Unit-I

Passive satellites: Satellites which reflect the incident electromagnetic radiation without any modification or amplification. Passive satellites can't generate power they simply reflect the incident power.

Active satellites: Satellites which can transmit power are called active satellite. They can amplify or modify the incident signal for transmission.

Frequency Allocation for Satellite Communications

Band	Frequency Range	Total Bandwidth	General Application
L	1 to 2 GHz	1 GHz	Mobile satellite service (MSS)
S	2 to 4 GHz	2 GHz	MSS, NASA, deep space research
C	4 to 8 GHz	4 GHz	Fixed satellite service (FSS)
X	8 to 12.5 GHz	4.5 GHz	FSS military, terrestrial earth exploration, and meteorological satellites
Ku	12.5 to 18 GHz	5.5 GHz	FSS, broadcast satellite service (BSS)
K	18 to 26.5 GHz	8.5 GHz	BSS, FSS
Ka	26.5 to 40 GHz	13.5 GHz	FSS

Satellite Orbits – 1

- Earth satellites are typically in four orbits
  - Low Earth Orbit (LEO)
  - Medium Earth Orbit (MEO)
  - Geostationary Earth Orbit (GEO)
  - Highly Elliptical Earth Orbit (HEO)

These are usually highly elliptical; eccentricity > 0.1

These are usually circular; eccentricity < 0.001

Satellite Orbits – 2A

- Orbit ranges (altitudes)
  - LEO ~250 to ~1,500 km
  - MEO ~2,500 to ~15,000 km
  - GEO 35,786.03 km
  - HEO examples:
    - ~500 to ~39,152 km Molniya (“Flash of lightning”)
    - ~ 16,000 to ~ 133,000 km Chandra

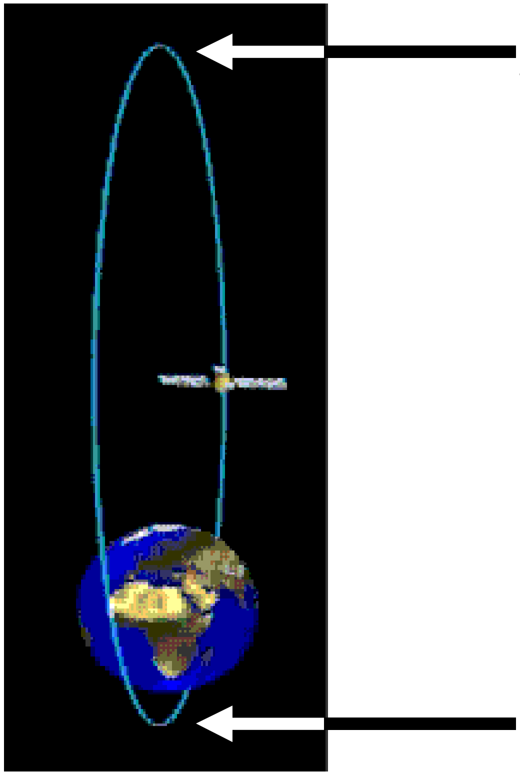
Mean earth radius is 6,378.137 km

Period of one-half sidereal day

Period of 64 hours and 18 minutes

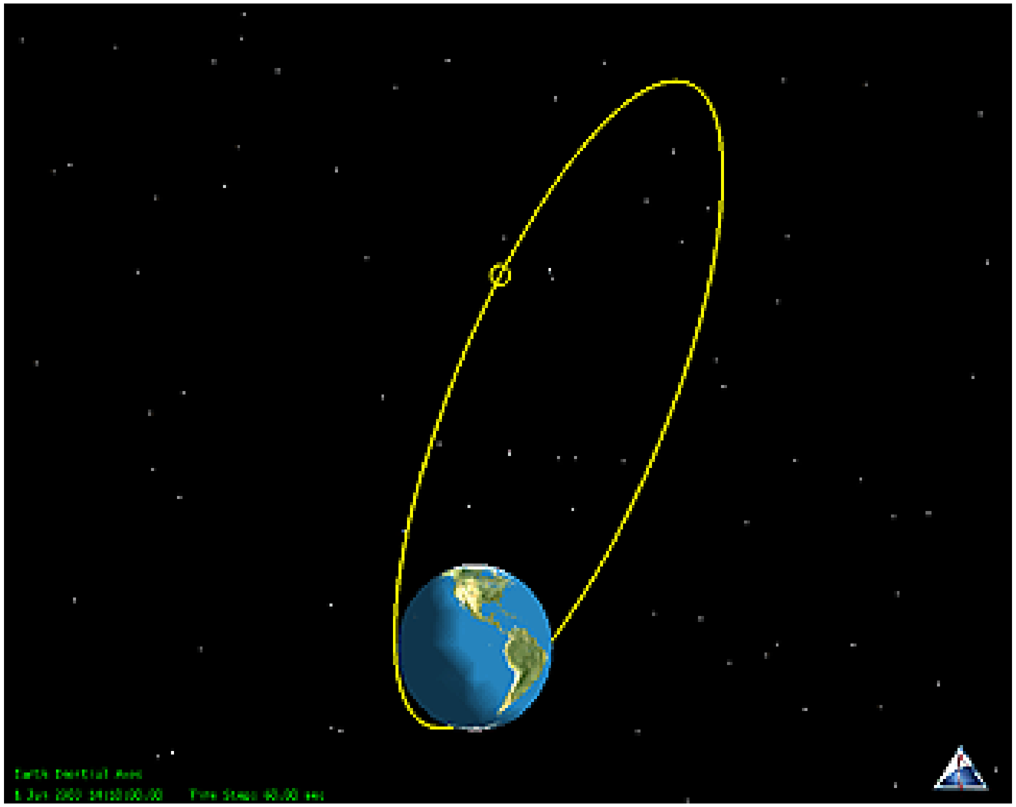
Satellite Orbits – 2D

- Some special orbits
  - Molniya (contd.)



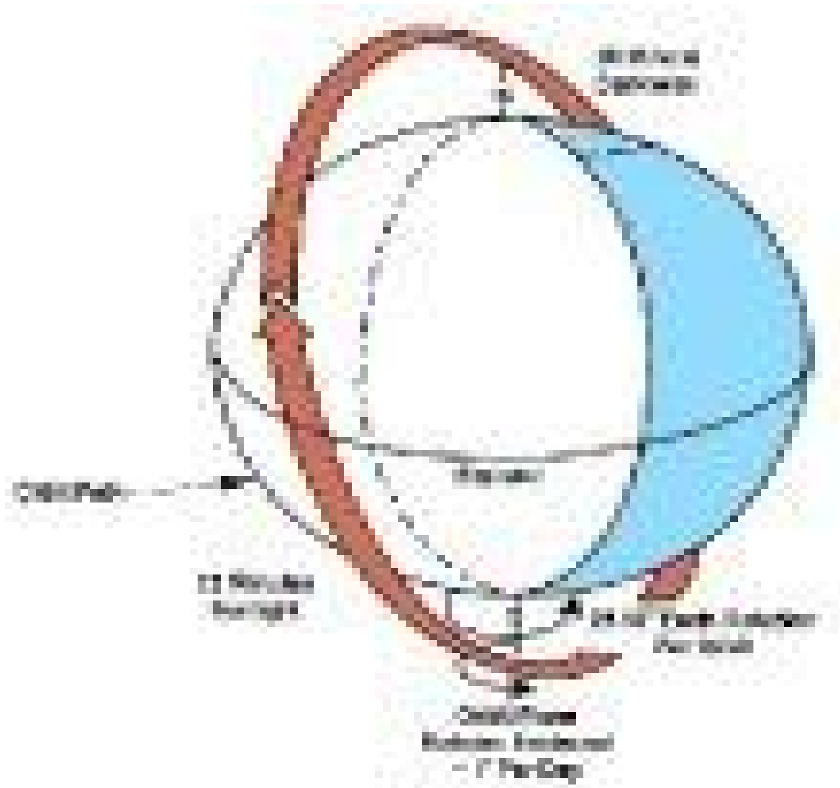
Satellite Orbits – 2C

- Some special orbits
  - Molniya



Satellite Orbits – 2B

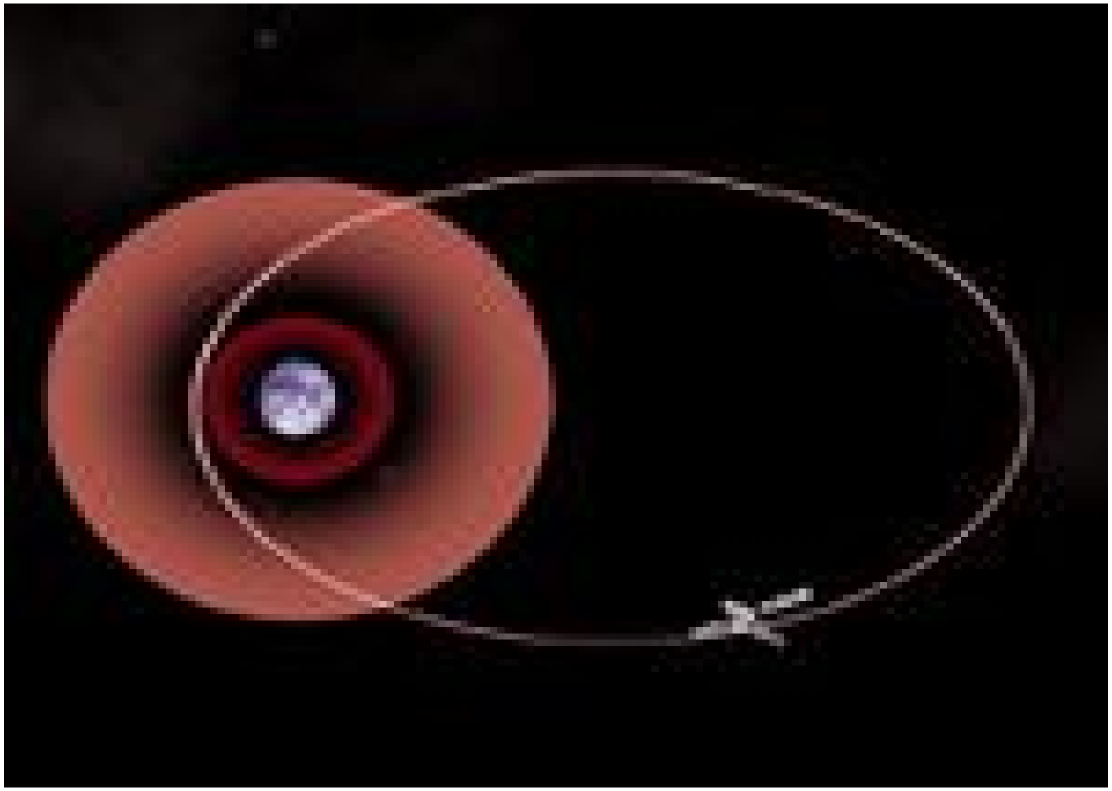
- Some special orbits
  - Sun synchronous



Sometimes called a "retrograde" orbit as it is effectively launched more than 90^{o} to the equator

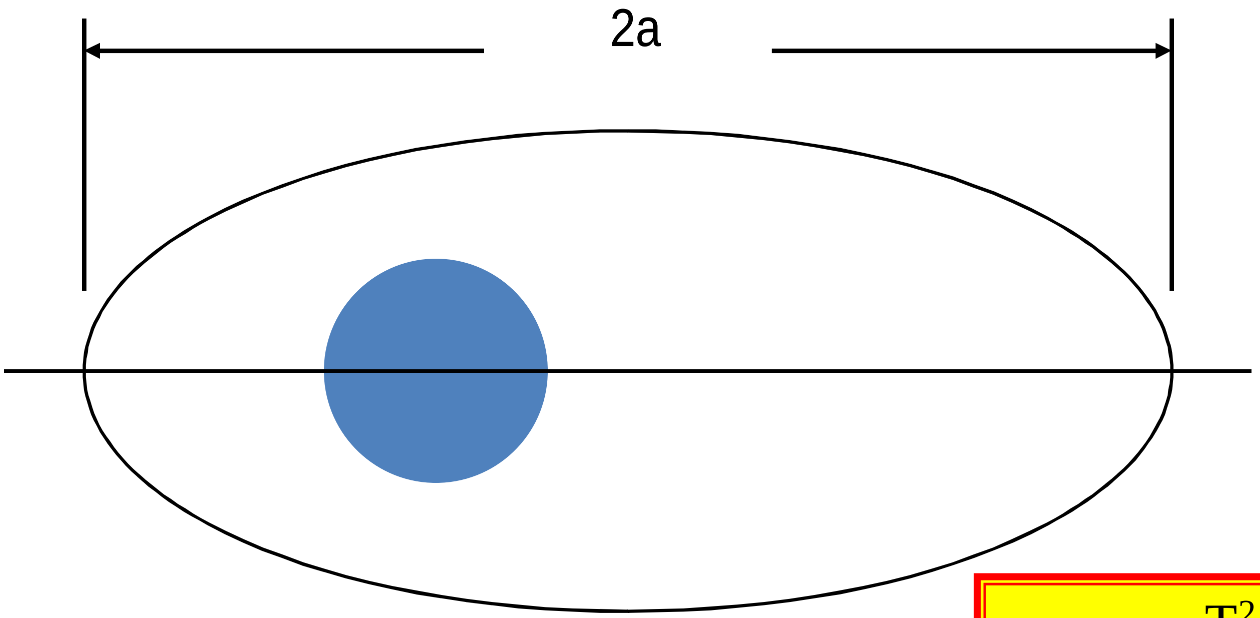
Satellite Orbits – 2F

- Some special orbits
  - Chandra



Satellite Orbits – 3

- Orbit period, T (seconds)



μ is Kepler's constant

$$T^2 = (4\pi^2 a^3)/\mu$$

$$\mu = 3.986004418 \times 10^5\ km^3/s^2$$

Satellite Orbits-4

- Orbit period, T – examples

Orbital height	Orbital period	
500 km	1 h 34.6 min	Typical LEO
1,000 km	1 h 45.1 min	Typical LEO
5,000 km	3 h 21.3 min	Typical MEO
10,000 km	5 h 47.6 min	Typical MEO
35,786 km	23 h 56.04 min	GEO
402,000 km	28 days	Moon's orbit
148,800,000 km	365.25 days	Earth's orbit

One-Way Delay Times – 1

GEO satellite: 35,786 km

One-way delay:
119.3 ms

MEO satellite: 10,355 km
One-way delay:
34.5 ms

LEO satellite: 800 km
One-way delay:
2.7 ms

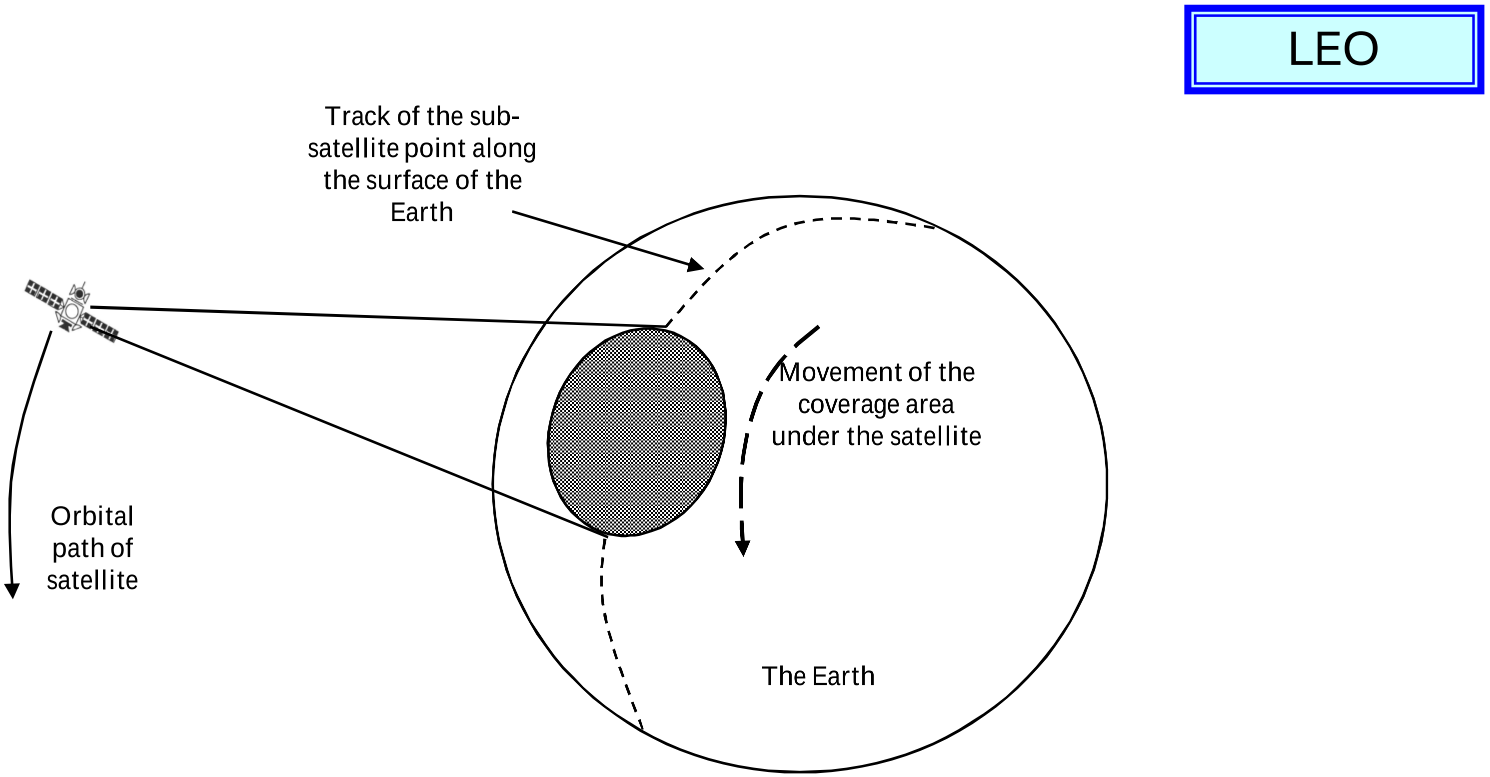
Satellite Orbits-5

- Orbit velocities (m/s)
  - LEO ~ 7 km/s
  - MEO ~ 5 km/s
  - GEO = 3.0747 km/s

$v = (\mu/r)^{1/2}$
where r = radius from center of earth

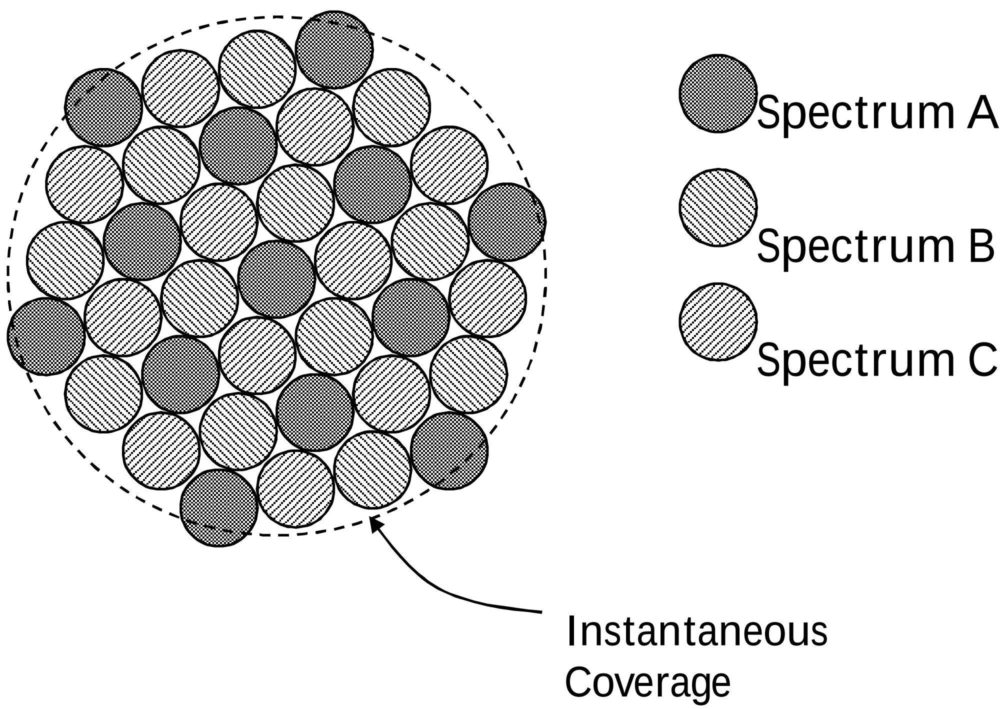
GEO Orbital radius = 35,786.03 + 6,378.137 km
Orbital circumference = 2 π 42,164.167 km
Orbital period = (2 π 42,164.167)/3.0747 seconds
= 86,162.96699 seconds
= 23 hours 56.04 minutes

Satellite Orbits – Coverages – 1



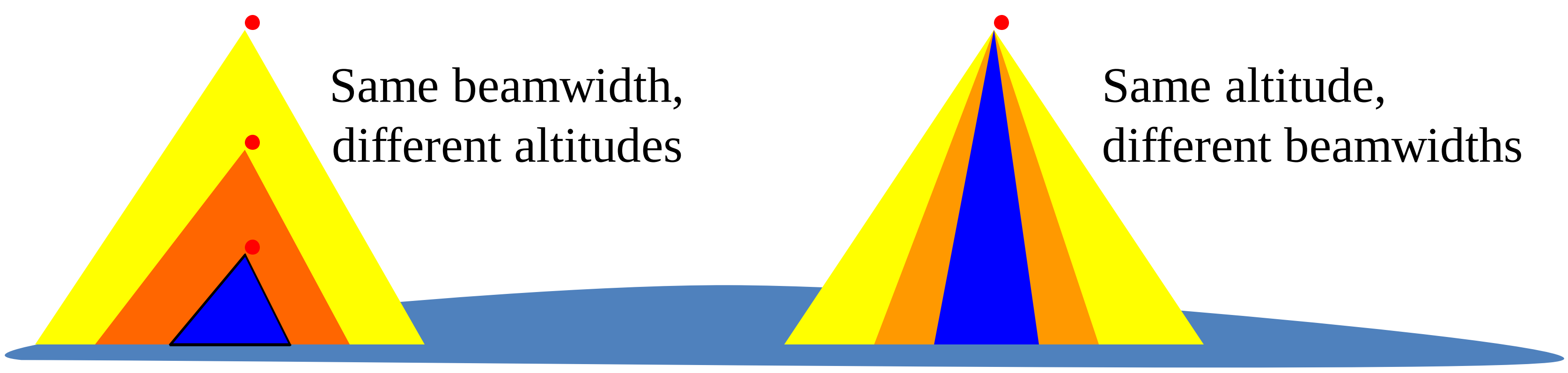
Satellite Orbits – Coverages – 2

Multiple beams



Satellite Orbits – Coverages – 5

- Satellite coverages – 1
  - Determined by two principal factors
    - Height of satellite above the Earth
    - Beamwidth of satellite antenna



Satellite Orbits – Coverages – 6

- Satellite coverages – 2
  - Orbital plane usually optimized
    - Equatorial orbits – simplest, equal N-S coverage
    - Inclined orbits – cover most of populated Earth
    - Polar orbits – cover all of the Earth at some point
    - Retrograde orbits – gives sun synchronized orbit
  - LEO chosen for two reasons usually
    - Low link power needed
    - good optical resolution

Satellite Orbits – Coverages – 7

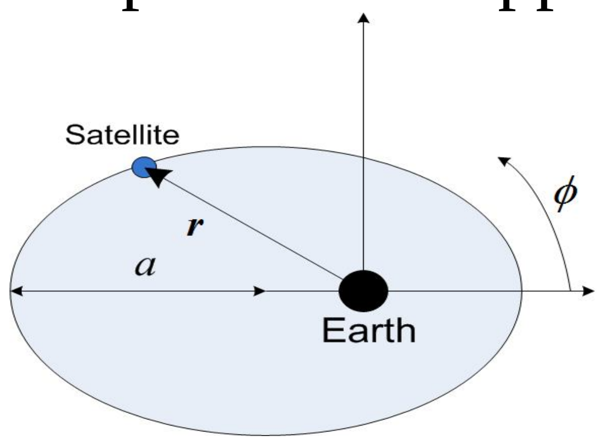
- Satellite coverages – 3
  - MEO chosen for a variety of reasons
    - GPS half sidereal orbit covers same tracks alternately
    - Compromise between LEO and GEO delay
    - Compromise between LEO and GEO total number
  - GEO chosen for two reasons mainly
    - Optimizes broadcast capabilities
    - Simplest earth terminal implementation

Satellite Orbits – Coverages – 8

- We will now look at one of the most important figure that will help you calculate satellite coverages, look angles, required beamwidths, separation angles between satellites, and distances between earth stations and satellites, and between satellites in a constellation.

Kepler's laws

- Johannes Kepler published laws of planetary motion in solar system in early 17th century
- Laws explained extensive astronomical planetary measurements performed by Tycho Brahe
- Kepler's laws were proved by Newton's theory of gravity in mid 18th century
- Kepler's laws approximate motion of satellites around



1. $$r = \frac{p}{1 + e\cos(\phi)}$$

2. $$\boldsymbol{r} \times \frac{d\boldsymbol{r}}{dt} = \text{const}$$

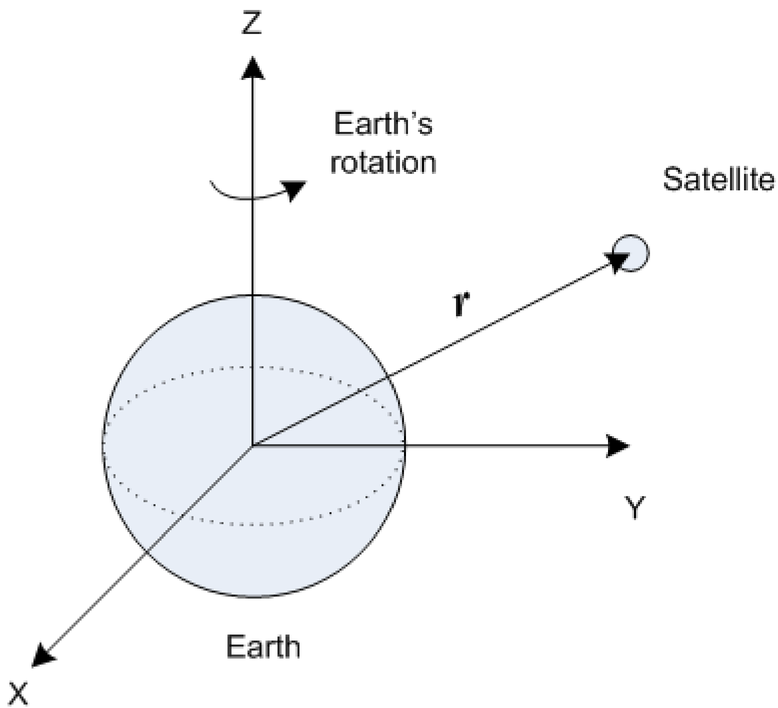
3. $$\frac{T^2}{a^3} = \text{const}$$

Kepler’s laws (as applicable to satellite motion)

1. The orbit of a satellite is an ellipse with the Earth at one of the two foci
2. A line joining a satellite and the Earth’s center sweeps out equal areas during equal intervals of time
3. The square of the orbital period of a satellite is directly proportional to the cube of the semi-major axis of its orbit.

