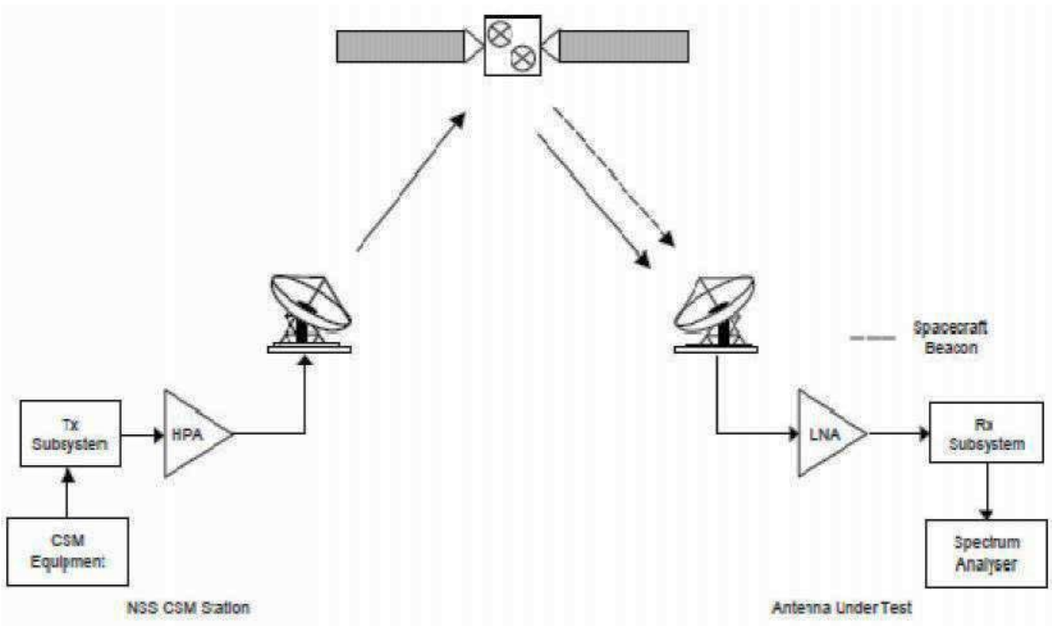


Figure One possible arrangement for Measurement of G/T

- Adjust the centre frequency of your spectrum analyzer to receive the SES WORLD SKIES beacon (data to be provided on the satellite used for testing)
- Carefully peak the antenna pointing and adjust the polarizer by nulling the cross polarized signal. You cannot adjust polarization when using the circularly polarized SES WORLD SKIES beacon.

Configure the spectrum analyser as follows:

Centre Frequency: Adjust for beacon or test signal frequency (to be advised).
Use marker to peak and marker to centre functions.

- Frequency Span: 100 KHz
- Resolution Bandwidth: 1 KHz
- Video Bandwidth: 10 Hz (or sufficiently small to limit noise variance)
- Scale: 5 dB/div
- Sweep Time: Automatic
- Attenuator Adjust to ensure linear operation. Adjust to provide the "Noise floor delta" described in steps 7 and 8.

- To insure the best measurement accuracy during the following steps, adjust the spectrum analyser amplitude (reference level) so that the measured signal, carrier or noise, is approximately one division below the top line of the spectrum analyser display.

- Record the frequency and frequency offset of the test signal from the nominal frequency:

  For example, assume the nominal test frequency is 11750 MHz but the spectrum analyser shows the peak at 11749 MHz. The frequency offset in this case is -1 MHz.

- Change the spectrum analyser centre frequency as specified by SES WORLD SKIES so that the measurement is performed in a transponder guard band so that only system noise power of the earth station and no satellite signals are received. Set the spectrum analyser frequency as follows:

  Centre Frequency = Noise slot frequency provided by the PMOC

- Disconnect the input cable to the spectrum analyser and confirm that the noise floor drops by at least 15 dB but no more than 25dB. This confirms that the spectrum analyser's noise contribution has an insignificant effect on the measurement. An input attenuation value allowing a "Noise floor Delta" in excess of 25 dB may cause overloading of the spectrum analyser input. (i) Reconnect the input cable to the spectrum analyser.

- Activate the display line on the spectrum analyser.

- Carefully adjust the display line to the noise level shown on the spectrum analyser. Record the display line level.
- Adjust the spectrum analyser centre frequency to the test carrier frequency recorded in step previous step.
- Carefully adjust the display line to the peak level of the test carrier on the spectrum analyser. Record the display line level.
- Determine the difference in reference levels between steps (l) and (j) which is the (C+N)/N.
- Change the (C+N)/N to C/N by the following conversion:
- This step is not necessary if the (C+N)/N ratio is more than 20 dB because the resulting correction is less than 0.1 dB.

$$\left(\frac{C}{N}\right) = 10\log_{10}\left(10^{\frac{\left(\frac{C+N}{N}\right)}{10}} - 1\right) \quad \text{dB}$$

- Calculate the carrier to noise power density ratio (C/No) using:

$$\left(\frac{C}{No}\right) = \left(\frac{C}{N}\right) - 2.5 + 10\log_{10}(RBW \ \ x \ \ SA_{corr}) \quad \text{dB}$$

The 2.5 dB figure corrects the noise power value measured by the log converters in the spectrum analyser to a true RMS power level, and the SA correction factor takes into account the actual resolution filter bandwidth

Calculate the G/T using the following:

$$\left(\frac{G}{T}\right) - \left(\frac{C}{No}\right) - (EIRP_{SC} - A_{corr}) + (\Gamma SL + L_a) - 228.6 \quad \text{dB/K}$$

where,

EIRPSC – Downlink EIRP measured by the PMOC (dBW)
Acorr – Aspect correction supplied by the PMOC (dB)

FSL – Free Space Loss to the AUT supplied by the PMOC (dB) La – Atmospheric attenuation supplied by the PMOC (dB)

- Repeat the measurement several times to check consistency of the result.

Antenna Gain:

Antenna gain is usually **defined** as the ratio of the power produced by the **antenna** from a far-field source on the **antenna's** beam axis to the power produced by a hypothetical lossless isotropic **antenna**, which is equally sensitive to signals from all directions.

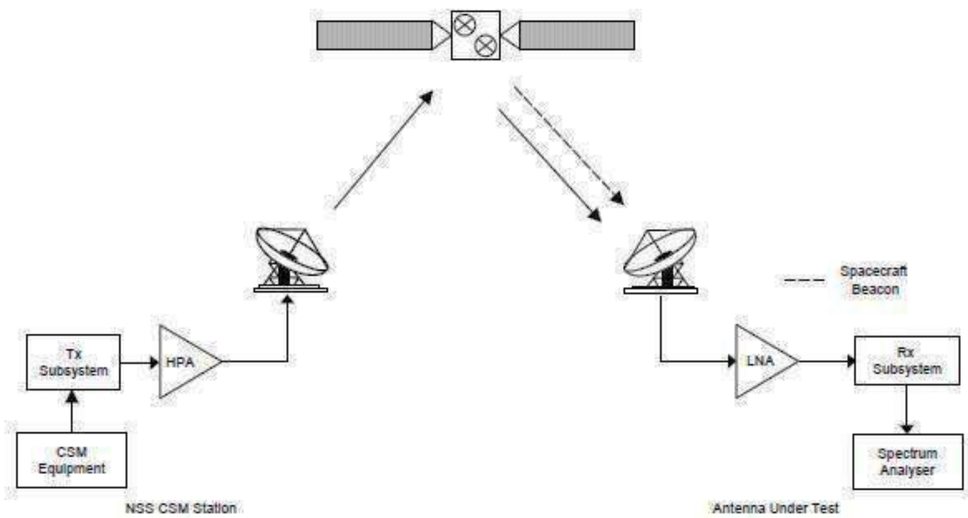


Figure One possible arrangement for Measurement of Antenna Gain

Two direct methods of measuring the Rx gain can be used; integration of the Rx side lobe pattern or by determination of the 3dB and 10dB beamwidths.

The use of pattern integration will produce the more accurate results but would require the AUT to have a tracking system. In both cases the test configurations for measuring Rx gain are identical, and are illustrated in Figure.

In order to measure the Rx gain using pattern integration the AUT measures the elevation and azimuth narrowband (±5° corrected) sidelobe patterns.

The AUT then calculates the directive gain of the antenna through integration of the sidelobe patterns. The Rx gain is then determined by reducing the directive gain by the antenna inefficiencies.

In order to measure the Rx gain using the beamwidth method, the AUT measures the corrected azimuth and elevation 3dB/10dB beamwidths. From these results the Rx gain of the antenna can be directly calculated using the formula below.

$$G = 10\mathrm{Log}_{10}\left[\frac{1}{2}\left(\frac{31000}{(Az_3)(El_3)} + \frac{91000}{(Az_{10})(El_{10})}\right)\right] - F_{Loss} - R_{Loss}$$

where:

G is the effective antenna gain (dBi)
Az3 is the corrected azimuth 3dB beamwidth (°) El3
is the elevation 3dB beamwidth (°)
Az10 is the corrected azimuth 10dB beamwidth (°)
El10 is the elevation 10dB beamwidth (°)
FLoss is the insertion loss of the feed (dB)

RLoss is the reduction in antenna gain due to reflector inaccuracies, and is given by:

RLoss =4.922998677(Sdev f)2 dB

where:

Sdev is the standard deviation of the actual reflector surface (inches)
f is the frequency (GHz)

SYSTEM RELIABILITY AND DESIGN LIFETIME

SYSTEM RELIABILITY

Satellites are designed to operate dependably throughout their operational life, usually a number of years. This is achieved through stringent quality control and testing of parts and subsystems before they are used in the construction of the satellite.

Redundancy of key components is often built in so that if a particular part or subassembly fails, another can perform its functions.In addition, hardware and software on the satellite are often designed so that ground controllers can reconfigure the satellite to work around a part that has failed.

DESIGN LIFETIME

The Milstar constellation has demonstrated exceptional reliability and capability, providing vital protected communications to the warfighter," said Kevin Bilger, vice president and general manager, Global Communications Systems, Lockheed Martin Space Systems in Sunnyvale. "Milstar's robust system offers our nation worldwide connectivity with flexible, dependable and highly secure satellite communications."

The five-satellite Milstar constellation has surpassed 63 years of combined successful operations, and provides a protected, global communication network for the joint forces of the U.S. military. In addition, it can transmit voice, data, and imagery, and offers video teleconferencing capabilities.

The system is the principal survivable, endurable communications structure that the President, the Secretary of Defense and the Commander, U.S. Strategic Command use to maintain positive command and control of the nation's strategic forces.In addition to this 10-year milestone for Flight-5, each of the first two Milstar satellites have been on orbit for over 16 years – far exceeding their 10-year design life.

The next-generation Lockheed Martin-built Advanced EHF satellites, joining the Milstar constellation, provide five times faster data rates and twice as many connections, permitting transmission of strategic and tactical military communications, such as real-time video, battlefield maps and targeting data. Advanced EHF satellites are designed to be fully interoperable and backward compatible with Milstar.

Headquartered in Bethesda, Md., Lockheed Martin is a global security company that employs about 123,000 people worldwide and is principally engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services. The Corporation's net sales for 2011 were $46.5 billion.

UNIT IV

SATELLITE ACCESS AND CODING TECHNIQUES

Modulation and Multiplexing: Voice, Data, Video, and Analog – Digital Transmission System, Digital Video Broadcast, Multiple Access: FDMA, TDMA, CDMA, DAMA Assignment Methods, Compression – Encryption, Coding Schemes.

4.1 INTRODUCTION TO MODULATION AND MULTIPLEXING

Communications satellites are used to carry telephone, video, and data signals, and can use both analog and digital modulation techniques.

Modulation:

Modification of a carrier's parameters (amplitude, frequency, phase, or a combination of them) in dependence on the symbol to be sent.

Multiplexing:

Task of multiplexing is to assign space, time, frequency, and code to each communication channel with a minimum of interference and a maximum of medium utilization Communication channel refers to an association of sender(s) and receiver(s) that want to exchange data one of several constellations of a carrier's parameters defined by the used modulation scheme.

Voice, Data, Video:

The modulation and multiplexing techniques that were used at this time were analog, adapted from the technology developed for the change to digital voice signals made it easier for long-distance.

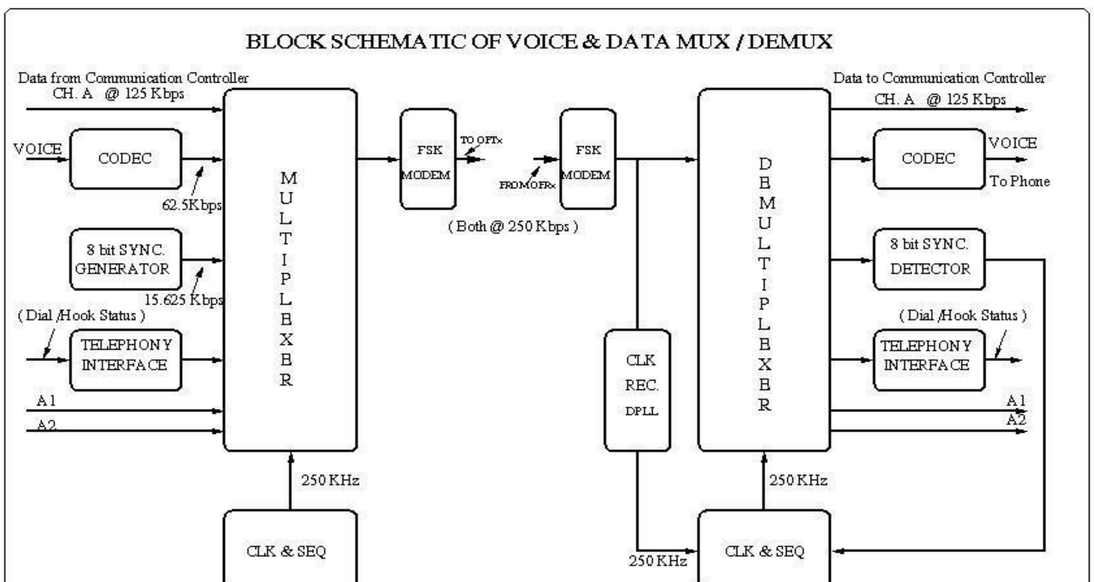


Fig 4.1 Modulation and Multiplexing: Voice/Data/Video

Communication carriers to mix digital data and telephone Fiber-optic Cable Transmission Standards System Bit rate (Mbps) 64 - kbps Voice channel capacity Stuffing bits and words are added to the satellite data stream as needed to fill empty bit and word spaces.

Primarily for video provided that a satellite link's overall carrier-to-noise but in to older receiving equipment at System and Satellite Specification Ku-band satellite parameters.

Modulation and Multiplexing:

In analog television (TV) transmission by satellite, the baseband video signal and one or two audio subcarriers constitute a composite video signal.

Digital modulation is obviously the modulation of choice for transmitting digital data are digitized analog signals may conveniently share a channel with digital data, allowing a link to carry a varying mix of voice and data traffic.

Digital signals from different channels are interleaved for transmission through time division multiplexing TDM carry any type of traffic â€” the bent pipe transponder that can carry voice, video, or data as the marketplace demands.

Hybrid multiple access schemes can use time division multiplexing of baseband channels which are then modulate.

4.1.1 ANALOG – DIGITAL TRANSMISSION SYSTEM:

Analog vs. Digital Transmission:
Compare at two levels:

1. Data—continuous (audio) vs. discrete (text)
2. Signaling—continuously varying electromagnetic wave vs. sequence of voltage pulses.

Also Transmission—transmits without regard to signal content vs. being concerned with signal content. Difference in how attenuation is handled, but not focus on this.

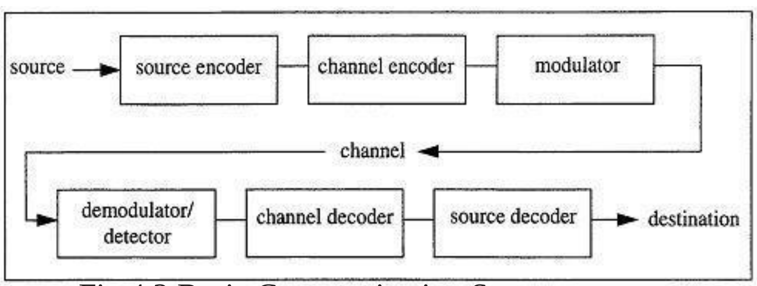


Fig 4.2 Basic Communication Systems

Seeing a shift towards digital transmission despite large analog base. Because of

- Improving digital technology
- Data integrity. Repeaters take out cumulative problems in transmission. Can thus transmit longer distances.
- Easier to multiplex large channel capacities with digital
- Easy to apply encryption to digital data
- Better integration if all signals are in one form. Can integrate voice, video and digital data.

4.1.2 DIGITAL DATA/ANALOG SIGNALS:

Must convert digital data to analog signal such device is a modem to translate between bit-serial and modulated carrier signals?

- To send digital data using analog technology, the sender generates a carrier signal at some continuous tone (e.g. 1-2 kHz in phone circuits) that looks like a sine wave. The following techniques are used to encode digital data into analog signals.

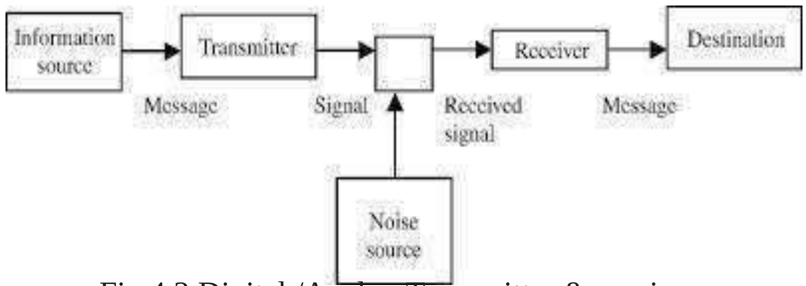


Fig 4.3 Digital /Analog Transmitter & receiver

Resulting bandwidth is centered on the carrier frequency.

- Amplitude-shift modulation (keying): vary the amplitude (e.g. voltage) of the signal. Used to transmit digital data over optical fiber.
- Frequency-shift modulation: two (or more tones) are used, which are near the carrier frequency. Used in a full-duplex modem (signals in both directions).
- Phase-shift modulation: systematically shift the carrier wave at uniformly spaced intervals.

For instance, the wave could be shifted by 45, 135, 225, 315 degree at each timing mark. In this case, each timing interval carries 2 bits of information.

Why not shift by 0, 90, 180, 270? Shifting zero degrees means no shift, and an extended set of no shifts leads to clock synchronization difficulties.
Frequency division multiplexing (FDM): Divide the frequency spectrum into smaller sub channels, giving each user exclusive use of a sub channel (e.g., radio and TV). One problem with FDM is that a user is given all of the frequency to use, and if the user has no data to send, bandwidth is wasted — it cannot be used by another user.

Time division multiplexing (TDM): Use time slicing to give each user the full bandwidth, but for only a fraction of a second at a time (analogous to time sharing in operating systems). Again, if the user doesn't have data to sent during his time slice, the bandwidth is not used (e.g., wasted).

Statistical multiplexing: Allocate bandwidth to arriving packets on demand. This leads to the most efficient use of channel bandwidth because it only carries useful data.That is, channel bandwidth is allocated to packets that are waiting for transmission, and a user generating no packets doesn't use any of the channel resources.

Digital Video Broadcasting (DVB):

Digital Video Broadcasting (DVB) has become the synonym for digital television and for data broadcasting world-wide.

DVB services have recently been introduced in Europe, in North- and South America, in Asia, Africa and Australia.

This article aims at describing what DVB is all about and at introducing some of the technical background of a technology that makes possible the broadcasting.

