SATELLITE COMMUNICATIONS

UNIT-II

SYLLABUS

UNIT-I:

Communication Satellite: Orbit and Description: A brief History of Satellite Communication, Satellite Frequency bands, Satellite Systems, Applications, Orbital Period and Velocity, Effects of Orbital inclination, Azimuth and Elevation, Coverage and Slant range, Eclipse, Orbital perturbations , Placement of a Satellite in a Geo-Stationary Orbit.

UNIT-II:

Satellite Sub-Systems: Altitude and orbit control system, TT&C Sub-System, Altitude control Sub-System, Power Systems, Communication Subsystems, Satellite antenna Equipment.

Satellite Link: Basic transmission theory, system noise temperature and G/T ratio, Basic Link Analysis, Interference Analysis, Design of satellite links for specified C/N, (with and without frequency Re-use), Link Budget.

UNIT-III:

Propagation effects: Introduction, Atmospheric Absorption, Cloud Attenuation, Tropospheric and Ionospheric Scintillation and Low angle fading, Rain Induced attenuation, rain induced cross polarization interference.

Multiple Access: Frequency Division Multiple Access(FDMA), Intermodulation, Calculation of C/N. Time Division Multiple Access(TDMA), Frame structure, Burst structure, Satellite Switched TDMA Onboard processing, Demand Assignment Multiple Access (DAMA) – Types of Demand Assignment, Characteristics, CDMA Spread Spectrum Transmission and Reception

UNIT-IV:

Earth Station Technology: Transmitters, Receivers, Antennas, Tracking systems, Terrestrial Interface, Power Test methods, Lower Orbit Considerations.

Satellite Navigation & Global Positioning Systems: Radio and Satellite Navigation, GPS Position Location principles, GPS Receivers, GPS C/A code accuracy, Differential GPS.

UNIT-V:

Satellite Packet Communications: Message Transmission by FDMA: M/G/1 Queue, Message Transmission by TDMA, PURE ALOHA-Satellite Packet Switching, Slotted Aloha, Packet Reservation, Tree Algorithm.

TEXT BOOKS:

1. Satellite Communications- Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003, John Wiley & Sons.

2. Satellite Communication Engineering- Wilbur L. Pritchand, Robert A Nelson and Henri G.Suyderhoud, 2nd Edition, Pearson Publications.
3. Digital Satellite Communications-Tri. T.Ha, 2nd Edition, 1990, Mc. Graw Hill.

REFERENCE BOOKS:

1. Satellite Communications- Dennis Roddy, 2nd Edition, 1996, McGraw Hill.
2. Satellite Communications: Design Principles- M. Richharia, 2nd Edition,BS Publications, 2003.
3. Digital Satellite Communications-Tri. T. Ha,2nd Ed.,MGH,1990.
4. Fundamental of Satellite Communications- K. N Raja Rao, PHI, 2004

Orbital Perturbations

Theoretically, an orbit described by Kepler is ideal as Earth is considered to be a perfect sphere and the force acting around the Earth is the centrifugal force. This force is supposed to balance the gravitational pull of the earth.
In reality, other forces also play an important role and affect the motion of the satellite. These forces are the gravitational forces of Sun and Moon along with the atmospheric drag.

Effect of Sun and Moon is more pronounced on geostationary earth satellites where as the atmospheric drag effect is more pronounced for low earth orbit satellites.

Effects of Non-spherical Earth

As the shape of Earth is not a perfect sphere, it causes some variations in the path followed by the satellites around the primary. As the Earth is bulging from the equatorial belt, and keeping in mind that an orbit is not a physical entity, and it is the forces resulting from an oblate Earth which act on the satellite produce a change in the orbital parameters.
This causes the satellite to drift as a result of regression of the nodes and the latitude of the point of perigee (point closest to the Earth). This leads to rotation of the line of apsides. As the orbit itself is moving with respect to the Earth, the resultant changes are seen in the values of argument of perigee and right ascension of ascending node.

ue to the non-spherical shape of Earth, one more effect called as the “Satellite Graveyard” is seen. The non-spherical shape leads to the small value of eccentricity (10^{-5}) at the equatorial plane. This causes a gravity gradient on GEO satellite and makes them drift to one of the two stable points which coincide with minor axis of the equatorial ellipse.

Gravitational forces of other planets.