Derivation of satellite orbit (1)

- Based on Newton’s theory of gravity and laws of motion
- Satellite moves in a plane that contains Earth’s origin
- Acting force is gravity
- Mass of Earth is much larger than the mass of a satellite



Satellite in Earth's orbit

Gravitational force on the satellite

$$\boldsymbol{F} = -\frac{GM_E m\boldsymbol{r}}{r^3}$$

Newton's 2nd law

$$\boldsymbol{F} = m\boldsymbol{a} = m\frac{d^2\boldsymbol{r}}{dt^2}$$

Combining the two

$$\frac{d^2\boldsymbol{r}}{dt^2} + \frac{\boldsymbol{r}}{r^3}\mu = 0$$

Differential equation that determines the orbit

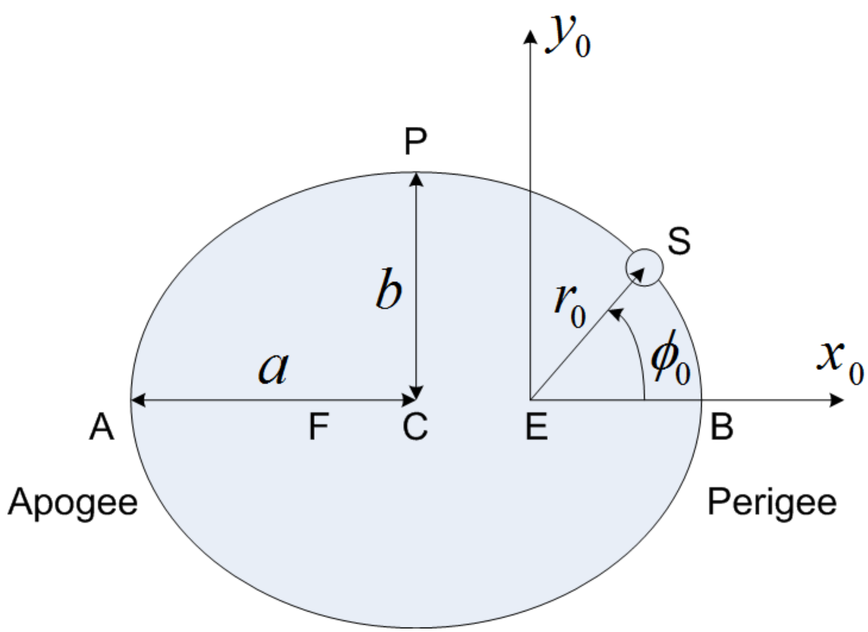
Constants

$$G = 6.672\times10^{-11}\,\mathrm{Nm^2/kg^2}$$

$$M_E = 5.98\times10^{24}\,\mathrm{kg}$$

$$\mu = 3.983\times10^5\,\mathrm{km^3/s^2}$$

Describing the orbit of a satellite



- E and F are focal points of the ellipse
- Earth is one of the focal points (say E)
- a – major semi axis
- b – minor semi axis
- *Perigee* – point when the satellite is closest to Earth
- *Apogee* – point when the satellite is furthest from Earth
- The parameters of the orbit are related
- Five important results:
  1. Relationship between a and p
  2. Relationship between *b* and *p*
  3. Relationship between eccentricity, perigee and apogee distances
  4. 2nd Kepler's law
  5. 3rd Kepler's law

$$r_0 = \frac{p}{1 + e\cos\phi_0}$$

Elliptic trajectory – cylindrical coordinates

$$ES + FS = 2a$$

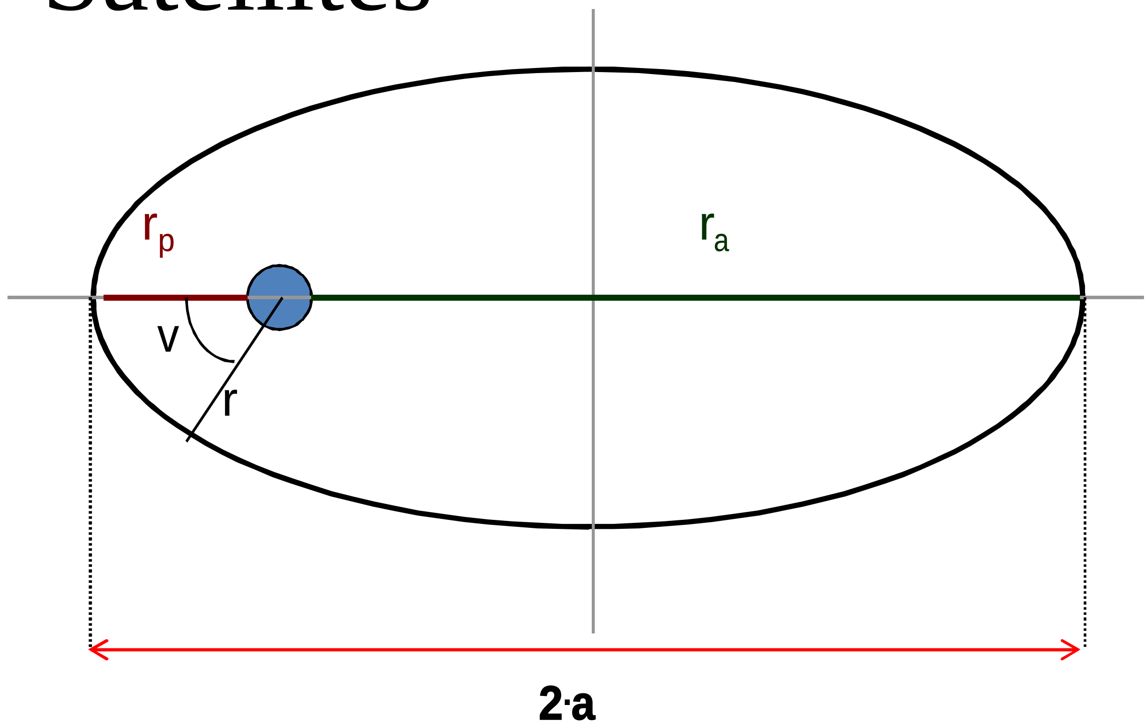
Basic relationship of ellipse

Locating the satellite in the orbit

- Algorithm summary:

  1. Calculate average angular velocity: $\eta = \mu^{1/2} / a^{3/2}$
  2. Calculate mean anomaly: $M = \eta(t - t_p)$
  3. Solver for eccentric anomaly: $M = E - e\sin(E)$
  4. Find polar coordinates: $r_0 = a[1 - e\cos(E)]; \phi_0 = \cos^{-1}\left[\frac{a(1-e^2) - r_0}{er_0}\right]$
  5. Find rectangular coordinates $x_0 = r_0\cos(\phi_0); y_0 = r_0\sin(\phi_0)$

Definitions of terms for earth-orbiting Satellites



e=0: circle

e<1: ellipse

e=1: parabola

e>1: hyperbola

$$r = \frac{a(1-e^2)}{1-e\cos v}$$

a: semimajor axis

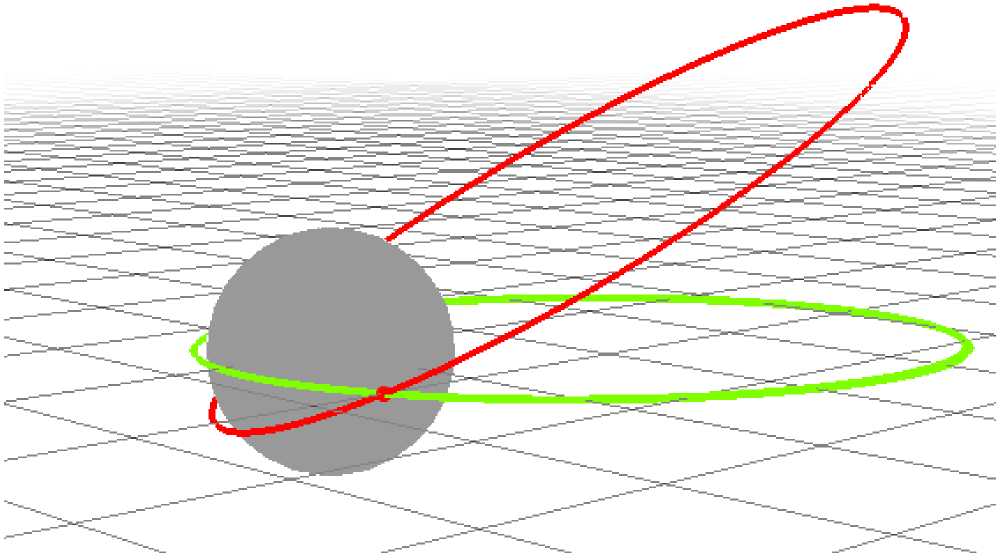
e: eccentricity

v: true anomaly (0…360 deg)

r_p: Radius of periapsis (perihelion) $$r_p = a(1-e)$$

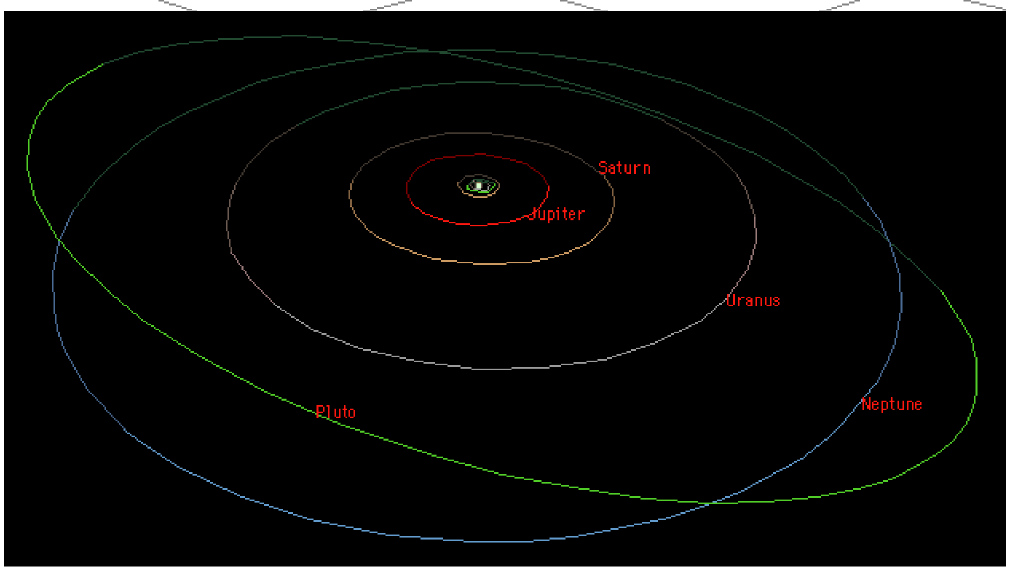
r_a: Radius of apoapsis (aphelion) $$r_a = a(1+e)$$

Definitions of terms for earth-orbiting Satellites



i: inclination (0…180 deg)

(always towards a reference plane)

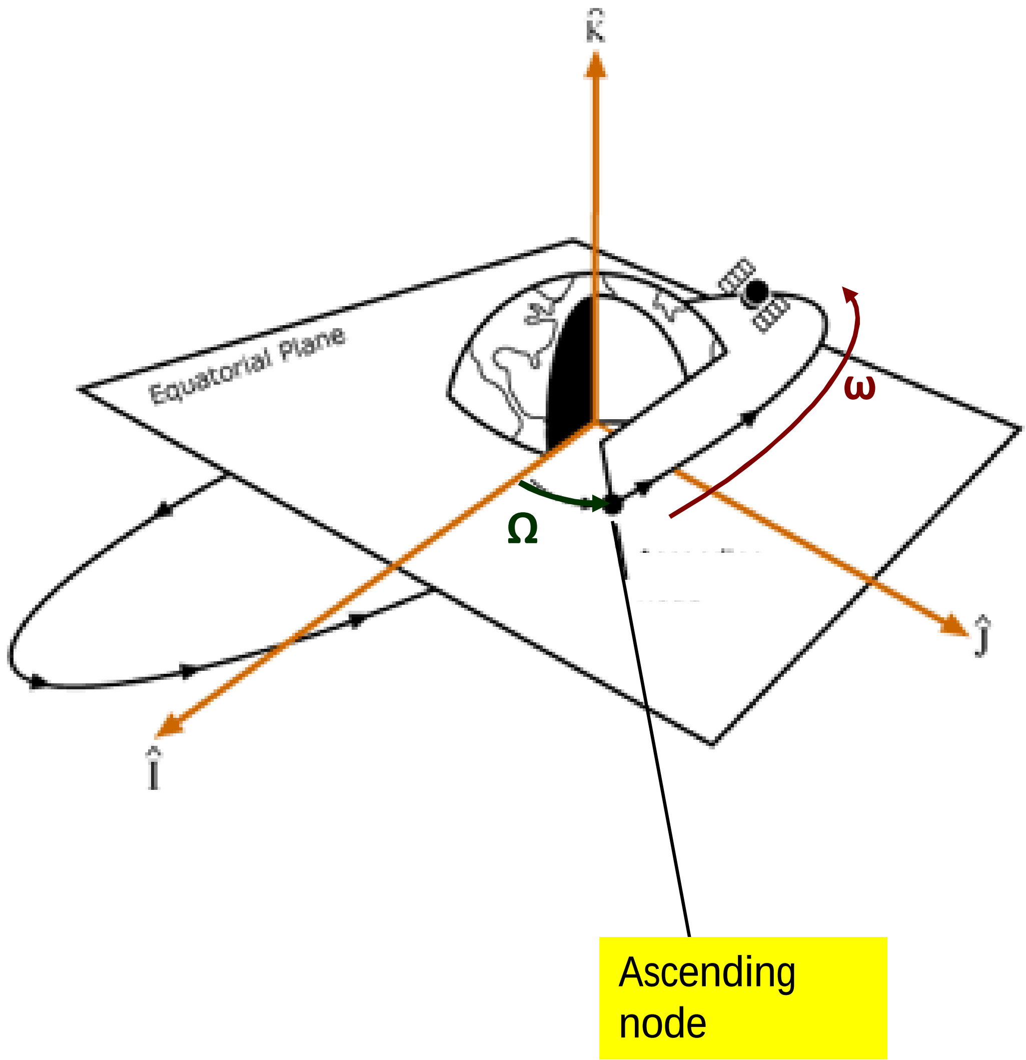


Reference plane for solar system orbits:

• Ecliptic=(plane of Earth's orbit around the Sun)

• All planetary orbital planes are oriented within a few degrees from the ecliptic

Basic orbital elements (continued)



Ω: Right ascension of the ascending node (0...360 deg)

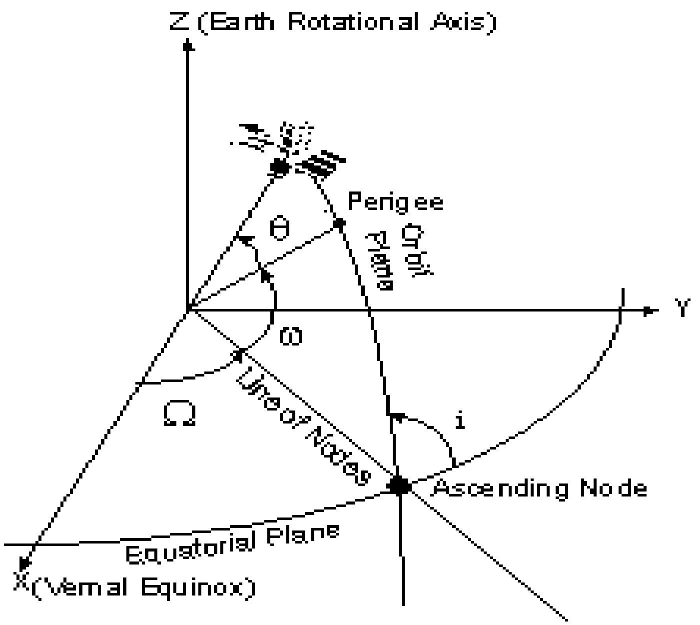
(always towards a reference direction)

ω: Argument of periapsis

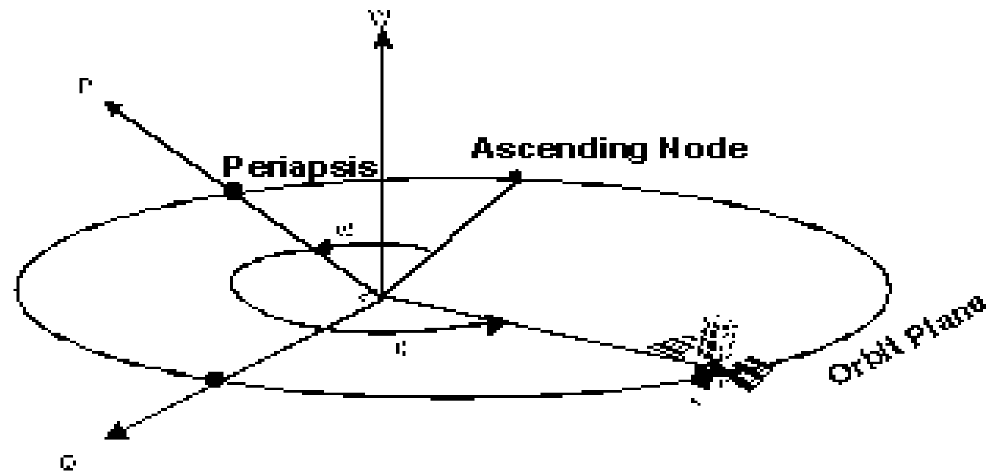
Definitions of terms for earth-orbiting Satellites

Parameter	Definition
Semimajor Axis	Half the distance between the two points in the orbit that are farthest apart
Apogee/Perigee Radius	Measured from the center of the Earth to the points of maximum and minimum radius in the orbit
Apogee/Perigee Altitude	Measured from the "surface" of the Earth (a theoretical sphere with a radius equal to the equatorial radius of the Earth) to the points of maximum and minimum radius in the orbit
Period	The duration of one orbit, based on assumed two-body motion
Mean Motion	The number of orbits per solar day (86,400 sec/24 hour), based on assumed two-body motion
Eccentricity	The shape of the ellipse comprising the orbit, ranging between a perfect circle (eccentricity = 0) and a parabola (eccentricity = 1)

Parameters determining orbit orientation

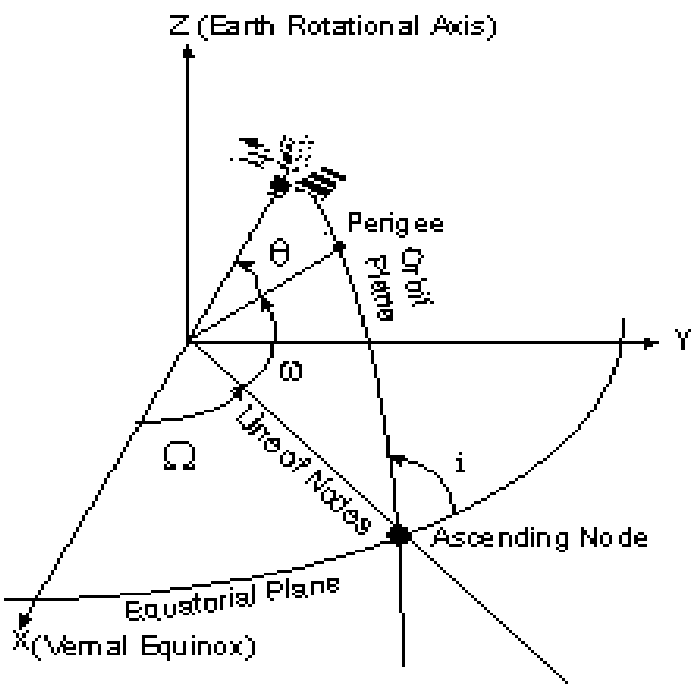


Orbit Geometry

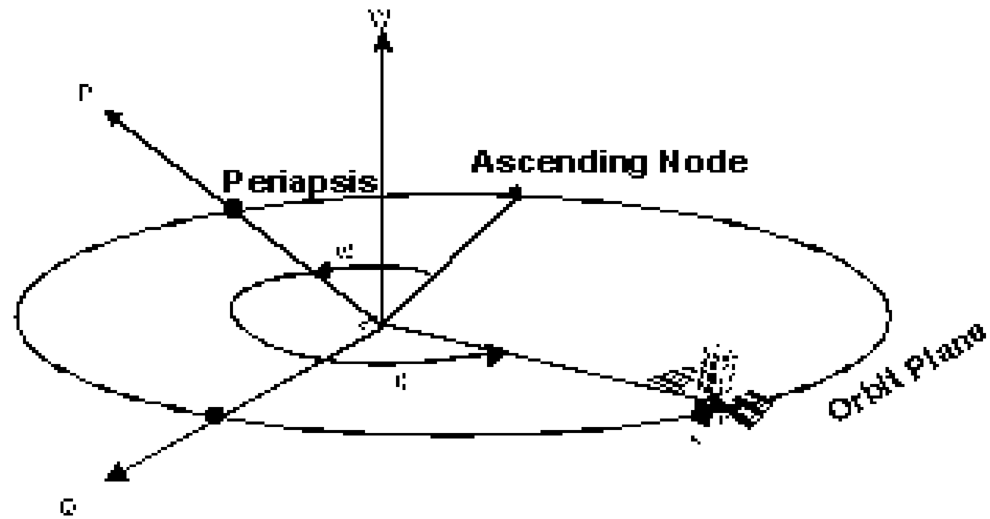


Legend:

- Ω = right ascension of ascending node
- ω = argument of perigee/periapsis
- i = inclination
- θ = true anomaly



Orbit Geometry



Legend:

- Ω = right ascension of ascending node
- ω = argument of perigee/periapsis
- i = inclination
- θ = true anomaly

Orbital perturbations

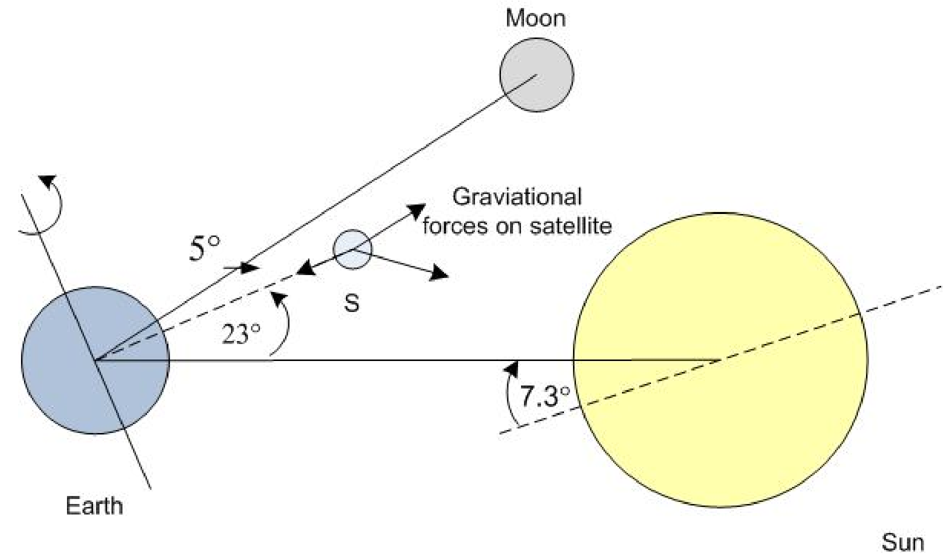
- Orbital perturbation – difference between real orbit and Keplerian orbit obtained from two body equations of motion
- Major sources of orbital perturbations
  - Perturbations due to non-ideal Earth
  - Third body perturbations
  - Atmospheric drag
  - Solar radiation and solar wind
- Importance of perturbation source depends on the satellite altitude
- Modeling of the real satellite orbit
  - Find "osculating orbit" at some time
  - Assume orbit elements vary linearly with time
  - Use measured data to determine rate of change for orbital parameters

Effects of non-ideal Earth

- Earth is not a sphere
  - Equatorial radius: ~ 6,378 km
  - Polar radius: ~ 6,356 km (about 22km smaller)
  - Equatorial radius not constant (small variations ~ 100m)
- Earth mass distribution
  - Earth mass distribution not uniform
  - Regions of mass concentrations: mascons
- Non-ideal Earth causes non-ideal gravitational field
- For LEO and MEO satellites this effect is not very significant
- GEO satellites are impacted the most
  - GEO satellites drift towards mascons in the “east-west” direction
  - Longitudes of two stable equilibrium points: 75°E and 252°E (or 108°W)
  - Longitudes of two unstable equilibrium points: 162°E and 348°E (or 12°W)

Third-body perturbation

- Motion of the satellite is not a "two-body" problem
- Satellite experiences gravitational pull from Sun and Moon as well
- The orbital relationship is complex and time dependent
- Gravitational forces from Sun and Moon tend to move satellite out of the orbit
- Under these condition the orbit will precess and its inclination will change (up to 1°/year)
- In practice:
  - Some of these effects are planed
  - Most of these effects are corrected using the on-board fuel



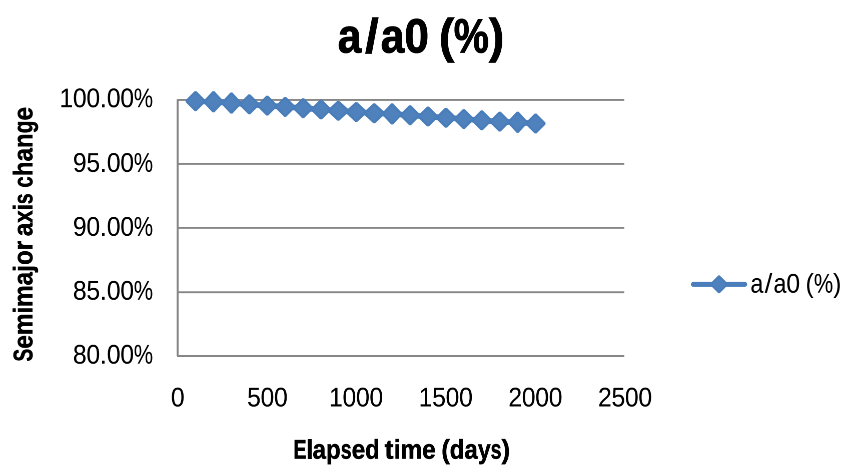
Orbital position of a satellite the Earth, the Sun and the Moon

Atmospheric drag

- Significant for satellites below 1000km
- Drag reduces the velocity of the satellite
  - Semi-major axis is reduced
  - Eccentricity is reduced
- Approximate equation for change of semi-major axis

$$a = a_0 \left[1 + \frac{n'_0}{n_0} (t - t_0) \right]^{-2/3}$$

where
a_0 – semi-major axis at t0
n_0 – mean motion (revs/day)
n'_0 – first derivative of mean motion (rev/day^2)



Note: change is relatively small and it is long term. In practice it can be easily resolved through satellite maneuvering.

GEOSTATIONARY ORBIT

- In the equatorial plane
- Orbital Period = 23 h 56 min. 4.091 s
  = one ***Sidereal Day*** (defined as one complete rotation relative to the fixed stars)
- Satellite appears to be **stationary** over a point on the equator to an observer
- Radius of orbit, ***r***, = 42,164.57 km

NOTE: Radius = orbital height + radius of the earth

Average radius of earth = 6,378.14 km

Geostationary Earth Orbit (GEO)

- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.

GEO (cont.)

- Advantages
  - A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.
  - GEO satellites have a 24 hour view of a particular area.
  - These factors make it ideal for satellite broadcast and other multipoint applications.

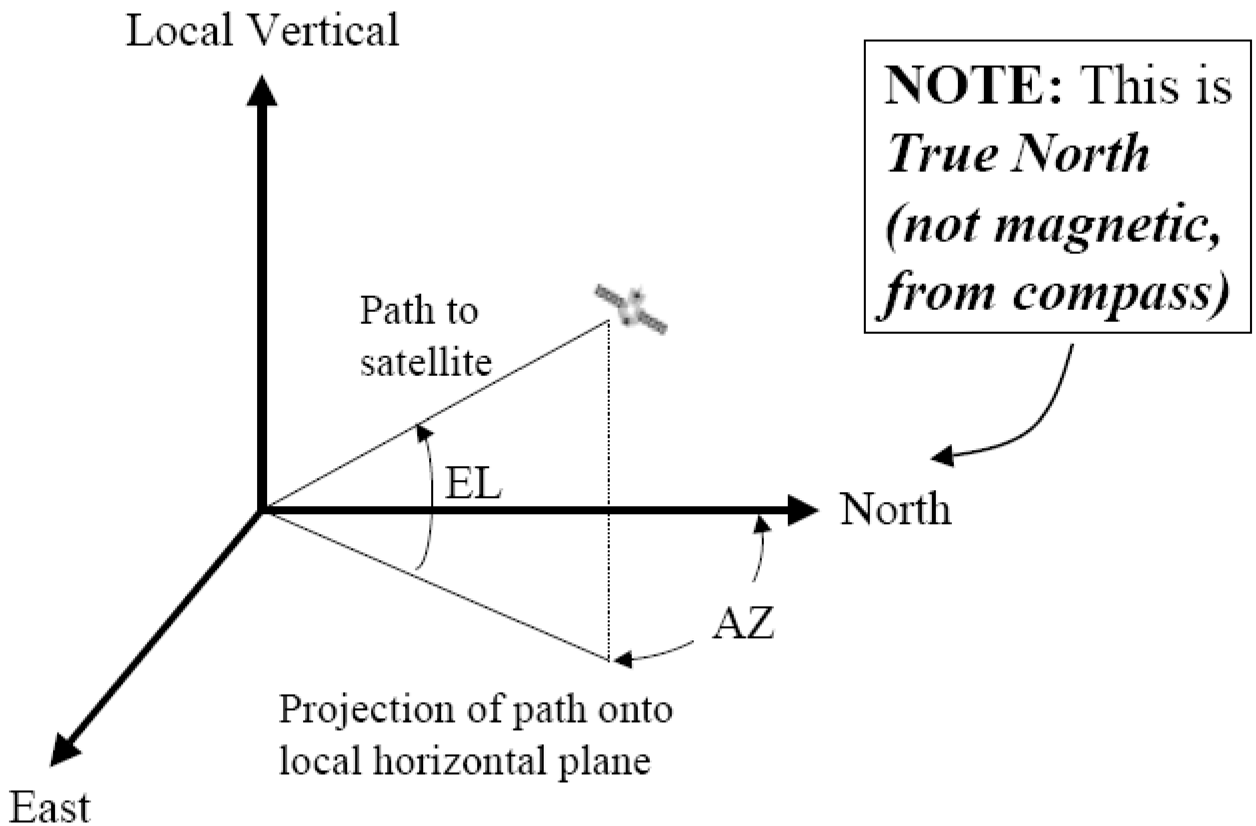
GEO (cont.)

- Disadvantages
  - A GEO satellite’s distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
  - GEO satellites, centered above the equator, have difficulty broadcasting signals to near polar regions

Antenna Look Angle

- Look angles: The coordinates to which an ES must point to communicate with a satellite. These are *azimuth* (AZ) and *elevation angle* (EL)
  - AZ: The angle measured from N to E to projection of satellite path onto horizontal plane
  - EL: The angle measured from the horizontal plane to the orbit plane
- The *subsatellite point*: The point, on the earth's surface, of intersection between a line from the earth's center to the satellite

Look Angle Definition



Calculating Look Angle

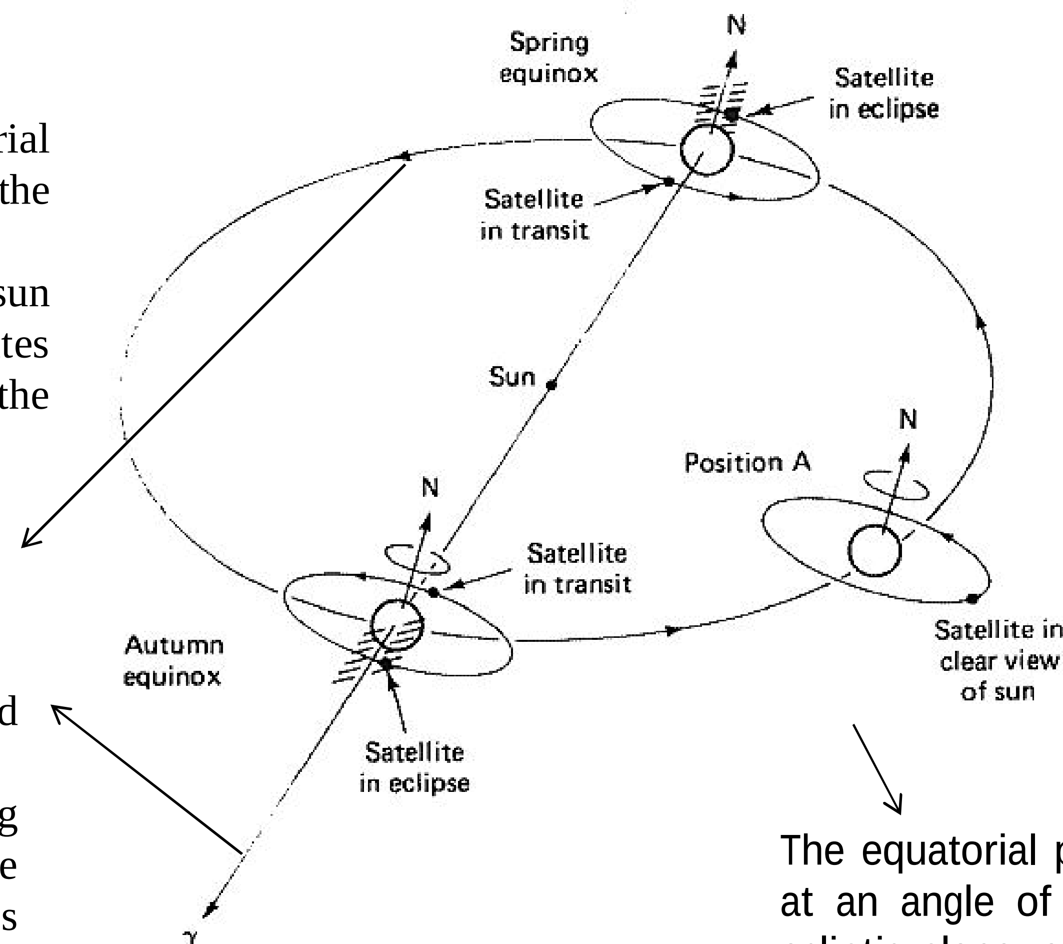
- ***Need*** six Orbital Elements
- ***Calculate*** the orbit from these Orbital Elements
- ***Define*** the orbital plane
- ***Locate*** satellite at time ***t*** with respect to the ***First Point of Aries***
- ***Find location*** of the Greenwich Meridian relative to the first point of Aries
- ***Use Spherical Trigonometry*** to find the position of the satellite relative to a point on the earth's surface

LIMITS OF VISIBILITY

- There are a number of perturbing forces that cause an orbit to depart from the ideal keplerian orbit.
- The period for a geostationary satellite is 23 h, 56 min, 4 s, or 86,164 s.
- The reciprocal of this is 1.00273896 rev/day,
- The east and west limits of geostationary are visible from any given Earth station.
- These limits are set by the geographic coordinates of the Earth station and antenna elevation.
- The lowest elevation is zero (in theory) but in practice, to avoid reception of excess noise from Earth some finite minimum value of elevation is issued.
- The earth station can see a satellite over a geostationary arc bounded by **+/- (81.3^0)** about the earth station's longitude.