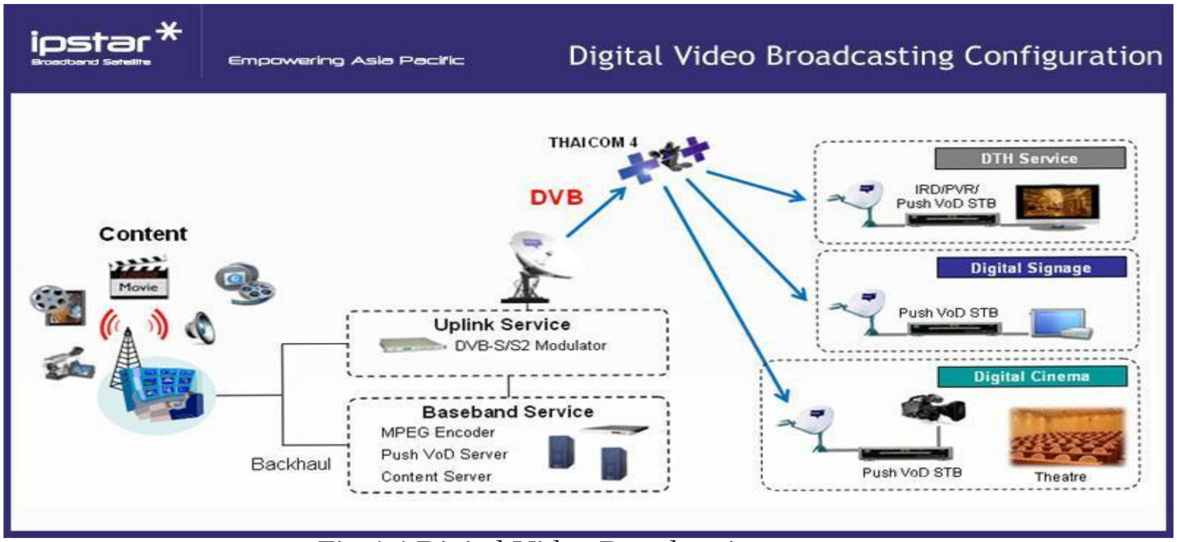


Fig 4.4 Digital Video Broadcasting systems

4.2 DUPLEXING

For voice or data communications, must assure two way communication (duplexing, it is possible to talk and listen simultaneously). Duplexing may be done using frequency or time domain techniques.

- Forward (downlink) band provides traffic from the BS to the mobile
- Reverse (uplink) band provides traffic from the mobile to the BS.

FREQUENCY DIVISION DUPLEXING (FDD):

Provides two distinct bands of frequencies for every user, o ne for downlink and one for uplink. A large interval be tween these frequency bands must be allowed so that interference is minimized.

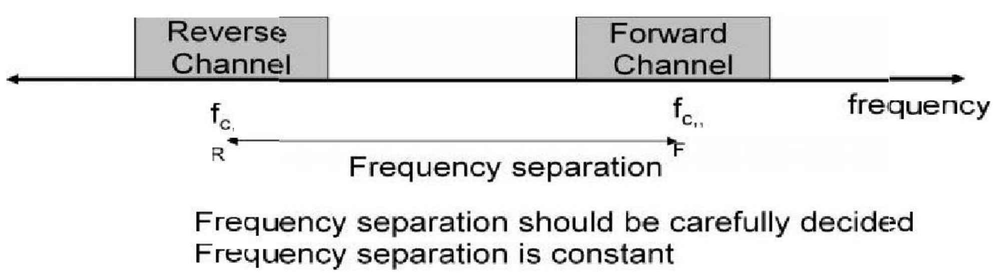


Fig 4.5 Frequency Separation

TIME DIVISION DUPLEXING (TDD):

In TDD communications, both directions of transmission use one contiguous frequency allocation, but two separate time slots to provide both a forward and reverse link.

Because transmission from mobile to BS and from BS to mobile alternates in time, this scheme is also known as “ping pong”.

As a consequence of the use of the same frequency band, the communication quality in both directions is the same. This is different from FDD.

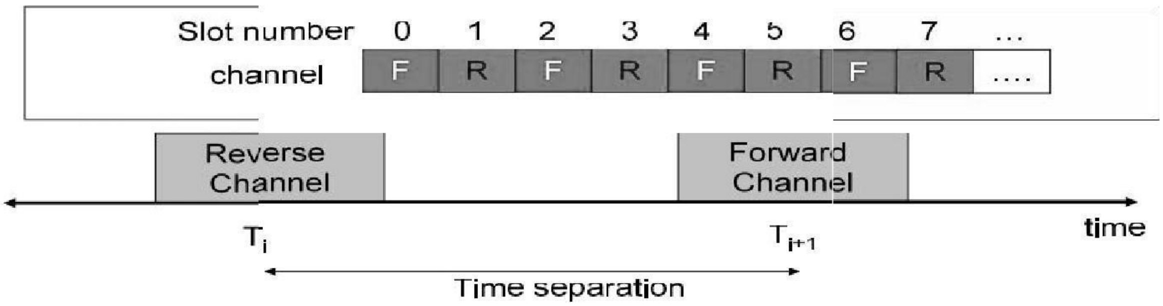


Fig 4.6 Time Slot

4.3 SINGLE ACCESS

With single access, a single modulated carrier occupies the whole of the available bandwidth of a transponder. Single-access operation is used on heavy-traffic routes and requires large earth station antennas.

The earth station employs a 30-m-diameter antenna and a parametric amplifier, which together provide a minimum [G/ T] of 37.5 dB/K.

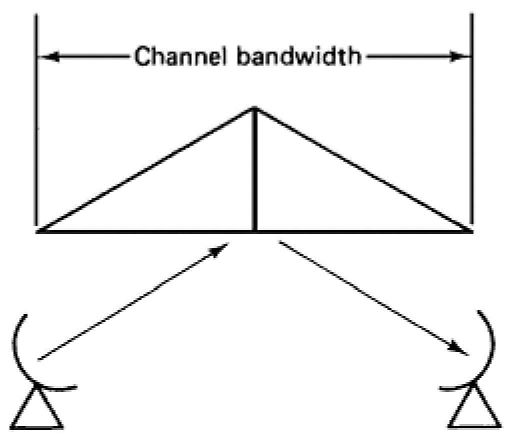


Fig 4.7 Frequency Modulation Single Access.

4.4 MULTIPLE ACCESS TECHNIQUES

With the increase of channel demands and the number of earth stations, efficient use of a satellite transponder in conjunction with many stations has resulted in the development of multiple access techniques. Multiple access is a technique in which the satellite resource (bandwidth or time) is divided into a number of nonoverlapping segments and each segment is allocated exclusively to each of the large number of earth stations who seek to communicate with each other.

There are three known multiple access techniques. They are:

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

The transmission from the BS in the downlink can be heard by each and every mobile user in the cell, and is referred as broadcasting. Transmission from the mobile users in the uplink to the BS is many-to-one, and is referred to as multiple access.
Multiple access schemes to allow many users to share simultaneously a finite amount of radio spectrum resources. Should not result in severe degradation in the performance of the system as compared to a single user scenario. Approaches can be broadly grouped into two categories: narrowband and wideband.
Multiple Accessing Techniques : with possible conflict and conflict- free

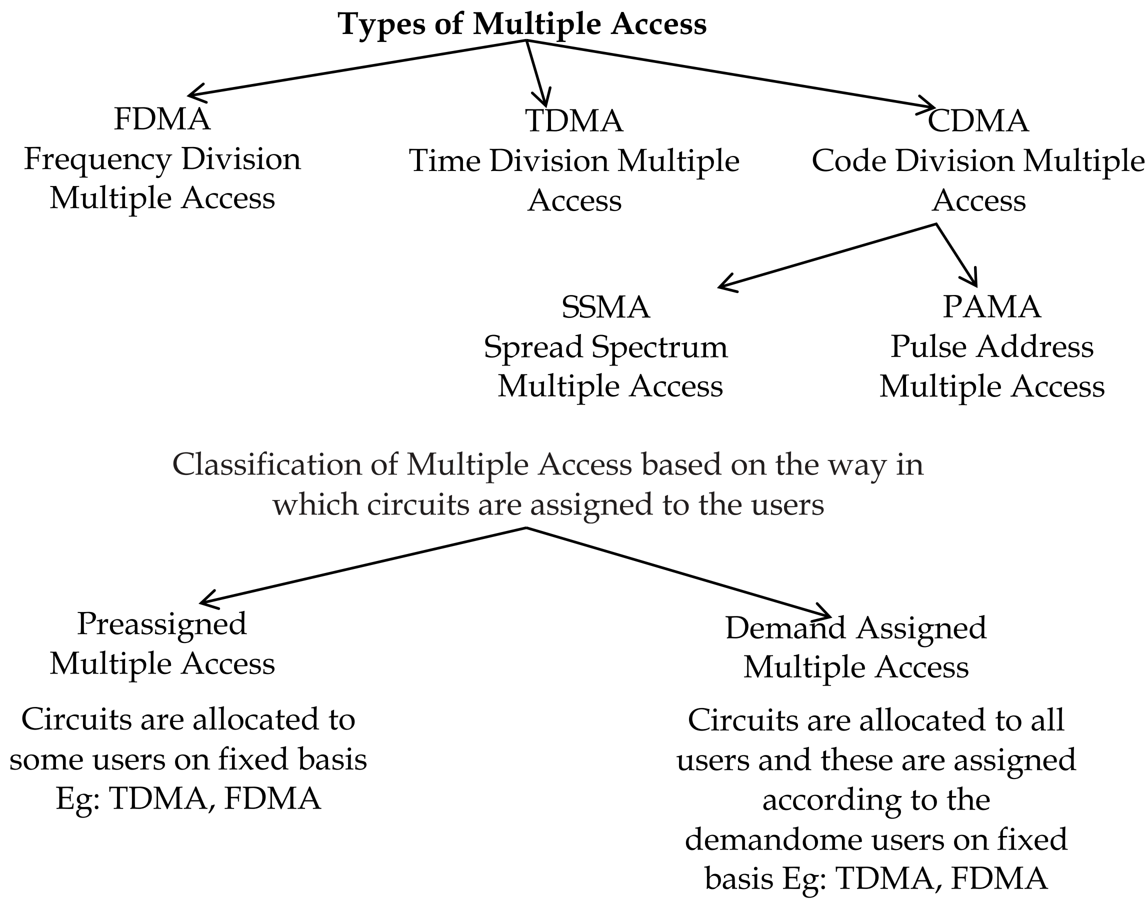


Fig 4.8 Types of Multiple Access

4.4.1 FREQUENCY DIVISION MULTIPLE ACCESS: (FDMA)

The most widely used of the multiple access techniques is FDMA. In FDMA, the available satellite bandwidth is divided into portions of non-overlapping frequency slots which are assigned exclusively to individual earth stations. A basic diagram of an FDMA satellite system is shown in Fig.

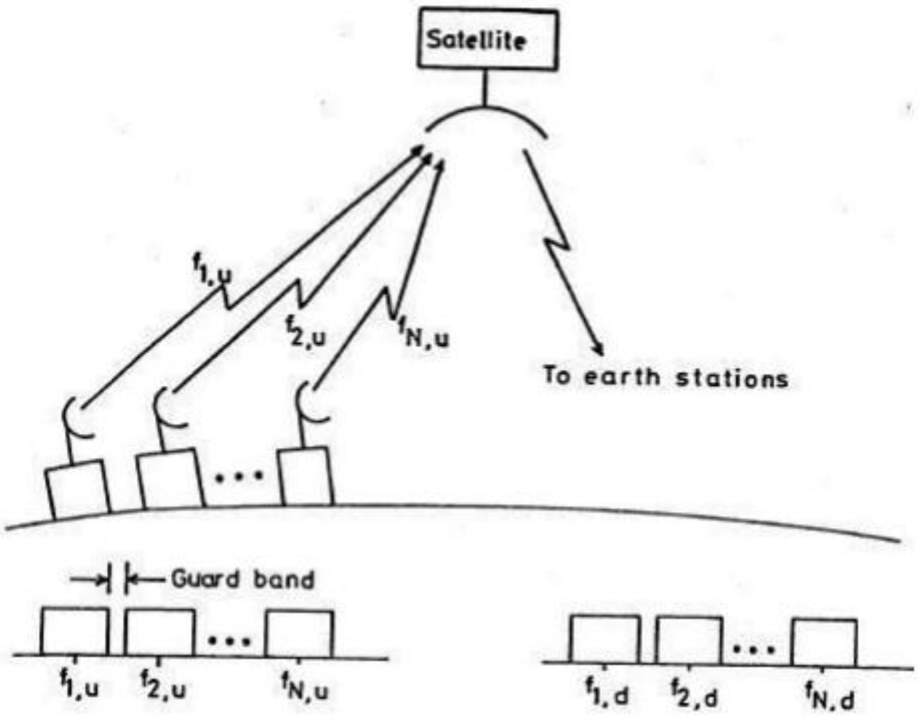


Fig 4.9 FDMA Satellie System

In FDMA, each user is allocated a unique frequency band or channel. During the period of the call, no other user can share the same frequency band.

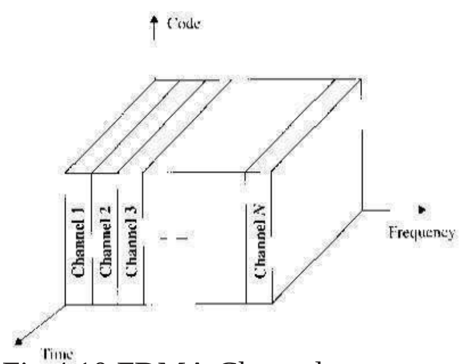


Fig 4.10 FDMA Channels

- All channels in a cell are available to all the mobiles. Channel assignment is carried out on a first-come first- served basis.
- The number of channels, given a frequency spectrum BT, depends on the modulation technique (hence Bw or Bc) and the guard bands between the channels guard.

- These guard bands allow for imperfect filters and oscillators and can be used to minimize adjacent channel interference.

- FDMA is usually implemented in narrowband systems.

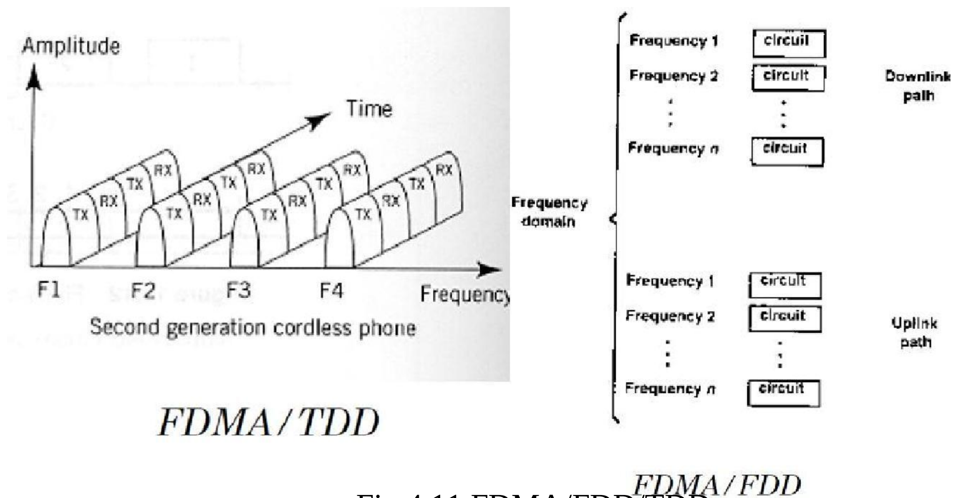


Fig 4.11 FDMA/FDD/TDD

Examples of this technique are

1. FDM/FM/FDMA used in INTELSAT II & III and SCPC satellite systems.
2. SPACE (signal-channel-per-carrier PCM multiple access demand assignment equipment) used in INTELSAT IV in which channels are assigned on demand to earth stations is considered as a FDMA system.

In FDMA systems, multiple signals from the same or different earth stations with different carrier frequencies are simultaneously passed through a satellite transponder. Because of the nonlinear mode of the transponder, FDMA signals interact with each other causing intermodulation products (intermodulation noise) which are signals at all combinations of sum and difference frequencies as shown in the example given in Fig.

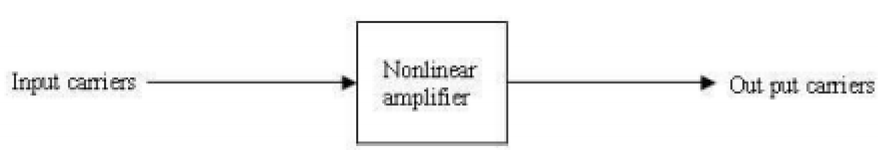


Fig 4.12 FDMA Non Linear Amplifier

The power of these intermodulation products represents a loss in the desired signal power. In addition, if these intermodulation products appear within the bandwidth of the other signals, they act as interference for these signals and as a result the BER performances will be degraded. The other major disadvantage of the FDMA system is the need for accurate uplink power control among network stations in order to mitigate the weak signal suppression effect caused by the disproportionate power sharing of the transponder power.

Nonlinear effects in FDMA:

- In a FDMA system, many channels share the same antenna at the BS. The power amplifiers or the power combiners, when operated at or near saturation are nonlinear.
- The nonlinear ties generate inter-modulation frequencies.
- Undesirable harmonics generated outside the mobile radio band cause interference to adjacent services.
- Undesirable harmonics present inside the band cause interference to other users in the mobile system.

Forms of DMA:

1. Fixed-assignment multiple access (FAMA)
   - The assignment of capacity is distributed in a fixed manner among multiple stations
   - Demand may fluctuate
   - Results in the significant underuse of capacity

2. Demand-assignment multiple access (DAMA)
   - Capacity assignment is changed as needed to respond optimally to demand changes amon the multiple stations

Pre Assignmed FDMA:

Frequency slots may be preassigned to analog and digital signals, and to illustrate the method, analog signals in the FDM/FM/FDMA format will be considered first. As the acronyms indicate, the signals are frequency-division multiplexed, frequency modulated (FM), with FDMA to the satellite.

For Ex, Consider each earth station will be assumed to transmit a 60-channel supergroup. Each 60-channel supergroup is then frequency modulated onto a carrier which is then upconverted to a frequency in the satellite uplink band.

Figure shows the situation for three earth stations:

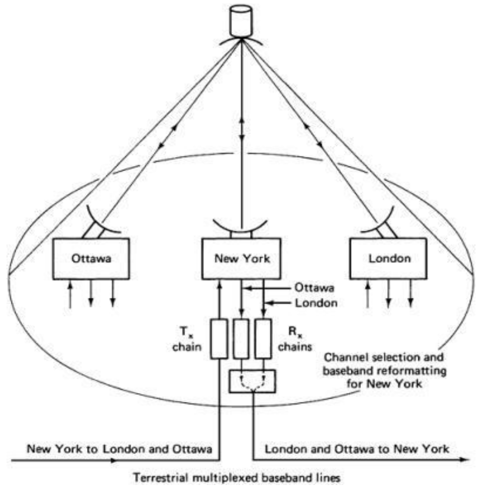


Fig 4.13 Preassigned FDMA System

one in Ottawa, one in New York, and one in London. All three earth stations access a single satellite transponder channel simultaneously, and each communicates with both of the others. Thus it is assumed that the satellite receive and transmit antenna beams are global, encompassing all three earth stations. Each earth station transmits one uplink carrier modulated with a 60-channel supergroup and receives two similar downlink carriers.

Demand Assigned FDMA:

In the demand-assigned mode of operation, the transponder frequency bandwidth is subdivided into a number of channels. A channel is assigned to each carrier in use, giving rise to the single-channel-per-carrier mode of operation discussed in the preceding section.

As in the preassigned access mode, carriers may be frequency modulated with analog information signals, these being designated FM/SCPC, or they may be phase modulated with digital information signals, these being designated as PSK/SCPC.
Demand assignment may be carried out in a number of ways.

1. In the polling method, a master earth station continuously polls all the earth stations in sequence, and if a call request is encountered, frequency slots are assigned from the pool of available frequencies. The polling delay with such a system tends to become excessive as the number of participating earth stations increases.