Planet	Gravitational force
Earth	0.9
Sun	6 x 10-4
Mercury	2.6×10^{-10}
Venus	1.9×10^{-8}
Mars:	7.1×10^{-10}
Jupiter:	3.2×10^{-8}
Saturn:	2.3×10^{-9}
Uranus:	8×10^{-11}

Neptune	3.6 x 10^{-11}
Pluto	10^{-12}
Moon	3.3 x 10^{-6}
Earth Oblateness	10^{-3}

Working satellites are made to drift back to their position but out-of-service satellites are eventually drifted to these points, and making that point a Satellite Graveyard.

A graveyard orbit, also called a super synchronous orbit, junk orbit or disposal orbit, is an orbit significantly above GEO where satellites are intentionally placed at the end of their operational life. It is a measure performed in order to lower the probability of collisions with operational spacecraft and of the generation of additional space debris. The points where the graveyard is made are separated by 1800 on the equator and are set approximately on 75^0 E longitude and 105^0 W longitude.

Atmospheric Drag

For Low Earth orbiting satellites, the effect of atmospheric drag is more pronounces. The impact of this drag is maximum at the point of perigee. Drag (pull towards the Earth) has an effect on velocity of Satellite (velocity reduces).

Attitude Control & Orbit Control:

The attitude and orbit of a satellite must be controlled so that that satellite's antennas point toward the earth and so that the user knows where in the sky to look for the satellite. This is particularly important for GEO satellites since the earth station antennas that are used with GEO satellites are normally fixed and movement of the satellite away from its appointed position in the sky will cause a loss of signal. There are several forces acting on an orbiting satellite that tend to change its attitude and orbit. The most important are the gravitational fields of the sun and moon, irregularities in the earth's gravitational field, solar pressure from the sun and variations in the earth's magnetic field. The earth is not quite a perfect sphere. At the equator there are bulges of about 65m at longitudes 162^o E and 348^o W, with the result that a satellite is accelerated toward one of the two stable points in the GEO orbit at longitude 75^o E and 105^o W as shown in Fig given below.

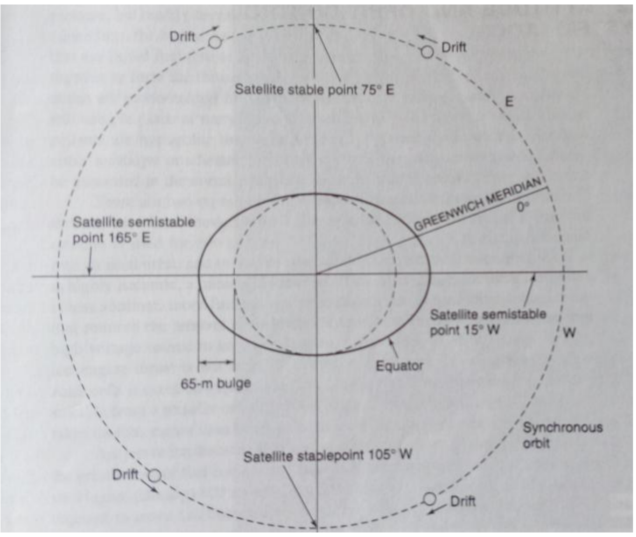


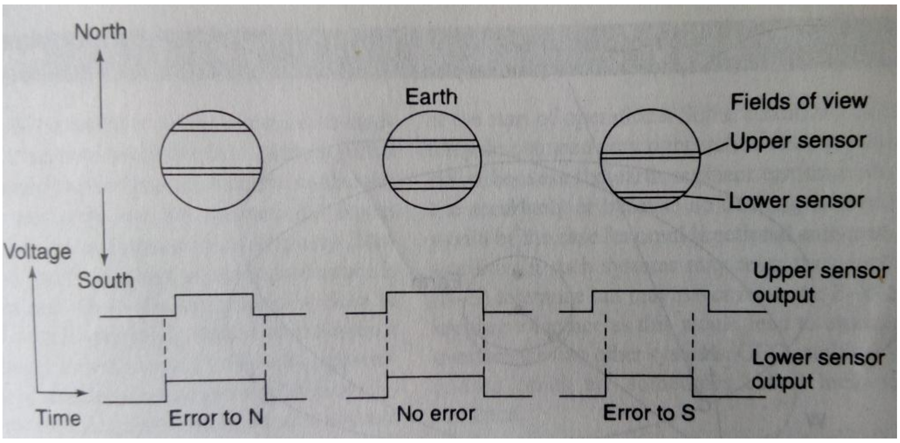
Figure 2.1: Drift of a Geo Synchronous Satellite in the orbit

To maintain accurate station keeping the satellite must be periodically accelerated in the opposite direction to the forces acting on it. This is done as a sequence of station keeping manoeuvres, using small rocket motors(sometime called gas jets or thrusters) that can be controlled from the earth via th TTC&M system.