EARTH ECLIPSE OF A SATELLITE

If the earth's equatorial plane coincided with the plane of the earth's
orbit around the sun geostationary satellites would be eclipsed by the earth once each day.



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

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

EARTH ECLIPSE OF A SATELLITE

- 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.
- The solar cells of the satellite become non-functional during the eclipse period and the satellite is made to operate with the help of power supplied from the batteries.

SUN TRANSIT OUTAGE

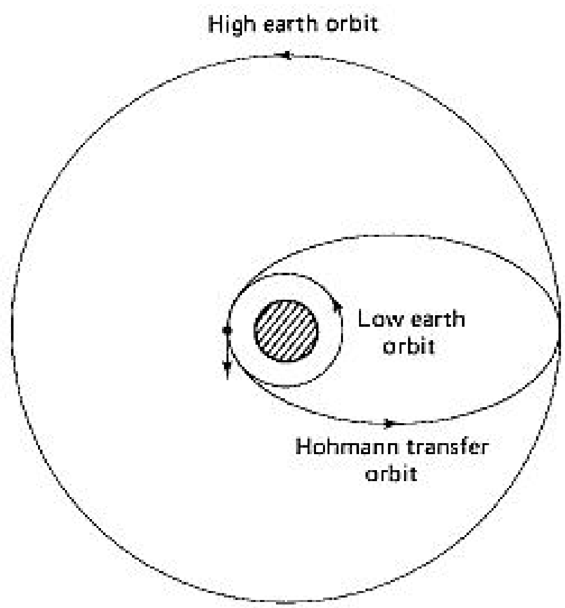
- Transit of the satellite between earth and sun
- The sun comes within the beamwidth of the earth station antenna.
- When this happens, the sun appears as an extremely noisy source which completely blanks out the signal from the satellite .
- An increase in the error rate, or total destruction of the signal.
- This effect is termed ***sun transit outage***, and it lasts for short periods
- The occurrence and duration of the sun transit outage depends on the latitude of the earth station, a maximum outage time of 10 min.
- Sun outages occur in February, March, September and October, that is, around the time of the equinoxes.
- As the sun radiates strongly at the microwave frequencies used to communicate with satellites (C-band, Ka band and Ku band) the sun swamps the signal from the satellite.

Launching Orbits

- Low Earth Orbiting satellites are directly injected into their orbits.
- This cannot be done incase of GEOs as they have to be positioned 36,000kms above the Earth‟s surface.
- Launch vehicles are hence used to set these satellites in their orbits. These vehicles are reusable.
- They are also known as “Space Transportation System‟ (STS).

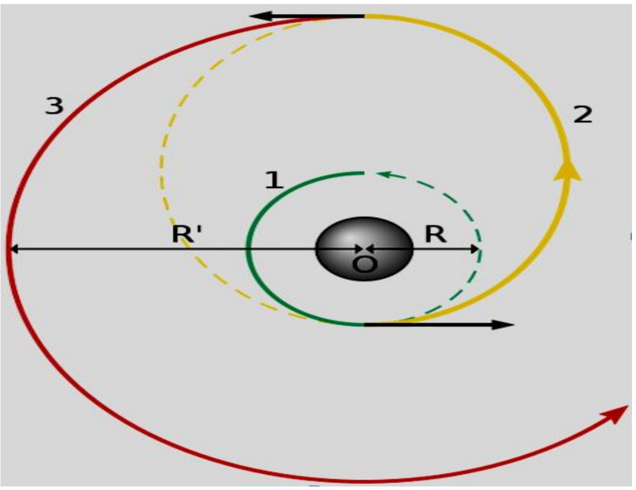
Launching Orbits

- When the orbital altitude is greater than 1,200 km it becomes expensive to directly inject the satellite in its orbit.
- For this purpose, a satellite must be placed in to a transfer orbit between the initial lower orbit and destination orbit.
- The transfer orbit is commonly known as “Hohmann-Transfer Orbit”



Launching Orbits

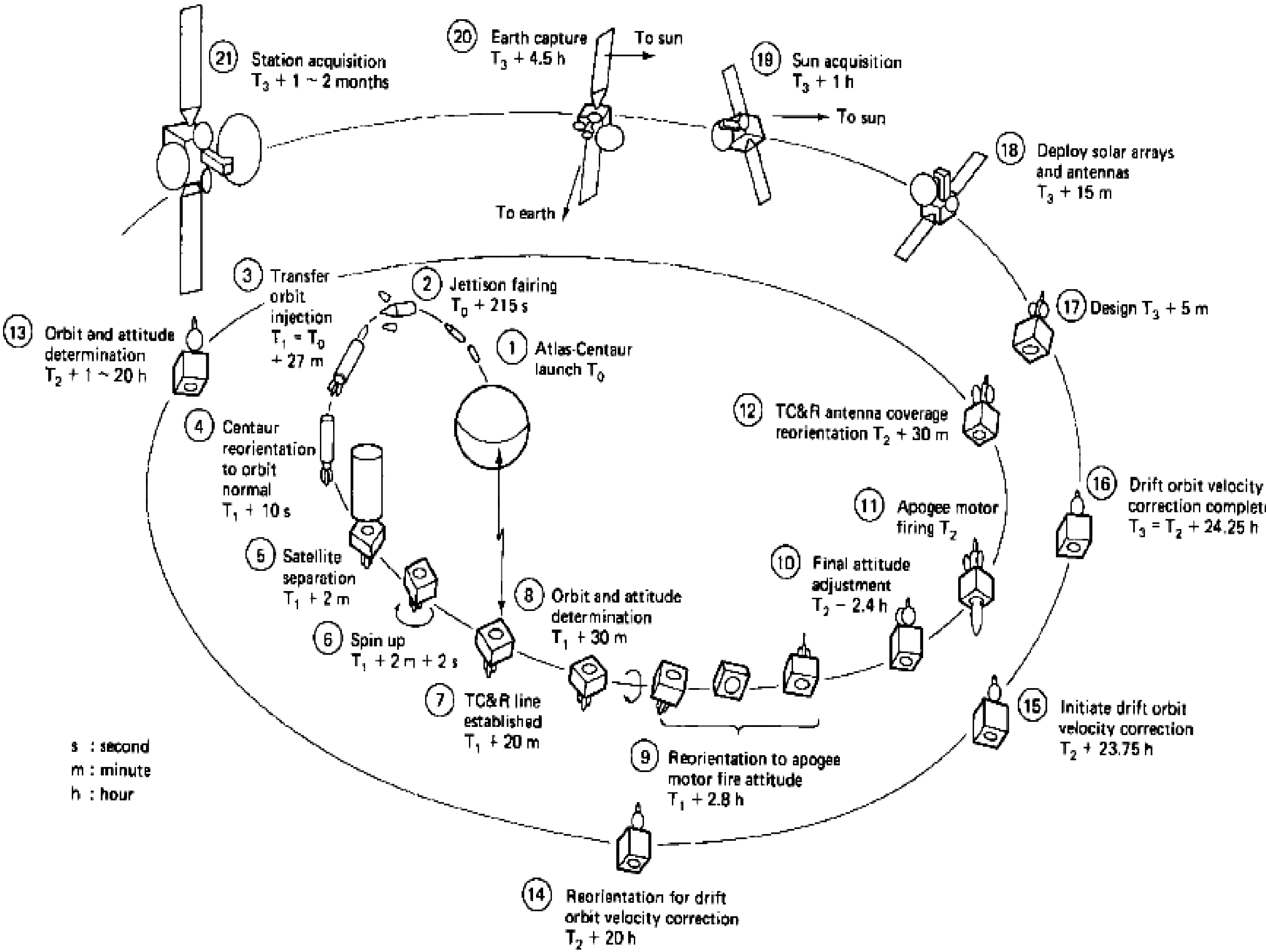
- The transfer orbit is selected to minimize the energy required for the transfer.
- This orbit forms a tangent to the low attitude orbit at the point of its perigee and tangent to high altitude orbit at the point of its apogee.



- The rocket injects the satellite with the required thrust into the transfer orbit.
- With the STS, the satellite carries a perigee kick motor which imparts the required thrust to inject the satellite in its transfer orbit.
- Similarly, an apogee kick motor (AKM) is used to inject the satellite in its destination orbit.

Launching Orbits

- Generally it takes 1-2 months for the satellite to become fully functional. The Earth Station performs the Telemetry Tracking and Command (TTC) function to control the satellite transits and functionalities
- It is better to launch rockets closer to the equator because the Earth rotates at a greater speed here than that at either pole.
- This extra speed at the equator means a rocket needs less thrust (and therefore less fuel) to launch into orbit.
- In addition, launching at the equator provides an additional 1,667 km/h of speed once the vehicle reaches orbit.
- This speed bonus means the vehicle needs less fuel, and that freed space can be used to carry more pay load.



21 Station acquisition T_3 + 1 ~ 2 months
20 Earth capture T_3 + 4.5 h
To sun
To earth
19 Sun acquisition T_3 + 1 h
To sun
18 Deploy solar arrays and antennas T_3 + 15 m
17 Design T_3 + 5 m
3 Transfer orbit injection T_1 = T_0 + 27 m
2 Jettison fairing T_0 + 215 s
1 Atlas-Centaur launch T_0
13 Orbit and attitude determination T_2 + 1 ~ 20 h
4 Centaur reorientation to orbit normal T_1 + 10 s
12 TC&R antenna coverage reorientation T_2 + 30 m
16 Drift orbit velocity correction complete T_3 = T_2 + 24.25 h
11 Apogee motor firing T_2
5 Satellite separation T_1 + 2 m
10 Final attitude adjustment T_2 − 2.4 h
8 Orbit and attitude determination T_1 + 30 m
6 Spin up T_1 + 2 m + 2 s
7 TC&R line established T_1 + 20 m
15 Initiate drift orbit velocity correction T_2 + 23.75 h
9 Reorientation to apogee motor fire attitude T_1 + 2.8 h
s : second
m : minute
h : hour
14 Reorientation for drift orbit velocity correction T_2 + 20 h

Unit-II
THE SPACE SEGMENT

The Power Supply

consists of solar panels and backup batteries that generate power when the satellite passes into the earth’s shadow.

Attitude Control

- The environmental effects
- Spin stabilization
- Dual-spin stabilization
- Three-axis active control
- Momentum exchange systems
- Passive gravity gradient stabilization

Attitude control systems comparisons

A comparison of various control systems

Control System	Reference Orientation	Range of Orientation Accuracy (Deg)	Slew Rate Capability	Payload Efficiency	Life Expectancy (Years)
Spin	Sun/Earth Inertial	0.01 to 1.0	None	Low	7–10
Dual Spin	Sun/Earth Inertial	0.01 to 1.0	None	High	5–10
Three Axis	Sun/Earth Inertial	0.01 to 1.0	Arbitrary	High	3–7
Momentum Bias	Sun/Earth Inertial	0.01 to 1.0	None	High	5–15
Gravity Gradient	Earth Pointing	1 to 10	None	Low	>10

Control actuator torque values

Torque Control System	Available Torque Range (newton · meters)
Reaction control (RCS)	10^{-2} to 10
Magnetic torquer	10^{-2} to 10^{-1}
Gravity gradient	10^{-6} to 10^{-3}
Aerodynamic	10^{-5} to 10^{-3}
Reaction wheel (RW)	10^{-1} to 1
Control moment gyro (CMG)	10^{-2} to 10^{3}

Attitude control-Environmental effects

- Solar radiation pressure
  - Force
  - Torque: induced by CM & solar CP offset. Can compensate with differential reflectivity or reaction wheels.
- Gravity gradient torque
- Geo-Magnetic (near field) torque: model spacecraft as a magnetic dipole
- Aerodynamic torque: drag coeeficient C_D=2.2 for a spherical shape satellite; C_D=3 for a cylinder. Only a factor for LEO.

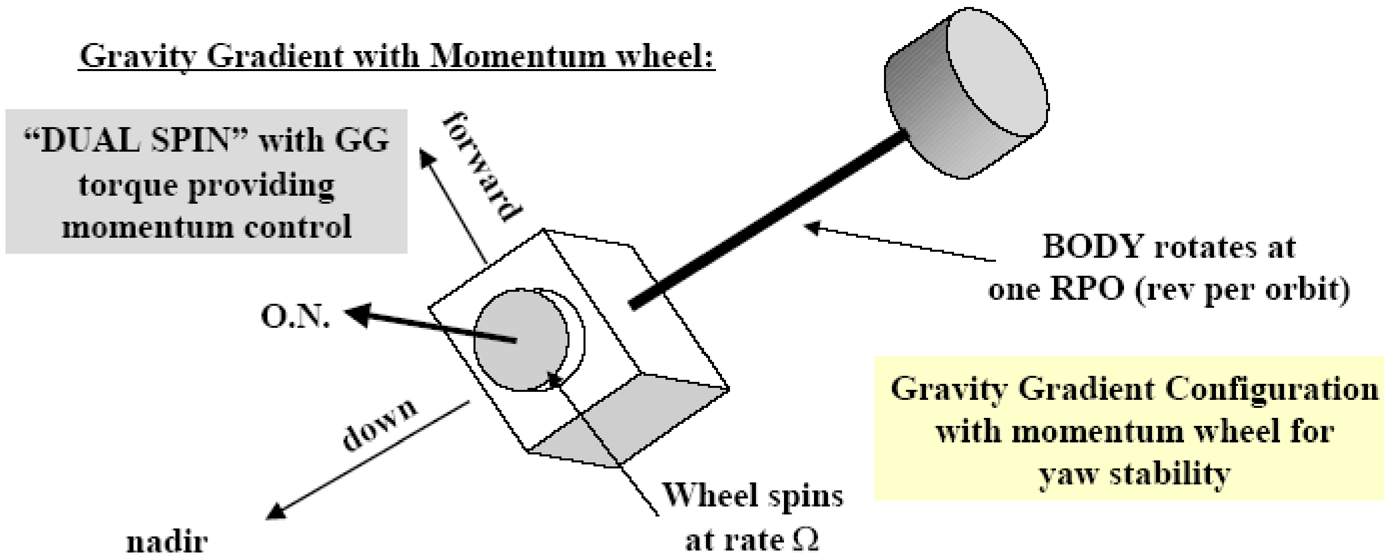
Attitude control: spin/dual-spin stabilization

- Spin stabilization:
  - Requires stable inertia ratio: $I_z > I_x = I_y$
  - Requires nutation damper: ball-in-tube, viscous ring, active damping
  - Requires torquers to control precession (spin axis drift) magnetically or with jets
  - Inertially oriented
- Dual-spin stabilization
  - Two bodies rotating at different rates about a common axis
  - Behave like simple spinners, but part is despun (antenna, sensor)
  - Requires torquer for momentum control and nutation dampers for stability
  - Allows relaxation of major axis rule

Attitude control: Three-axis active control

- Reaction wheels most common actuators
- Fast; continuous feedback control
- Moving parts
- Internal torque only; external still need “momentum dumping” (off-loading)
- Relatively high power, weight, cost
- Control logic simple for independent axes

Attitude control: Gravity gradient stabilization



- Requires stable inertias: $I_z \ll I_x$, I_y
- Requires libration dampers: hysteresis rods
- Requires no torquers
- Earth oriented

Attitude control: momentum wheel stabilization

- Reaction wheel (RW) systems
- Momentum bias systems: a single RW is aligned along the pitch axis of the spacecraft which is oriented along the normal to the orbital plane.
- Control moment gyro (CMG) systems
  - Single gimbal CMG
  - Double gimbal CMG
- RW has smaller output than CMG; CMG has singularity in momentum envelope.

Station keeping
Ground-Based vs. Autonomous Orbit Control

- Traditionally, orbit maintenance and control is implemented from the ground
  - Thruster commands may be stored on board for later execution
  - In the past, there was no realistic alternative
- Autonomous navigation systems make autonomous orbit control possible, economical, and safe – but still non-traditional

Ground-Based vs. Autonomous Orbit Control

- Orbit and attitude control are analogous with several important differences
  - Attitude control must be continuous to avoid a major system upset, with the possible risk to the spacecraft and the mission
  - Orbit control is inherently fail-safe; nothing bad happens immediately if it is not done
  - Frequency of control:
    - Attitude control: typically 1 to 10 Hz,
    - Orbit control: 10^{-4} to 10^{-5} Hz
      - Less computational burden, more time to react if things don't work right

Things to Look For

- Avoid "double booking" – look for joint implementation of orbit and attitude determination and control when optimizing system performance
- Reasonable initial design will incorporate all functions into a single processor, although there may be other reasons to distribute
- Overall objective is to minimize the cost and risk of determining and controlling the orbit and attitude for the ENTIRE MISSION!!!!

Thermal Control Systems

The primary source of energy in the solar system is electromagnetic radiation from the Sun. Although the gravitational potential energy of the Sun is significant, it cannot be used for conventional heating, cooling, and electrical power for spacecraft.

Planet	Distance (AU)		Solar radiation (W/m^2)	
	Perihelion	Aphelion	maximum	minimum
Mercury	0.3075	0.4667	14,446	6,272
Venus	0.7184	0.7282	2,647	2,576
Earth	0.9833	1.017	1,413	1,321
Mars	1.382	1.666	715	492
Jupiter	4.950	5.458	55.8	45.9
Saturn	9.048	10.12	16.7	13.4
Uranus	18.38	20.08	4.04	3.39
Neptune	29.77	30.44	1.54	1.47

Thermal Control Systems

- Temperatures on or in a spacecraft are influenced by the sum of heat inputs (sources) and heat outputs (sinks)

- Temperature and heat energy are also defined by the heat flow in and out of the spacecraft material(s), and by the thermal heat capacity of the material(s)
  - Heat capacity is the heat energy required to change the temperature of a material by one degree

- Temperatures of specific areas of a spacecraft are also affected by the conductivity of other components in contact, and by the other heat transfer mechanisms, not just surface radiation absorption and emission

Thermal Control Systems

Heat sources (inputs)

1. Solar radiation (insolation) at the Earth is 1340 W/m^2 (seasonal average)

- Actual value ranges from approximately 1310 to 1420 W/m^2
- The equivalent (peak blackbody) temperature of the Sun is approximately 5,800K

2. Earth's infrared radiation is 240 W/m^2 in LEO from the atmosphere and surface heat (varies with orbit altitude)

- The Earth's equivalent blackbody temperature is approximately 290K

3. Earth's reflected solar energy is 400 W/m^2 (30% of direct solar energy reflected in the upper atmosphere) (varies with orbit altitude)

4. Spacecraft internal heat is also a heat source that comes from electrical power used in nearly all onboard systems

Thermal Control Systems

Heat sinks (outputs)

- Heat removal from spacecraft is almost always done by radiated energy (thermal radiators)
  - Several early manned missions used evaporative cooling, but using liquids for cooling is inefficient

- Heat emission to space is based on the infrared blackbody temperature of the spacecraft surface(s) (emission component) and the temperature of the background (absorption component)

Thermal Control Systems

A quick look at the challenges of a spacecraft thermal system

Spacecraft temperatures vary widely since:

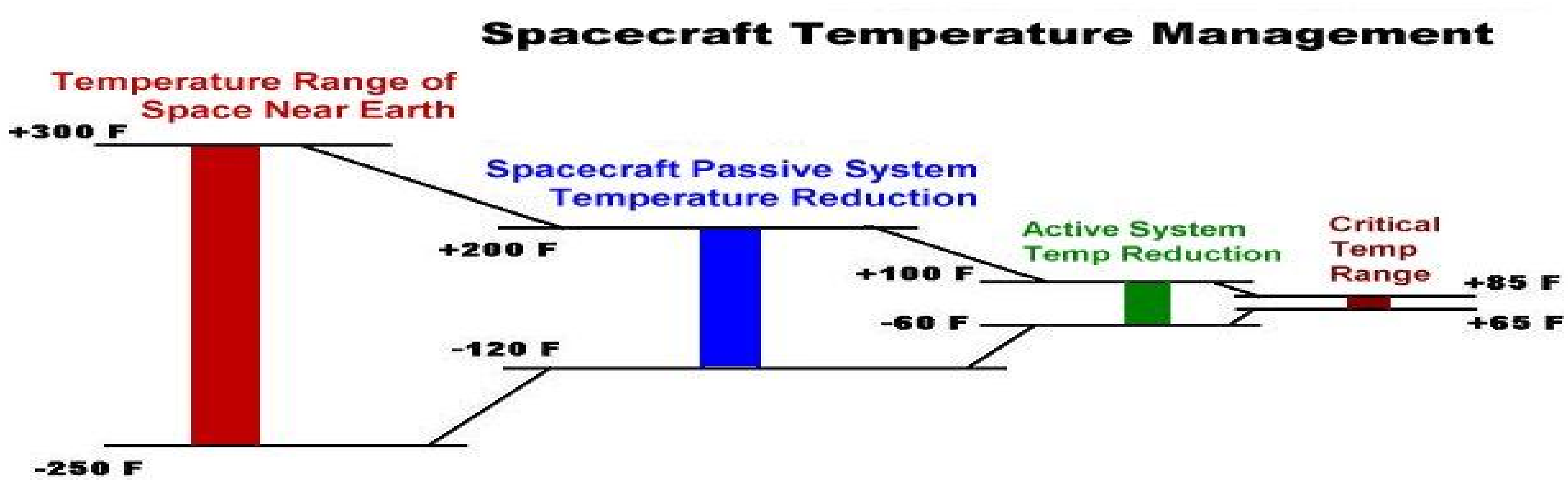
- Spacecraft encounter temperature extremes that range from the orbit of Mercury to the orbit of Pluto and beyond
- Each spacecraft has a variety of heat inputs and heat outputs
- Each spacecraft has complex surface geometries and materials which affect emission and absorption
- There are various levels of heat transfer inside and at the surface of the spacecraft that change almost continually
  - Transfer includes complicated paths of conduction and radiation
- There are continual changes in heat inputs and heat outputs because of spacecraft movement, orbital motion, and/or flight trajectories

Thermal Control Systems

This is a graphic representation of the extreme temperatures encountered in the near-Earth space environment, and the temperature range restrictions on a hypothetical spacecraft

Passive thermal components are capable of reducing the temperature extremes, but only to a limited range

Beyond this, active systems would be required for a narrower temperature range



Thermal Control Systems

Passive thermal components

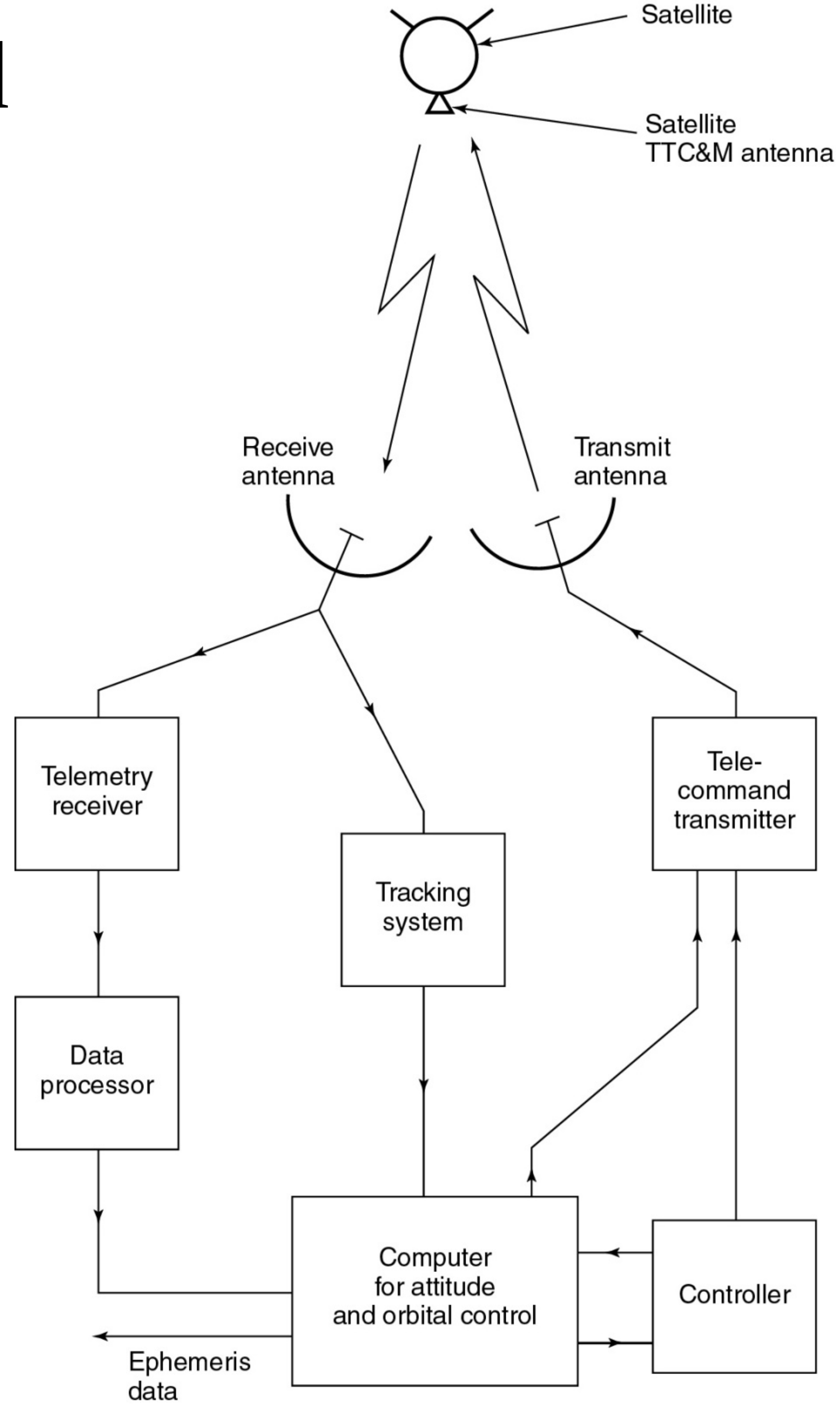
1. Radiator panels
2. Coatings
3. Heat pipes
4. Insulation
5. Conductive structures and components
6. Louvers
7. Sun shields
8. Radioisotope heater units

Thermal Control Systems

Active thermal components

1. Electric cooling devices
2. Stored cryogenics
3. Liquid heating/cooling loops
4. Electric heaters
5. Shutters

Telemetry ,tracking and command sub system



TTC&M

- MAJOR FUNCTIONS
  - Reporting spacecraft health
  - Monitoring command actions
  - Determining orbital elements
  - Launch sequence deployment
  - Control of thrusters
  - Control of payload (communications, etc.)

TELEMETRY - 1

- Monitor All Important
  - Temperature
  - Voltages
  - Currents
  - Sensors
- Transmit Data To Earth
- Record Data At Ttc&m Stations

NOTE: Data are usually multiplexed with a priority rating. There are usually two telemetry modes.

TELEMETRY - 2

- TWO TELEMETRY PHASES OR ***MODES***
  - Non-earth pointing
    - During the launch phase
    - During “Safe Mode” operations when the spacecraft loses tracking data
  - Earth-pointing
    - During parts of the launch phase
    - During routine operations

NOTE: for critical telemetry channels

TRACKING

- Measure Range Repeatedly
- Can Measure Beacon Doppler Or The Communication Channel
- Compute Orbital Elements
- Plan Station-keeping Maneuvers
- Communicate With Main Control Station And Users

COMMAND

- During Launch Sequence
  - Switch On Power
  - Deploy Antennas And Solar Panels
  - Point Antennas To Desired Location
- In Orbit
  - Maintain Spacecraft Thermal Balance
  - Control Payload, Thrusters, Etc.