2. Instead of using a polling sequence, earth stations may request calls through the master earth station as the need arises. This is referred to as **centrally controlled random access.** The requests go over a digital orderwire, which is a narrowband digital radio link or a circuit through a satellite transponder reserved for this purpose. Frequencies are assigned, if available, by the master station, and when the call is completed, the frequencies are returned to the pool. If no frequencies are available, the blocked call requests may be placed in a queue, or a second call attempt may be initiated by the requesting station.

3. As an alternative to centrally controlled is **Distributed Control random Access** (Eg. **SPADE** system operated by INTELSAT on some of its satellite)

SPADE System:

- The word Spade is a loose acronym for **SCPC pulse-code-modulated multiple-access demand-assignment** equipment.
- Spade was developed by Comsat for use on the INTELSAT satellites (see, e.g., Martin, 1978) and is compatible with the INTELSAT SCPC preassigned system.
- However, the distributed-demand assignment facility requires a **common signaling channel (CSC)**. This is shown in Fig.

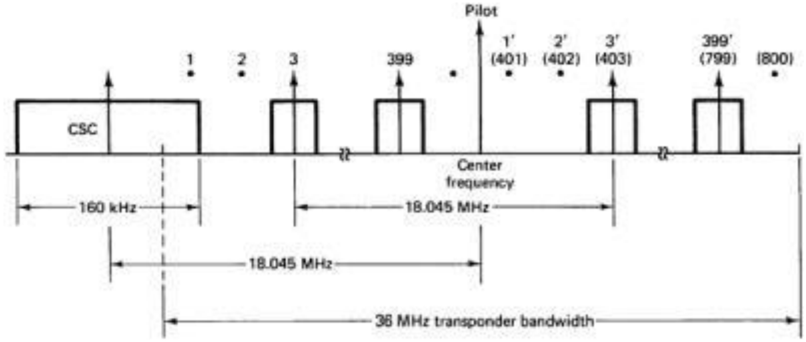


Fig 4.14 Channeling scheme for the Spade system.

- The CSC bandwidth is 160 kHz, and its center frequency is 18.045 MHz below the pilot frequency, as shown in Fig..
- Signaling information is routed through the CSC. Each earth station has DASS unit (Demand Assignment Signaling and Switching unit). It is used to perform the functions needed by the CSC.
- To avoid interference with the CSC, voice channels 1 and 2 are left vacant, and to maintain duplex matching, the corresponding channels 1 and 2 are also left vacant.
- Recalling from previous secetion that channel 400 also must be left vacant, this requires that channel 800 be left vacant for duplex matching.
- Thus six channels are removed from the total of 800, leaving a total of 794 one-way or 397 full-duplex voice circuits, the frequencies in any pair being separated by 18.045 MHz, as shown in Fig. . (An alternative arrangement is shown in Freeman, 1981.)

Channeling Scheme for Spade System:

- All the earth stations are permanently connected through the CSC.
- This is shown diagrammatically in Fig. for six earth stations A, B, C, D, E, and F.
- Each earth station has the facility for generating any one of the 794 carrier frequencies using frequency synthesizers.
- Furthermore, each earth station has a memory containing a list of frequencies available and the list is continuously updated through CSC.

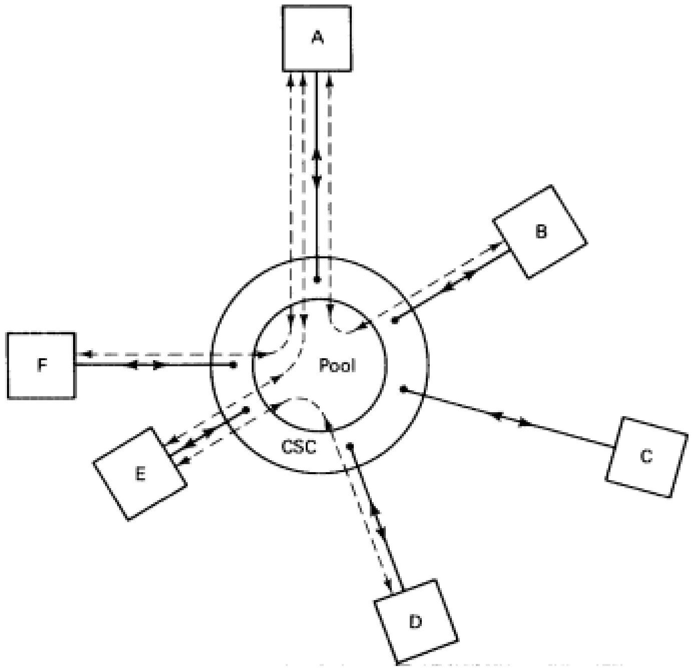


Fig 4.15 Diagrammatic representation of SPADE system

- Suppose that a call to station F is initiated from station C.
- Station C will first select a frequency pair at random from those currently available on the list, and signal this information to station F through the CSC.
- Station F must acknowledge through the CSC, that it can complete the circuit.
- Once the circuit is established, the other stations are instructed, through the CSC, to remove this frequency pair from the list.
- The round trip time between station C initiating the call and the station F acknowledging it is about 600 ms.
- During this time, the two frequencies chosen at station C may be assigned to another circuit.
- In this event, station C will receive the information on the CSC update and will immediately choose another pair at random even before hearing back from station F.
- Once a call has been completed and the circuit disconnected, the two frequencies are returned to the pool, the information again being transmitted through the CSC to all earth stations.
- Each earth station has equipment called the demand assignment signalling and switching unit which performs the function required by the CSC.
- The channel pair is automatically located to an incoming call by a DASS unit. Each SPADE terminal maintains a complete assignment map for the entire system.
- Before a station selects a channel, it first analysis the assignment map, chooses an unused channel and indicates its choices on the DASS network.
- The associated return channel completes the circuit.

4.4.2 TIME DIVISION MULTIPLE ACCESS: (TDMA)

- TDMA systems divide the channel time into frames. Each frame is further partitioned into time slots. In each slot only one user is allowed to either transmit or receive.
- Unlike FDMA, only digital data and digital modulation must be used.
- Each user occupies a cyclically repeating time slot, so a channel may be thought of as a particular time slot of every frame, where *N* time slots comprise a frame.

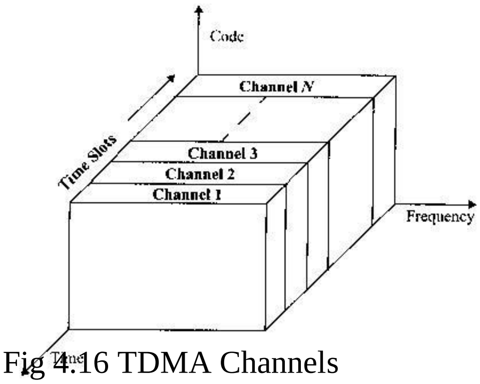


Fig 4.16 TDMA Channels

- With TDMA, only one carrier uses the transponder at any one time, and therefore, intermodulation products, which result from the nonlinear amplification of multiple carriers, are absent.
- This leads to one of the most significant advantages of TDMA, which is that the TWT can be operated at maximum power output or saturation level.
- Because the signal information is transmitted in bursts, TDMA is only suited to digital signals.
- Digital data can be assembled into burst format for transmission and reassembled from the received bursts through the use of digital buffer memories.
- Figure illustrates the basic TDMA concept, in which the stations transmit bursts in sequence.
- Burst synchronization is required, and in the system illustrated in Fig. 14.10, one station is assigned solely for the purpose of transmitting reference bursts to which the others can be synchronized.
- The time interval from the start of one reference burst to the next is termed a frame. A frame contains the reference burst R and the bursts from the other earth stations, these being shown as A, B, and C in Fig. 14.10.

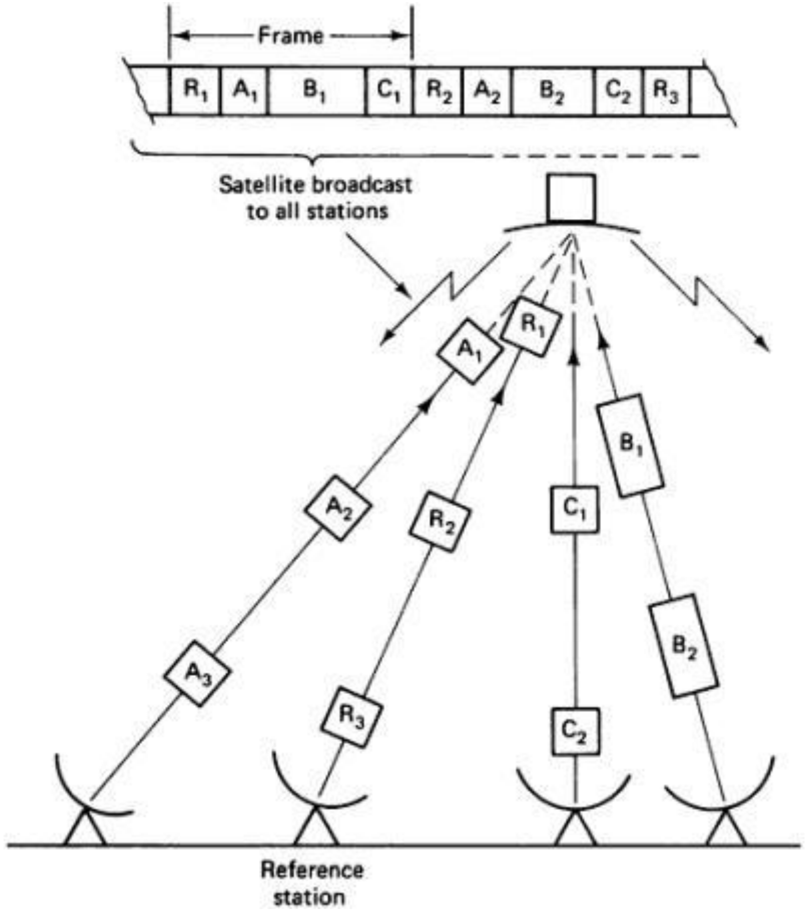


Fig 4.17 Time-division multiple access (TDMA) using a reference station for burst synchronization.

- Figure illustrates the basic principles of burst transmission for a single channel.
- Overall, the transmission appears continuous because the input and output bit rates are continuous and equal.
- However, within the transmission channel, input bits are temporarily stored and transmitted in bursts. Since the time interval between bursts.
- Time interval between Burst is the frame time $T_{F,}$ The required Buffer capacity is

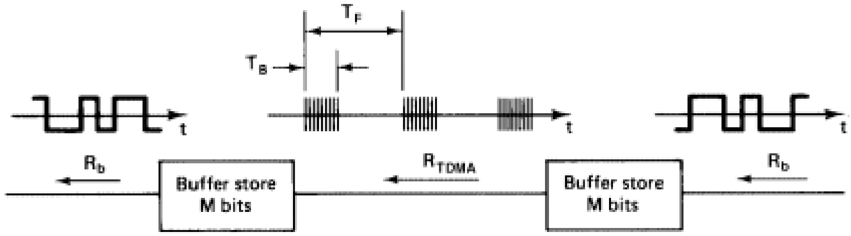
$$M= R_bT_F$$

The M bits are transmitted in the burst time T_B, and the transmission rate (Burst Bit Rate) is

$$R_{TDMA}= M/T_b$$

$$= M (T_F/T_b)$$

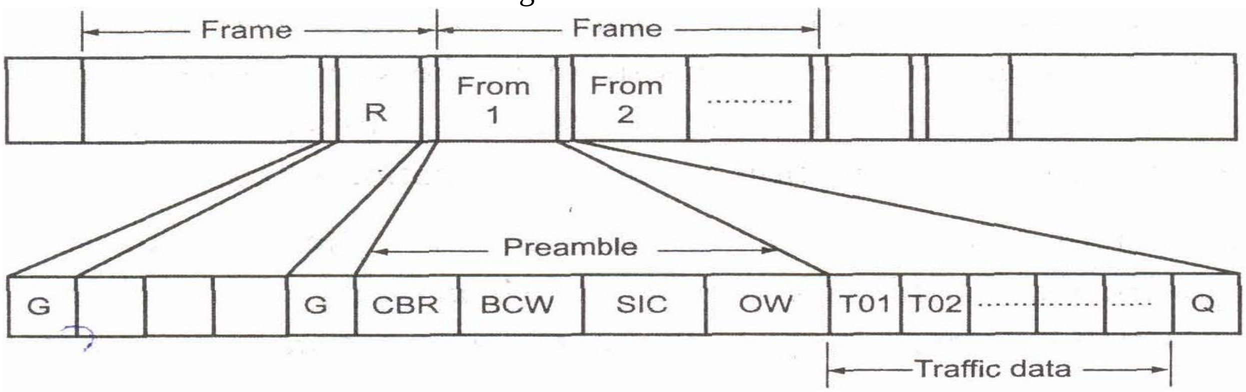
It is also referred to as Burst Rate.



4.18 TDMA Burst Bit Rate

TDMA – Transmission

- In TDMA, the transmit timing of the bursts is accurately synchronized so that the transponder receives one burst at a time.
- Each earth station receives an entire burst stream and extracts the bursts intended for it.
- A frame consists of a number of bursts originating from a community of earth stations in a network.
- A TDMA frame structure is shown in Fig.



Where,

G	– Guard Time
CBR	- Carrier and Bit Timing Recovery
BCW	- Burst Code Word
SIC	- Station Identification Code
Q	- Postamble

Fig 4.19 TDMA Frame Format

- It consists of two reference bursts RB1and RB2, traffic bursts and the guard time between bursts.
- As can be seen, each TDMA frame has two reference bursts RB1 and RB2.
- The primary reference burst (PRB), which can be either RB1 or RB2, is transmitted by one of the earth stations in the network designated as the primary reference earth station.
- For reliability, a second reference burst (SRB) is transmitted by a secondary reference earth station.
- To ensure an undisrupted service for the TDMA network, automatic switchover between these two reference stations is provided.
- The reference bursts carry no traffic information and are used to provide synchronization for all earth stations in the network.
- The traffic bursts carry information from the traffic earth station.
- Each earth station accessing a transponder may transmit one or two traffic bursts per TDMA frame and may position them anywhere in the frame according to a burst time plan that coordinates traffic between earth stations in the network.
- The Guard time between bursts ensures that the bursts never overlap at the input to the transponder.
- The TDMA bursts structure of the reference and traffic burst are given in Fig

Various sequences in the reference burst and traffic burst are as follows:

1. **Carrier and bit timing recovery (CBTR)**
   The CBTR pattern provides information for carrier and timing recovery circuits of the earth station demodulator. The length of the CBTR sequence depends on the carrier-to-noise ratio at the input of the demodulator and the acquisition range. For example, the 120 Mb/s TDMA system of INTELSAT V has a 48 symbol pattern for carrier recovery and a 128 symbol pattern for bit timing recovery.

2. **Unique word (UW)**
   The unique word sequence in the reference burst provides the receive frame timing that allows an earth station to locate the position of a traffic burst in the frame. The UW in the traffic burst marks the beginning of the traffic burst and provides information to an earth station so that it selects only those traffic bursts intended for it. The UW is a sequence of ones and zeros selected to exhibit good correlation properties to enhance detection. The UW of the INTELSAT V TDMA system has a length of 24 symbols.

3. **Teletype (TTY) and voice order wire (VOW)**
   Teletype and voice order wire patterns carry instructions to and from earth stations. The number of symbols for each of the patterns is 8 symbols for the INTELSAT V TDMA.

4. **Service channel (SC)**
   The service channel of the reference burst carriers management instructions such as burst time plan which gives the coordination of traffic between earth stations, i.e. position, length, and source and destination earth stations corresponding to traffic bursts in the TDMA frame.

   The channel also carries monitoring and control information to the traffic stations. The SC of the traffic burst carries the traffic station's status to the reference station (value of transmit delay used and reference station from which the delay is obtained). It also contains other information such as the high bit error rate and UW loss alarms to other traffic stations. The INTELSAT V TDMA has an 8-symbol SC for each of the bursts.

Carrier and bit timing recovery	UW	TTY	Service Channel	VOW	Control and delay channel

a) Reference Burst

Carrier and bit timing recovery	UW	TTY	Service Channel	VOW	Traffic Data
←——— Preamble ———→					

b) Traffic Burst

Fig 4.20 Reference Burst and Traffic Burst

5. **Control and delay channel (CDC)**
   The control and delay channel pattern carries acquisition and synchronization information to the traffic earth stations to enable them to adjust their transmit delays so that bursts arrive at the satellite transponder within the correct time slots in the frame. It also carries the reference station status code which enables them to identify the primary and secondary reference bursts. Eight symbols are allocated for this channel in the INTELSAT V TDMA.

6. **Traffic data**
   This portion contains the information from a source traffic station to a destination traffic station. The informants can be voice, data, video or facsimile signals. The traffic data pattern is divided into blocks of data (referred to as subburst).

The size of each data block is given by:

Subburst size (symbols) = symbol rate (symbols/sec) X frame length (sec).

The INTELSAT TDMA with a frame length of T f = 2 msec for PCM voice data has a subburst size of 64 symbols long.

TDMA- Features:

- Burst transmission since channels are used on a time sharing basis. Transmitter can be turned off during idle periods.
- Multiple channels per carrier or RF channels.
- Narrow or wide bandwidth – depends on factors such as modulation scheme, number of voice channels per carrier channel.
- High ISI – Higher transmission symbol rate, hence resulting in high ISI. Adaptive equalizer required.
- A guard time between the two time slots must be allowed i n order to avoid interference, especially in the uplink direction. All mobiles should synchronize with BS to minimize interference.
- Efficient power utilization: FDMA systems require a 3- to 6-dB power back off in order to compensate for inter-modulation effects.
- Efficient handoff: TDMA systems can take advantage of the fact that the transmitter is switched off during idle time slots to improve the handoff procedure. An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening to neighboring base station during the idle slot of the TDMA frame.
- Efficiency of TDMA
- Efficiency of TDMA is a measure of the percentage of bits per frame which contain transmitted data. The transmitted data include source and channel coding bits.

$$\eta_f = \frac{b_T - b_{OH}}{b_T} * 100\%$$

bOH includes all overhead bits such as preamble, guard bits, etc.

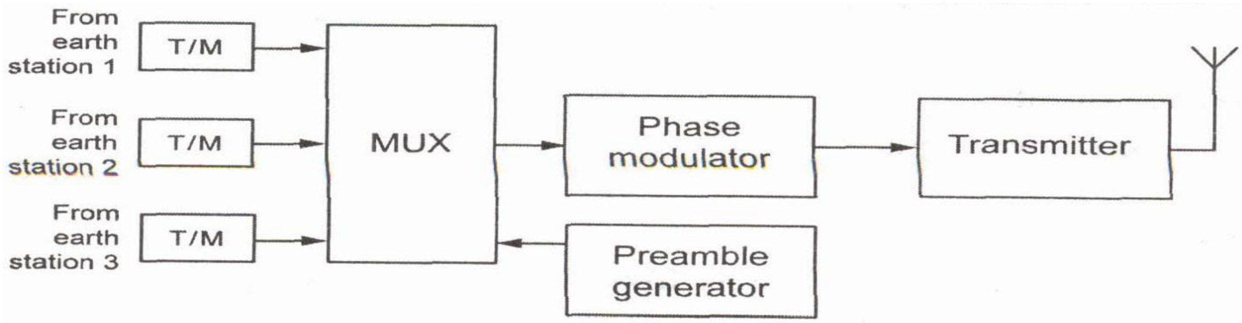


Fig 4.21 Block Diagram- TDMA - transmitter

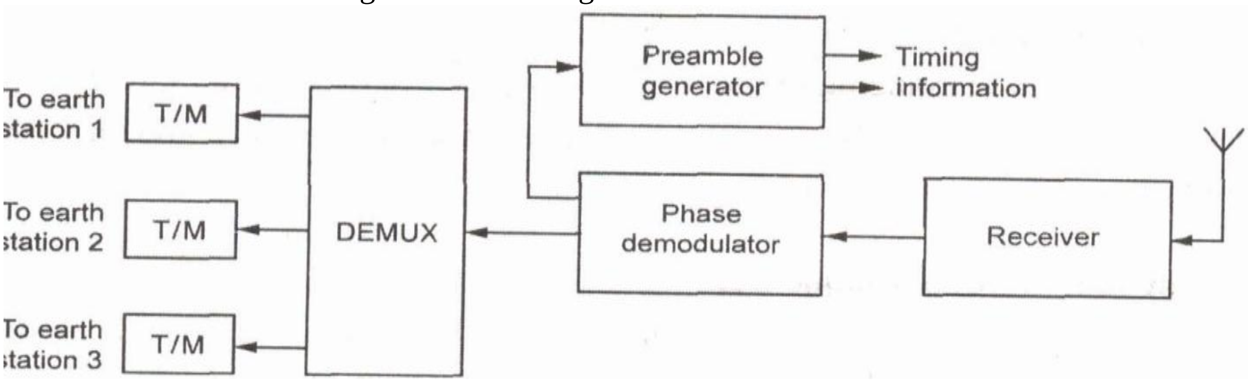


Fig 4.22 Block Diagram- TDMA – Receiver

4.4.3 CODE DIVISION MULTIPLE ACCESS (CDMA):

CDMA Features:

- Spreading signal (code) consists of chips
- Has Chip period and hence, chip rate
- Spreading signal use a pseudo-noise (PN) sequence (a pseudo-random sequence)
- PN sequence is called a code word
- Each user has its own cord word
- Code words are orthogonal. (low autocorrelation)
- Chip rate is order of magnitude larger than the symbol rate.
- The receiver correlator distinguishes the senders signal by examining the wideband signal with the same time-synchronized spreading code
- The sent signal is recovered by dispreading process at the receiver.