Attitude Control System

The *attitude* of a satellite refers to its orientation in space. Much of the equipment carried aboard a satellite is there for the purpose of controlling its attitude. Attitude control is necessary, for example, to ensure that directional antennas point in the proper directions. In the case of earth environmental satellites, the earth-sensing instruments must cover the required regions of the earth, which also requires attitude control. A number of forces, referred to as *disturbance torques*, can alter the attitude, some examples being the gravitational fields of the earth and the moon, solar radiation, and meteorite impacts.

Attitude control must not be con-fused with station keeping, which is the term used for maintaining a satellite in its correct orbital position, although the two are closely related. To exercise attitude control, there must be available some measure of a satellite's orientation in space and of any tendency for this to shift. In one method, infrared sensors, referred to as *horizon detectors*, are used to detect the rim of the earth against the background of space. With the use of four such sensors, one for each quadrant, the center of the earth can be readily established as a reference point.



Usually, the attitude-control process takes place aboard the satellite, but it is also possible for control signals to be transmitted from earth, based on attitude data obtained from the satellite.

Also, where a shift in attitude is desired, an *attitude maneuver* is executed. The control signals needed to achieve this maneuver may be transmitted from an earth station. Controlling torques may be generated in a number of ways. *Passive attitude control* refers to the use of mechanisms which stabilize the satellite without putting a drain on the satellite's energy supplies; at most, infrequent use is made of these supplies, for example, when thruster jets are impulsed to provide corrective torque. Examples of passive attitude control are *spin stabilization* and *gravity gradient stabilization*.

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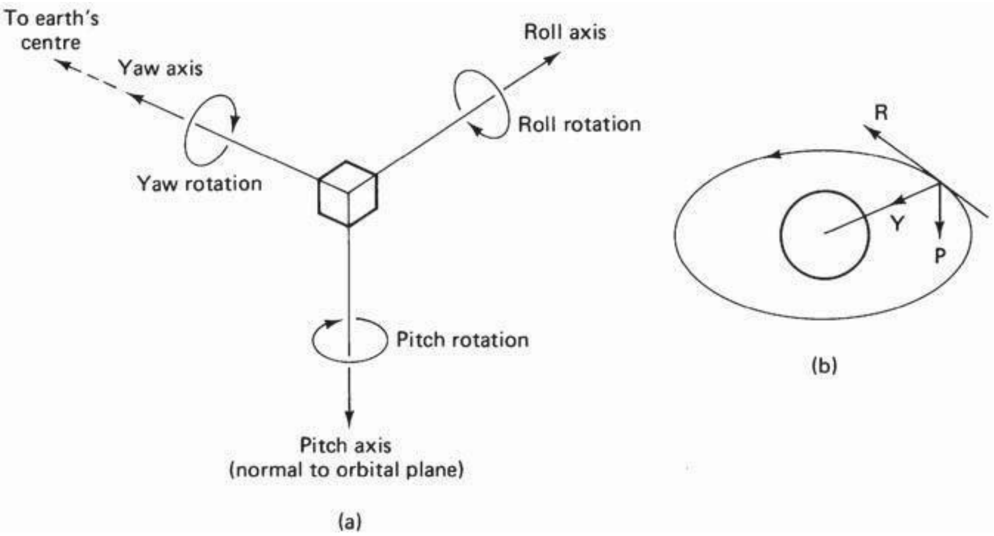

Figure 2.1 (*a*) Roll, pitch, and yaw axes. The yaw axis is directed toward the earth's center, the pitch axis is normal to the orbital plane, and the roll axis is perpendicular to the other two. (*b*) RPY axes for the geostationary orbit. Here, the roll axis is tangential to the orbit and lies along the satellite velocity vector.