Transponder

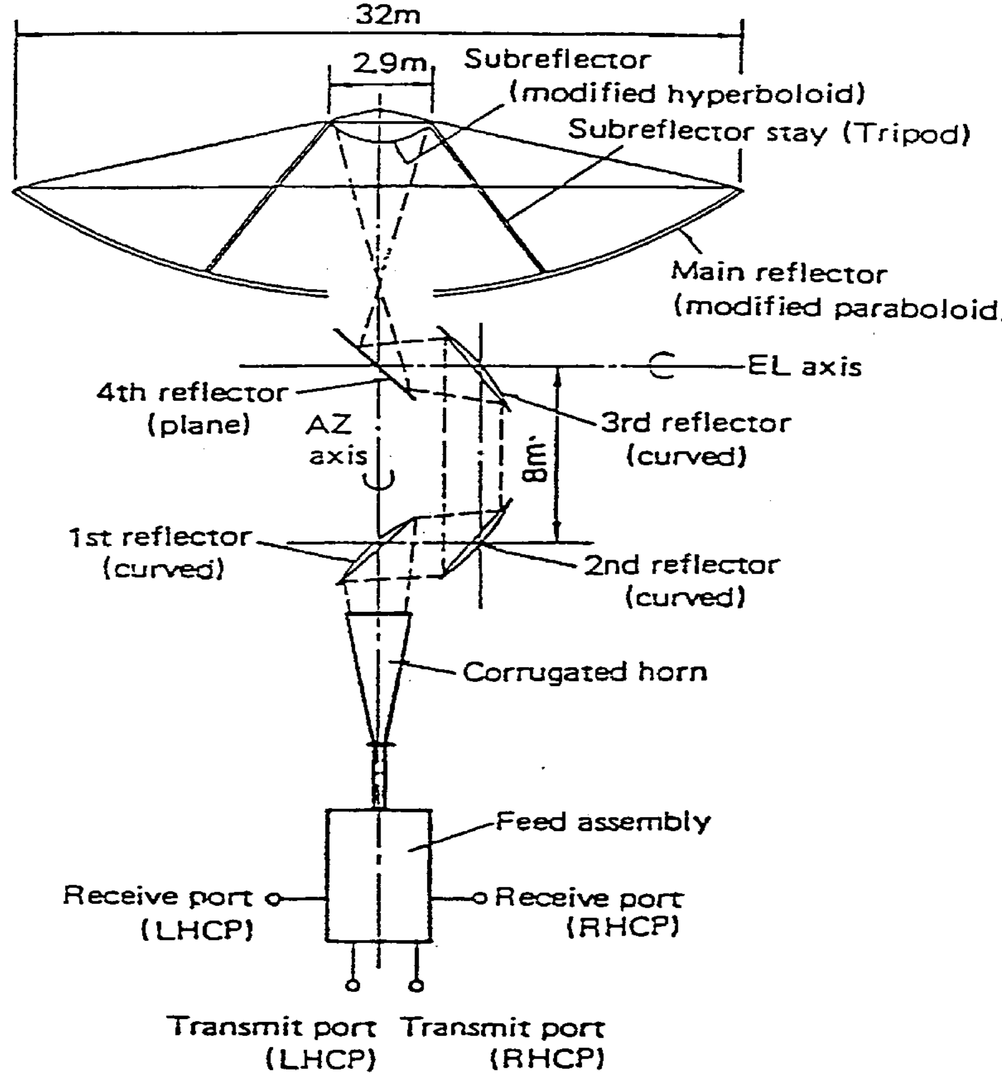
The transponder is essentially a receiver which receives the signal transmitted from the earth by the uplink, amplifies it and retransmits it with the downlink, with a different frequency. Thus the word “Transponder” is formed by combining the two words- TRANSmitter and resPONDER. Most satellites have anything between 10 to 30 transponders of different bandwidth on board. Transponders can be either active or passive. A passive transponder allows a computer or robot to identify an object. Magnetic labels, such as those on credit cards and store items, are common examples. The transponder unit can be physically tiny, and its information can be sensed up to several feet away. Simple active transponders are employed in location, identification, and navigation systems for commercial and private aircraft. The input (receiver) and output (transmitter) frequencies are pre-assigned. Transponders of this type can operate over distances of thousands of miles.

Antenna subsystem

An Antenna subsystem for receiving and transmitting signals. Most communication satellites contain several transponders utilizing the whole available 500 MHz of bandwidth, and serveral antennas. Some antennas have wide beams (17.3 degree) for earth coverage, while some have narrow beams (4.5 degree) for densely populated reqions. The narrow or spot beam antennas will have increase ERP (Effective Radiated Power) and hence a larger antenna gain. Either earth-coverage or spot-beam antennas can be used on the down-link by switching.

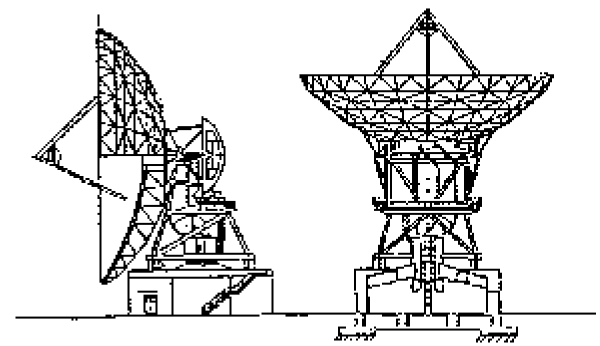
Earth Station Technology Antennas (1)

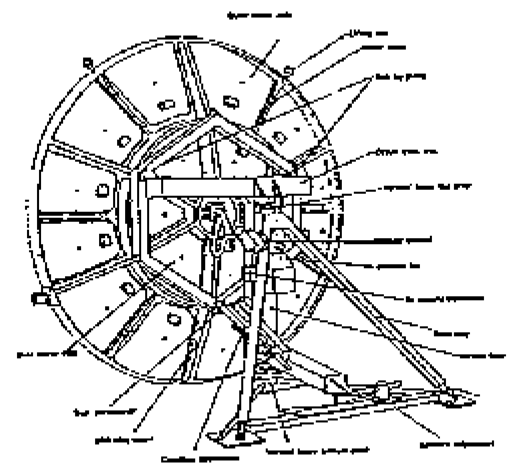
- Cassegrain Antenna with focussed beam feed



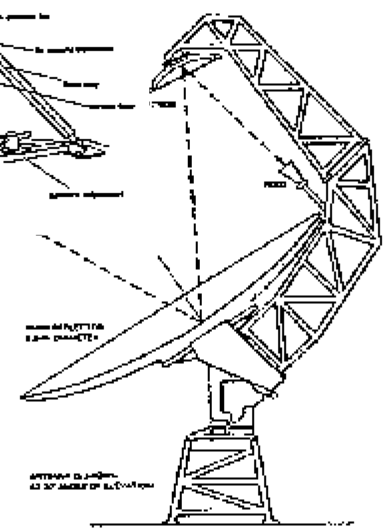
Earth Station Technology Antennas (2)

- Large earth station antenna with wheel-and-track mount

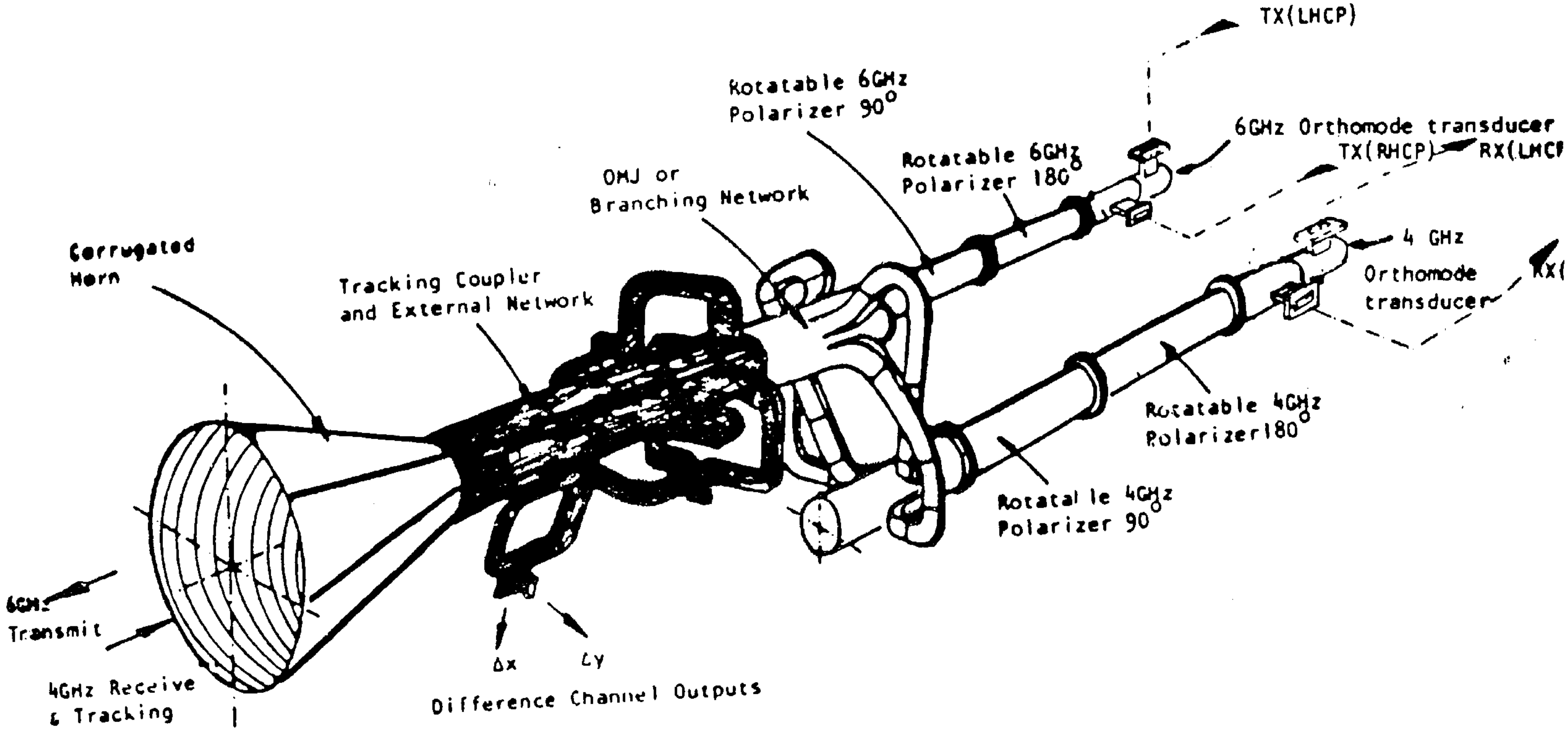




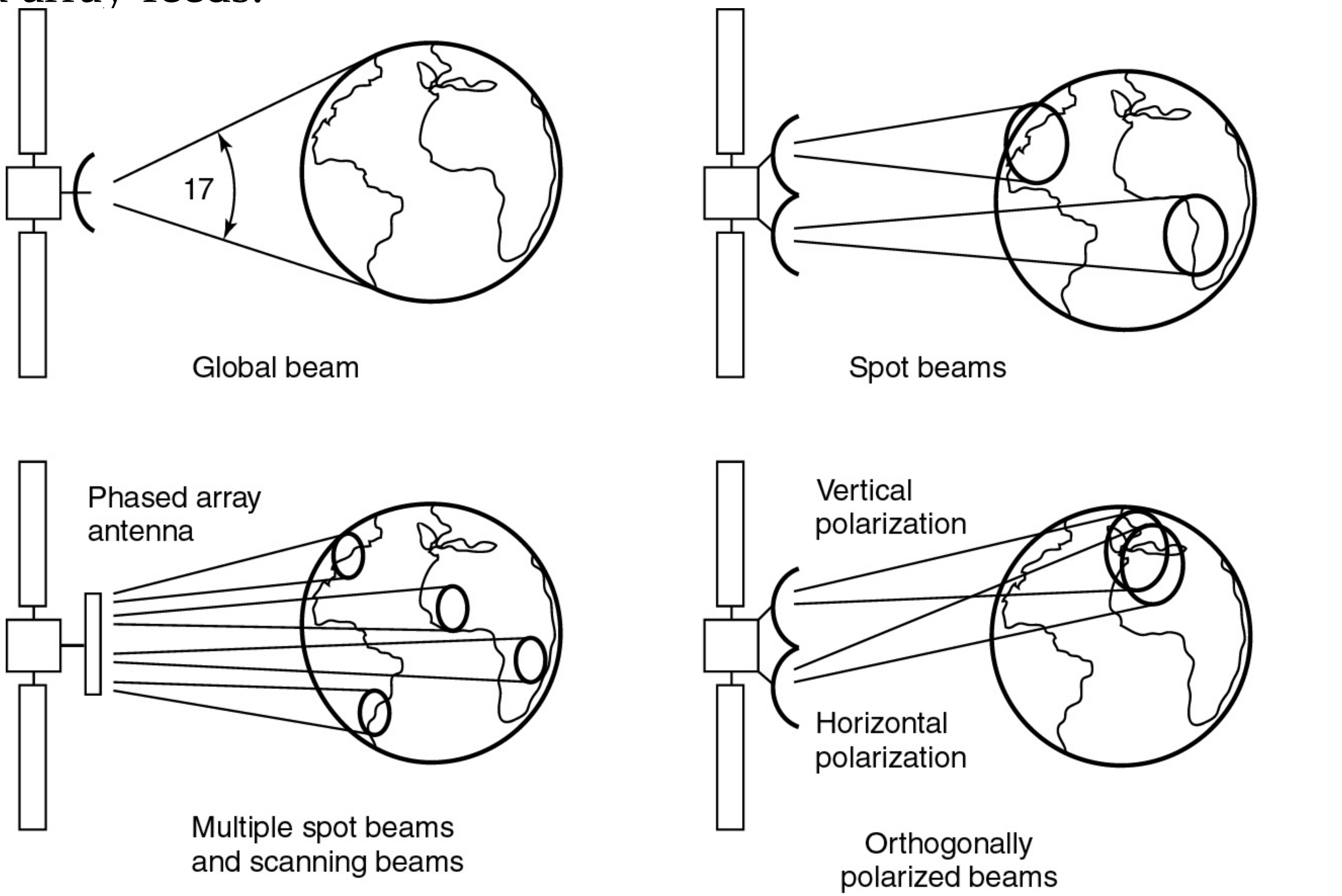
- Small earth station antenna employing an elevation-over-azimuth mount



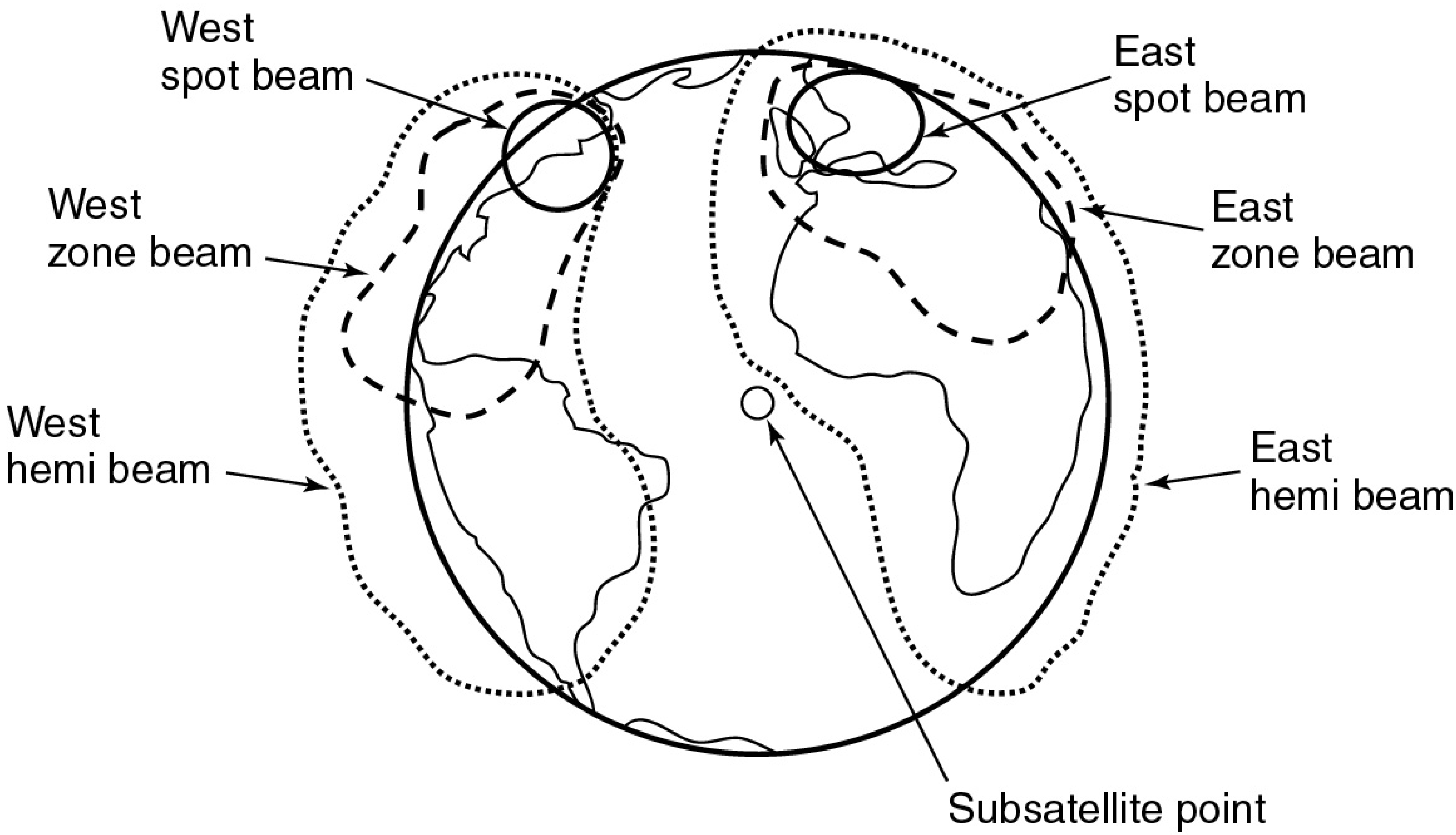
Typical Earth Station Antennas
Primary feedchain



Typical satellite antenna patterns and coverage zones. The antenna for the global beam is usually a waveguide horn. Scanning beams and shaped beams require phased array antennas or reflector antennas with phased array feeds.



Typical coverage patterns for Intelsat satellites over the Atlantic Ocean.



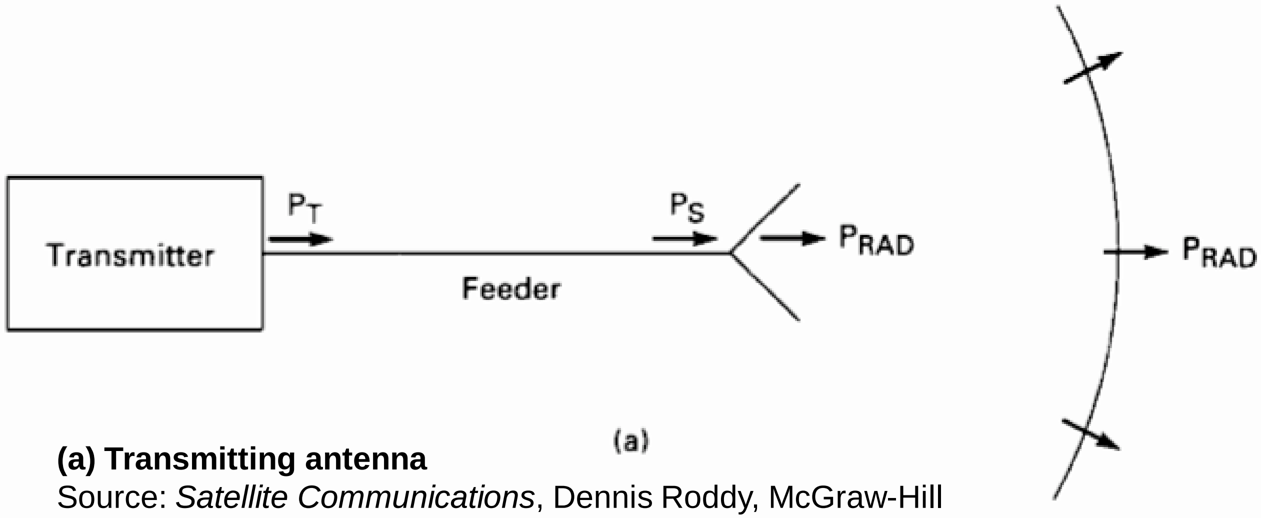
UNIT III
EARTH SEGMENT AND ANTENNAS

Transmit-Receive Earth Stations

- In some situations, a transmit-only station is required
- For example,
  - in relaying TV signals to the remote TV receive-only stations
- Transmit-receive stations provide both functions

Isotropic Radiator

- 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} ($< P_T$).



(a) Transmitting antenna
Source: *Satellite Communications*, Dennis Roddy, McGraw-Hill

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.

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

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

MICROWAVE ANTENNA

Definition

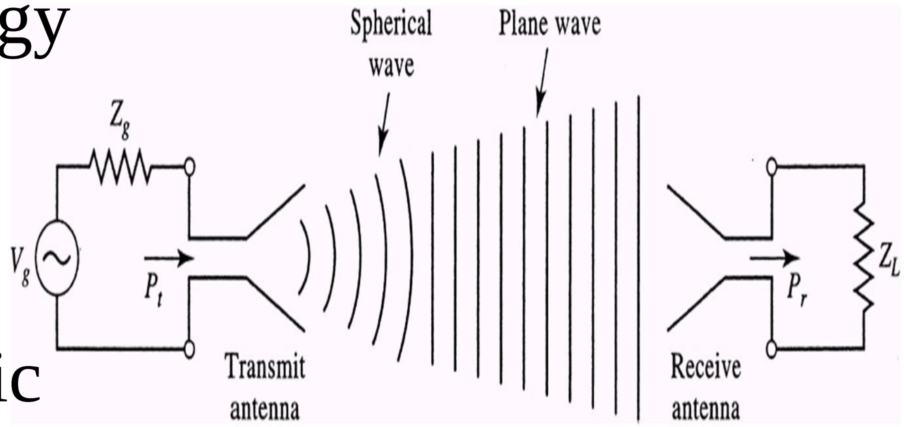
A conductor or group of conductors used either for radiating electromagnetic energy into space or for collecting it from space.

or

Is a structure which may be described as a metallic object, often a wire or a collection of wires through specific design capable of converting high frequency current into EM wave and transmit it into free space at light velocity with high power (kW) besides receiving EM wave from free space and convert it into high frequency current at much lower power (mW).

Basic operation of transmit and receive antennas

- Electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into space.



Basic operation of transmit and receive antennas

On the receiving end, electromagnetic energy is converted into electrical energy by the antenna and fed into the receiver

Basic operation of transmit and receive antennas (cont)

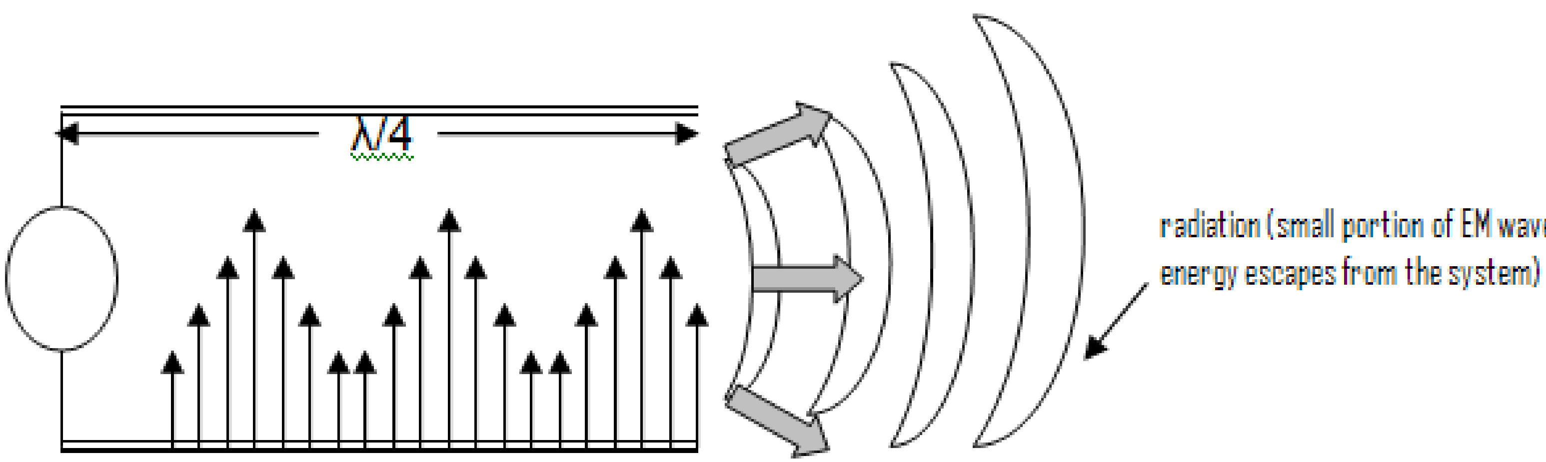
- Transmission - radiates electromagnetic energy into space
- Reception - collects electromagnetic energy from space
- In two-way communication, the same antenna can be used for transmission and reception.
- Short wavelength produced by high frequency microwave, allows the usage of highly directive antenna. For long distant signal transmission, the usage of antenna at microwave frequency is more economical. Usage of waveguide is suitable for short distant signal transmission.

FUNCTION OF ANTENNA

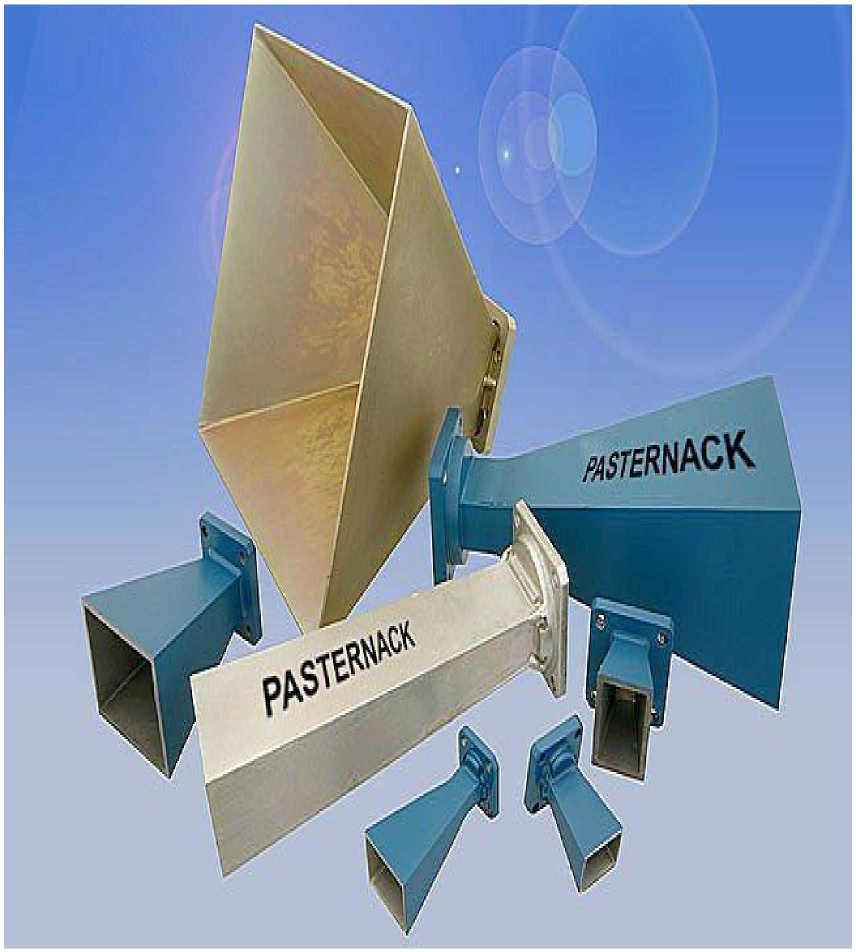
- Transmit energy with high efficiency .
- Receive energy as low as mW.
- Provide matching between transmitter and free space and between free space and receiver, thus maximum power transfer is achieve besides preventing the occurrence of reflection.
- Directs radiation toward and suppresses radiation
- Two common features exist at the antenna Tx and Rx antenna is the radiation pattern and impedance, but it is different in terms of transmission power and reception power.

FUNCTION OF ANTENNA (cont)

- Mismatch exist that is surrounding space as load.
- Since the two wires are closed together and in opposite direction (180°), therefore it is apparent that the radiation from one tip will cancelled that from the other.
- Figure below, shows the energy transmitted into free space via an open ended λ/4 transmission line. The



A - HORN / APERTURE ANTENNA

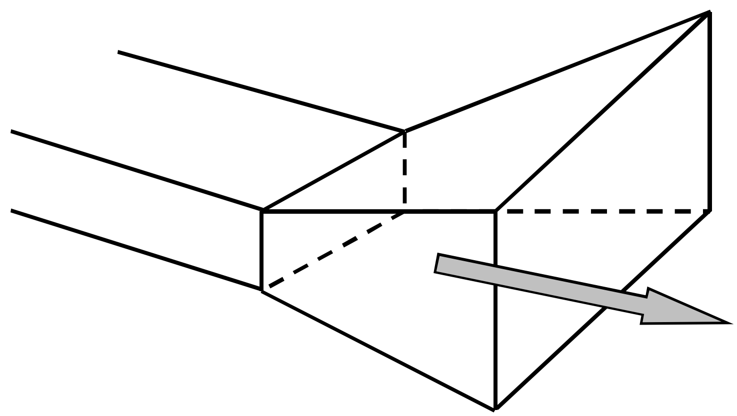


Horn antenna

- Like parabolic reflectors, HORN RADIATORS can use to obtain directive radiation at microwave frequencies
- Horn radiators are used with waveguides because they serve both as an impedance-matching device and as a directional radiator. Horn radiators may be fed by coaxial and other types of lines

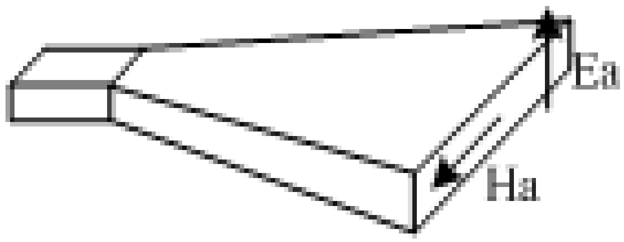
Horn Antenna

- Horn radiators are constructed in a variety of shapes, as illustrated in figure .
- The shape of the horn determines the shape of the field pattern. The ratio of the horn length to the size of its mouth determines the beam angle and directivity. In general, the larger the mouth of the horn, the more directive is the field pattern.

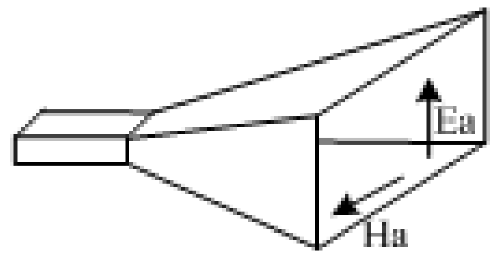


Horn radiator

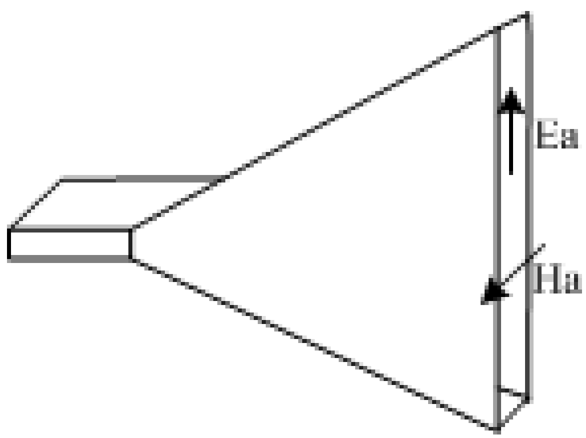
DIFFERENT TYPES OF HORN ANTENNA



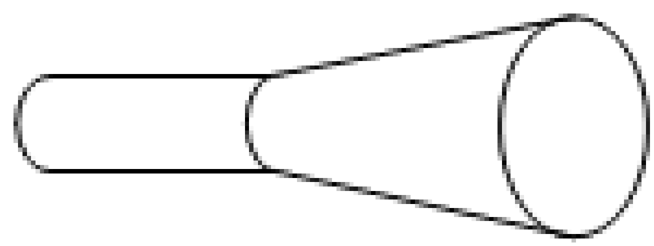
H-plane sectoral horn



Pyramidal horn



E-plane sectoral horn



Conical Horn Antenna

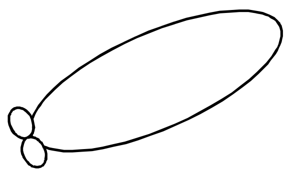
THREE TYPES OF HORN ANTENNA

- Horn antenna tapered / flared in one dimension only i.e in E-plane or H-plane (known as sectoral horn).
- Horn antenna tapered / flared in two dimension i.e in E-plane and H-plane (known as pyramidal horn).
- Conical taper / flares uniformly in all direction i.e in circular form.