CDMA Advantages:

- Low power spectral density.
  Signal is spread over a larger frequency band
  Other systems suffer less from the transmitter

- Interference limited operation
  All frequency spectrum is used

- Privacy
  The code word is known only between the sender and receiver. Hence other users cannot decode the messages that are in transit

- Reduction of multipath affects by using a larger spectrum

CDMA Data:

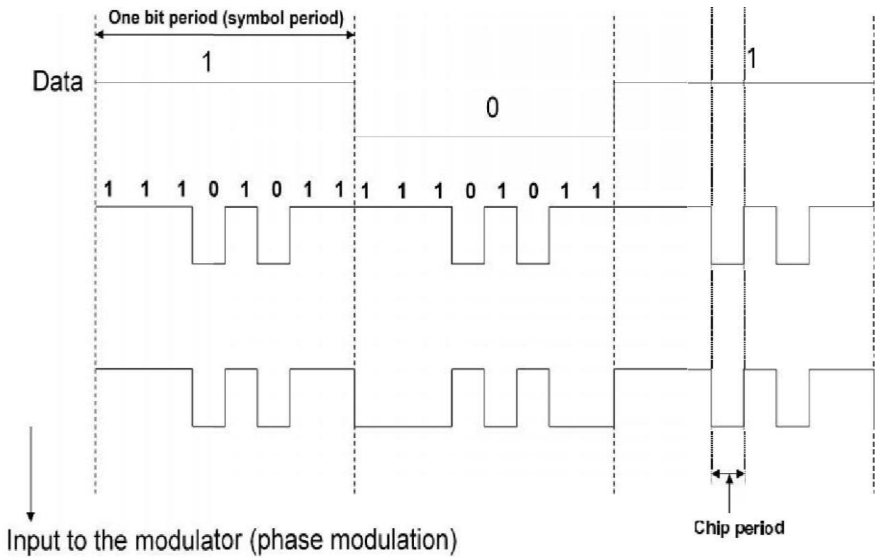
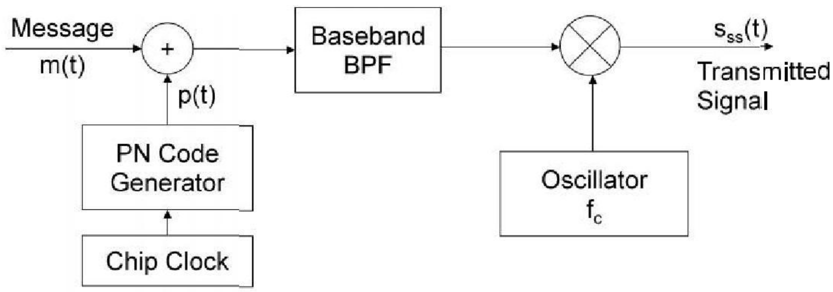


Fig 4.23 CDMA Channels transmission

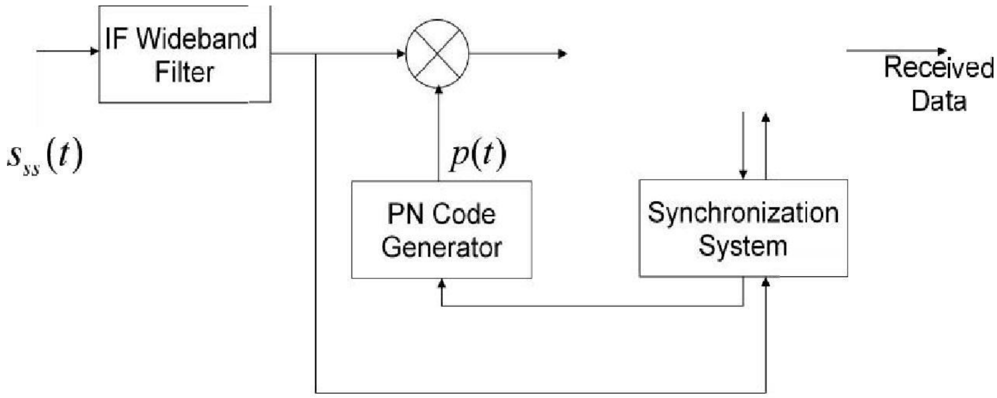
DSSS Transmitter:



$$s_{ss}(t) = \sqrt{\frac{2E_s}{T_s}}\, m(t)\, p(t) \cos(2\pi f_c t + \theta)$$

Fig 4.24 CDMA Transmitter

DSSS Receiver



$$s_1(t) = \sqrt{\frac{2E_s}{T_s}} m(t) \cos(2\pi f_c t + \theta)$$

Fig 4.25 CDMA Receiver

FDMA/CDMA

Available wideband spectrum is frequency divided into number narrowband radio channels. CDMA is employed inside each channel.

DS/FHMA

The signals are spread using spreading codes (direct sequence signals are obtained), but these signal are not transmitted over a constant carrier frequency; they are transmitted over a frequency hopping carrier frequency.

Time Division CDMA (TCDMA)

Each cell is using a different spreading code (C DMA employed between cellss) that is conveyed to the mobiles in its range. Inside each cell (inside a CDMA channel), TDMA is employed to multiplex multiple users.

Time Division Frequency Hopping

- At each time slot, the user is hopped to a new frequency according to a pseudo-random hopping sequence.
- Employed in severe co-interference and multi-path environments. Bluetooth and GSM are using this technique
- A large number of independently steered high-gain beams can be formed without any resulting degradation in SNR ratio.
- Beams can be assigned to individual users, thereby assuring that all links operate with maximum gain.
- Adaptive beam forming can be easily implemented to improve the system capacity by suppressing co channel interference.

Advantage of CDMA

- It is recognized that CDMA's capacity gains over TDMA
- FDMA are entirely due to Its tighter, dynamic control over the use of the power domain.
- Choosing a new non-orthogonal PN sequence a CDMA system does not encounter the difficulties of choosing a spare carrier frequency or time slot to carry a Traffic Channel
- Ensure that interference will not be too great if it begins to transmit -that there is still enough space left in the power domain.

Disadvantages of CDMA:

- Satellite transponders are channelized too narrowly for roadband CDMA, which is the most attractive form of CDMA.
- Power control cannot be as tight as it is in a terrestrial system because of long round-trip delay.

Channel Allocation Schemes:

In radio resource management for wireless and cellular network, channel allocation schemes are required to allocate bandwidth and communication channels to base stations, access points and terminal equipment.

The objective is to achieve maximum system spectral efficiency in bit/s/Hz/site by means of frequency reuse, but still assure a certain grade of service by avoiding co-channel interference and adjacent channel interference among nearby cells or networks that share the bandwidth. There are two types of strategies that are followed:-

Fixed: FCA, fixed channel allocation: Manually assigned by the network operator

Dynamic:

DCA, dynamic channel allocation,
DFS, dynamic frequency selection
Spread spectrum

FCA:

In **Fixed Channel Allocation** or **Fixed Channel Assignment** (FCA) each cell is given a predetermined set of frequency channels.

FCA requires manual frequency planning, which is an arduous task in TDMA and FDMA based systems, since such systems are highly sensitive to co-channel interference from nearby cells that are reusing the same channel. This result in traffic congestion and some calls being lost when traffic gets heavy in some cells, and idle capacity in other cells.

DCA and DFS:

Dynamic Frequency Selection (DFS) may be applied in wireless networks with several adjacent non-centrally controlled access points.

A more efficient way of channel allocation would be **Dynamic Channel Allocation** or **Dynamic Channel Assignment** (DCA) in which voice channel are not allocated to cell permanently, instead for every call request base station request channel from MSC.

Spread Spectrum:

Spread spectrum can be considered as an alternative to complex DCA algorithms. Spread spectrum avoids co channel interference between adjacent cells, since the probability that users in nearby cells use the same spreading code is insignificant.

Thus the frequency channel allocation problem is relaxed in cellular networks based on a combination of Spread spectrum and FDMA, for example IS95 and 3G systems.

In packet based data communication services, the communication is bursty and the traffic load rapidly changing. For high system spectrum efficiency, DCA should be performed on a packet-by-packet basis.

Examples of algorithms for packet-by-packet DCA are **Dynamic Packet Assignment** (DPA), Dynamic Single Frequency Networks (DSFN) and **Packet and resource plan scheduling** (PARPS).

Spread Spectrum Techniques:

In telecommunication and radio communication, spread-spectrum techniques are methods by which a signal (e.g. an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.
These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming, to prevent detection, and to limit power flux density (e.g. in satellite downlinks).

Spread-spectrum telecommunications this is a technique in which a telecommunication signal is transmitted on a bandwidth considerably larger than the frequency content of the original information.

Spread-spectrum telecommunications is a signal structuring technique that employs direct sequence, frequency hopping, or a hybrid of these, which can be used for multiple access and/or multiple functions.

Frequency-hopping spread spectrum (FHSS), direct-sequence spread spectrum (DSSS), time-hopping spread spectrum (THSS), chirp spread spectrum (CSS).

Techniques known since the 1940s and used in military communication systems since the 1950s "spread" a radio signal over a wide frequency range several magnitudes higher than minimum requirement.

Resistance to jamming (interference). DS (direct sequence) is good at resisting continuous-time narrowband jamming, while FH (frequency hopping) is better at resisting pulse jamming.

Resistance to fading. The high bandwidth occupied by spread-spectrum signals offer some frequency diversity, i.e. it is unlikely that the signal will encounter severe multipath fading over its whole bandwidth, and in other cases the signal can be detected using e.g. a Rake receiver.

Multiple access capability, known as code-division multiple access (CDMA) or code-division multiplexing (CDM). Multiple users can transmit simultaneously in the same frequency band as long as they use different spreading codes.

4.5 COMPRESSION

Compression basically employs redundancy in the data.

Type of Compression	Applications
Temporal	1D data, 1D signals, Audio etc.,
Spatial	Correlation between neighboring pixels or data items
Spectral	correlation between color or luminescence components. This uses the frequency domain to exploit relationships between frequency of change in data
Psycho Visual	Exploit perceptual properties of the human visual system.

Compression can be categorised in two broad ways:

Lossless Compression :
where data is compressed and can be reconstituted (uncompressed) without loss of detail or information. These are referred to as bit-preserving or reversible compression systems also.

Lossy Compression :
where the aim is to obtain the best possible fidelity for a given bit-rate or minimizing the bit-rate to achieve a given fidelity measure. Video and audio compression techniques are most suited to this form of compression.

If an image is compressed it clearly needs to uncompressed (decoded) before it can viewed/listened to. Some processing of data may be possible in encoded form however. Lossless compression frequently involves some form of entropy encoding and are based in information theoretic techniques.

Lossy compression use source encoding techniques that may involve transform encoding, differential encoding or vector quantization.

4.5.2 MPEG COMPRESSION STANDARDS

MPEG is a group within the International Standards Organization and the International Electrochemical Commission (ISO/IEC) that undertook the job of defining standards for the transmission and storage of moving pictures and sound.

The standards are concerned only with the bit stream syntax and the decoding process, not with how encoding and decoding might be implemented. Syntax covers matters such as bit rate, picture resolution, time frames for audio, and the packet details for transmission.

The design of hardware for the encoding and decoding processes is left to the equipment manufacturer. The MPEG standards currently available are MPEG-1, MPEG-2, MPEG-4, MPEG-7 and MPEG-21.

Standard	Application
MPEG-1	The original standard for encoding and decoding streaming video and audio files.
MPEG-2	The standard for digital television, this compresses files for transmission of high-quality video.
MPEG-4	The standard for compressing high-definition video into smaller-scale files that stream to computers, cell phones and PDAs (personal digital assistants).
MPEG-7	It is a multimedia content description standard This description will be associate with the content itself, to allow fast and efficient searching for material that is of interest to the user.
MPEG-21	It is also referred to as the Multimedia Framework. The standard that interprets what digital content to provide to which individual user so that media plays flawlessly under any language, machine or user conditions

MPEG – 1

In Digital Broadcast Service (DBS) systems, MPEG-1 is used for audio compression, and MPEG-2 is used for video compression. Both of these MPEG standards cover audio and video, but MPEG-1 video is not designed for DBS transmissions.

MPEG-1 audio supports mono and two channel stereo only, which is considered adequate for DBS systems currently in use.

MPEG-2 audio supports multichannel audio in addition to mono and stereo. It is fully compatible with MPEG-1 audio.

The need for audio compression can be seen by considering the bit rate required for high-quality audio. The bit rate is equal to the number of samples per second (the sampling frequency fs) multiplied by the number of bits per sample n:

$$R_b = f_s * n$$

For a stereo CD recording, the sampling frequency is 44.1 kHz, and the number of bits per sample is 16:

$$R_b = 44.1 * 10^3 * 16 * 2 = 1411.2\ kb/s$$

The factor 2 appears on the right-hand side because of the two channels in stereo. This bit rate, approximately 1.4 Mb/s, represents too high a fraction of the total bit rate allowance per channel, and hence the need for audio compression.

Audio compression in MPEG exploits certain perceptual phenomena in the human auditory system. In particular, it is known that a loud sound at one particular frequency will mask a less intense sound at a nearby frequency.

For example, consider a test conducted using two tones, one at 1000 Hz, which will be called the masking tone and the other at 1100 Hz, the test tone. Starting with both tones at the same level, say, 60 dB above the threshold of hearing, if now the level of the 1000Hz tone is held constant while reducing the level of the 1100-Hz tone, a point will be reached where the 1100-Hz tone becomes inaudible. The 1100-Hz tone is said to be masked by the 1000-Hz tone.

Assume for purposes of illustration that the test tone becomes inaudible when it is 18 dB below the level of the masking tone. This 18 dB is the masking threshold. It follows that any noise below the masking threshold also will be masked. For the moment, assuming that only these two tones are present, then it can be said that the noise floor is 18 dB below the masking tone. If the test-tone level is set at, say, 6 dB below the masking tone, then of course it is 12 dB above the noise floor. This means that the signal-to noise ratio for the test tone need be no better than 12 dB. Now in a pulsecode modulated (PCM) system the main source of noise is that arising from the quantization process.

The signal-to-quantization noise ratio is given by

$$\left(\frac{S}{N}\right)_q = 2^{2n}$$

Where n is the number of bits per sample. In decibels this is

$$\left[\frac{S}{N}\right]_q = 10 \log 2^{2n} \cong 6n\ dB$$

This shows that increasing n by 1 bit increases the signal-to-quantization noise ratio by 6 dB. Another way of looking at this is to say that a 1-bit decrease in n increases the quantization noise by 6 dB.

In the example above where 12 dB is an adequate signal-to-noise ratio, the above Equation shows that only 2 bits are needed to encode the 1100-Hz tone (i.e., the levels would be quantized in steps represented by 00, 01, 10, 11). By way of contrast, the CD samples taken at a sampling frequency of 44.1 kHz are quantized using 16 bits to give a signal-to-quantization noise ratio of 96 dB. Returning to the example of two tones, in reality, the audio signal will not consist of two single tones but will be a complex signal covering a wide spectrum of frequencies.

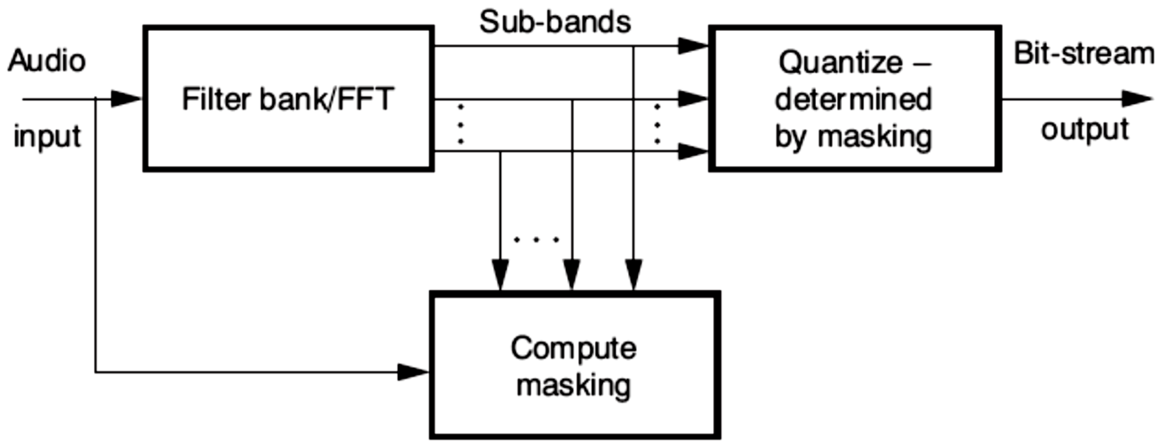


Fig 4.26 MPEG-1 Block Schematic

In MPEG-1, two processes take place in parallel, as illustrated in Fig. The filter bank divides the spectrum of the incoming signal into sub bands. In parallel with this the spectrum is analyzed to permit identification of the masking levels. The masking information is passed to the quantizer, which then quantizes the sub bands according to the noise floor.

The masking discussed so far is referred to as frequency masking for the reasons given earlier. It is also an observed phenomenon that the masking effect lasts for a short period after the masking signal is removed. This is termed temporal masking, and it allows further compression in that it extends the time for which the reduction in quantization applies.

The compressed bit rate for MPEG-1 audio used in DBS systems is 192 kb/s.

MPEG -2

In DBS systems, MPEG-2 is used for video compression. As a first or preprocessing step, the analog outputs from the red (R), green (G), and blue (B) color cameras are converted to a luminance component (Y) and two chrominance components (Cr) and (Cb). This is similar to the analog NTSC arrangement

In matrix notation, the equation relating the three primary colors to the Y, Cr, and Cb components is

$$\begin{bmatrix} Y \\ C_r \\ C_B \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

It is an observed fact that the human eye is less sensitive to resolution in the color components (Cr and Cb) than the luminance (Y) component. This allows a lower sampling rate to be used for the color components. This is referred to as chroma subsampling, and it represents one step in the compression process.