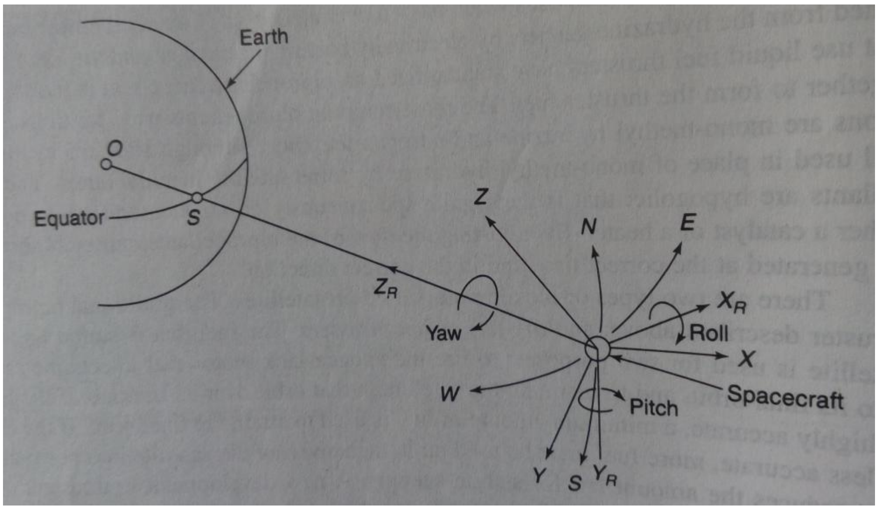

Figure: Axis system of Satellite Attitude Control

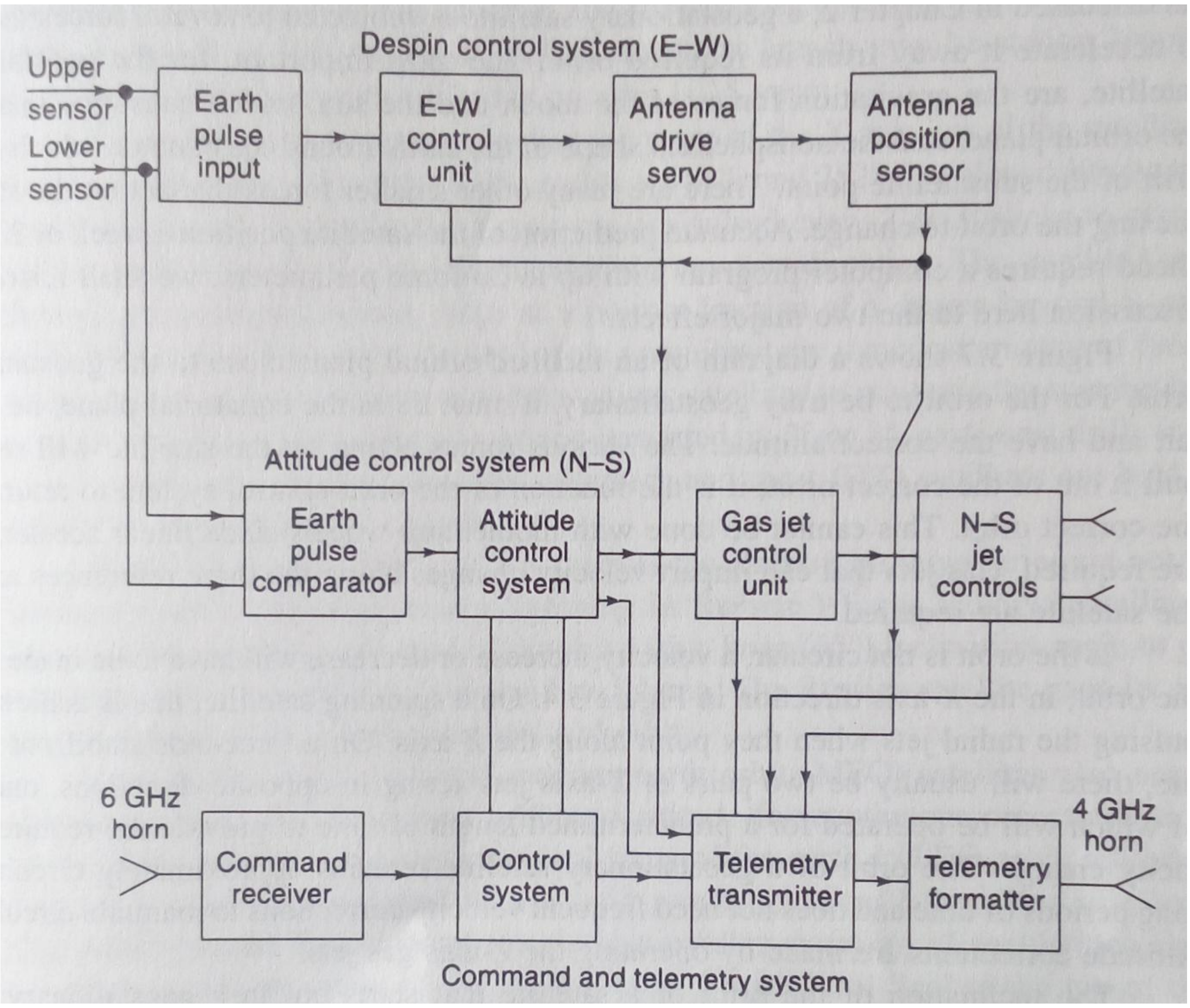

Figure: Typical Onboard control system for a spinner satellite

The other form of attitude control is *active control.* With active attitude control, there is no overall stabilizing torque present to resist the disturbance torques. Instead, corrective torques is applied as required in response to disturbance torques. Methods used to generate active control torques include momentum wheels, electromagnetic coils, and mass expulsion devices, such as gas jets and ion thrusters.

In the absence of disturbance torques, the spinning satellite would maintain its correct attitude relative to the earth. Disturbance torques is generated in a number of ways, both external and internal to the satellite.

Solar radiation, gravitational gradients, and meteorite impacts are all examples of external forces which can give rise to disturbance torques. Motor- bearing friction and the movement of satellite elements such as the antennas also can give rise to disturbance torques.