THE DIFFERENCES BETWEEN THE E-, H-PLANE & PYRAMIDAL HORN SECTORAL ANTENNA

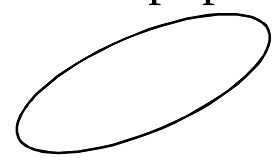
E- PLANE HORN SECTORAL ANTENNA

Radiation pattern exhibits side lobe



H- PLANE HORN SECTORAL ANTENNA

Radiation pattern exhibits no side lobe, thus more popular.



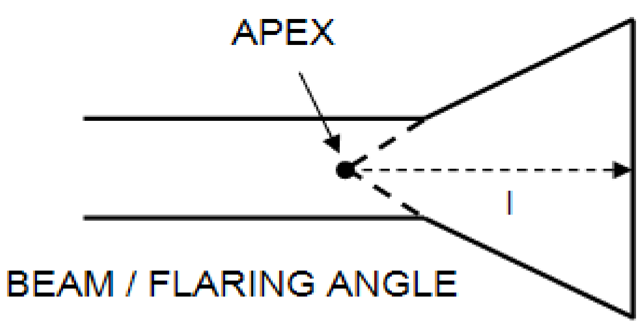
PYRAMIDAL HORN ANTENNA

Radiation pattern flares in 2 direction i.e in E-plane and H-plane. Therefore improves directivity.

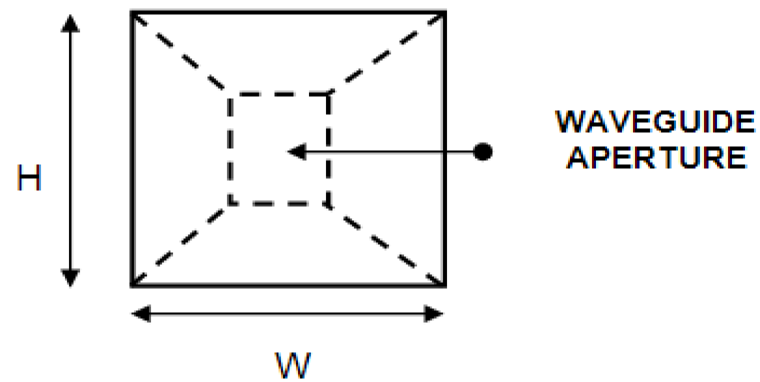
DIMENSION OF HORN ANTENNA

DIMENSION OF HORN ANTENNA

SIDE VIEW



END / FRONT VIEW



Whereby ;

$$A = H \times W, \ m^2$$

A - area (m^2); H – height (m); W – width (m)

DIMENSION OF HORN ANTENNA (cont)

BEAM WIDTH ; $\alpha = \dfrac{80}{W / \lambda}$

α = beam width (°) ;

W = horn width (m)

λ = wavelength of the operational frequency (m)

GAIN ; $G = \dfrac{4 \pi k A}{\lambda^2}$

G = gain;

A = area (m^2)

k = uniform phase distribution & e.m field amplitude across the aperture (0.5 -0.6)

B- PARABOLIC (REFLECTOR / DISH) ANTENNA

- Is a big dish like structure made from metal or wire mesh / grid.
- Mesh hole $\leq \lambda / 12$.
- Widely used in microwave propagation via free space.
- Also known as secondary antenna since it depends on primary antenna which acts as a feeder at the focal point (horn antenna or dipole antenna) to enhance the performance quality of the transmitter and the receiver

Introduction of parabolic antenna

- A **parabolic antenna** is a high-gain reflector antenna used for radio, television and data communications, and also for radiolocation (radar), on the UHF and SHF parts of the electromagnetic spectrum
- With the advent of TVRO and DBS satellite television, the parabolic antenna became a ubiquitous feature of urban, suburban, and even rural landscapes.

Parabolic Antenna

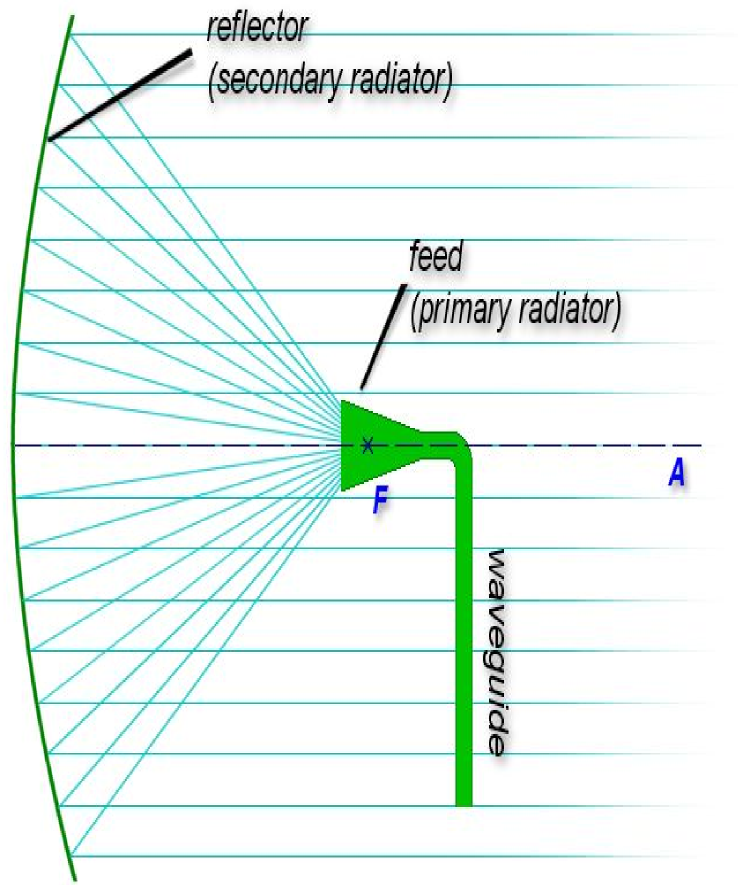
Why is it used?

- At higher microwave frequencies the physical size of the antenna becomes much smaller which in turn reduces the gain and directivity of the antenna
- The desired directivity can be achieved using suitably shaped parabolic reflector behind the main antenna which is known as primary antenna or feed .

Working rules

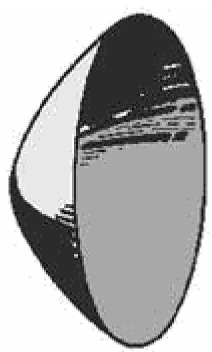
- A parabolic reflector follows the principle of geometrical optics.

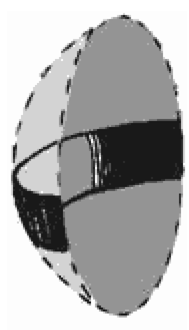
- When parallel rays of light incident on the reflector they will converge at focus or when a point source of light is kept at focus after reflection by the reflector they form a parallel beam of rays



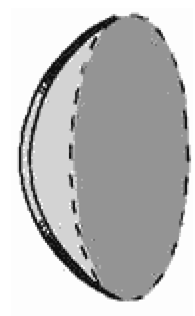
Basic Parabolic

- The basic paraboloid reflector used to produce different beam shapes required by special applications. The basic characteristics of the most commonly used paraboloids are presented as below:

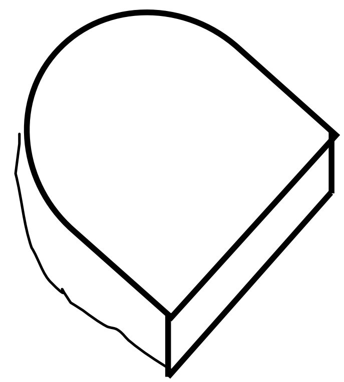




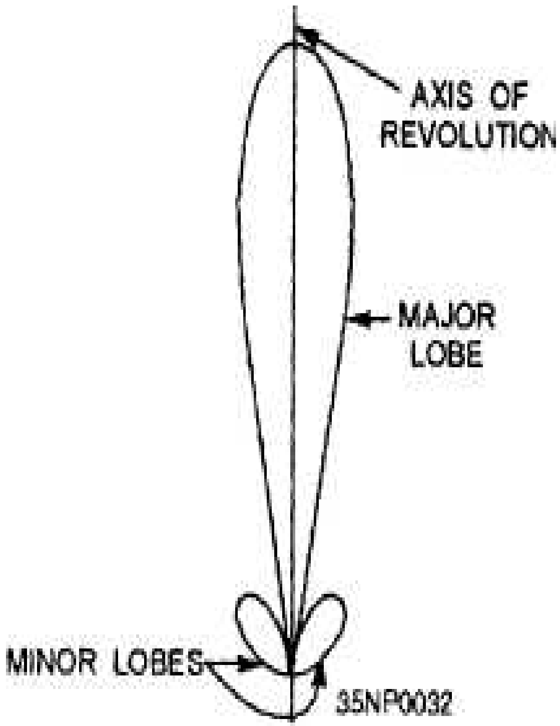
(A)

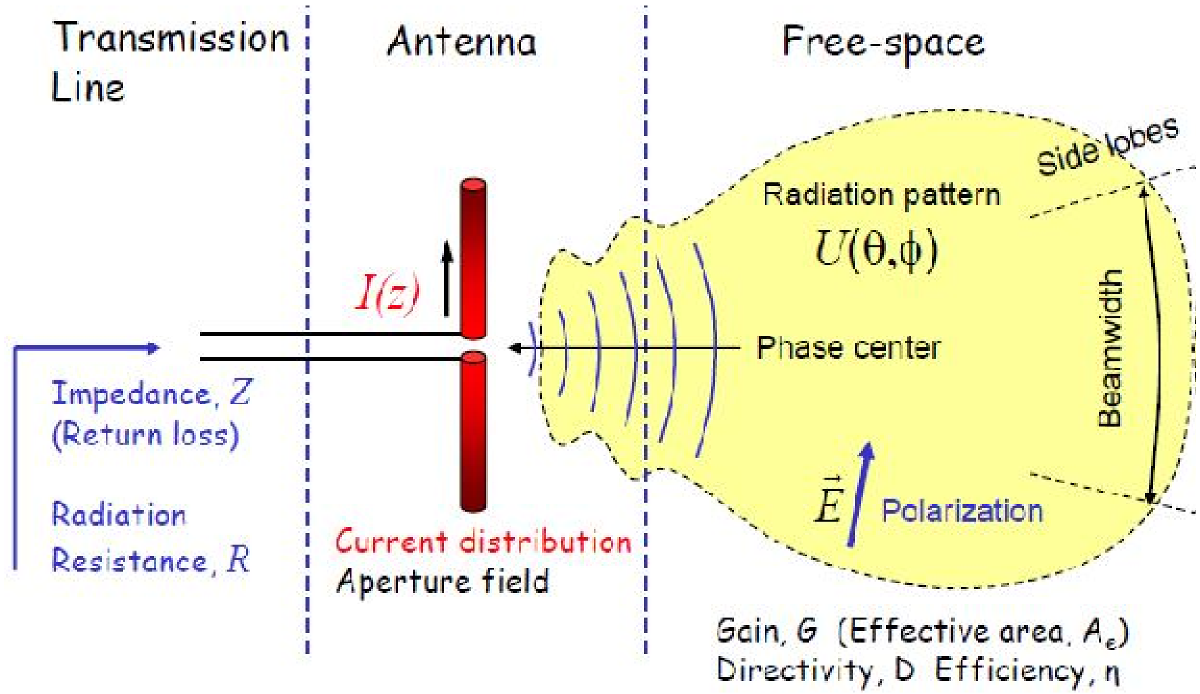


(B)



PARABOLIC RADIATION PATTERN





Parabolic radiation pattern

PARABOLIC (REFLECTOR / DISH) ANTENNA as TRANSMITTER

- The wave at the focus point will be directed to the main reflector and will be reflected parallel to the parabola axis. Thus the wave will travel at the same the and phase at A`E` (XY) line and the plane wave produce will be transmitted to the free space.
- Waves are emitted from the focal point of the wall and bounced back in line with the axis of the parabola and will arrive on time and with the same phase of the line and will form the next plane waves emitted into free space

PARABOLIC (REFLECTOR / DISH) ANTENNA as RECEIVER

- The plane wave received which is parallel to the parabola axis will be reflected by the main reflector to the focus point.
- All received waves parallel to the axis of the parabola will be reflected by the wall to the point of convergence.
- This characteristic makes the parabola antenna to possess high gain and a confined beam width.
- These features causes a parabola has a high gain and width of the focused beam.

Double-Reflector Antennas

Some of the shortcomings of paraboloidal reflectors can be overcome by adding a secondary reflector. The contour of the added reflector determines how the power will be distributed across the primary reflector and thereby gives control over amplitude in addition to phase in the aperture.

This can be used to produce very low spillover or to produce a specific low-sidelobe distribution. The secondary reflector may also be used to relocate the feed close to the source or receiver. By suitable choice of shape, the apparent focal length can be enlarged so that the feed size is convenient, as is sometimes necessary for monopulse operation.

The Cassegrain antenna, derived from telescope designs, is the most common antenna using multiple reflectors. The feed illuminates the hyperboloidal subreflector, which in turn illuminates the paraboloidal main reflector. The feed is placed at one focus of the hyperboloid and the paraboloid focus at the other. A similar antenna is the gregorian, which uses an ellipsoidal subreflector in place of the hyperboloid.

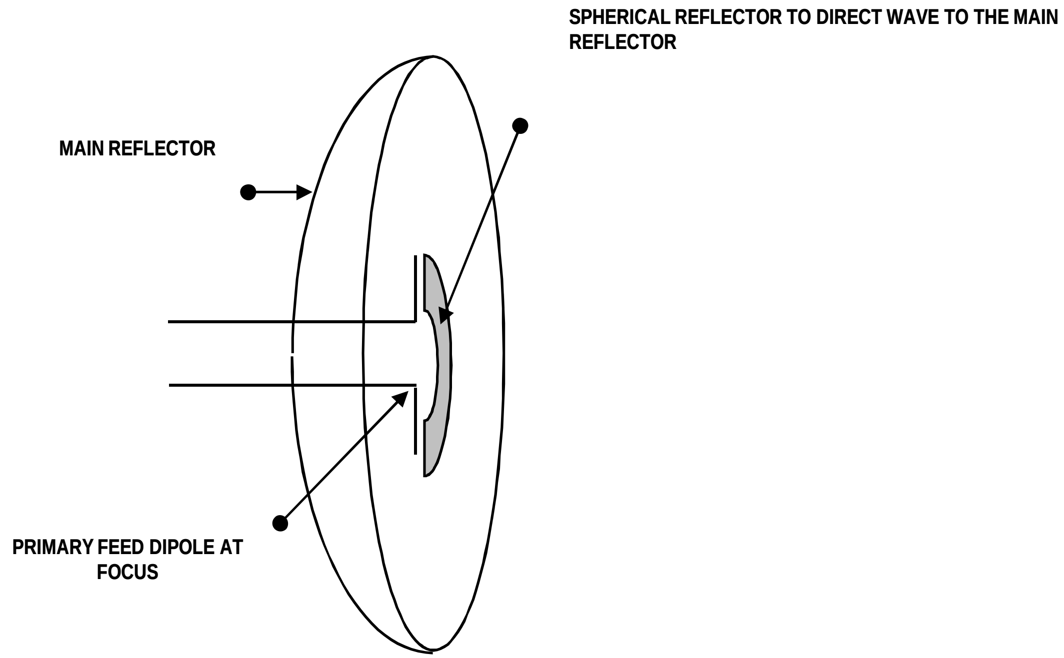
Parabolic antennas are also classified by the type of feed, i.e. how the radio waves are supplied to the antenna.

- The primary antenna is placed at the parabolic focus point.

- Reason: produce better transmission and reception. (enhance directivity and gain)

- The primary antenna has to be used together with the reflector to avoid the flaring of the radiation pattern and thus reduced the directivity.

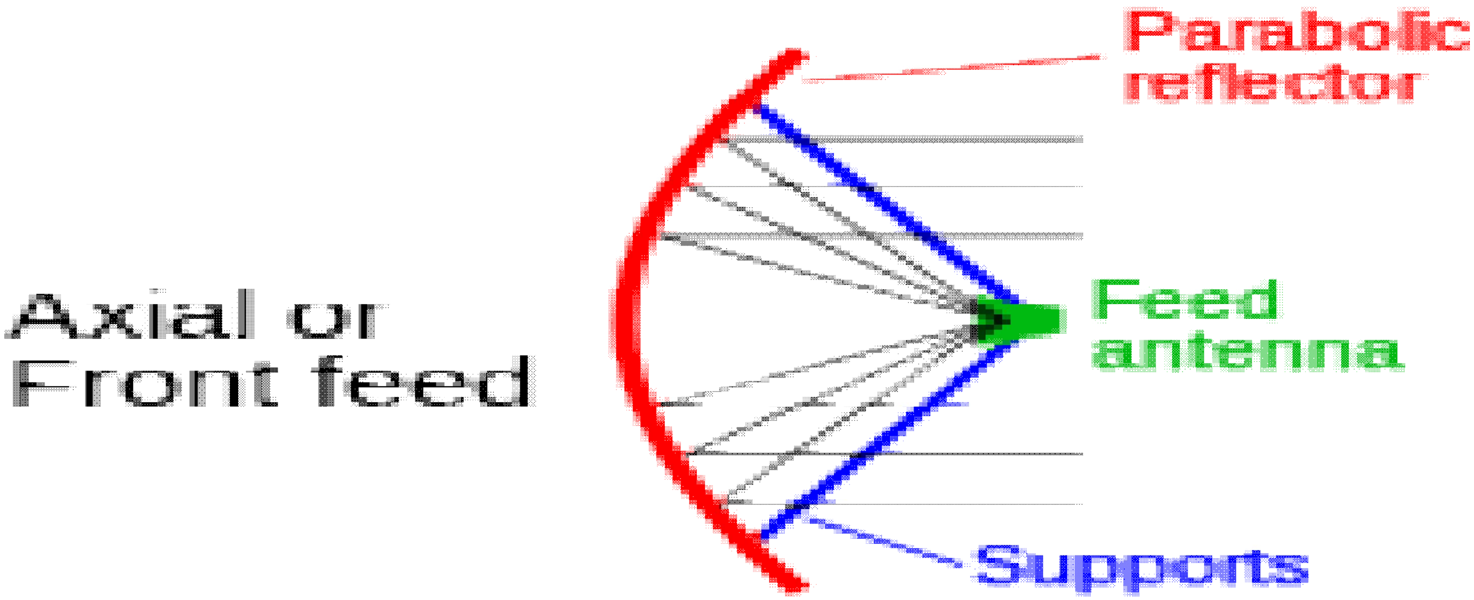
DIPOLE FEEDER



AXIAL OR FRONT FEED

- The most common type of feed, with the feed antenna located in front of the dish at the focus, on the beam axis.
- A disadvantage of this type is that the feed and its supports block some of the beam, which limits the aperture efficiency to only 55 - 60%.

AXIAL OR FRONT FEED



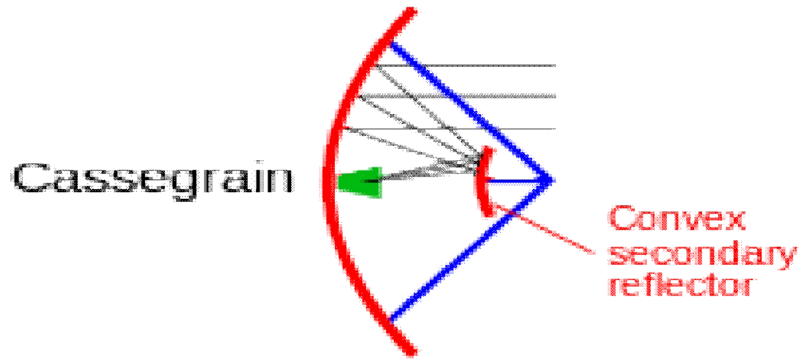
OFF-AXIS OR OFFSET FEED

- The reflector is an asymmetrical segment of a paraboloid, so the focus, and the feed antenna, is located to one side of the dish.
- The purpose of this design is to move the feed structure out of the beam path, so it doesn't block the beam.
- It is widely used in home satellite television dishes, which are small enough that the feed structure would otherwise block a significant percentage of the signal.
- Offset feed is also used in multiple reflector designs such as the Cassegrain and Gregorian.

CASSEGRAIN FEED

- The feed is located on or behind the dish, and radiates forward, illuminating a convex hyperboloidal secondary reflector at the focus of the dish.
- The radio waves from the feed reflect back off the secondary reflector to the dish, which forms the outgoing beam

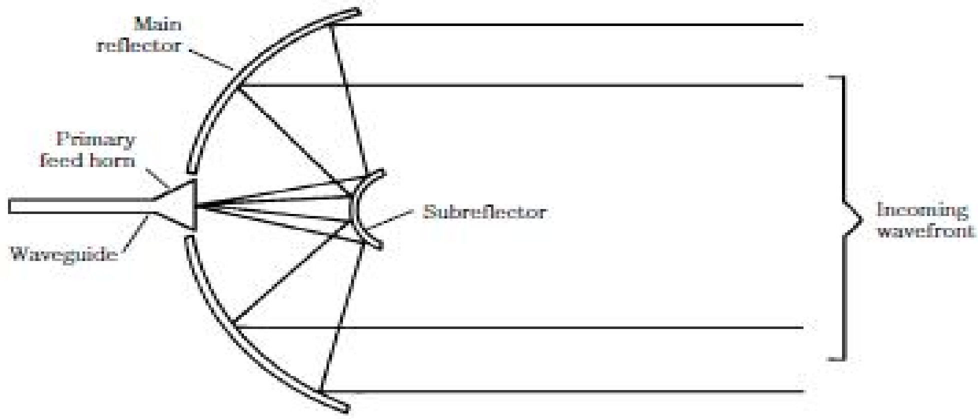
CASSEGRAIN FEED



•The advantage of this configuration is that the feed, with its waveguides and "front end" electronics does not have to be suspended in front of the dish, so it is used for antennas with complicated or bulky feeds, such as large satellite communication antennas and radio telescopes.

• Aperture efficiency is on the order of 65 - 70%.

CASSEGRAIN FEED



19-29B Parabolic antenna Cassegrain feed.

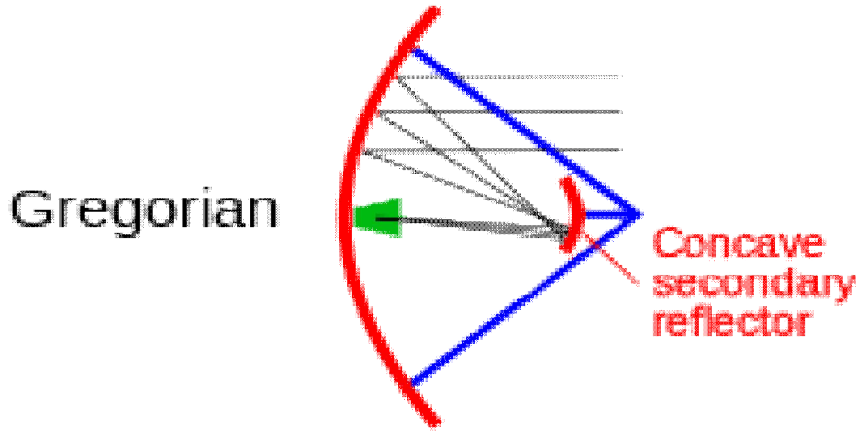
- Focus points for the secondary and primary reflectors will meet at the same point.

- Radiation from the horn antenna will be reflected by the secondary reflector and transmitted to the primary reflector to collimate the radiation.

GREGORIAN FEED

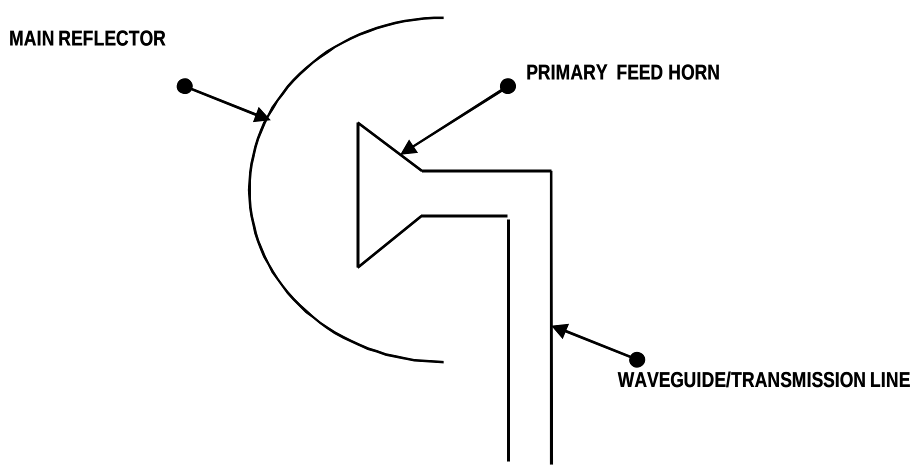
- Similar to the Cassegrain design except that the secondary reflector is concave, (ellipsoidal) in shape.

- Aperture efficiency over 70% can be achieved.



HORN FEED

- It is widely used as a primary feeder, because of the flaring directivity pattern , thus preventing refraction.



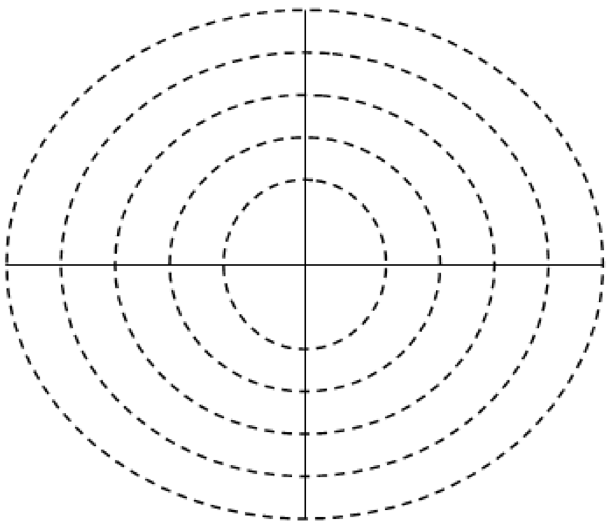
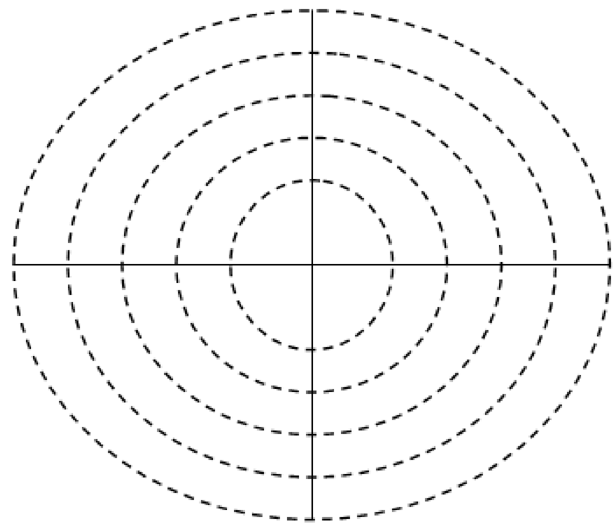
FACTORS AFFECTING THE ANTENNA

RADIATION PATTERN

Radiation pattern refers to the performance ot the antenna for example when it is mounted far away from objects such as buildings or mountain (earth) by which reflecting signal might affect the shape of the pattern.

FACTORS AFFECTING THE ANTENNA

Figures below show the 3-dimensional models (polar graf/diagram) of field strength or power density measurements made at a fixed distance from an antenna in a given plane.

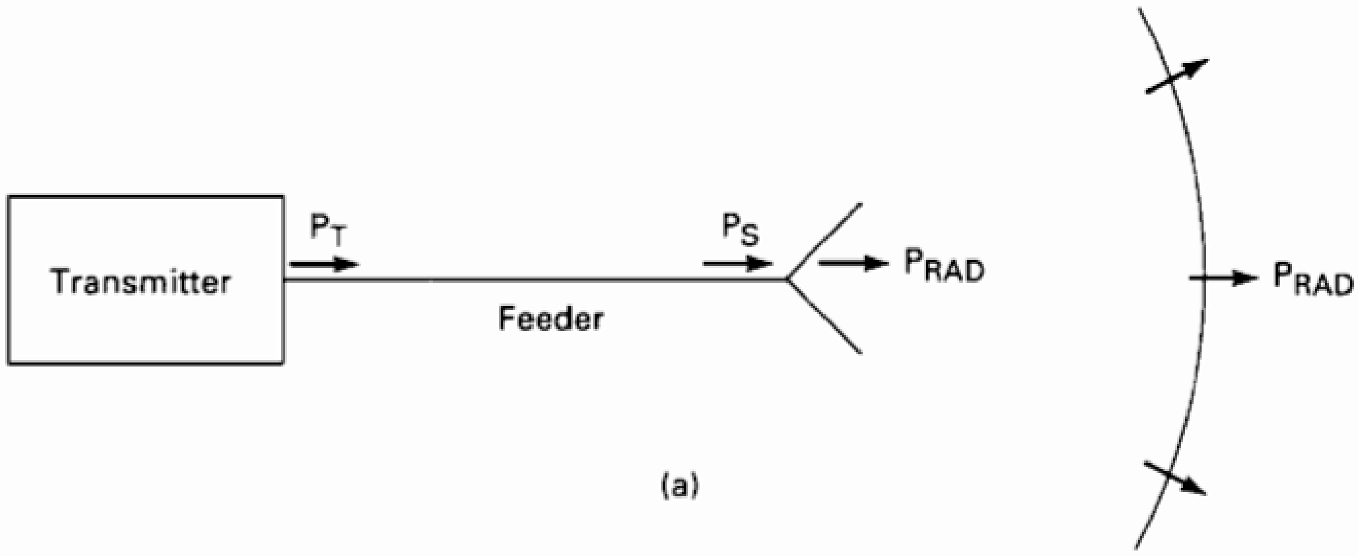
<table>
<tr><td></td><td></td></tr>
<tr><td>The maximum radiation is in the direction of 90° from the reference point of the absolute radiation pattern (radiation pattern is plotted in the form of Є or P)</td><td>RELATIVE RADIATION PATTERN
Є or P is plotted with respect to the reference point.</td></tr>
</table>

UNIT- IV

THE SPACE LINK & SATELLITE ACCES

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} ($< P_T$).