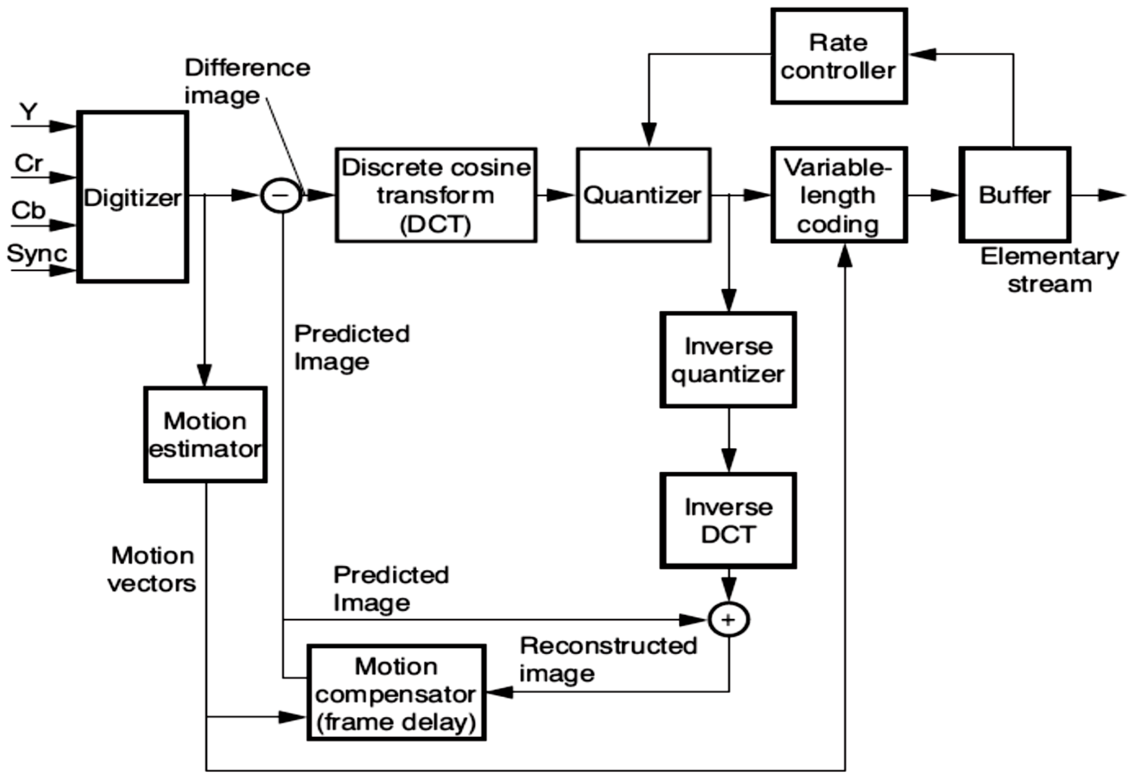


Fig 4.27 MPEG-2 encoder paths.

Sampling is usually indicated by the ratios Y: U: V where Y represents the luminance (or luma) sampling rate, U the Cb sampling rate, and V the Cr sampling rate. The values for YUV are normalized to a value of 4 for Y, and ratios commonly encountered with digital TV are 4:4:4, 4:2:2 and 4:2:0.

4:4:4 means that the sampling rates of Y, Cb, and Cr are equal. Each pixel would get three digital words, one for each of the component signals. If the words are 8-bits then each pixel would be encoded in 3 bytes.

4:2:2 means that the Cb and Cr signals are sampled at half the rate of the Y signal component. Every two pixels would have two bytes for the Y signal, one byte for the Cb signal and one byte for the Cr signal, resulting in 4 bytes for the 2-pixel block.

4:2:0 means that Cb and Cr are sampled at half the Y sampling rate, but they are sampled only on alternate scan lines. Thus vertical as well as horizontal resolution is reduced by half. A 2 * 2 pixel block would have 6 bytes, 4 bytes for Y, 1 byte for Cb and 1 byte for Cr. MPEG-2 uses 4:2:0 sampling.

Following the digitizer, difference signals are formed, and the discrete cosine transform (DCT) block converts these to a “spatial frequency” domain. The familiar Fourier transform transforms a time signal g(t) to a frequency domain representation G(f), allowing the signal to be filtered in the frequency domain. Here, the variables are time t and frequency f. In the DCT situation, the input signals are functions of the x (horizontal) and y (vertical) space coordinates, g(x, y). The

DCT transforms these into a domain of new variables u and v, G(u, v). The variables are called spatial frequencies in analogy with the time-frequency transform. It should be noted that g(x, y) and G(u, v) are discrete functions.

In the quantizer following the DCT transform block, the discrete values of G(u, v) are quantized to predetermined levels. This reduces the number of levels to be transmitted and therefore provides compression. The components of G(u, v) at the higher spatial frequencies represent finer spatial resolution. The human eye is less sensitive to resolution at these high spatial frequencies; therefore, they can be quantized in much coarser steps. This results in further compression.

Compression is also achieved through motion estimation. Frames in MPEG-2 are designated I, P, and B frames, and motion prediction is achieved by comparing certain frames with other frames.

The I frame is an independent frame, meaning that it can be reconstructed without reference to any other frames. A P (for previous) frame is compared with the previous I frame, and only those parts which differ as a result of movement need to be encoded. The comparison is carried out in sections called macroblocks for the frames. A macroblock consists of 16 * 16 pixels. A B (for bidirectional) frame is compared with the previous I or P frame and with the next P frame. This obviously means that frames must be stored in order for the forward comparison to take place. Only the changes resulting from motion are encoded, which provides further compression.

An estimate of the compression required can be made by assuming a value of 200 Mb/s for the uncompressed bit rate for SDTV, and taking 5 Mb/s as typical of that for a TV channel, the compression needed is on the order 200/5 = 40:1. The 5 Mb/s would include audio and data, but these should not take more than about 200 kb/s.

The whole encoding process relies on digital decision-making circuitry and is computationally intensive and expensive. The decoding process is much simpler because the rules for decoding are part of the syntax of the bit stream. Decoding is carried out in the integrated receiver decoder (IRD) unit.

MPEG – 4:

MPEG-4 was developed jointly by the Video Coding Experts/Group (VCEG) of the International Telecommunication Union (ITU), Telecommunication Standardization Sector (ITU-T) which uses the designation H.264, and the MPEG of the ISO/IEC.

This version of MPEG is known by at least six different names (H.264, H.26L, ISO/IEC 14496-10, JVT, MPEG-4 AVC, and MPEG-4 Part 10) and the abbreviation AVC is commonly used to denote advanced video coding. Following the usage in Sullivan et al., it will be denoted here by H.264/AVC. Areas of application include video telephony, video storage and retrieval (DVD and hard disk), digital video broadcast, and others.

In general terms, MPEG-4 provides many features not present with other compression schemes, such as interactivity for viewers, where objects within a scene can be manipulated, but from the point of view of satellite television, the major advantage is the reduction in bit rate offered.

About a 2:1 reduction in bit rate, on average is achievable with H.264/AVC compared with MPEG-2. Fidelity Range Extensions (FRExt) was added to H.264/AVC that can provide a reduction of as much as 3:1 in certain situations.

FRExt supports 4:2:2 and 4:4:4 sampling. As with MPEG-2 the analog outputs from the red (R), green (G), and blue (B) color cameras are converted to a luminance component (Y) and two chrominance components (Cr) and (Cb) but with a different M matrix, this being:

$$\begin{bmatrix} Y \\ C_r \\ C_B \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.587 & 0.0722 \\ -0.119977 & -0.331264 & 0.523589 \\ 0.561626 & -0.418688 & -0.051498 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

It follows that any format conversion would require a matrix recalculation. H.264/AVC takes advantage of the increases in processing power available from computer chips, but at the cost of more expensive equipment, both for the TV broadcaster and the consumer.

As with MPEG-2, frames are compared for changes through comparing macro blocks of 16 * 16 pixels, but H.264/AVC also allows for comparisons of sub macro blocks of pixel groups 16 * 8, 8 * 16, 8 * 8, 8 * 4, 4 * 8, and 4 * 4. At present it is not backward compatible with MPEG-2, which may present a problem with some high definition TV.

4.5 CODING METHODS

At the broadcast center, the high-quality digital stream of video goes through an MPEG encoder, which converts the programming to MPEG-4 video of the correct size and format for the satellite receiver in your house.

Encoding works in conjunction with compression to analyze each video frame and eliminate redundant or irrelevant data and extrapolate information from other frames. This process reduces the overall size of the file. Each frame can be encoded in one of three ways:

As an **intraframe**, which contains the complete image data for that frame. This method provides the least compression.

As a **predicted** frame, which contains just enough information to tell the satellite receiver how to display the frame based on the most recently displayed intraframe or predicted frame

As a **bidirectional** frame, which displays information from the surrounding intraframe or predicted frames. Using data from the closest surrounding frames, the receiver **interpolates** the position and color of each pixel.

This process occasionally produces **artifacts --** glitches in the video image. One artifact is **macroblocking,** in which the fluid picture temporarily dissolves into blocks.

Macroblocking is often mistakenly called **pixilating,** a technically incorrect term which has been accepted as slang for this annoying artifact.

There really are pixels on your TV screen, but they're too small for your human eye to perceive them individually -- they're tiny squares of video data that make up the image you see. (For more information about pixels and perception,

The rate of compression depends on the nature of the programming. If the encoder is converting a newscast, it can use a lot more predicted frames because most of the scene stays the same from one frame to the next.

In more fast-paced programming, things change very quickly from one frame to the next, so the encoder has to create more intraframes. As a result, a newscast generally compresses to a smaller size than something like a car race.

4.5.1 Encryption and Transmission:

After the video is compressed, the provider encrypts it to keep people from accessing it for free. Encryption scrambles the digital data in such a way that it can only be **decrypted** (converted back into usable data) if the receiver has the correct decryption algorithm and security keys.

Once the signal is compressed and encrypted, the broadcast center beams it directly to one of its satellites. The satellite picks up the signal with an onboard dish, amplifies the signal and uses another dish to beam the signal back to Earth, where viewers can pick it up.

Video and Audio Compression:

Video and Audio files are very large beasts. Unless we develop and maintain very high bandwidth networks (Gigabytes per second or more) we have to compress to data.

Relying on higher bandwidths is not a good option -- M25 Syndrome: Traffic needs ever increases and will adapt to swamp current limit whatever this is.

As we will compression becomes part of the representation or *coding* scheme which have become popular audio, image and video formats. Some popular coding techniques are

1. Entrophy Encoding
   - Repetitive Sequence Supression
     - Zero Length Suppresion
     - Run Length Encoding
   - Statistical Encoding
     - Pattern Substitution
     - Shannon Fano & Huffman Coding

2. Source Coding
   - Transform Coding
     - FFT Fast Fourier Transform

DCT Discrete Cosine Transform

- Differential Coding

  DPCM – Differential Pulse Code Modulation
  DM – Delta Modulation
  ADPCM– Adaptive Differential Pulse Code Modulation
- Vector Quantisation

ENCRYPTION:

It is the most effective way to achieve data security. To read an **encrypted** file, you must have access to a secret key or password that enables you to decrypt it. Unencrypted data is called **plain text** ; **encrypted** data is referred to as **cipher text.**

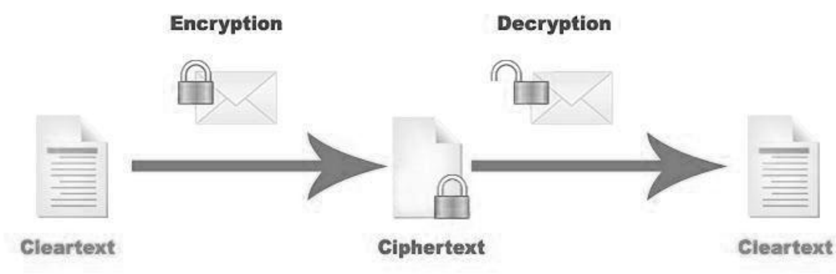


Fig 4.28 Encryption Methods

SYMMETRIC KEY ENCRYPTION:

In symmetric-key schemes, the encryption and decryption keys are the same. Thus communicating parties must have the same key before they can achieve secret communication.

In public-key encryption schemes, the encryption key is published for anyone to use and encrypt messages. However, only the receiving party has access to the decryption key that enables messages to be read.

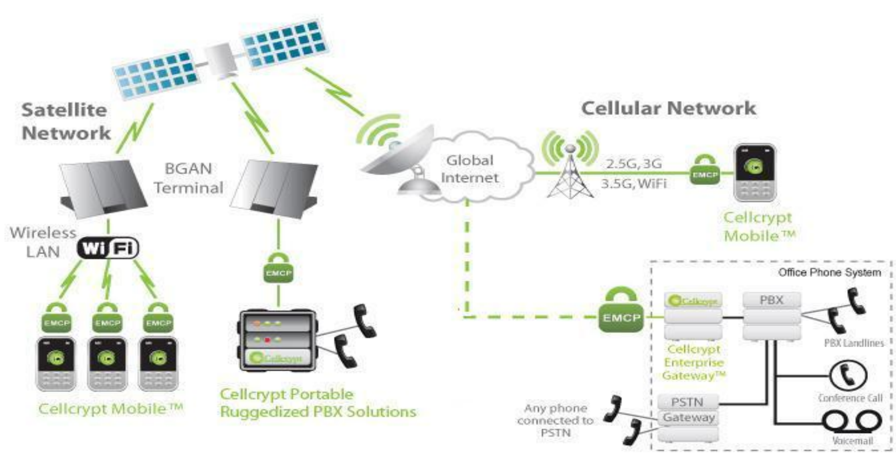


Fig 4.29 General block diagram Encryption methods

DECRYPTION:

It is the process of taking encoded or encrypted text or other data and converting it back into text that you or the computer are able to read and understand.

This term could be used to describe a method of un-encrypting the data manually or with un-encrypting the data using the proper codes or keys.

Data may be encrypted to make it difficult for someone to steal the information. Some companies also encrypt data for general protection of company data and trade secrets. If this data needs to be viewable, it may require decryption

UNIT V

SATELLITE APPLICATIONS

INTELSAT Series, INSAT, VSAT, Mobile Satellite Services: GSM, GPS, INMARSAT, LEO, MEO, Satellite Navigational System. GPS Position Location Principles, Differential GPS, Direct Broadcast satellites (DBS/DTH).

5.1 INTELSAT SERIES

INTELSAT stands for International Telecommunications Satellite. The organization was created in 1964 and currently has over 140 member countries and more than 40 investing entities.

In July 2001 INTELSAT became a private company and in May 2002 the company began providing end-to-end solutions through a network of teleports, leased fiber, and points of presence (PoPs) around the globe.

Starting with the Early Bird satellite in 1965, a succession of satellites has been launched at intervals of a few years. Figure 1.1 illustrates the evolution of some of the INTELSAT satellites. As the figure shows, the capacity, in terms of number of voice channels, increased dramatically with each succeeding launch, as well as the design lifetime.

These satellites are in geostationary orbit, meaning that they appear to be stationary in relation to the earth. At this point it may be noted that geosta-tionary satellites orbit in the earth's equatorial plane and their position is specified by their longitude.

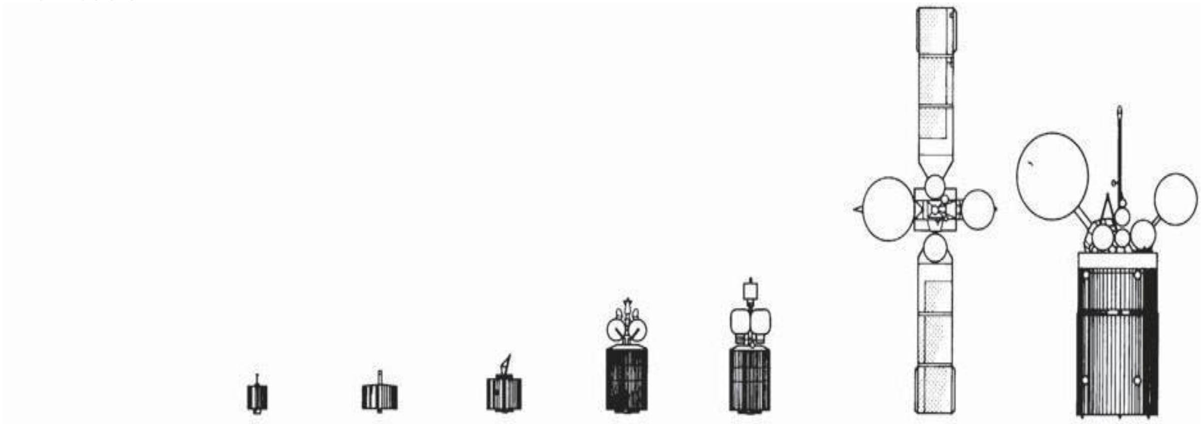
For international traffic, INTELSAT covers three main regions—the Atlantic Ocean Region (AOR), the Indian Ocean Region (IOR), and the Pacific Ocean Region (POR) and what is termed Intelsat America's Region.

For the ocean regions the satellites are positioned in geostationary orbit above the particular ocean, where they provide a transoceanic telecommunications route. For example, INTELSAT satellite 905 is positioned at 335.5° east longitude.

The INTELSAT VII-VII/A series was launched over a period from October 1993 to June 1996. The construction is similar to that for the V and VA/VB series, shown in Fig. in that the VII series has solar sails rather than a cylindrical body.

The VII series was planned for service in the POR and also for some of the less demanding services in the AOR. The antenna beam coverage is appropriate for that of the POR. Figure shows the antenna beam footprints for the C-band hemispheric coverage and zone coverage, as well as the spot beam coverage possible with the Ku-band antennas. When used in the AOR, the VII series satellite is inverted north for south, minor adjustments then being needed only to optimize the antenna patterns for this region. The lifetime of these satellites ranges from 10 to 15 years depending on the launch vehicle.

Recent figures from the INTELSAT Web site give the capacity for the INTELSAT VII as 18,000 two-way telephone circuits and three TV channels; up to 90,000 two-way telephone circuits can be achieved with the use of "digital circuit multiplication."



Designation: Intelsat	I	II	III	IV	IV A	V	V A/V B	VI
Year of first launch	1965	1966	1968	1971	1975	1980	1984/85	1986/87
Prime contractor	Hughes	Hughes	TRW	Hughes	Hughes	Ford Aerospace	Ford Aerospace	Hughes
Width (m)	0.7	1.4	1.4	2.4	2.4	2.0	2.0	3.6
Height (m)	0.6	0.7	1.0	5.3	6.8	6.4	6.4	6.4
Launch vehicles		Thor Delta		Atlas-Centaur		Atlas-Centaur and Ariane	Atlas-Centaur and Ariane	STS and Ariane
Spacecraft mass in transfer orbit (kg)	68	182	293	1385	1489	1946	2140	12,100/3720
Communications payload mass (kg)	13	36	56	185	190	235	280	800
End-of-life (EOL) power of equinox (W)	40	75	134	480	800	1270	1270	2200
Design lifetime (years)	1.5	3	5	7	7	7	7	10
Capacity (number of voice channels)	480	480	2400	8000	12,000	25,000	30,000	80,000
Bandwidth (MHz)	50	130	300	500	800	2137	2480	3520

Fig 5.1 INTELSAT Series

The INTELSAT VII/A has a capacity of 22,500 two-way telephone circuits and three TV channels; up to 112,500 two-way telephone circuits can be achieved with the use of digital circuit multiplication. As of May 1999, four satellites were in service over the AOR, one in the IOR, and two in the POR.

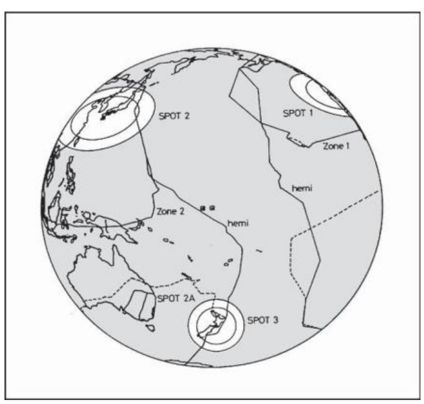


Fig 5.2 Region of glob

The INTELSAT VIII-VII/A series of satellites was launched over the period February 1997 to June 1998. Satellites in this series have similar capacity as the VII/Aseries, and the lifetime is 14 to 17 years.