(a) Transmitting antenna
Source: *Satellite Communications*, Dennis Roddy, McGraw-Hill

EIRP - 1

- An isotropic radiator is an antenna which radiates in all directions equally
- Antenna gain is relative to this standard
- Antennas are fundamentally passive
  – No additional power is generated
  – Gain is realized by focusing power
- Effective Isotropic Radiated Power (EIRP) is the amount of power the transmitter would have to produce if it was radiating to all directions equally
- Note that EIRP may vary as a function of direction because of changes in the antenna gain vs. angle

EIRP - 2

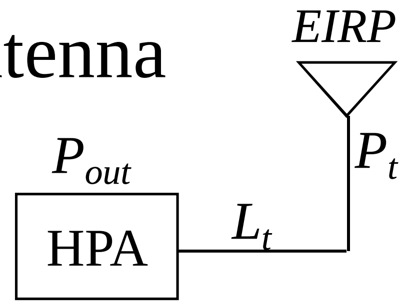
- The output power of a transmitter HPA is:

$$P_{out} \text{ watts}$$

- Some power is lost before the antenna:

$$P_t = P_{out} / L_t \text{ watts reaches the antenna}$$

$$P_t = \text{Power into antenna}$$



- The antenna has a gain of:

$$G_t \text{ relative to an isotropic radiator}$$

- This gives an effective isotropic radiated power of:

$$EIRP = P_t G_t \text{ watts relative to a 1 watt isotropic radiator}$$

Received Power

- We can rewrite the power flux density now considering the transmit antenna gain:

$$F = \frac{EIRP}{4\pi R^2} = \frac{P_t G_t}{4\pi R^2} \ \text{W/m}^2$$

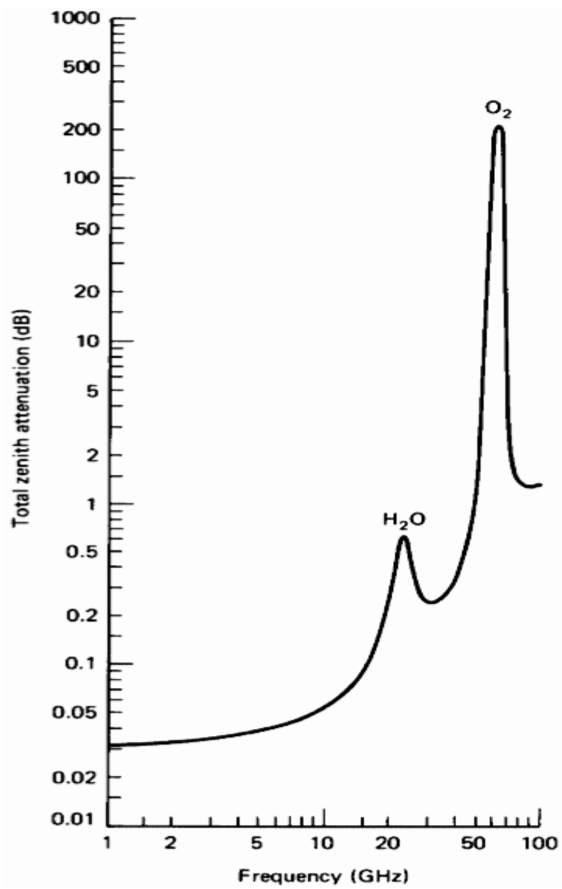
- The power available to a receive antenna of area A_r m^2 we get:

$$P_r = F \text{ x } A_r = \frac{P_t G_t A_r}{4\pi R^2}$$

Transmission losses

- Different types of atmospheric losses can perturb radio wave transmission in satellite systems:
  - Atmospheric absorption;
  - Atmospheric attenuation;
  - Traveling ionospheric disturbances.

Atmospheric Absorption



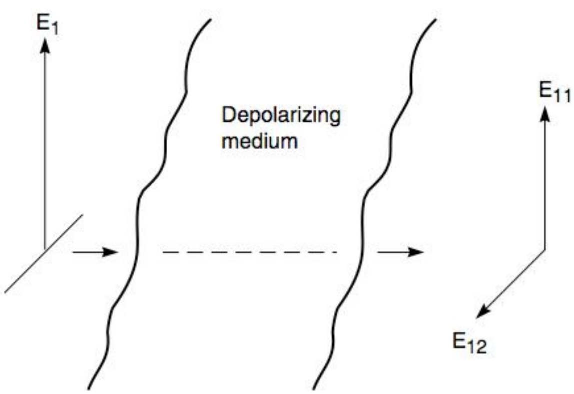
- Energy absorption by atmospheric gases, which varies with the frequency of the radio waves.
- Two absorption peaks are observed (for 90º elevation angle):
  - 22.3 GHz from resonance absorption in water vapour (H_2O)
  - 60 GHz from resonance absorption in oxygen (O_2)
- For other elevation angles:
  - $[AA] = [AA]_{90} \operatorname{cosec} \theta$

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:
  - $A = \alpha L$ [dB]
  - where α [dB/km] is called the specific attenuation, and can be calculated from specific attenuation coefficients in tabular form that can be found in a number of publications;
  - where 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.

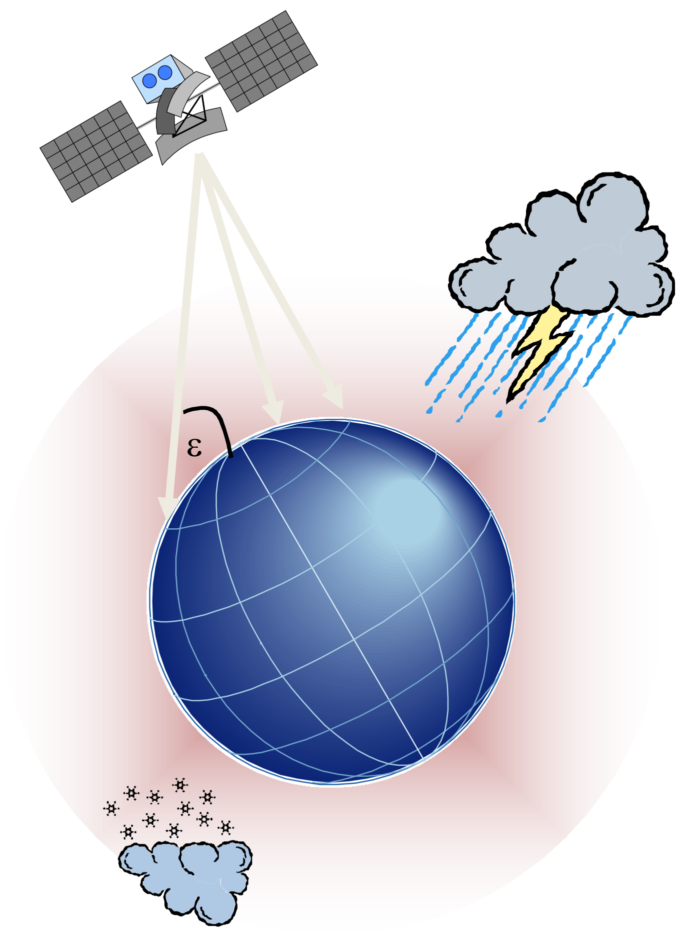
Cross-Polarisation Discrimination

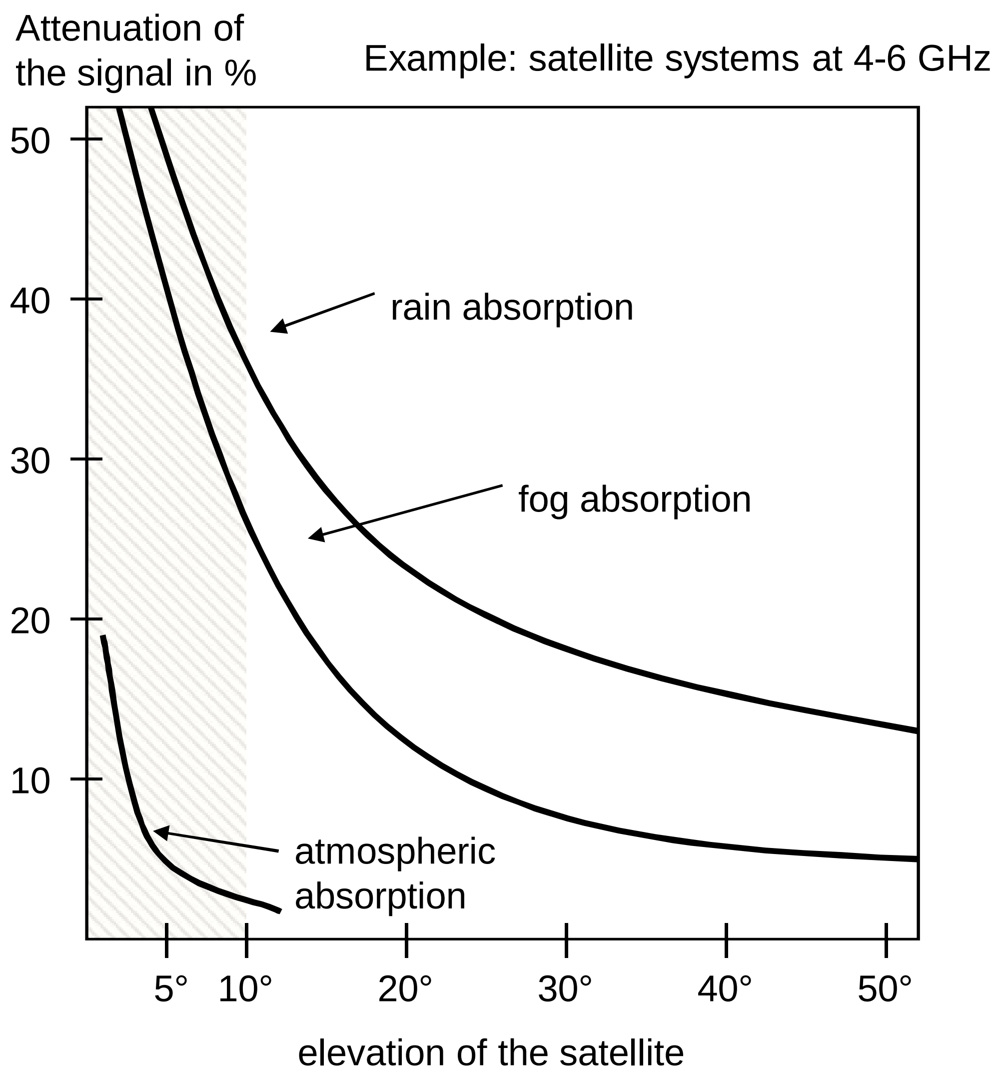
- Depolarisation can cause interference where orthogonal polarisation is used to provide isolation between signals, as in the case of frequency reuse.
- The most widely used measure to quantify the effects of polarisation interference is called Cross-Polarisation Discrimination (XPD):
  - $XPD = 20 \log (E_{11}/E_{12})$

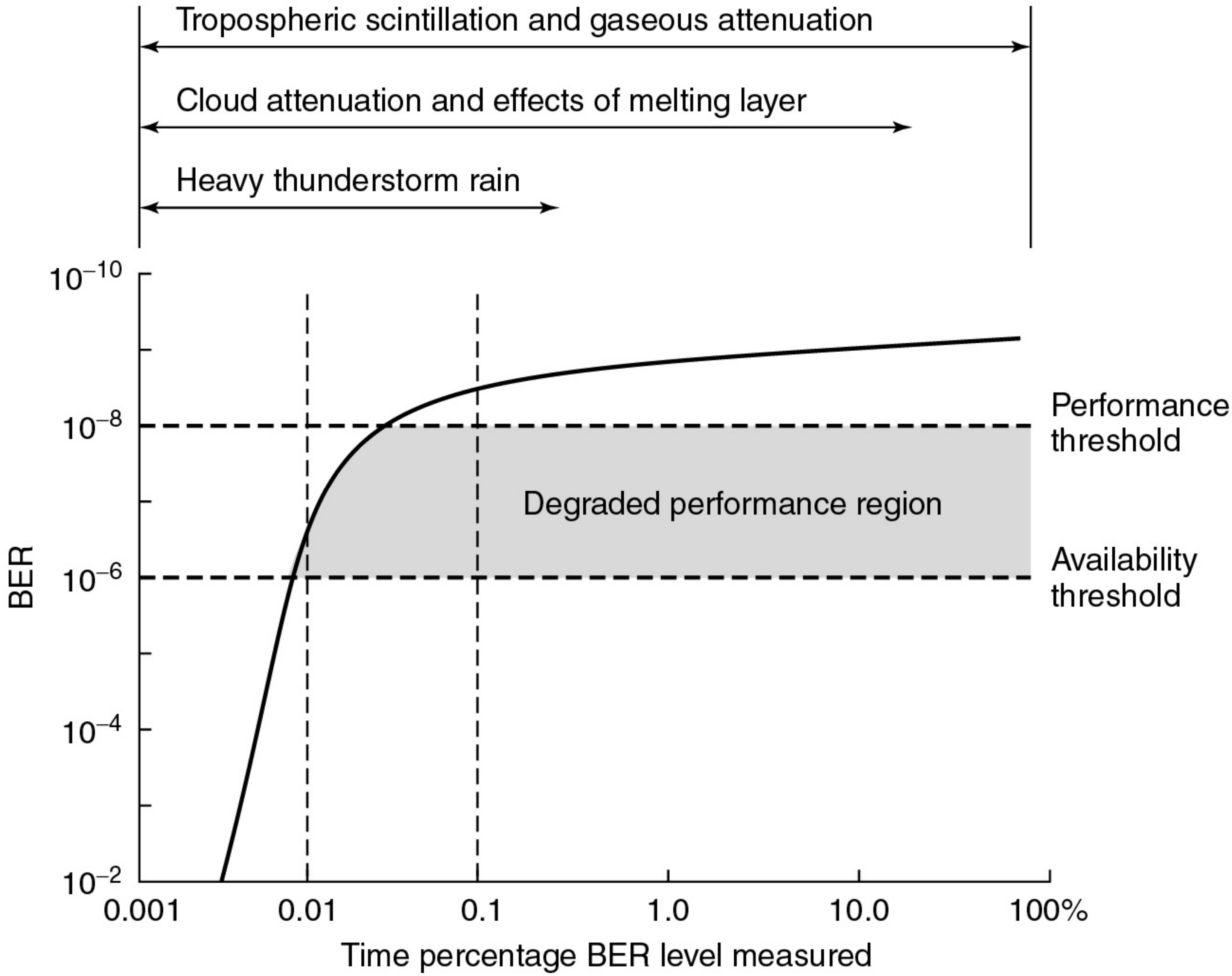


- To counter depolarising effects circular polarising is sometimes used.
- Alternatively, if linear polarisation is to be used, polarisation tracking equipment may be installed at the antenna.

Atmospheric attenuation







Tropospheric scintillation and gaseous attenuation
Cloud attenuation and effects of melting layer
Heavy thunderstorm rain
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
BER
Performance threshold
Degraded performance region
Availability threshold
0.001
0.01
0.1
1.0
10.0
100%
Time percentage BER level measured

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.

Why calculate Link Budgets?

- 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.
- Operation thresholds depend on:
  - Modulation scheme being used.
  - Desired communication quality.
  - Coding gain.
  - Additional overheads.
  - Channel Bandwidth.
  - Thermal Noise power.

Link Budget parameters

- Transmitter power at the antenna
- Antenna gain compared to isotropic radiator
- 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

More complete formulation

- Demonstrated formula assumes idealized case.
- Free Space Loss (L_p) represents spherical spreading only.
- 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)

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

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 and [G] is the transmitting antenna gain in dB.
- **$[G_R]$** 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

Link Power Budget

Tx *EIRP*

<u>Transmission:</u>
HPA Power
Transmission Losses (cables & connectors)
Antenna Gain

Antenna Pointing Loss
Free Space Loss
Atmospheric Loss (gaseous, clouds, rain)
Rx Antenna Pointing Loss

<u>Reception:</u>
Antenna gain
Reception Losses (cables & connectors)
Noise Temperature Contribution

Rx P_r

Translating to dBs

- The transmission formula can be written in dB as:

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

- This form of the equation is easily handled as a spreadsheet (additions and subtractions!!)

- 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***.

Link Power Budget

Tx *EIRP*

Transmission:
+ HPA Power
- Transmission Losses
  (cables & connectors)
+ Antenna Gain

- Antenna Pointing Loss
- Free Space Loss
- Atmospheric Loss
(gaseous, clouds, rain)
- Rx Antenna Pointing Loss

Reception:
+ Antenna gain
- Reception Losses
  (cables & connectors)
+ Noise Temperature
Contribution

Rx P_r

Easy Steps to a Good Link Power Budget

- First, draw a sketch of the link path
  - Doesn't have to be artistic quality
  - Helps you find the stuff you might forget
- Next, think carefully about the system of interest
  - Include all significant effects in the link power budget
  - Note and justify which common effects are insignificant here
- Roll-up large sections of the link power budget
  - Ie.: TXd power, TX ant. gain, Path loss, RX ant. gain, RX losses
  - Show all components for these calculations in the detailed budget
  - Use the rolled-up results in build a link overview
- Comment the link budget
  - Always, always, ***always*** use units on parameters (dBi, W, Hz ...)

Closing the Link

- 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 in closing the link:

  $\text{Margin} = P_r – C_{min}$

- Equivalently:

  Margin > 0 ➔ Link Closed

  Margin < 0 ➔ Link not closed

System Noise Power

- Performance of system is determined by C/N ratio.
- Most systems require C/N > 10 dB.

  (Remember, in dBs: C - N > 10 dB)
- Hence usually: C > N + 10 dB
- We need to know the noise temperature of our receiver so that we can calculate N, the noise power ($N = P_n$).
- T_n (noise temperature) is in Kelvins (symbol K):

$$T\left[K\right] = T\left[{}^{0}C\right] + 273$$

$$T\left[K\right] = \left(T\left[{}^{0}F\right] - 32\right)\frac{5}{9} + 273$$

Noise Spectral Density

- N = K.T.B ➔ N/B = N_0 is the noise spectral density (density of noise power per hertz):

$$N_0 = \frac{N}{B} = \frac{kT_s B}{B} = kT_s \text{ (dBW/Hz)}$$

- N_0 = noise spectral density is constant up to 300GHz.
- All bodies with Tp >0K radiate microwave energy.

System Noise Temperature

1) System noise power is proportional to system noise temperature
2) Noise from different sources is uncorrelated (AWGN)

Additive White Gaussian Noise (AWGN)

- Therefore, we can
  - Add up noise powers from different contributions
  - Work with noise temperature directly
- So: $T_s = T_{transmitted} + T_{antenna} + T_{LNA} + T_{lineloss} + T_{RX}$
- But, we must:
  - Calculate the effective noise temperature of each contribution
  - Reference these noise temperatures to the same location

Reducing Noise Power

- Make B as small as possible – just enough bandwidth to accept all of the signal power (C).
- Make T_S as small as possible
  - Lowest T_{RF}
  - Lowest T_{in} (How?)
  - High G_{RF}
- If we have a good low noise amplifier (LNA), i.e., low T_{RF}, high G_{RF}, then rest of receiver does not matter that much.

$$T_S = \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right] \cong T_{RF} + T_{in}$$

Effect of Rain

- Attenuation due to rain
  - Presence of raindrops can severely degrade the reliability and performance of communication links
  - The effect of rain depends on drop shape, drop size, rain rate, and frequency
- Estimated attenuation due to rain:

$$A = aR^b$$

  - A = attenuation (dB/km)
  - R = rain rate (mm/hr)
  - a and b depend on drop sizes and frequency

Design of the Satellite Link

- The satellite link is probably the most basic in microwave communications since a line-of-sight path typically exists between the Earth and space.
- This means that an imaginary line extending between the transmitting or receiving Earth station and the satellite antenna passes only through the atmosphere and not ground obstacles.

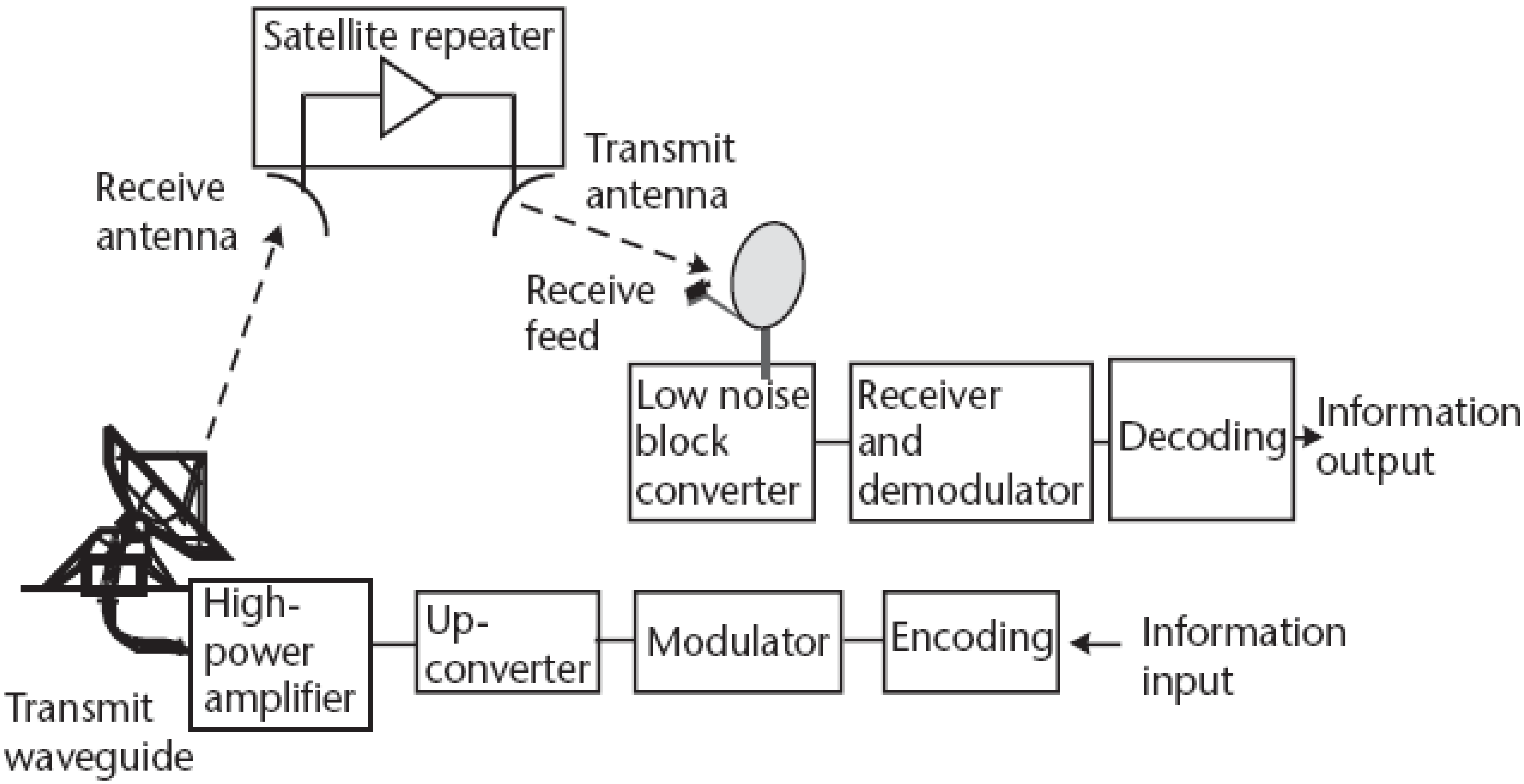
Design of the Satellite Link

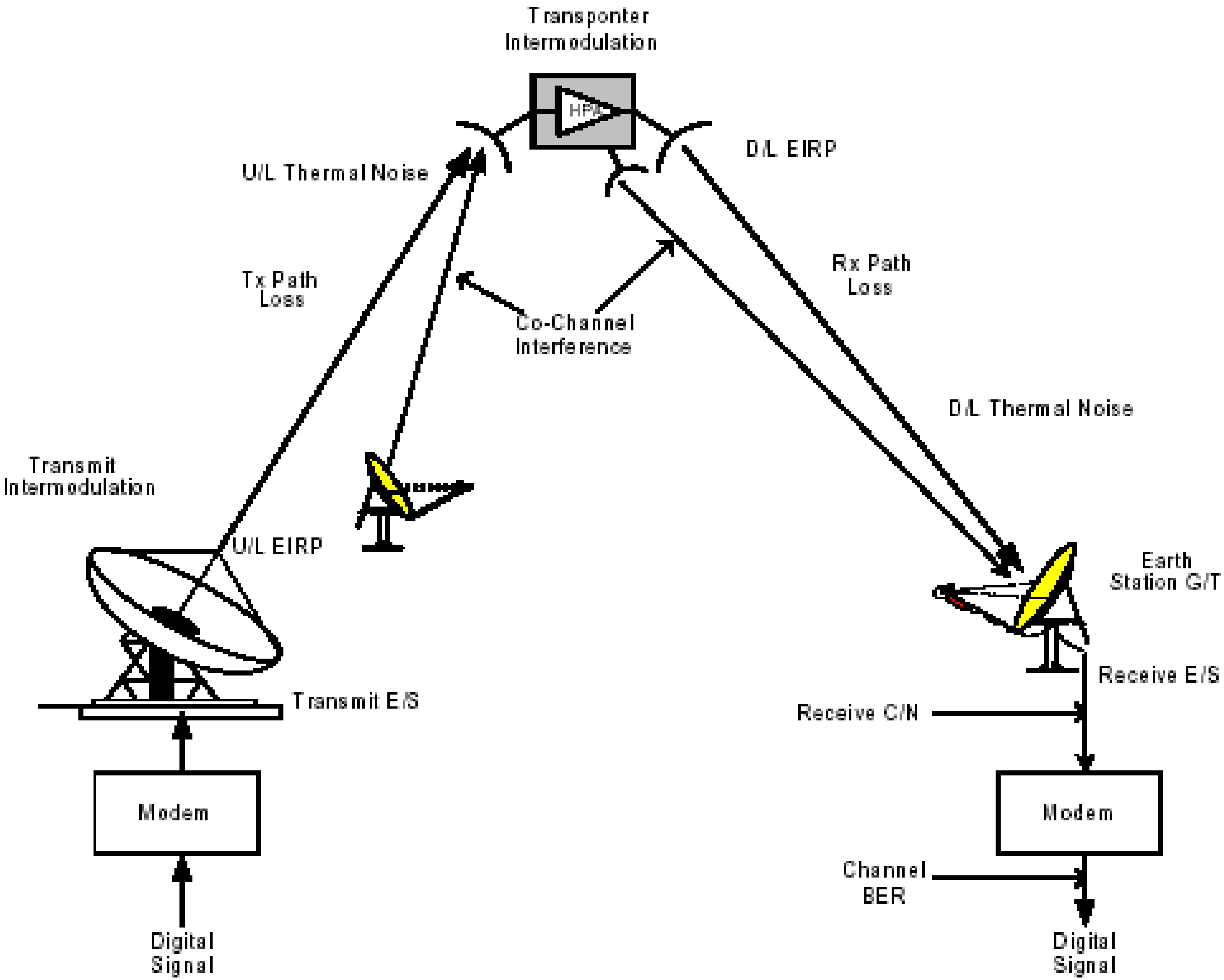
- Free-space attenuation is determined by the inverse square law, which states that the power received is inversely proportional to the square of the distance.
- There are, however, a number of additional effects that produce a significant amount of degradation and time variation.
- These include rain, terrain effects such as absorption by trees and walls, and some less-obvious impairment produced by unstable conditions of the air and ionosphere.

Design of the Satellite Link

- It is the job of the communication engineer to identify all of the significant contributions to performance and make sure that they are properly taken into account.
- The required factors include the performance of the satellite itself,
- The configuration and performance of the uplink and downlink Earth stations, and
- The impact of the propagation medium in the frequency band of interest.

Design of the Satellite Link





Transponter
Intermodulation
HPA
D/L EIRP
U/L Thermal Noise
Tx Path
Loss
Co-Channel
Interference
Rx Path
Loss
D/L Thermal Noise
Transmit
Intermodulation
U/L EIRP
Earth
Station G/T
Transmit E/S
Receive E/S
Receive C/N
Modem
Modem
Channel
BER
Digital
Signal
Digital
Signal

Satellite Link Design

The four factors related to satellite system design:

1. The weight of satellite
2. The choice frequency band
3. Atmospheric propagation effects
4. Multiple access technique

- The major frequency bands are 6/4 GHz, 14/11 GHz and 30/20 GHz (Uplink/Downlink)
- At geostationary orbit there is already satellites using both 6/4 and 14/11 GHz every 2˚(minimum space to avoid interference from uplink earth stations)

Satellite link design -Uplink

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

C/N

$$[C/N_0]_D = [EIRP]_D + [G/T]_D - [LOSSES]_D - [k]$$

$$[C/N_0]_U = [EIRP]_U + [G/T]_U - [LOSSES]_U - [k]$$

Multiple Access System

- Applications employ multiple-access systems to allow two or more Earth stations to simultaneously share the resources of the same transponder or frequency channel.
- These include the three familiar methods:
  - FDMA,
  - TDMA, and
  - CDMA.
- Another multiple access system called space division multiple access (SDMA) has been suggested in the past. In practice, SDMA is not really a multiple access method but rather a technique to reuse frequency spectrum through multiple spot beams on the satellite.
- Because every satellite provides some form of frequency reuse (cross-polarization being included), SDMA is an inherent feature in all applications.

Multiple Access System

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

Multiple Access System

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

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

Multiple Access System

- Multiple access is always required in networks that involve two-way communications among multiple Earth stations.
- The selection of the particular method depends heavily on the specific communication requirements, the types of Earth stations employed, and the experience base of the provider of the technology.
- All three methods are now used for digital communications because this is the basis of a majority of satellite networks.