It is standard practice to have a spare satellite in orbit on high-reliability routes (which can carry pre-emptible traffic) and to have a ground spare in case of launch failure.

Thus the cost for large international schemes can be high; for example, series IX, described later, represents a total investment of approximately $1 billion.

5.2 INSAT

INSAT or the **Indian National Satellite System** is a series of multipurpose geostationary satellites launched by ISRO to satisfy the telecommunications, broadcasting, meteorology, and search and rescue operations.

Commissioned in 1983, INSAT is the largest domestic communication system in the Asia Pacific Region. It is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. The overall coordination and management of INSAT system rests with the Secretary-level INSAT Coordination Committee.

INSAT satellites provide transponders in various bands (C, S, Extended C and Ku) to serve the television and communication needs of India. Some of the satellites also have the Very High Resolution Radiometer (VHRR), CCD cameras for metrological imaging.

The satellites also incorporate transponder(s) for receiving distress alert signals for search and rescue missions in the South Asian and Indian Ocean Region, as ISRO is a member of the Cospas Sarsat programme.

5.2.1 INSAT SYSTEM:

The Indian National Satellite (INSAT) System Was Commissioned With The Launch Of INSAT- 1B In August 1983 (INSAT-1A, The First Satellite Was Launched In April 1982 But Could Not Fulfill The Mission).

INSAT System ushered in a Revolution in India’s Television and Radio Broadcasting, Telecommunications and Meteorological Sectors. It Enabled The Rapid Expansion Of TV And Modern Telecommunication Facilities To Even The Remote Areas And Off-Shore Islands.

5.2.2 SATELLITES IN SERVICE:

The 24 Satellites Launched In The Course Of the INSAT Program, 10 Are Still In Operation.INSAT-2E

It Is The Last Of The Five Satellites In INSAT-2 Series. It Carries Seventeen C-Band And Lower Extended C-Band Transponders Providing Zonal And Global Coverage With An Effective Isotropic Radiated Power (EIRP) Of 36 dBW.

It Also Carries A Very High Resolution Radiometer (VHRR) With Imaging Capacity In The Visible (0.55-0.75 μm), Thermal Infrared (10.5-12.5 μm) And Water Vapour (5.7-7.1 μm) Channels And Provides 2x2 Km, 8x8 Km And 8x8 Km Ground Resolution Respectively.

INSAT- 3A

The Multipurpose Satellite, INSAT-3A, Was Launched By Ariane In April 2003. It Is Located At 93.5 Degree East Longitude. The Payloads On INSAT-3A Are As Follows:

12 Normal C -Band Transponders (9 Channels Provide Expanded Coverage From Middle East To South East Asia With An EIRP Of 38 dBW, 3 Channels Provide India Coverage With An EIRP Of 36 dBW and 6 Extended C-Band Transponders Provide India Coverage With An EIRP of 36 dBW)

A CCD Camera Provides 1x1 Km Ground Resolution, In The Visible (0.63-0.69 μm), Near Infrared (0.77-0.86 μm) And Shortwave Infrared (1.55-1.70 μm) Bands.

INSAT-3D

Launched In July 2013, INSAT-3D Is Positioned At 82 Degree East Longitude. INSAT -3D Payloads Include Imager, Sounder, Data Relay Transponder And Search & Rescue Transponder. All the Transponders Provide Coverage over Large Part Of The Indian Ocean Region Covering India, Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka And Tanzania For Rendering Distress Alert Services

INSAT-3E

Launched In September 2003, INSAT - 3E Is Positioned At 55 Degree East Longitude And Carries 24 Normal C-Band Transponders Provide An Edge Of Coverage EIRP Of 37 dBW Over India And 12 Extended C-Band Transponders Provide An Edge Of Coverage EIRP Of 38 dBW Over India.

KALPANA-1

KALPANA-1 Is An Exclusive Meteorological Satellite Launched By PSLV In September 2002. It Carries Very High Resolution Radiometer And DRT Payloads To Provide Meteorological Services. It Is Located At 74 Degree East Longitude. Its First Name Was METSAT. It Was Later Renamed As KALPANA-1 To Commemorate Kalpana Chawla.

Configured For Audio-Visual Medium Employing Digital Interactive Classroom Lessons And Multimedia Content, EDUSAT Was Launched By GSLV In September 2004. Its Transponders And Their Ground Coverage Are Specially Configured To Cater To The Educational Requirements.

GSAT-2

Launched By The Second Flight Of GSLV In May 2003, GSAT-2 Is Located At 48 Degree East Longitude And Carries Four Normal C-Band Transponders To Provide 36 Dbw EIRP With India Coverage, Two Ku Band Transponders With 42 Dbw EIRP Over India And An MSS Payload Similar To Those On INSAT-3B And INSAT-3C.

INSAT-4 Series:

Fig 5.3 INSAT 4A

INSAT-4A is positioned at 83 degree East longitude along with INSAT-2E and INSAT-3B. It carries 12 Ku band 36 MHz bandwidth transponders employing 140 W TWTAs to provide an EIRP of 52 dBW at the edge of coverage polygon with footprint covering Indian main land and 12 C- band 36 MHz bandwidth transponders provide an EIRP of 39 dBW at the edge of coverage with expanded radiation patterns encompassing Indian geographical boundary, area beyond India in southeast and northwest regions.

Tata Sky, a joint venture between the TATA Group and STAR uses INSAT-4A for distributing their DTH service

- INSAT-4A
- INSAT-4B
- Glitch In INSAT 4B
- INSAT-4CR
- GSAT-8 / INSAT-4G
- GSAT-12 /GSAT-10
- China-Stuxnet Connection

5.3 VSAT

VSAT stands for very small aperture terminal system. This is the distinguishing feature of a VSAT system, the earth-station antennas being typically less than 2.4 m in diameter. The trend is toward even smaller dishes, not more than 1.5 m in diameter.

In this sense, the small TVRO terminals for direct broadcast satellites could be labeled as VSATs, but the appellation is usually reserved for private networks, mostly providing two-way communications facilities.

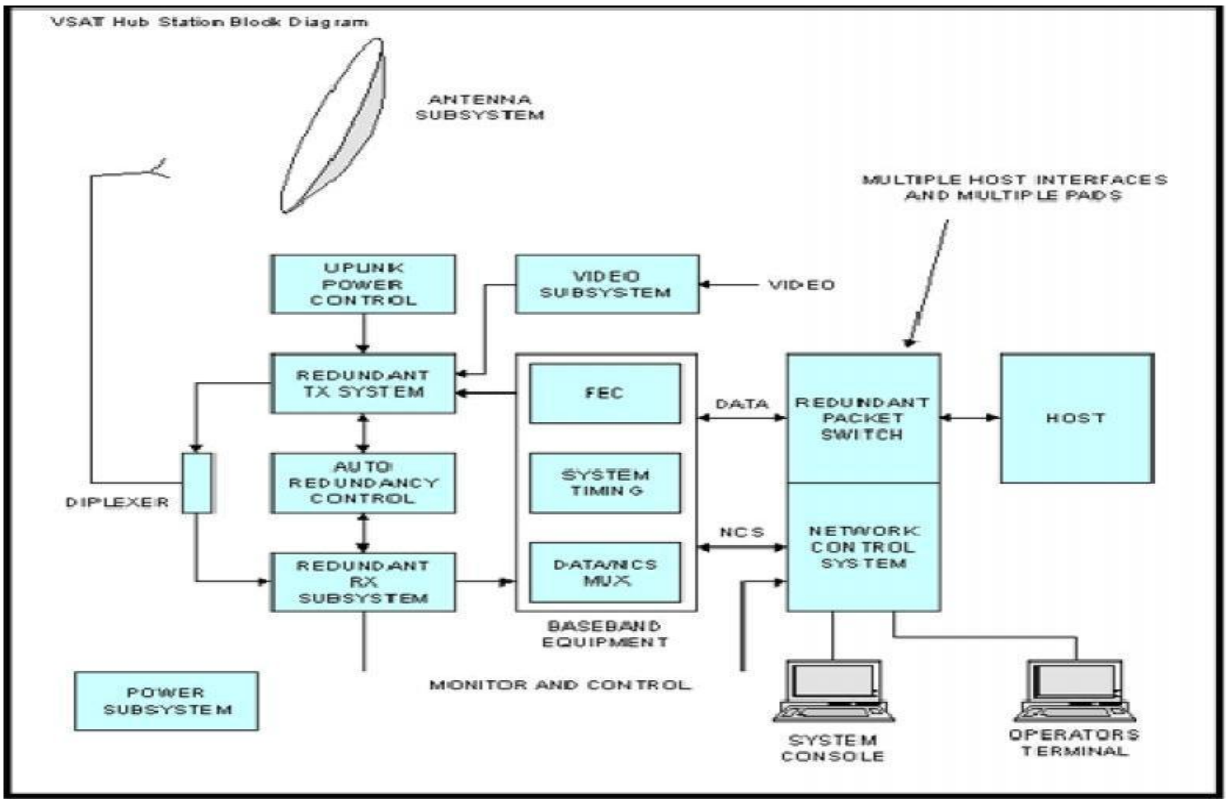


Fig 5.4 VSAT Block Diagrams

Typical user groups include banking and financial institutions, airline and hotel booking agencies, and large retail stores with geographically dispersed outlets.

5.3.1 VSAT NETWORK

The basic structure of a VSAT network consists of a hub station which provides a broadcast facility to all the VSATs in the network and the VSATs themselves which access the satellite in some form of multiple- access mode.

The hub station is operated by the service provider, and it may be shared among a number of users, but of course, each user organization has exclusive access to its own VSAT network.

Time division multiplex is the normal downlink mode of transmission from hub to the VSATs, and the transmission can be broadcast for reception by all the VSATs in a network, or address coding can be used to direct messages to selected VSATs.

A form of demand assigned multiple access (DAMA) is employed in some systems in which channel capacity is assigned in response to the fluctuating demands of the VSATs in the network.

Most VSAT systems operate in the Ku band, although there are some C-band systems in existence.

5.3.2 APPLICATIONS

- Supermarket shops (tills, ATM machines, stock sale updates and stock ordering).
- Chemist shops - Shoppers Drug Mart - Pharmaprix. Broadband direct to the home. e.g. Downloading MP3 audio to audio players.
- Broadband direct small business, office etc, sharing local use with many PCs.
- Internet access from on board ship Cruise ships with internet cafes, commercial shipping communications.

5.4 MOBILE SATELLITE SERVICES

5.4.1 GSM

SERVICES AND ARCHITECTURE

If your work involves (or is likely to involve) some form of wireless public communications, you are likely to encounter the GSM standards. Initially developed to support a standardized approach to digital cellular communications in Europe, the "Global System for Mobile Communications" (GSM) protocols are rapidly being adopted to the next generation of wireless telecommunications systems.

In the US, its main competition appears to be the cellular TDMA systems based on the IS-54 standards. Since the GSM systems consist of a wide range of components, standards, and protocols.

The GSM and its companion standard DCS1800 (for the UK, where the 900 MHz frequencies are not available for GSM) have been developed over the last decade to allow cellular communications systems to move beyond the limitations posed by the older analog systems.

Analog system capacities are being stressed with more users that can be effectively supported by the available frequency allocations. Compatibility between types of systems had been limited, if non-existent.

By using digital encoding techniques, more users can share the same frequencies than had been available in the analog systems. As compared to the digital cellular systems in the US (CDMA [IS- 95] and TDMA [IS-54]), the GSM market has had impressive success. Estimates of the numbers of telephones run from 7.5 million GSM phones to .5 million IS54 phones to .3 million for IS95.

GSM has gained in acceptance from its initial beginnings in Europe to other parts of the world including Australia, New Zealand, countries in the Middle East and the Far East. Beyond its use in cellular frequencies (900 MHz for GSM, 1800 MHz for DCS1800), portions of the GSM signaling protocols are finding their way into the newly developing PCS and LEO Satellite communications systems.

While the frequencies and link characteristics of these systems differ from the standard GSM air interface, all of these systems must deal with users roaming from one cell (or satellite beam) to another, and bridge services to public communication networks including the Public Switched Telephone Network (PSTN), and public data networks (PDN).

THE GSM ARCHITECTURE INCLUDES SEVERAL SUBSYSTEMS

The Mobile Station (MS)
These digital telephones include vehicle, portable and hand-held terminals. A device called the Subscriber Identity Module (SIM) that is basically a smart-card provides custom information about users such as the services they've subscribed to and their identification in the network

The Base Station Sub-System (BSS)
The BSS is the collection of devices that support the switching networks radio interface. Major components of the BSS include the Base Transceiver Station (BTS) that consists of the radio modems and antenna equipment.

In OSI terms, the BTS provides the physical interface to the MS where the BSC is responsible for the link layer services to the MS. Logically the transcoding equipment is in the BTS, however, an additional component.

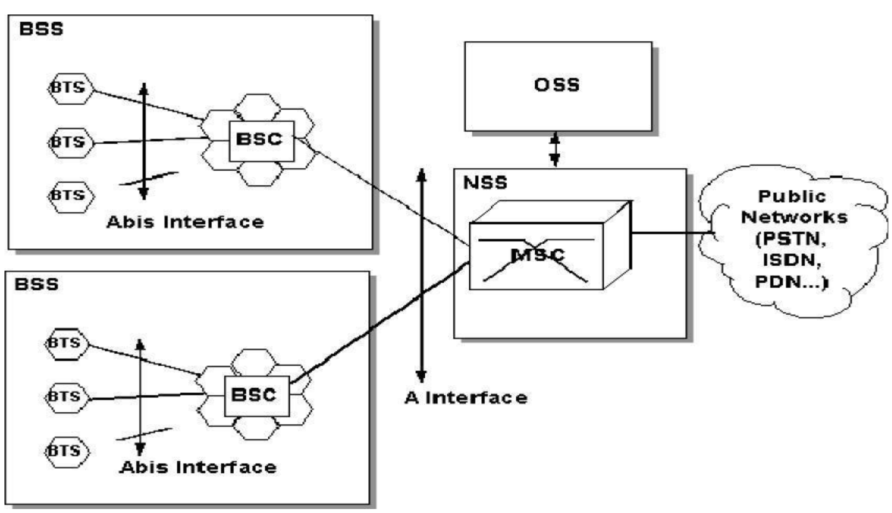


Fig 5.5 GSM Block Diagrams

The Network and Switching Sub-System (NSS)

The NSS provides the switching between the GSM subsystem and external networks along with the databases used for additional subscriber and mobility management.
Major components in the NSS include the Mobile Services Switching Center (MSC), Home and Visiting Location Registers (HLR, VLR). The HLR and VLR databases are interconnected through the telecomm standard Signaling System 7 (SS7) control network.

The Operation Sub -System (OSS)

The OSS provides the support functions responsible for the management of network maintenance and services. Components of the OSS are responsible for network operation and maintenance, mobile equipment management, and subscription management and charging.

SEVERAL CHANNELS ARE USED IN THE AIR INTERFACE

FCCH	The frequency correction channel - provides frequency synchronization information in a burst
SCH	Synchronization Channel - shortly following the FCCH burst (8 bits later), provides a reference to all slots on a given frequency
PAGCH	Paging and Access Grant Channel used for the transmission of paging information requesting the setup of a call to a MS.
RACH	Random Access Channel - an inbound channel used by the MS to request connections from the ground network. Since this is used for the first access attempt by users of the network, a random access scheme is used to aid in avoiding collisions.
CBCH	Cell Broadcast Channel - used for infrequent transmission of broadcasts by the ground network.
BCCH	Broadcast Control Channel - provides access status information to the MS. The information provided on this channel is used by the MS to determine whether or not to request a transition to a new cell
FACCH	Fast Associated Control Channel for the control of handovers
TCH/F	Traffic Channel, Full Rate for speech at 13 kbps or data at 12, 6, or 3.6 kbps
TCH/H	Traffic Channel, Half Rate for speech at 7 kbps, or data at 6 or 3.6 kbps.

Mobility Management:

One of the major features used in all classes of GSM networks (cellular, PCS and Satellite) is the ability to support roaming users. Through the control signaling network, the MSCs interact to locate and connect to users throughout the network.

"Location Registers" are included in the MSC databases to assist in the role of determining how and whether connections are to be made to roaming users. Each user of a GSM MS is assigned a Home Location Register (HLR) that is used to contain the user's location and subscribed services.

DIFFICULTIES FACING THE OPERATORS CAN INCLUDE

a. **Remote/ Rural Areas:**
   To service remote areas, it is often economically unfeasible to provide backhaul facilities (BTS to BSC) via terrestrial lines (fiber/microwave)

b. **Time to Deploy:**
   Terrestrial build-outs can take years to plan and implement.

c. **Areas of 'Minor' Interest:**
   These can include small isolated centers such as tourist resorts, islands, mines, oil exploration sites, hydro-electric facilities.

d. **Temporary Coverage:**
   Special events, even in urban areas, can overload the existing infrastructure.

GSM SERVICE SECURITY:

GSM was designed with a moderate level of service security. GSM uses several cryptographic algorithms for security. The A5/1, A5/2, and A5/3 stream ciphers are used for ensuring over-the-air voice privacy.

GSM uses General Packet Radio Service (GPRS) for data transmissions like browsing the web. The most commonly deployed GPRS ciphers were publicly broken in 2011The researchers revealed flaws in the commonly used GEA/1.

5.4.2 GLOBAL POSITIONING SYSTEM: (GPS)

The Global Positioning System (GPS) is a satellite based navigation system that can be used to locate positions anywhere on earth. Designed and operated by the U.S. Department of Defense, it consists of satellites, control and monitor stations, and receivers. GPS receivers take information transmitted from the satellites and uses triangulation to calculate a user's exact location. GPS is used on incidents in a variety of ways, such as:

- To determine position locations; for example, you need to radio a helicopter pilot the coordinates of your position location so the pilot can pick you up.
- To navigate from one location to another; for example, you need to travel from a lookout to the fire perimeter.
- To create digitized maps; for example, you are assigned to plot the fire perimeter and hot spots.
- To determine distance between two points or how far you are from another location.
- GPS is a satellite based navigation system. It uses a digital signal at about 1.5 GHz from each satellite to send data to the receiver. The receiver can then deduce its exact range from the satellite, as well as the geographic position (GP) of the satellite.

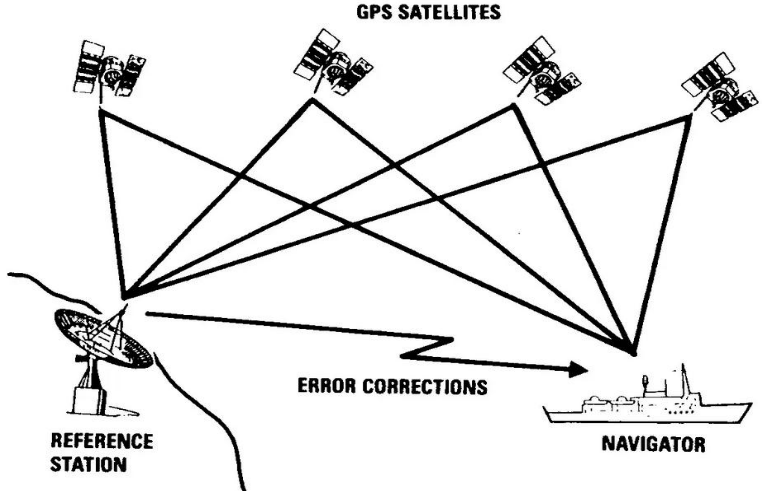


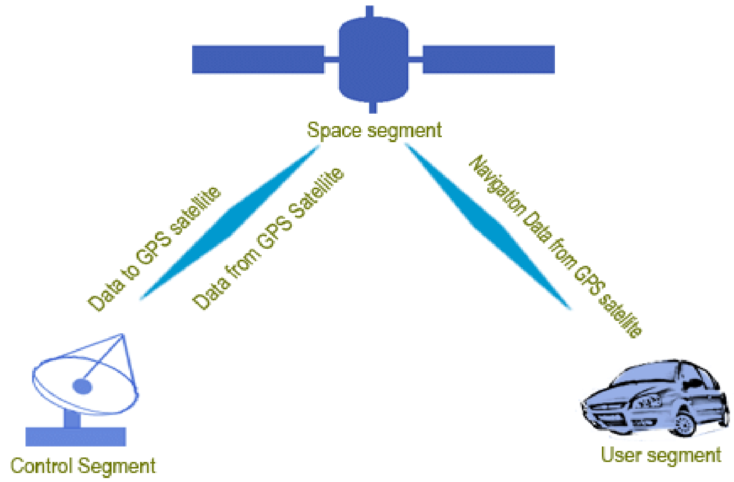
Fig 5.6 GPS Block Diagrams

THREE SEGMENTS OF GPS:

SPACE SEGMENT — Satellites orbiting the earth

The space segment is the number of satellites in the constellation. It comprises of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude.

The function of the space segment is utilized to route/navigation signals and to store and retransmit the route/navigation message sent by the control segment. These transmissions are controlled by highly stable atomic clocks on the satellites. The GPS Space Segment is formed by a satellite constellation with enough satellites to ensure that the users will have, at least, 4 simultaneous satellites in view from any point at the Earth surface at any time.



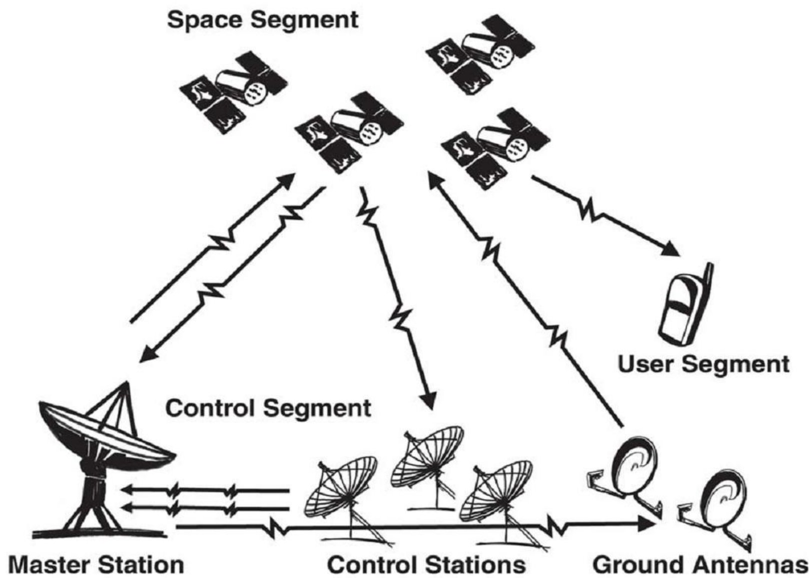


Fig 5.7 Three Segments of GPS

CONTROL SEGMENT — The control and monitoring stations

The control segment tracks the satellites and then provides them with corrected orbital and time information. The control segment consists of five unmanned monitor stations and one Master Control Station. The five unmanned stations monitor GPS satellite signals and then send that information to the Master Control Station where anomalies are corrected and sent back to the GPS satellites through ground antennas.

USER SEGMENT — The GPS receivers owned by civilians and military

The user segment comprises of the GPS receiver, which receives the signals from the GPS satellites and determine how far away it is from each satellite. Mainly this segment is used for the U.S military, missile guidance systems, civilian applications for GPS in almost every field. Most of the civilian uses this from survey to transportation to natural resources and from there to agriculture purpose and mapping too.

ADVANTAGES OF GPS

- GPS satellite based navigation system is an important tool for military, civil and commercial users
- Vehicle tracking systems GPS-based navigation systems can provide us with turn by turn directions
- Very high speed

DISADVANTAGES OF GPS

- GPS satellite signals are too weak when compared to phone signals, so it doesn’t work as well indoors, underwater, under trees, etc.
- The highest accuracy requires line-of-sight from the receiver to the satellite, this is why GPS doesn’t work very well in an urban environment.

USING A GPS RECEIVER

There are several different models and types of GPS receivers. While working with a GPS receiver it is important to have :

- A compass and a map.
- A downloaded GPS cable.
- Some extra batteries.
- Knowledge about the memory capacity of the GPS receiver to prevent loss of data, decrease in accuracy of data, or other problems.
- An external antenna whenever possible, especially under tree canopy, in canyons, or while driving.
- A set up GPS receiver according to incident or agency standard regulation; coordinate system.

5.4.3 LOCATION PRINCIPLES OF GPS:

The working/operation of Global positioning system is based on the 'trilateration' mathematical principle. The position is determined from the distance measurements to satellites. From the figure, the four satellites are used to determine the position of the receiver on the earth. The target location is confirmed by the 4^{th} satellite. And three satellites are used to trace the location place. A fourth satellite is used to confirm the target location of each of those space vehicles. Global positioning system consists of satellite, control station and monitor station and receiver.

The GPS receiver takes the information from the satellite and uses the method of triangulation to determine a user's exact position.

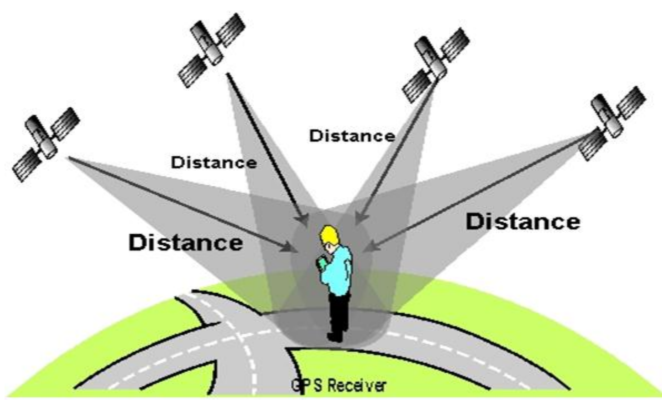


Fig 5.8 GPS Location Determination

PRECISE LOCATION OF SATELLITES

When a GPS receiver is first turned on, it downloads orbit information from all the satellites called an almanac. This process, the first time, can take as long as 12 minutes; but once this information is downloaded, it is stored in the receiver's memory for future use.

DISTANCE FROM EACH SATELLITE

The GPS receiver calculates the distance from each satellite to the receiver by using the distance formula: distance = velocity x time. The receiver already knows the velocity, which is the speed of a radio wave or 186,000 miles per second (the speed of light).

TRIANGULATION TO DETERMINE POSITION

The receiver determines position by using triangulation. When it receives signals from at least three satellites the receiver should be able to calculate its approximate position (a 2D position). The receiver needs at least four or more satellites to calculate a more accurate 3D position.

GPS ERROR

There are many sources of possible errors that will degrade the accuracy of positions computed by a GPS receiver. The travel time taken by the GPS satellite signals can be changed by atmospheric effects; when a GPS signal passes through the ionosphere and troposphere it is refracted, causing the speed of the signal to be different from the speed of a GPS signal in space. Another source of error is noise, or distortion of the signal which causes electrical interference or errors inherent in the GPS receiver itself. The information about satellite orbits will also cause errors in determining the positions, because the satellites are not really where the GPS receiver "thought" based on the information it received when it determine the positions.

Small variations in the atomic clocks on board the satellites can translate to large position errors; a clock error of 1 nanosecond translates to 1 foot or .3 meters user error on the ground. A multipath effect occurs when signals transmitted from the satellites bounce off a reflective surface before getting to the receiver antenna. During this process, the receiver gets the signal in straight line path as well as delayed path (multiple paths). The effect is similar to a ghost or double image on a TV set.

GEOMETRIC DILUTION OF PRECISION (GDOP)

Satellite geometry can also affect the accuracy of GPS positioning. This effect is refers as Geometric Dilution of Precision (GDOP). Which is refers to where the satellites are in related to one another, and is a measure of the quality of the satellite configuration. It can be able to modify other GPS errors. Most GPS receivers select the satellite constellation that will give the least uncertainty, the best satellite geometry.

GPS receivers usually report the quality of satellite geometry in terms of Position Dilution of Precision, or PDOP. PDOP are of two types, horizontal (HDOP) and vertical (VDOP) measurements (latitude, longitude and altitude). We can check the quality of the satellite positioning the receiver is currently available by the PDOP value. A low DOP indicates a higher probability of accuracy, and a high DOP indicates a lower probability of accuracy. Another term of PDOP is TDOP (Time Dilution of Precision). TDOP refers to satellite clock offset. On a GPS receiver can set a parameter known as the PDOP mask. This will cause the receiver to ignore satellite configurations that have a PDOP higher than the limit specified.

SELECTIVE AVAILABILITY (SA):

Selective Availability occurs when the DOD intentionally degraded; the accuracy of GPS signals is introducing artificial clock and ephemeris errors. During the implementation of SA, it was the largest component of GPS error, causing error of up to 100 meters. SA is a component of the Standard Positioning Service (SPS).

5.4.4 DIFFERENTIAL GPS

So far, we've learned how a GPS receiver calculates its position on earth based on the information it receives from four located satellites. This system works pretty well, but inaccuracies do pop up. For one thing, this method assumes the radio signals will make their way through the atmosphere at a consistent speed (the speed of light). In fact, the Earth's atmosphere slows the electromagnetic energy down somewhat, particularly as it goes through the ionosphere and troposphere. The delay varies depending on where you are on Earth, which means it's difficult to accurately factor this into the distance calculations. Problems can also occur when radio signals bounce off large objects, such as skyscrapers, giving a receiver the impression that a satellite is farther away than it actually is. On top of all that, satellites sometimes just send out bad almanac data, misreporting their own position.

Differential GPS (DGPS) helps correct these errors. The basic idea is to gauge GPS inaccuracy at a stationary receiver station with a known location. Since the DGPS hardware at the station already knows its own position, it can easily calculate its receiver's inaccuracy. The station then broadcasts a radio signal to all DGPS-equipped receivers in the area, providing signal correction information for that area. In general, access to this correction information makes DGPS receivers much more accurate than ordinary receivers.

The most essential function of GPS receiver is to pick up the transmissions of at least four satellites and combine the information in those transmissions with information in an electronic almanac, all in order to figure out the receiver’s position on Earth.

Once the receiver makes this calculation, it can tell you the latitude, longitude and altitude (or some similar measurement) of its current position. To make the navigation more user friendly, most receivers plug this raw data into map files stored in memory.

You can use maps stored in the receiver’s memory, connect the receiver to a computer that can hold more detailed maps in its memory, or simply buy a detailed map of your area and find your way using the receivers latitude and longitude readouts. Some receivers let you download detailed maps into memory or supply detailed maps with plug in map cartridges.

A standard GPS receiver will not only place you on a map at any particular location, but will also trace your path across a map as you move. If you leave your receiver on, it can stay in constant communication with GPS satellites to see how your location is changing.

With this information and its built-in clock, the receiver can give you several pieces of valuable information:

- How far you've traveled (Odometer)
- How long you've been traveling
- Your current speed (speedometer)
- Your average speed
- A "bread crumb" trail showing you exactly where you have traveled on the map
- The estimated time of arrival at your destination if you maintain your current speed

5.4.5 INMARSAT

Inmarsat-Indian Maritime SATellite is still the sole IMO-mandated provider of satellite communications for the GMDSS. Availability for GMDSS is a minimum of 99.9% Inmarsat has constantly and consistently exceeded this figure & independently audited by IMSO and reported on to IMO.

Now Inmarsat commercial services use the same satellites and network &Inmarsat A closes at midnight on 31 December 2007 Agreed by IMO – MSC/Circ.1076. Successful closure Programme almost concluded Overseen throughout by IMSO.

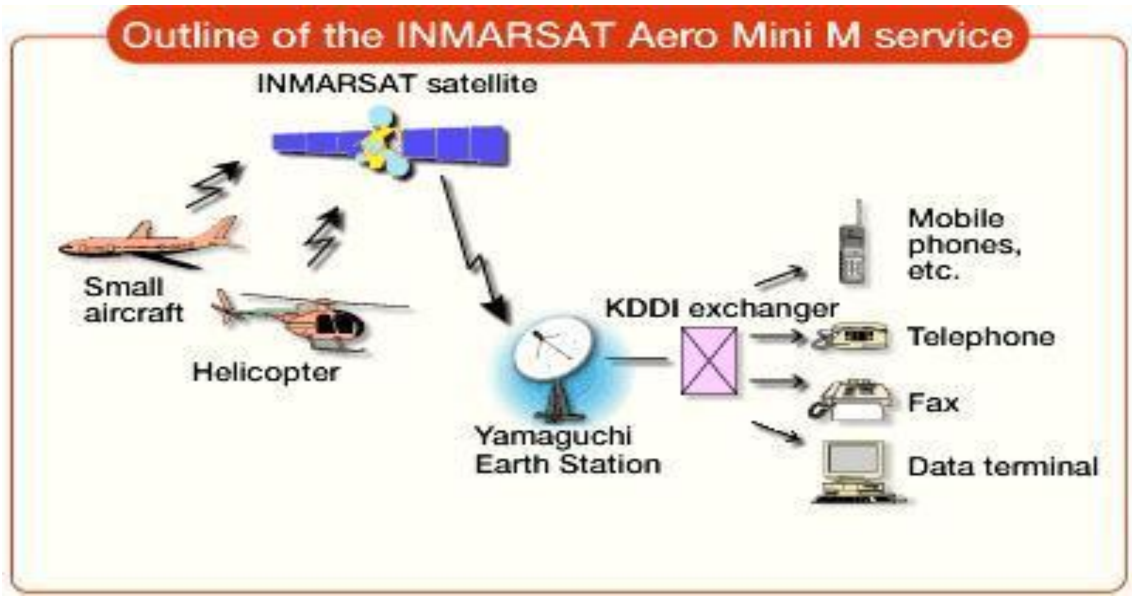


Fig 5.9 Outline of the INMARSAT

GMDSS services continue to be provided by:

- Inmarsat B, Inmarsat C/mini-C and Inmarsat Fleet F77
- Potential for GMDSS on Fleet Broadband being assessed

- The IMO Criteria for the Provision of Mobile Satellite Communications Systems in the Global Maritime Distress and Safety System (GMDSS).
- Amendments were proposed; potentially to make it simpler for other satellite systems to be approved.
- The original requirements remain and were approved by MSC 83
    - No dilution of standards
- Minor amendments only; replacement Resolution expected to be approved by the IMO 25^{th} Assembly
- Inmarsat remains the sole, approved satcom provider for the GMDSS.

5.4.6 DIFFERENT SATELLITE ORBITS

An orbit is the path that a satellite follows as it revolves around Earth. Satellites orbits vary depending on:

1) Altitude 2) Inclination 3) Orbital Period

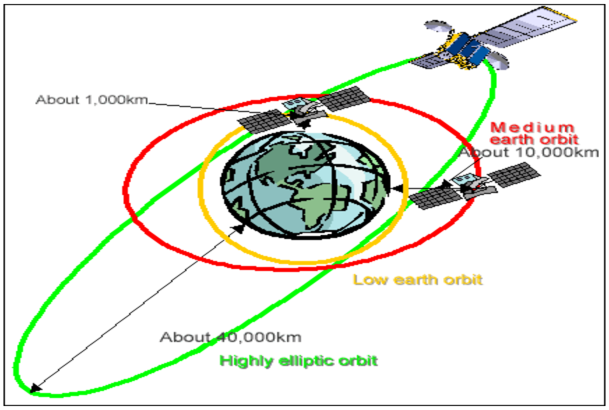


Fig 5.10 Satellite Orbits

Low Earth Orbit (LEO) Satellite Characteristics

- Circular/slightly elliptical orbit under 3000 km
- Orbit period ranges from 1.5 to 2 hours
- Diameter of coverage is about 8000 km
- Round-trip signal propagation delay less than 20 ms
- Maximum satellite visible time up to 20 min
- Used for Remote sensing satellites, altimeter satellites
- System must cope with large Doppler shifts
- Atmospheric drag results in orbital deterioration
- Low Earth Orbit satellites have a small area of coverage.
- The large majority of satellites are in low earth orbit
- The Iridium system utilizes LEO satellites (780km high)

Medium Earth Orbit (MEO) Satellite Characteristics

- Circular orbit at an altitude in the range of 6000 to 12,000 km
- Orbit period of 5 to 12 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 80 ms
- Maximum satellite visible time is a few hours
- Used for GPS satellites (12 hr periods – twice a day)

Geostationary Earth Orbit (GEO) Satellite Characteristics

1. A satellite in a geostationary orbit appears to be stationary with respect to the earth.
2. Three conditions are required for an orbit to be stationary.
   - The satellite must travel eastward at the same rotational speed as the earth.
   - The orbit must be circular.
   - The inclination of the orbit must be 0.
3. The radius of the geostationary orbit=42164km.

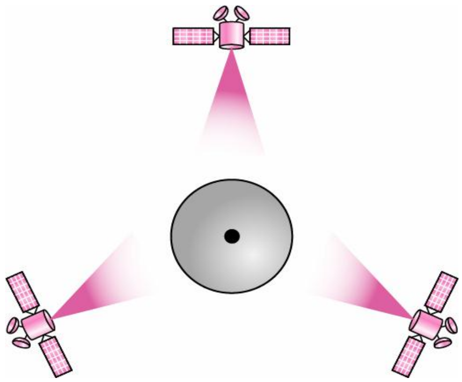


Fig 5.11 Satellites in Geosynchronous Orbit

Uses of Geostationary Orbits

Geostationary orbits are primarily used for two functions:

- Weather monitoring
- Telecommunications & Broadcasting
    - Commercial growth is focused on:
        - DTH TV (Direct To Home: Sky TV)
        - Phone, Fax, Video, Data services
        - Mobile Communications
        - VSAT & USAT
        - Digital Radio

Characteristics

- There is only one geostationary orbit possible around the earth Lying on the earth's equatorial plane. The satellite orbiting at the same speed as the rotational speed of the earth on its axis.
- They complete one orbit every 24 hours. This causes the satellite to appear stationary with respect to a point on the earth, allowing one satellite to provide continual coverage to a given area on the earth's surface
- One GEO satellite can cover approximately 1/3 of the world's surface. They are commonly used in communication systems
- User terminals do not have to track the satellite
- Only a few satellites can provide global coverage
- Maximum life-time (15 years or more)
- Above Van Allen Belt Radiation
- Often the lowest cost system and simplest in terms of tracking and high speed switching
- Altitudes of 36,000km
- The satellite needs 1 day to complete an orbit
  T = 86,000 sec (rounded), 86,000 sec = 1,433 min = 24hours (rounded)

Advantages of the GEO orbit

- No problem with frequency changes
- Tracking of the satellite is simplified
- High coverage area

Disadvantages of the GEO orbit

- Weak signal after traveling over 35,000 km
- Polar regions are poorly served
- Signal sending delay is substantial
- Large free space loss

Challenges of Geostationary (GEO) Orbit

- Transmission latency or delay of 250 millisecond to complete up/down link
- Satellite antennas must be of larger aperture size to concentrate power and to create narrower beams for frequency reuse
- Poor look angle elevations at higher latitudes

Comparison of Various Satellite Orbit

Features	GEO	MEO	LEO
Height (Km's)	36000	6000 - 12000	200 - 3000
Time per orbit (Hrs)	24	5 – 12	1.5
Speed (Km's / hr)	11000	19000	27000
Time Delay (ms)	250	80	10
Time in Site of Gateway	Always	2 – 4 hrs	< 15 min
Satellite for Global Coverage	3	10 – 12	50 - 70

5.4.7 SATELLITE NAVIGATIONAL SYSTEM

A **satellite Navigation** or **SATNAV** system is a system that uses satellites to provide autonomous geo-spatial positioning. It allows small electronic receivers to determine their location (Longitude, Latitude, and Altitude/Elevation) to high precision (within a few centimeters to meters) using time signals transmitted along a line of sight by radio from satellites.

The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver (Satellite Tracking). The signals also allow the electronic receiver to calculate the current local time to high precision, which allows time synchronization. These uses are collectively known as Positioning, Navigation and Timing (**PNT**).