Multiple Access System

- The digital form of a signal is easier to transmit and is less susceptible to the degrading effects of the noise, distortion from amplifiers and filters, and interference.
- Once in digital form, the information can be compressed to reduce the bit rate, and FEC is usually provided to reduce the required carrier power even further.
- The specific details of multiple access, modulation, and coding are often preselected as part of the application system and the equipment available on a commercial off-the-shelf (COTS) basis.

Multiple Access System

- The only significant analog application at this time is the transmission of cable TV and broadcast TV.
- These networks are undergoing a slow conversion to digital as well, which may in fact be complete within a few years.

FDMA

- Nearly every terrestrial or satellite radio communications system employs some form of FDMA to divide up the available spectrum.
- The areas where it has the strongest hold are in single channel per carrier (SCPC), intermediate data rate (IDR) links, voice telephone systems, VSAT data networks, and some video networking schemes.
- Any of these networks can operate alongside other networks within the same transponder.
- Users need only acquire the amount of bandwidth and power that they require to provide the needed connectivity and throughput.
- Also, equipment operation is simplified since no coordination is needed other than assuring that each Earth station remains on its assigned frequency and that power levels are properly regulated.
- However, inter-modulation distortion (IMD) present with multiple carriers in the same amplifier must be assessed and managed as well.

FDMA

- The satellite operator divides up the power and bandwidth of the transponder and sells off the capacity in attractively priced segments.
- Users pay for only the amount that they need. If the requirements increase, additional FDMA channels can be purchased.
- The IMD that FDMA produces within a transponder must be accounted for in the link budget; otherwise, service quality and capacity will degrade rapidly as users attempt to compensate by increasing uplink power further.
- The big advantage, however, is that each Earth station has its own independent frequency on which to operate.
- A bandwidth segment can be assigned to a particular network of users, who subdivide the spectrum further based on individual needs.
- Another feature, is to assign carrier frequencies when they are needed to satisfy a traffic requirement. This is the general class of demand assigned networks, also called demand-assigned multiple access (DAMA).

Time Division Multiple Access and ALOHA

- TDMA is a truly digital technology, requiring that all information be converted into bit streams or data packets before transmission to the satellite. (An analog form of TDMA is technically feasible but never reached the market due to the rapid acceptance of the digital form.)
- Contrary to most other communication technologies, TDMA started out as a high-speed system for large Earth stations.
- Systems that provided a total throughput of 60 to 250 Mbps were developed and fielded over the past 25 years.
- However, it is the low-rate TDMA systems, operating at less than 10 Mbps, which provide the foundation of most VSAT networks.
- As the cost and size of digital electronics came down, it became practical to build a TDMA Earth station into a compact package.

Time Division Multiple Access and ALOHA

- Lower speed means that less power and bandwidth need to be acquired (e.g., a fraction of a transponder will suffice) with the following benefits:
  - The uplink power from small terminals is reduced, saving on the cost of transmitters.
  - The network capacity and quantity of equipment can grow incrementally, as demand grows.

Time Division Multiple Access and ALOHA

- TDMA is a good fit for all forms of digital communications and should be considered as one option during the design of a satellite application.
- The complexity of maintaining synchronization and control has been overcome through miniaturization of the electronics and by way of improvements in network management systems.
- With the rapid introduction of TDMA in terrestrial radio networks like the GSM standard, we will see greater economies of scale and corresponding price reductions in satellite TDMA equipment.

Code Division Multiple Access

- CDMA, also called spread spectrum communication, differs from FDMA and TDMA because it allows users to literally transmit on top of each other.
- This feature has allowed CDMA to gain attention in commercial satellite communication.
- It was originally developed for use in military satellite communication where its inherent anti-jam and security features are highly desirable.
- CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems.

Code Division Multiple Access

- It has not been proven that CDMA is universally superior as this depends on the specific requirements.
- For example, an effective CDMA system requires contiguous bandwidth equal to at least the spread bandwidth.
- Two forms of CDMA are applied in practice:

  (1) direct sequence spread spectrum (DSSS) and

  (2) frequency hopping spread spectrum (FHSS).
- FHSS has been used by the OmniTracs and Eutel-Tracs mobile messaging systems for more than 10 years now, and only recently has it been applied in the consumer's commercial world in the form of the Bluetooth wireless LAN standard. However, most CDMA applications over commercial satellites employ DSSS (as do the cellular networks developed by Qualcomm).

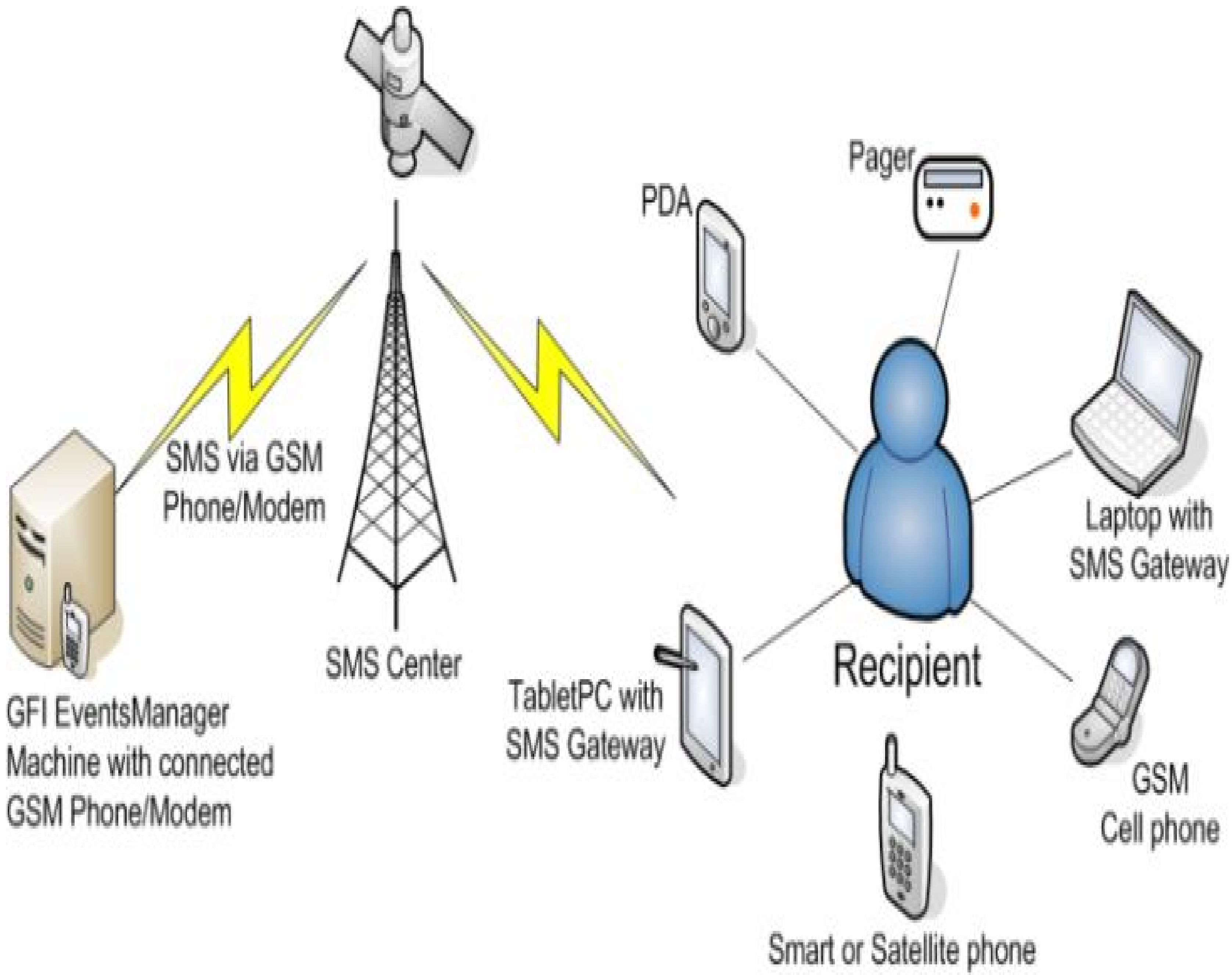
Code Division Multiple Access

- The first three functions are needed to extract the signal from the clutter of noise and other signals.
- The processes of demodulation, bit timing and detection, and FEC are standard for a digital receiver, regardless of the multiple access method.

satellite Mobile services: 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.



Pager
PDA
SMS via GSM
Phone/Modem
Laptop with
SMS Gateway
SMS Center
TabletPC with
SMS Gateway
Recipient
GFI EventsManager
Machine with connected
GSM Phone/Modem
GSM
Cell phone
Smart or Satellite phone

- ✓ 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).

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

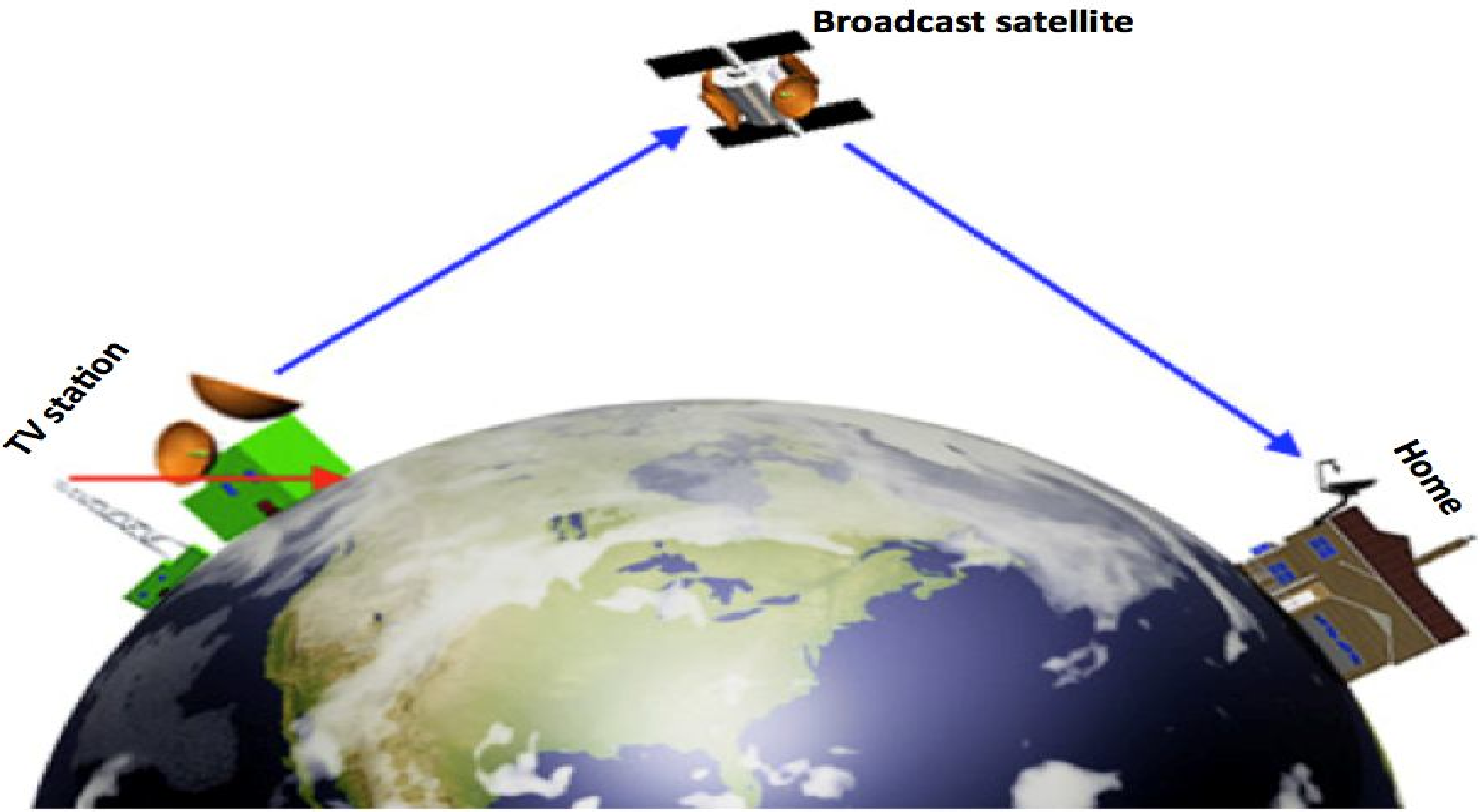
Several channels are used in the air interface

- ✓ **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.
- ✓ **TCH/H** - Traffic Channel, Half Rate for speech at 7 kbps, or data at 6 or 3.6 kbps

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.

Direct Broadcast satellites (DBS)



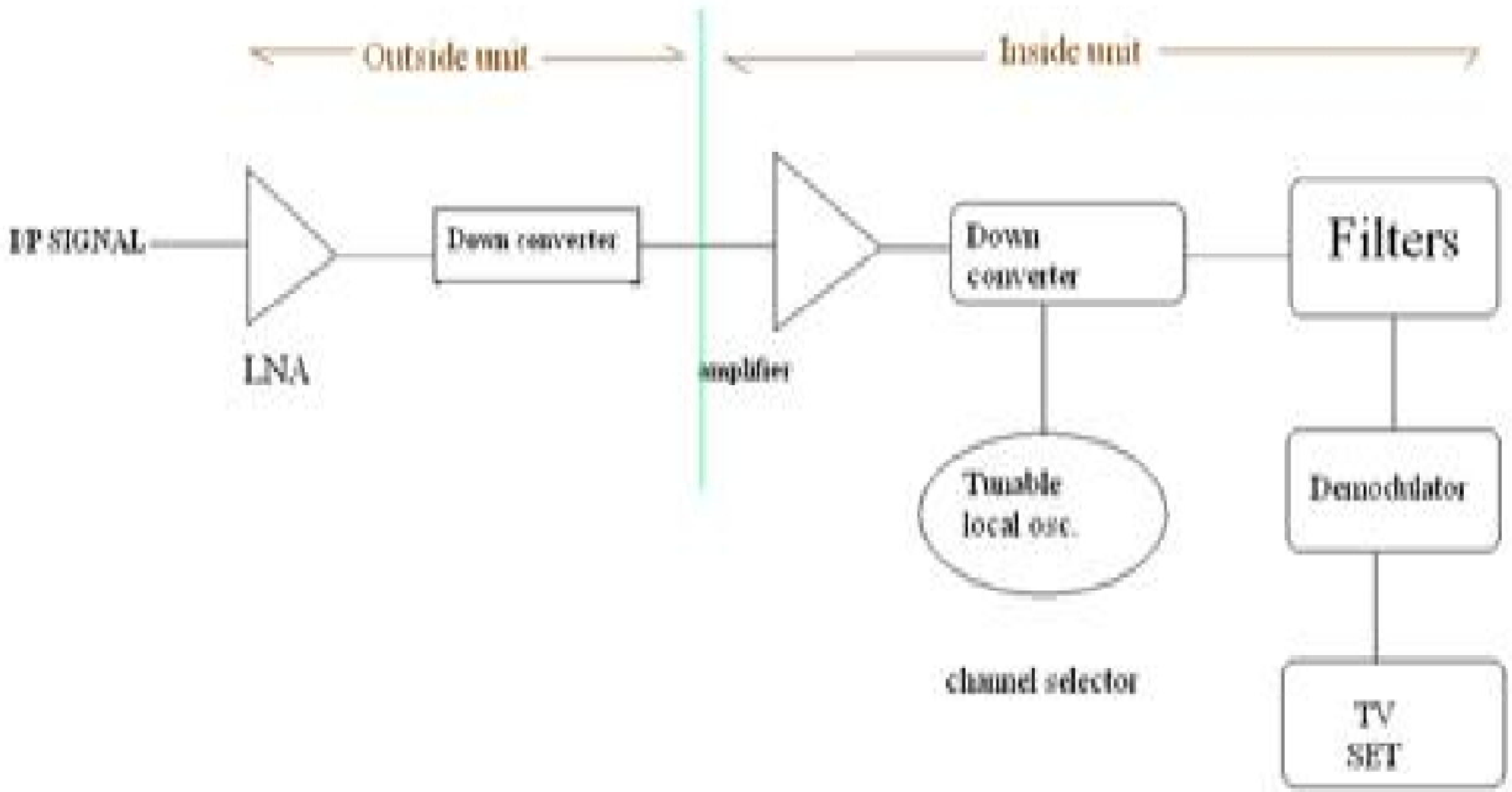
Direct Broadcast satellites (DBS)

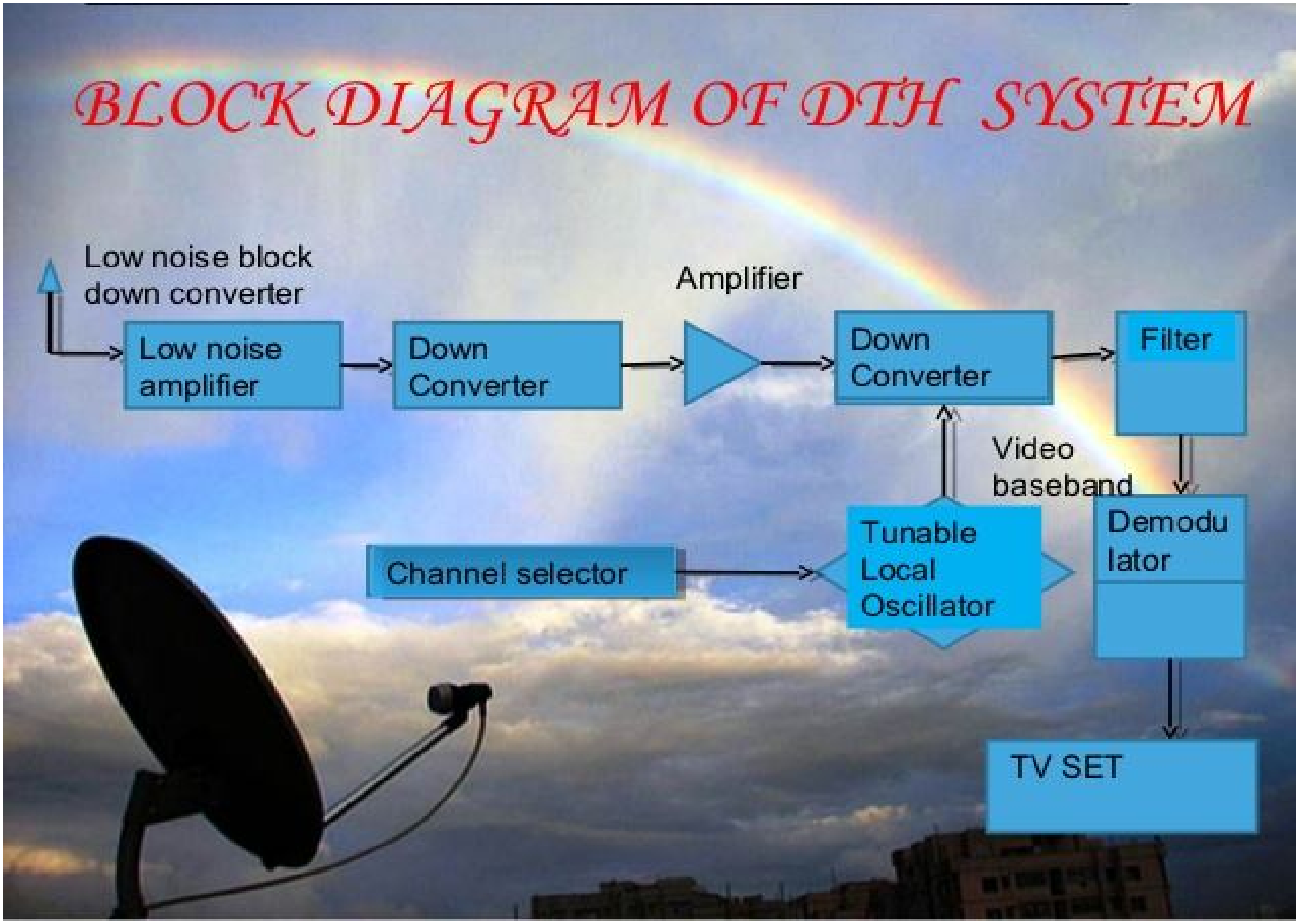
- ✓ Satellites provide *broadcast* transmissions in the fullest sense of the word, because antenna footprints can be made to cover large areas of the earth.
- ✓ The idea of using satellites to provide direct transmissions into the home has been around for many years, and the services pro- vided are known generally as *direct broadcast satellite* (DBS) services.
- ✓ Broadcast services include audio, television, and Internet services.

Direct to home Broadcast (DTH)

- ✓ DTH stands for Direct-To-Home television. DTH is defined as the reception of satellite programmes with a personal dish in an individual home.
- ✓ DTH Broadcasting to home TV receivers take place in the ku band(12 GHz).
- ✓ This service is known as Direct To Home service.
- ✓ DTH services were first proposed in India in 1996.
- ✓ Finally in 2000, DTH was allowed.
- ✓ The new policy requires all operators to set up earth stations in India
- ✓ within 12 months of getting a license. DTH licenses in India will cost $2.14 million and will be valid for 10 years.
- ✓ Working principal of DTH is the satellite communication. Broadcaster modulates the received signal and transmit it to the satellite in KU Band and from satellite one can receive signal by dish and set top box.

DTH Block Diagram

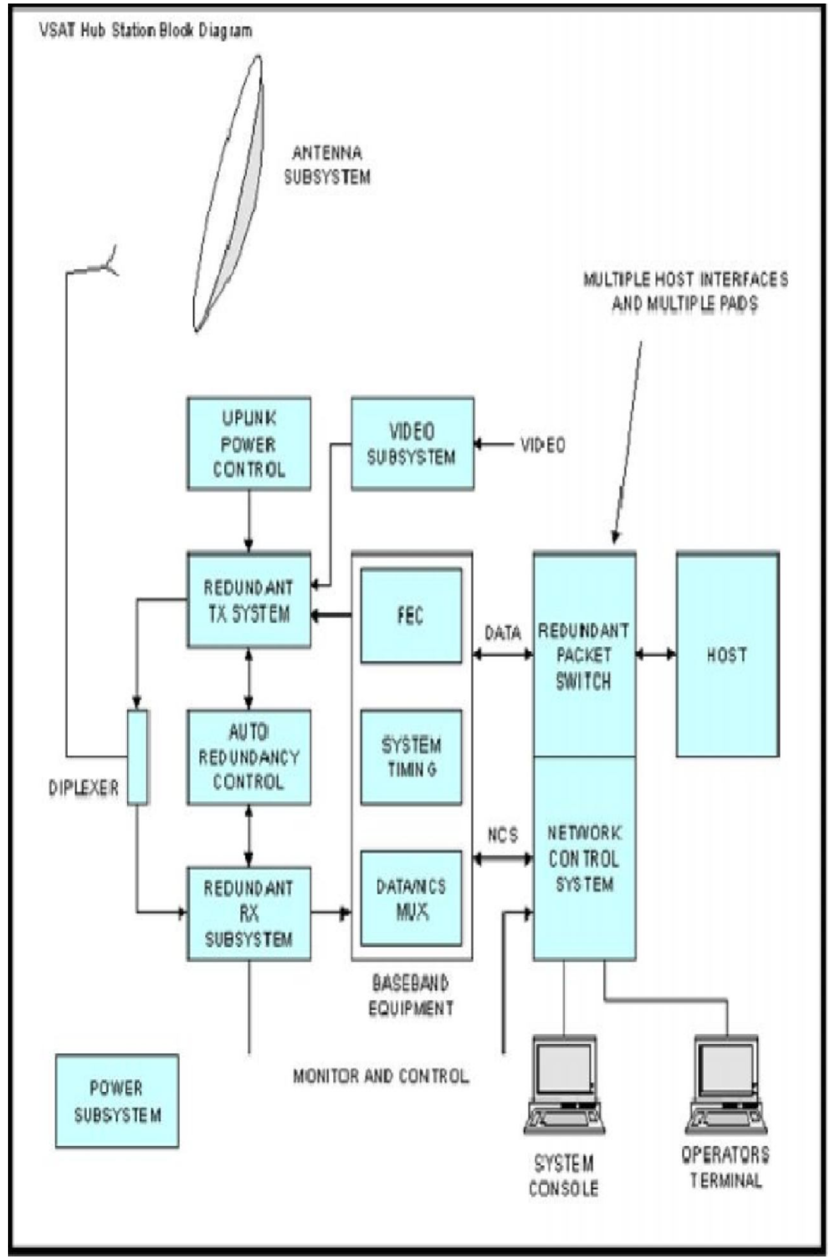


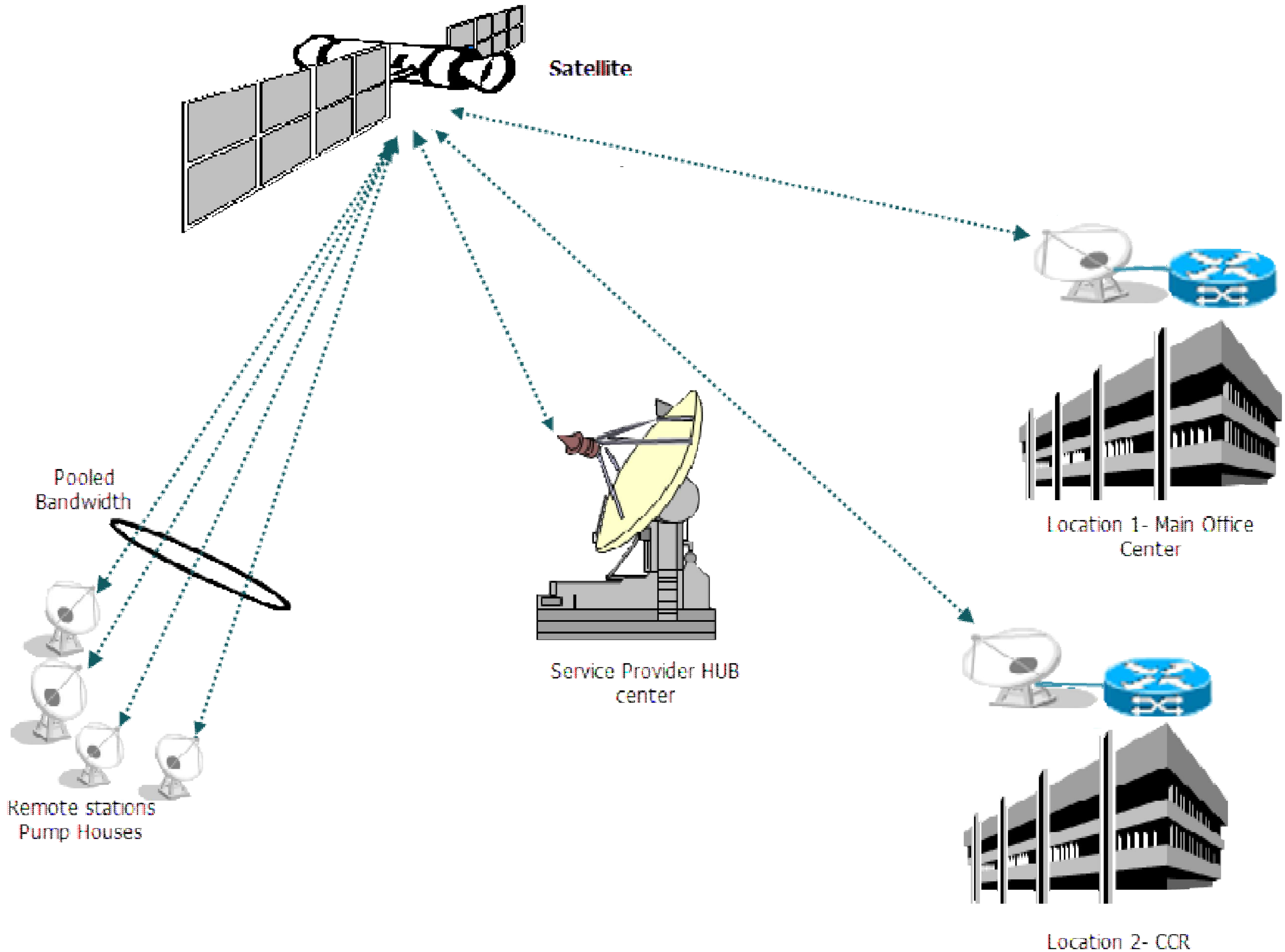

BLOCK DIAGRAM OF DTH SYSTEM
Low noise block
down converter
Low noise
amplifier
Down
Converter
Amplifier
Down
Converter
Filter
Video
baseband
Channel selector
Tunable
Local
Oscillator
Demodu
lator
TV SET

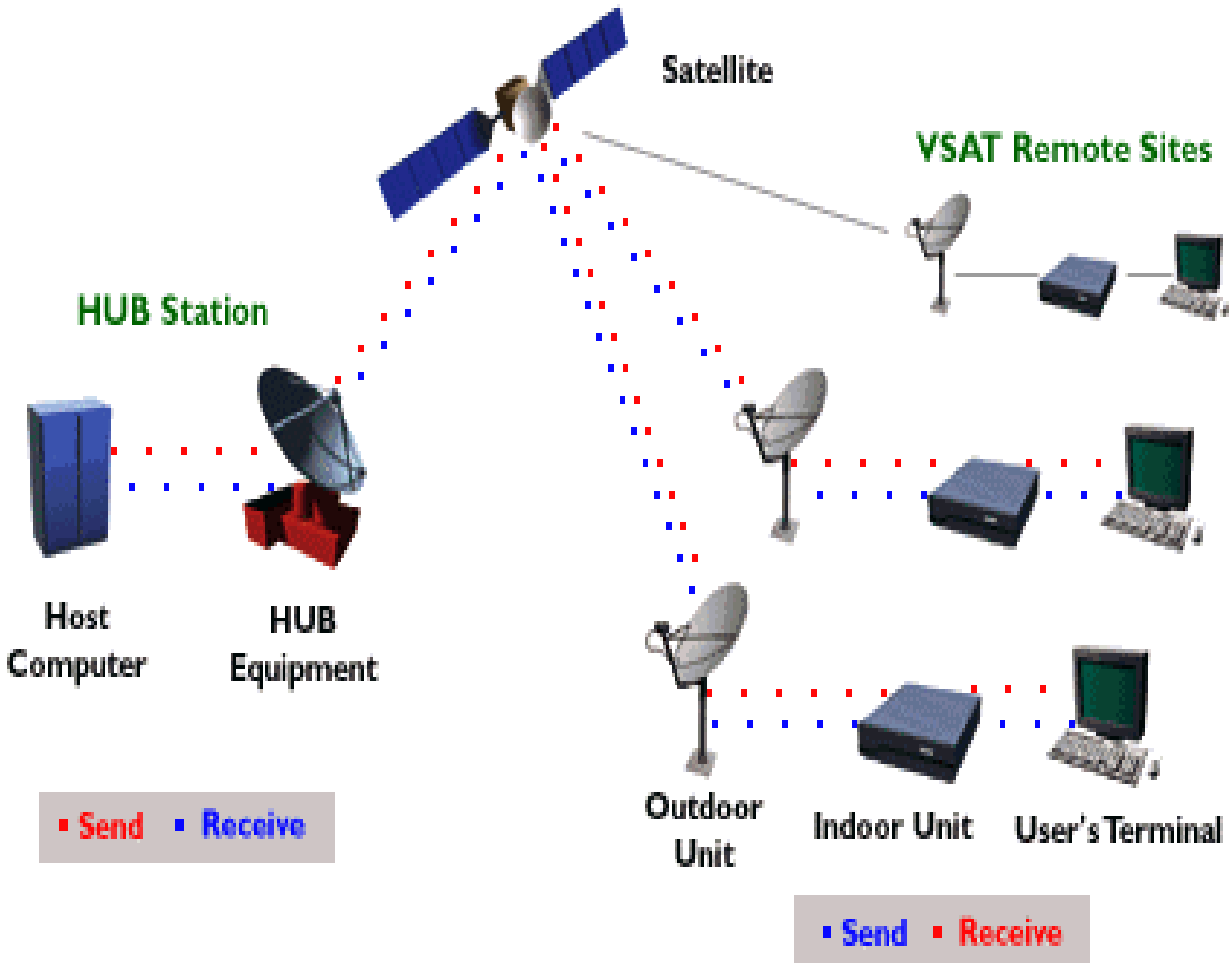
- ✓ A DTH network consists of a broadcasting centre, satellites, encoders, multiplexers, modulators and DTH receivers
- ✓ The encoder converts the audio, video and data signals into the digital format and the multiplexer mixes these signals.
- ✓ It is used to provide the DTH service in high populated area A Multi Switch is basically a box that contains signal splitters and A/B switches.
- ✓ A outputs of group of DTH LNBs are connected to the A and B inputs of the Multi Switch.