SATNAV systems operate independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the positioning information generated.

WORKING PRINCIPLE:

Satellite Navigation systems use a series of satellite placed in specific orbits around the earth to figure out where the receiver is located. The satellites transmit orbital and timing information. The receiver uses this information from several satellites to calculate its position. Commercial systems are accurate to a couple meters, but high end systems are accurate to a few centimeters.

TERMINOLOGY:

GPS (Global Positioning System) used to be an umbrella term for satellite navigation systems but now GPS is associated with the US owned NAVSTAR system. GNSS (Global Navigation Satellite System) is the umbrella term today for global systems, but only two global systems exist at this time. There are also regional satellite navigation systems, and regional satellite navigation systems that are in the infant stages of becoming global.

The Major satellite navigation systems are

- Two operational global satellite navigation systems exist in the world today (GPS and GLONASS)
- Two global satellite navigation systems are in development (Compass and Galileo)
- Three regional satellite navigation systems exist today (BeiDou, IRNSS and QZSS)

GPS

The NAVSTAR FPS system is composed of 24 satellites, and was created by the US department of defense; it can be accessed anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users worldwide and is freely accessible to anyone with a GPS receiver.

GLONASS

GLONASS is also composed of 24 satellites but was developed in the Soviet Union and is operated by the Russian aerospace defense forces. This SATNAV system is the only other navigational system in operation with global coverage and of comparable precision.

GALILEO (In Development)

GALILEO is a 30 satellite global navigation system currently being developed by the the European Union and European space agency, expected to be complete in 2019. One of the goals of this system is to provide a high precision positioning system for European nations that are independent from the Russian GLONASS, U.S, GPS, Indian IRNSS and Chinese Compass Systems.

COMPASS (In Development)

COMPASS is a global navigation system being developed by china that will consist of 35 satellites and is expected to be completed in 2020. It is the second generation of its regional BeiDou Satellite Navigation System (BDS), also known as BeiDou – 2.

QZSS

The Quasi Zenith Satellite System (QZSS) is a proposed three satellite regional time transfer and satellite based augmentation system for the global positioning system that would be receivable within japan and Australia.

BeiDou

The BeiDou Navigation satellite System (BDS) consists of two separate satellite constellations. The first is a limited test system known as BeiDou-1. BeiDou-1 consists of three satellite and offers limited coverage and applications. Its navigation services have been mainly for customers in china and neighboring regions. The second generation, BeiDou-2 (Compass), is a full scale global navigation system currently under construction.

IRNSS

The Indian regional Navigational Satellite System (IRNSS) is a regional satellite navigational system being developed by the Indian space research organization. When complete, it will be under control of the Indian government. IRNSS will provide standard service for civilian use and an encrypted restricted service for authorized users (Military)

5.5 RECEIVE-ONLY HOME TV SYSTEMS/ DIRECT BROADCAST SATELLITE

Planned broadcasting directly to home TV receivers takes place in the Ku (12-GHz) band. This service is known as direct broadcast satellite (DBS) service.

There is some variation in the frequency bands assigned to different geographic regions. In the Americas, for example, the down- link band is 12.2 to 12.7 GHz.

The comparatively large satellite receiving dishes [ranging in diameter from about 1.83 m (6 feet) to about 3 m (10 feet) in some locations, which may be seen in some “backyards” are used to receive downlink TV signals at C band (4GHz).

Originally such downlink signals were never intended for home reception but for network relay to commercial TV outlets (VHF and UHF TV broadcast stations and cable TV “head-end” studios)

Equipment is now marketed for home reception of C-band signals, and some manufacturers provide dual C-band/Ku-band equipment. A single mesh type reflector may be used which focuses the signals into a dual feed- horn, which has two separate outputs, one for the C-band signals and one for the Ku-band signals.

Much of television programming originates as first generation signals, also known as master broadcast quality signals.

These are transmitted via satellite in the C band to the network head- end stations, where they are retransmitted as compressed digital signals to cable and direct broadcast satellite providers.

- Another of the advantages, claimed for home C-band systems, is the larger number of satellites available for reception compared to what is available for direct broadcast satellite systems.
- Although many of the C-band transmissions are scrambled, there are free channels that can be received, and what are termed “wild feeds.”

- These are also free, but unannounced programs, of which details can be found in advance from various publications and Internet sources.
- C-band users can also subscribe to pay TV channels, and another advantage claimed is that subscription services are cheaper than DBS or cable because of the multiple-source programming available.
- The most widely advertised receiving system for C-band system appears to be 4DTV manufactured by Motorola.

This enables reception of:

- Free, analog signals and "wild feeds"
- Video Cipher ll plus subscription services
- Free Digi Cipher 2 services
- Subscription Digi Cipher 2 services

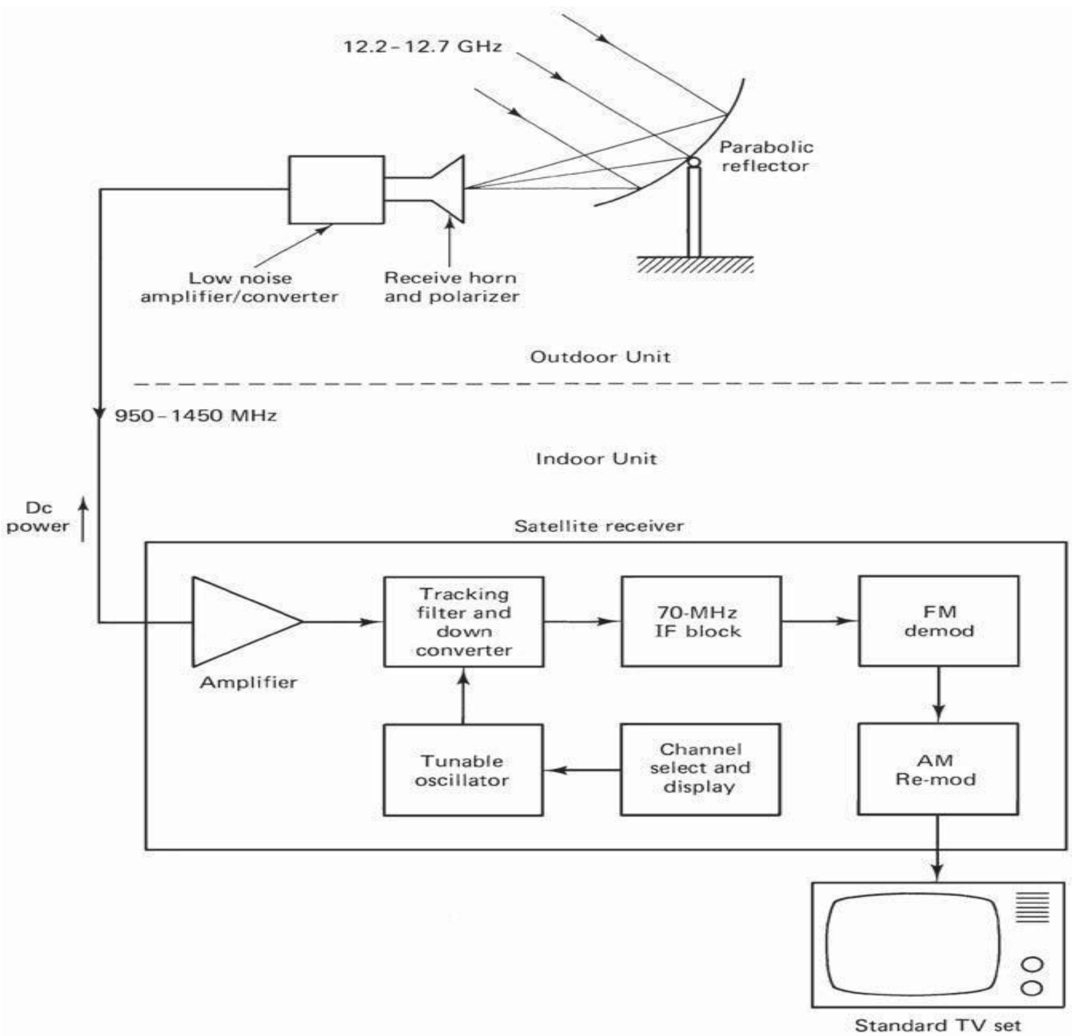


Fig 5.12 Home Terminal for DBS TV/FM reception.

THE OUTDOOR UNIT:

This consists of a receiving antenna feeding directly into a low-noise amplifier/converter combination. A parabolic reflector is generally used, with the receiving horn mounted at the focus. A common design is to have the focus directly in front of the reflector, but for better interference rejection, an offset feed may be used as shown.

Comparing the gain of a 3 m dish at 4 GHz with a 1 m dish at 12 GHz, the ratio D/l equals 40 in each case, so the gains will be about equal. Although the free-space losses are much higher at 12 GHz compared with 4 GHz.

The downlink frequency band of 12.2 to 12.7 GHz spans a range of 500 MHz, which accommodates 32 TV/FM channels, each of which is 24 MHz wide. Obviously, some overlap occurs between channels, but these are alternately polarized left-hand circular (LHC) and right-hand circular (RHC) or vertical/horizontal, to reduce interference to accept- able levels. This is referred to as polarization interleaving. A polarizer that may be switched to the desired polarization from the indoor control unit is required at the receiving horn.

The receiving horn feeds into a low-noise converter (LNC) or possibly a combination unit consisting of a low-noise amplifier (LNA) followed by a converter.

The combination is referred to as an LNB, for low-noise block. The LNB provides gain for the broadband 12 GHz signal and then converts the signal to a lower frequency range so that a low-cost coaxial cable can be used as feeder to the indoor unit.

THE INDOOR UNIT:

The signal fed to the indoor unit is normally a wideband signal covering the range 950 to 1450 MHz. This is amplified and passed to a tracking filter which selects the desired channel, as shown in Fig.

As previously mentioned, polarization interleaving is used, and only half the 32 channels will be present at the input of the indoor unit for any one setting of the antenna polarizer. This eases the job of the tracking filter, since alternate channels are well separated in frequency.

The selected channel is again down converted, this time from the 950- to 1450-MHz range to a fixed intermediate frequency, usually 70 MHz although other values in the very high frequency (VHF) range are also used.
The 70-MHz amplifier amplifies the signal up to the levels required for demodulation. A major difference between DBS TV and conventional TV is that with DBS, frequency modulation is used, whereas with conventional TV, amplitude modulation in the form of vestigial single side-band (VSSB) is used.

The 70 -MHz, FM intermediate frequency (IF) carrier therefore must be demodulated, and the baseband information used to generate a VSSB signal which is fed into one of the VHF/UHF channels of a standard TV set.

5.6 DIRECT TO HOME BROADCAST (DTH):

Direct to home technology refers to the satellite television broadcasting process which is actually intended for home reception. This technology is originally referred to as **direct broadcast satellite (DBS)** technology. The technology was developed for competing with the local cable TV distribution services by providing higher quality satellite signals with more number of channels.

In short, DTH refers to the reception of satellite signals on a TV with a personal dish in an individual home. The satellites that are used for this purpose is geostationary satellites. The satellites compress the signals digitally, encrypt them and then are beamed from high powered geostationary satellites. They are received by dishes that are given to the DTH consumers by DTH providers.

Though DBS and DTH present the same services to the consumers, there are some differences in the technical specifications. While DBS is used for transmitting signals from satellites at a particular frequency band [the band differs in each country], DTH is used for transmitting signals over a wide range of frequencies [normal frequencies including the KU and KA band]. The satellites used for the transmission of the DTH signals are not part of any international planned frequency band. DBS has changed its plans over the past few years so as to include new countries and also modify their mode of transmission from analog to digital. But DTH is more famous for its services in both the analog and digital services which includes both audio and video signals. The dishes used for this service is also very small in size. When it comes to commercial use, DBS is known for its service providing a group of free channels that are allowed for its targeted country.

DTH in India

India is one of the biggest DTH service providers in the world. The requirement is very high because of the high population and the increased number of viewers. The low cost of DTH when compared to other local cable providers is also one main reason for this substantial growth.

In India the DTH requirement is more than in any country as the population of viewers is at very high rate.

The first person who invented the technology for DTH war Sir Arthure Clarles Clarke, a british inventor in late 1946. The idea of DTH was first provided to India in 1996. But it was not approved then as there were concerns about national security. But the laws were changed by the year 2000 and thus DTH was allowed. Doordarshan was first to provide the service to the consumers from 1st of April, 2000.

According to the new rule, DTH providers are required to set up new stations within 12 months of getting the license. The cost of the license is almost $2.15 million in India with a validity of 10 years for renewal. The latest reports suggest that almost 25% of the total Indian population use this facility while others use local TV connections.

Some of the common DTH providers in India are

1. TATA Sky
2. BIG TV
3. Sun Direct DTH
4. Dish TV
5. Airtel DTH
6. Videocon DTH

Working of DTH

To know the working of DTH better, take a look at the diagram below.

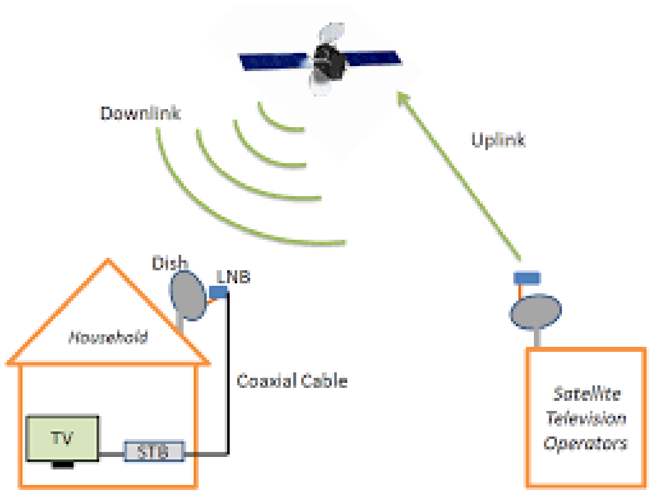


Figure DTH Service

For a DTH network to be transmitted and received, the following components are needed.

- Broadcasting Centre
- Satellites
- Encoders
- Multiplexers
- Modulators
- DTH receivers

It must be noted the channels that are broadcasted from the broadcasting centre hare not created by the DTH providers. The DTH providers pay other companies like HBO, Sony MAX and so on for the right to broadcast their channel to the DTH consumers through satellite. Thus the DTH provider acts as a mediator r broker between the consumers and the programme channels.

The broadcast centre is the main part of the whole system. It is from the broadcast station that the signals are sent to the satellites to be broadcasted. The broadcast station receives the signals from various program channels.

The satellite receives the signal from the broadcast centre and compresses the signals and makes them suitable for re-transmission to the ground.

The DTH providers give dish receivers for the viewers to receive the signal from the satellites. There may be one or multiple satellites that send the signals at the same time. The receiver receives the signal from them and is passed on to the Set Top Box [STB] receiver in the viewer's house.

The STB receiver changes the signal in a form suitable for our television and then passes it on to our TV. STB receiver consist of the following components

- Tuner
- Demodulator
- Decoder
- Microcontroller
- CAS System
- Amplifiers

Advantages of DTH Technology

- The main advantage is that this technology is equally beneficial to everyone. As the process is wireless, this system can be used in all remote or urban areas.
- High quality audio and video which are cost effective due to absence of mediators.
- Almost 4000 channels can be viewed along with 2000 radio channels. Thus the world's entire information including news and entertainment is available to you at home.
- As there are no mediators, a complaint can be directly expressed to the provider.
- With a single DTH service you will be able to use digital quality audio, video and also high speed broadband.
- It also offers interactive channels and program guides with customers having the choice to block out programming which they consider undesirable
- One of the great advantages of the cable industry has been the ability to provide local channels, but this handicap has been overcome by many DTH providers using other local channels or local feeds.

Disadvantages:

Among disadvantages, the biggest one is the capital cost that has to be borne initially. Since this involves setting up of a receiving apparatus at the subscribers end, the cost can be prohibitively high.

5.7 WORLD SPACE SERVICES:

World Space (Nasdaq: WRSP) is the world's only global media and entertainment company positioned to offer a satellite radio experience to consumers in more than 130 countries with five billion people, driving 300 million cars. World Space delivers the latest tunes, trends and information from around the world and around the corner.

World Space subscribers benefit from a unique combination of local programming, original World Space content and content from leading brands around the globe, including the BBC, CNN, Virgin Radio, NDTV and RFI. World Space's satellites cover two -thirds of the globe with six beams.

Each beam is capable of delivering up to 80 channels of high quality digital audio and multimedia programming directly to World Space Satellite Radios anytime and virtually anywhere in its coverage area. World Space is a pioneer of satellite-based digital radio services (DARS) and was instrumental in the development of the technology infrastructure used today by XM Satellite Radio.

Business Television (BTV) - Adaptations for Education:

Business television (BTV) is the production and distribution, via satellite, of video programs for closed user group audiences. It often has two-way audio interaction component made through a simple telephone line. It is being used by many industries including brokerage firms, pizza houses, car dealers and delivery services.

BTV is an increasingly popular method of information delivery for corporations and institutions. Private networks, account for about 70 percent of all BTV networks. It is estimated that by the mid- 1990s BTV has the potential to grow to a $1.6 billion market in North America with more and more Fortune 1,000 companies getting involved. The increase in use of BTV has been dramatic.

Institution updates, news, training, meetings and other events can be broadcast live to multiple locations. The expertise of the best instructors can be delivered to thousands of people without requiring trainers to go to the site. Information can be disseminated to all employees at once, not just a few at a time. Delivery to the workplace at low cost provides the access to training that has been denied lower level employees. It may be the key to re-training America's work force.

Television has been used to deliver training and information within businesses for more than 40 years. Its recent growth began with the introduction of the video cassette in the early 1970s. Even though most programming is produced for video cassette distribution, business is using BTV to provide efficient delivery of specialized programs via satellite.

The advent of smaller receiving stations - called very small aperture terminals (VSATs) has made private communication networks much more economical to operate. BTV has a number of tangible benefits, such as reducing travel, immediate delivery of time-critical messages, and eliminating cassette duplication and distribution hassles.

The programming on BTV networks is extremely cost-effective compared to seminar fees and downtime for travel. It is an excellent way to get solid and current information very fast. Some people prefer to attend seminars and conferences where they can read, see, hear and ask questions in person. BTV provides yet another piece of the education menu and is another way to provide professional development.

A key advantage is that its format allows viewers to interact with presenters by telephone, enabling viewers to become a part of the program. The satellite effectively places people in the same room, so that sales personnel in the field can learn about new products at the same time.

Speed of transmission may well be the competitive edge which some firms need as they introduce new products and services. BTV enables employees in many locations to focus on common problems or issues that might develop into crises without quick communication and resolution.

BTV networks transmit information every business day on a broad range of topics, and provide instructional courses on various products, market trends, selling and motivation. Networks give subscribers the tools to apply the information they have to real world situations.

5.8 GRAMSAT:

ISRO has come up with the concept of dedicated GRAMSAT satellites, keeping in mind the urgent need to eradicate illiteracy in the rural belt which is necessary for the all round development of the nation.

This Gramsat satellite is carrying six to eight high powered C -band transponders, which together with video compression techniques can disseminate regional and cultural specific audio-visual programmes of relevance in each of the regional languages through rebroadcast mode on an ordinary TV set.
The high power in C-band has enabled even remote area viewers outside the reach of the TV transmitters to receive programmers of their choice in a direct reception mode with a simple .dish antenna.

The salient features of GRAMSAT projects are:

- Its communications networks are at the state level connecting the state capital to districts, blocks and enabling a reach to villages.
- It is also providing computer connectivity data broadcasting, TV-broadcasting facilities having applications like e- governance, development information, teleconferencing, helping disaster management.
- Providing rural-education broadcasting.

However, the Gramsat projects have an appropriate combination of following activities.

- Interactive training at district and block levels employing suitable configuration
- Broadcasting services for rural development
- Computer interconnectivity and data exchange services
- Tele-health and tele-medicine services.