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 (Rana et al., 1990).
- The trend is toward even smaller dishes, not more than 1.5 m in diameter (Hughes et al., 1993).
- 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.
- Typical user groups include banking and financial institutions, airline and hotel booking agencies, and large retail stores with geographically dispersed outlets.




Satellite
Pooled Bandwidth
Service Provider HUB center
Location 1- Main Office Center
Location 2- CCR
Remote stations Pump Houses



Satellite
VSAT Remote Sites
HUB Station
Host Computer
HUB Equipment
Outdoor Unit
Indoor Unit
User's Terminal
Send
Receive
Send
Receive

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 (Rana et al., 1990).

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

Remote sensing is a method for getting information about of different objects on the planet, without any physical contacts with it.

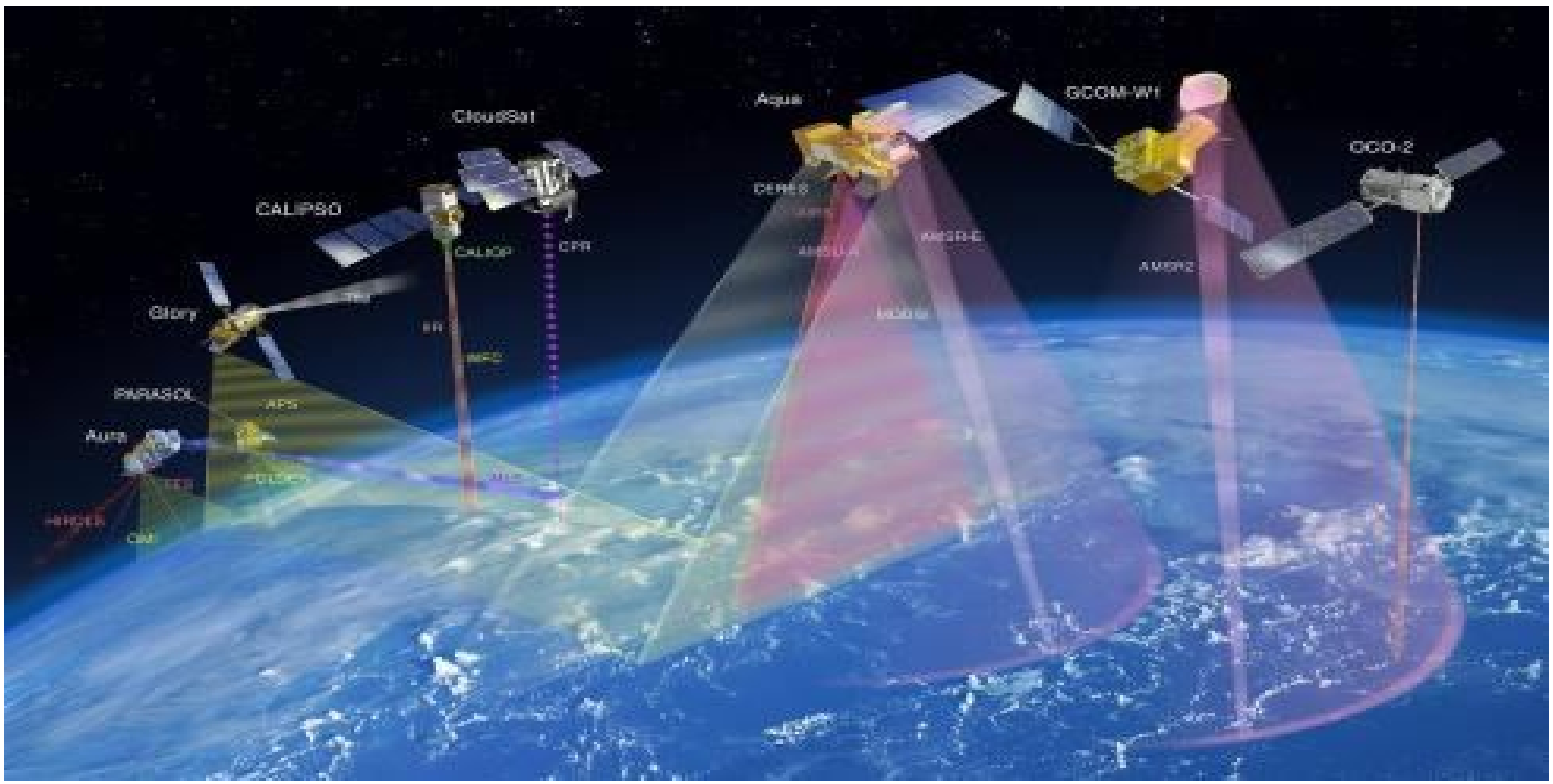


Image Source: cimss.ssec.wisc.edu

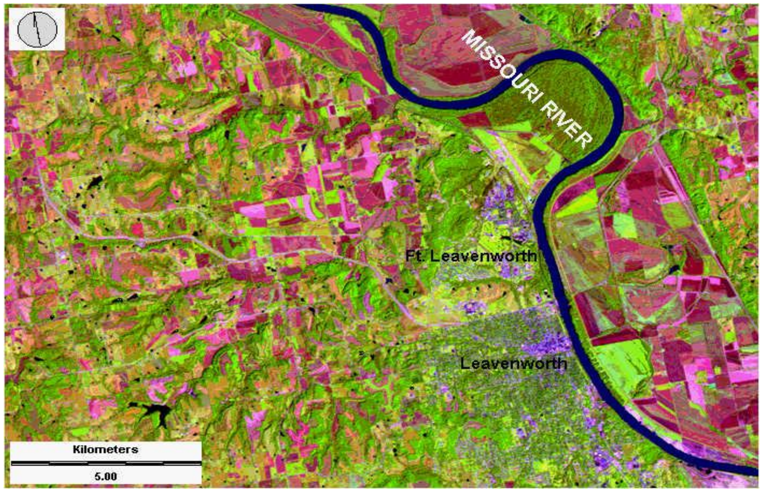
Remote sensing is a technology foe sampling electromagnetic radiation to acquire and read non-immediate geospatial data from which to pull info more or less features and objects on his Earths land surface, seas, and air.

- Provides a view for the large region
- Offers Geo-referenced information and digital information
- Most of the remote sensors operate in every season, every day, every time and even in real tough weather

Applications of remote sensing

Urbanization & Transportation

- Urban planning
- Roads network and transportation planni
- City expansion
- City boundaries by time
- Wetland delineation



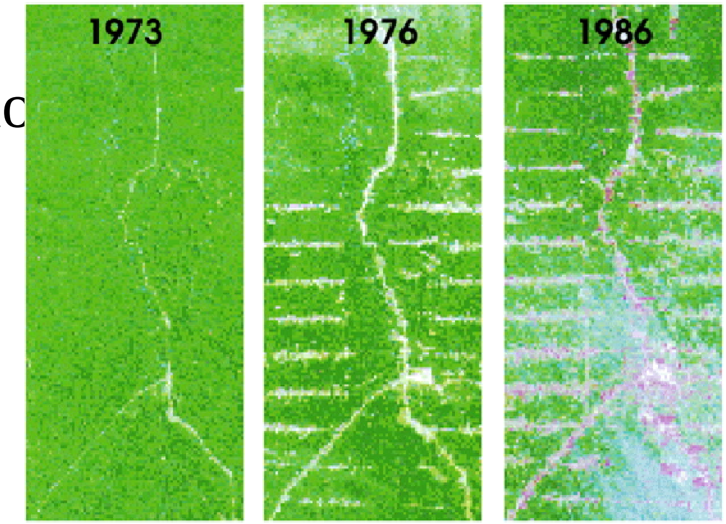
Agriculture

The application of remote sensing in agriculture include:

- Soil sensing
- Farm classification
- Farm condition assessment
- Agriculture estimation
- Mapping of farm and agricultural land characteristics
- Mapping of land management practices
- Compliance monitoring

Natural resource Management

- Forestry: biodiversity, forest, deforestatic
- Water source management
- Habitat analysis
- Environmental assessment
- Pest/disease outbreaks
- Impervious surface mapping
- Hydrology
- Mineral province
- Geomorphology



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.
- ✓ 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

- 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.

Three Segments of GPS:

Space Segment — Satellites orbiting the earth

- ✓ consists of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude.
- ✓ This high altitude allows the signals to cover a greater area.
- ✓ The satellites are arranged in their orbits so a GPS receiver on earth can receive a signal from at least four satellites at any given time.
- ✓ Each satellite contains several atomic clocks.

Control Segment — The control and monitoring stations

- ✓ Tracks the satellites and then provides them with corrected orbital and time information.
- ✓ 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 consists of the users and their GPS receivers.
- ✓ The number of simultaneous users is limitless.

How GPS Determines a Position

- ➢ The GPS receiver uses the following information to determine a position.
- ❖ 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.

Using a GPS Receiver

- ❖ There are several different models and types of GPS receivers.
- Refer to the owner’s manual for your GPS receiver and practice using it to become proficient.
- ❖ When working on an incident with a GPS receiver it is important to:
- ✓ Always have a compass and a map.
- ✓ Have a GPS download cable.
- ✓ Have extra batteries.
- ✓ Know memory capacity of the GPS receiver to prevent loss of data, decrease in accuracy of data,or other problems.
- ✓ Use an external antennae whenever possible, especially under tree canopy, in canyons, or while flying or driving.
- ✓ Set up GPS receiver according to incident or agency standard regulation; coordinate system.
- ✓ Take notes that describe what you are saving in the receiver.

INTELSAT

- Intelsat was created in 1964 as an intergovernmental treaty organization to operate a global satellite system for telecommunications services on a non-discriminatory basis.

- It provided telecommunicationS services to more than 147 countries and to all nations afterwards.

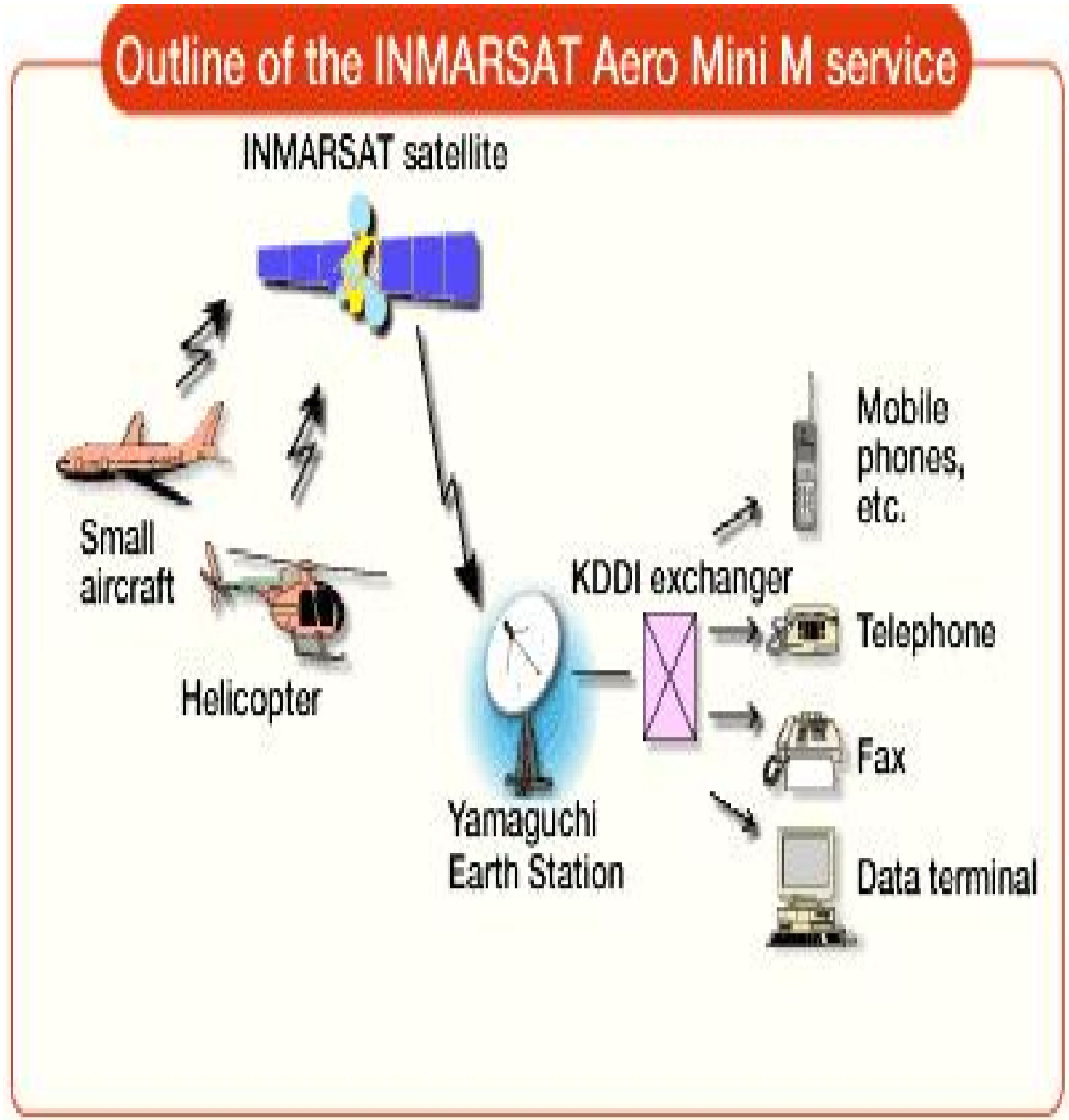
INTELSAT…

- It followed the policy of global price averaging, using revenues from high-traffic routes for developed countries and subsidize the less developed ones.

- In 1999, Intelsat owned and operated a global satellite system of 19 satellites bringing both public and commercial networks, video and Internet services to over 200 countries around the world.

INMARSAT

- Inmarsat-Indian Maritime Satellite
- sole IMO-mandated provider of satellite communications for the GMDSS
- Global Maritime Distress and Safety System (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.



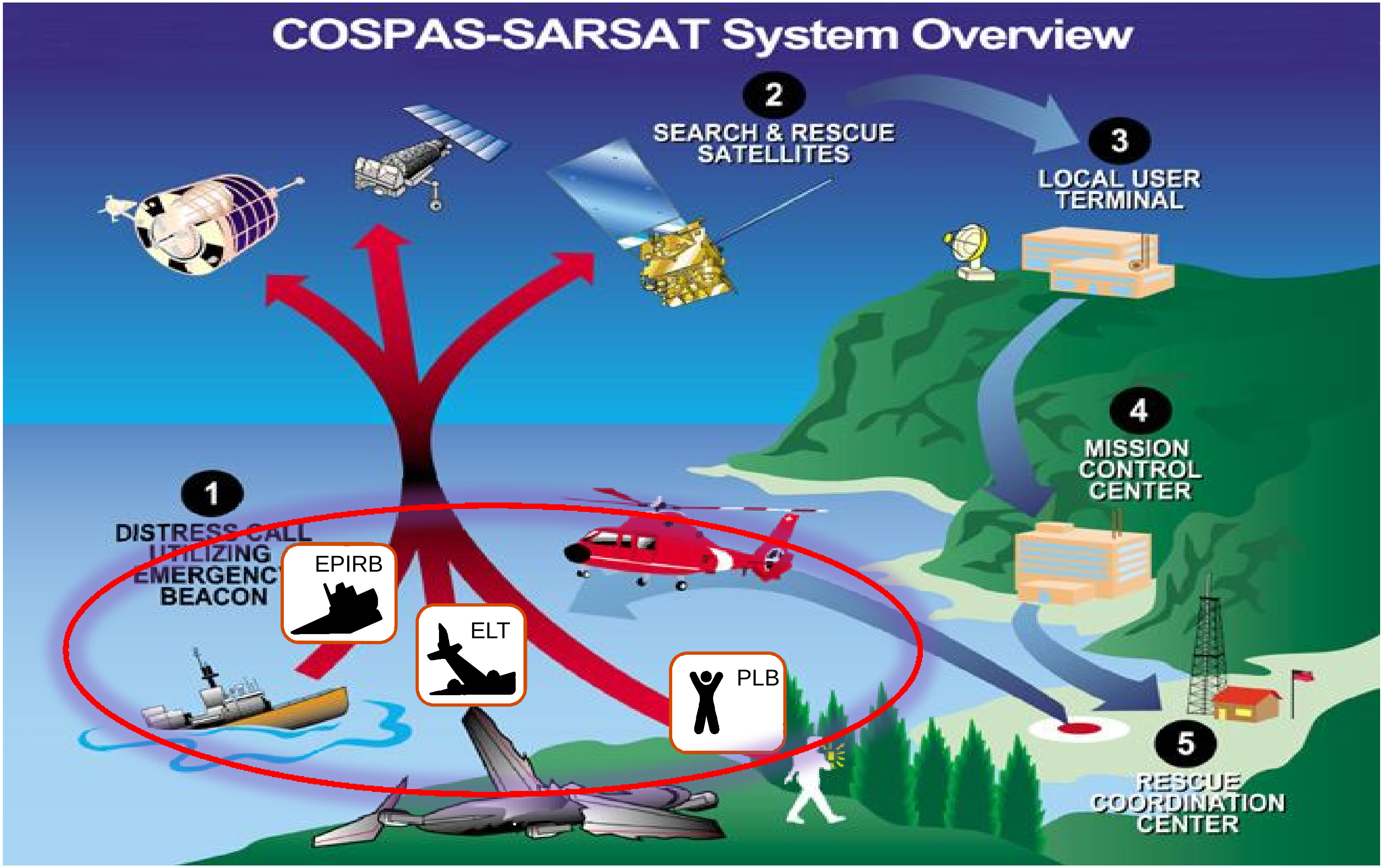

SEARCH AND RESCUE SATELLITE AIDED TRACKING (SARSAT)

COSPAS = **COsmicheskaya Systyema Poiska Aariynyich Sudov**

Which loosely translates into: "The Space System for the Search of Vessels in Distress"

SARSAT = **Search And Rescue Satellite Aided Tracking**

COSPAS-SARSAT User Segment



COSPAS-SARSAT
User Segment

Activation:

- Manual
- Automatic (Hydrostatic/G-Switch)

Signal:

- 406 MHz (Digital)
- 121.5 MHz (Analog) Homing

Applications:

- Maritime - Emergency Position-Indicating Radio Beacon (EPIRB)
- Aviation - Emergency Locator Transmitter (ELT)
- Personal/Land - Personal Locator Beacon (PLB)

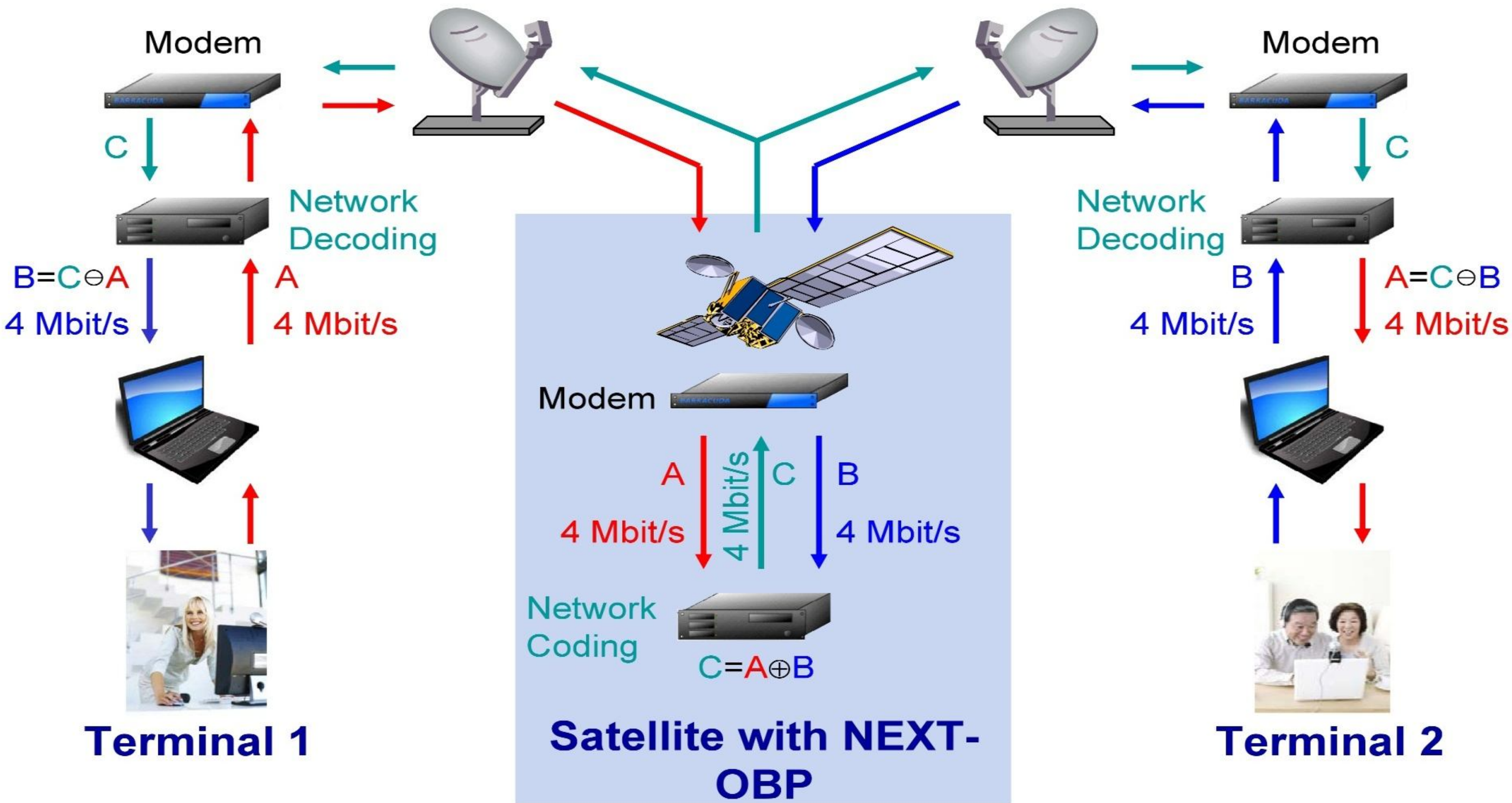
Positive Attributes of 406 MHz

- Every beacon has unique 15 hex identification
  - Unique ID allows registration with contact information
  - Non-Distress activations can be terminated with a phone call
  - Reduces stress on SAR assets
- More powerful transmitter (5 watts vs. 75 milliwatts) and digital signal increases accuracy of location by Doppler processing
- The system can discriminate between real beacon transmissions and non-beacon transmissions which reduces the resources spent on tracking interfering sources
- Global coverage provided by store and forward capability of Cospas-Sarsat satellites
- Increased system capacity due to short duration transmission, and spreading of frequency allocation

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 25th Assembly
- ✓ Inmarsat remains the sole, approved satcom provider for the GMDSS

Video Conferencing

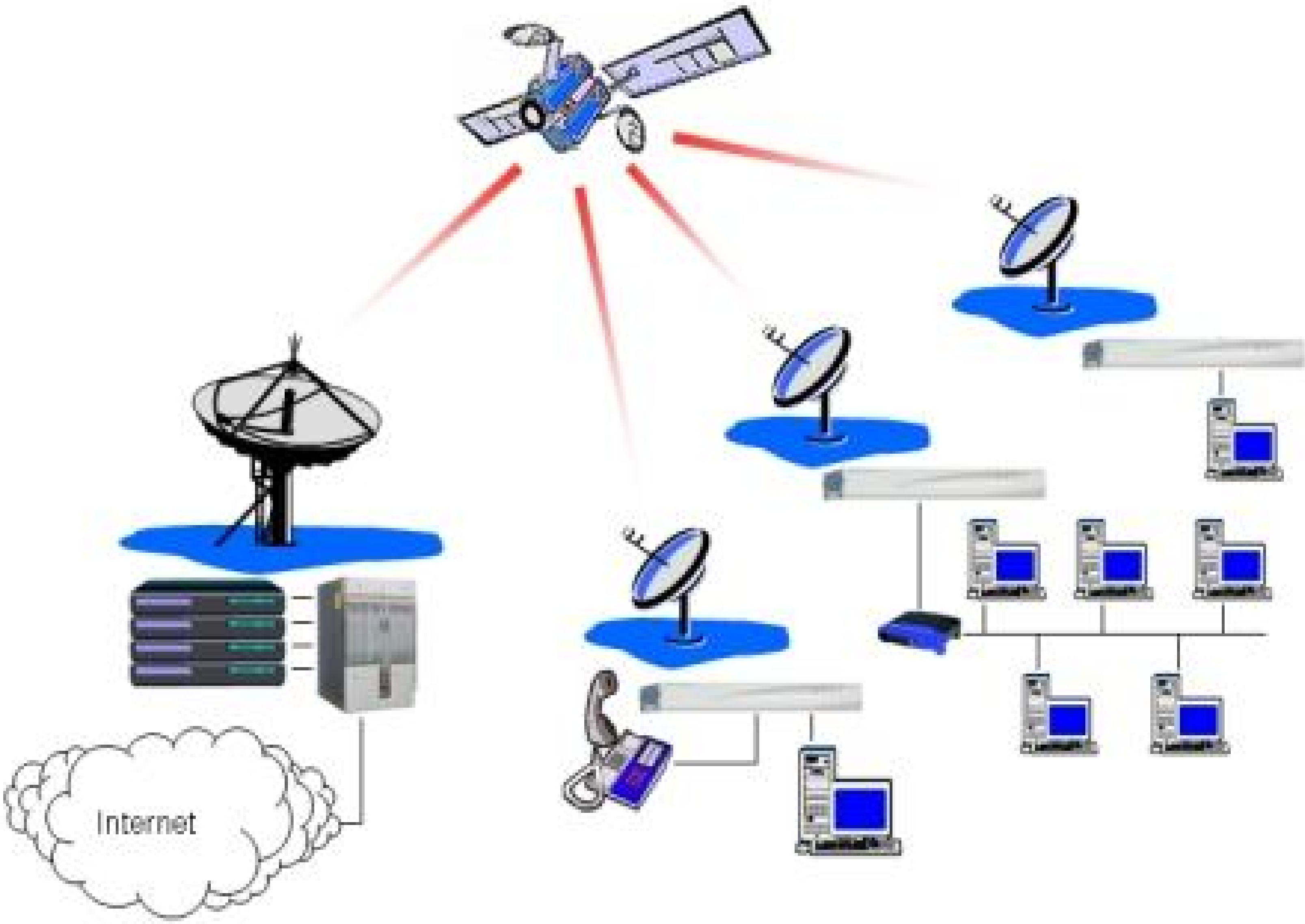


Video Conferencing (medium resolution)

- Video conferencing technology can be used to provide the same full, twoway interactivity of satellite broadcast at much lower cost.
- For Multi-Site meetings, video conferencing uses bridging systems to connect each site to the others.
- It is possible to configure a video conference bridge to show all sites at the same time on a projection screen or monitor.
- Or, as is more typical, a bridge can show just the site from which a person is speaking or making a presentation.
- The technology that makes interactive video conferencing possible, compresses video and audio signals, thus creating an image quality lower than that of satellite broadcasts.

Satellite Internet Connectivity

- ✓ **Satellite Internet access** is Internet access provided through communications satellites.
- ✓ Modern satellite Internet service is typically provided to users through geostationary satellites that can offer high data speeds, with newer satellites using Ka band to achieve downstream data speeds up to 50 Mbps.
- ✓ Satellite Internet generally relies on three primary components: a satellite in geostationary orbit (sometimes referred to as a geosynchronous Earth orbit, or GEO), a number of ground stations known as gateways that relay Internet data to and from the satellite via radio waves (microwave), and a VSAT (very-smallaperture terminal) dish antenna with a transceiver, located at the subscriber's premises.


Internet

Specialized services

Satellite-email services:

- ✓ The addition of Internet Access enables Astrium to act as an Internet Service Provider (ISP) capable of offering Inmarsat users a tailor-made Internet connection.
- ✓ With Internet services added to our range of terrestrial networks, you will no longer need to subscribe to a third party for Internet access (available for Inmarsat A, B, M, mini-M, Fleet, GAN, Regional BGAN & SWIFT networks).
- ✓ We treat Internet in the same way as the other terrestrial networks we provide, and thus offer unrestricted access to this service. There is no timeconsuming log-on procedure, as users are not required to submit a user-ID or password.

Description of E-mail Service:

- Astrium's E-Mail service allows Inmarsat users to send and receive e-mail directly through the Internet without accessing a public telephone network.

Features and Benefits

- No need to configure an e-mail client to access a Astrium e-mail account
- Service optimized for use with low bandwidth Inmarsat terminals
- Filter e-mail by previewing the Inbox and deleting any unwanted e-mails prior to downloading
- No surcharge or monthly subscription fees
- Service billed according to standard airtime prices for Inmarsat service used