The three axes which define a satellite's attitude are its *roll, pitch,* and *yaw* (RPY) axes. These are shown relative to the earth in Fig. 2.1. All three axes pass through the center of gravity of the satellite. For an equatorial orbit, movement of the satellite about the roll axis moves the antenna footprint north and south; movement about the pitch axis moves the footprint east and west; and movement about the yaw axis rotates the antenna footprint.

Spinning satellite stabilization:

Spin stabilization may be achieved with cylindrical satellites. The satellite is constructed so that it is mechanically balanced about one particular axis and is then set spinning around this axis. For geostationary satellites, the spin axis is adjusted to be parallel to the N-S axis of the earth, as illustrated in Fig. 2.2. Spin rate is typically in the range of 50 to 100 rev/min. Spin is initiated during the launch phase, by means of small gas jets or electrical motor.

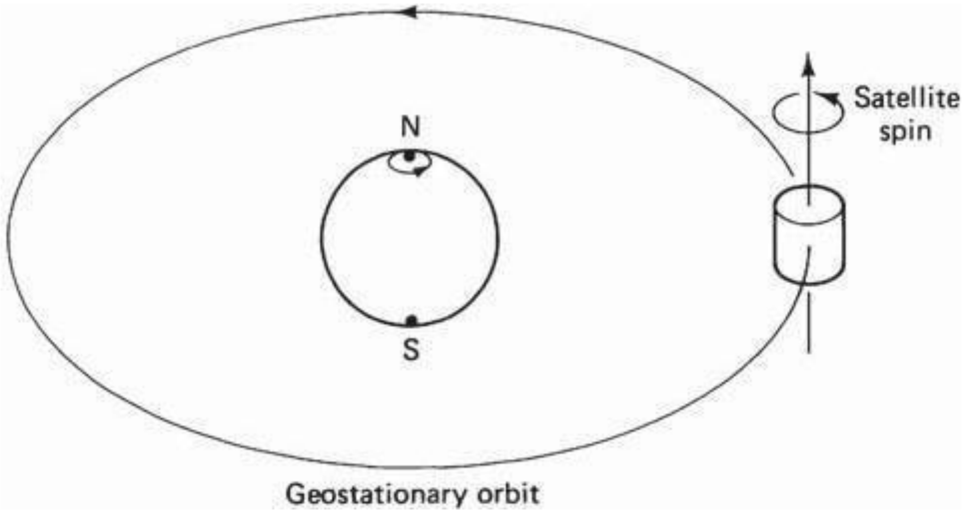

Figure 2.2: Spin stabilization in the geostationary orbit. The spin axis lies along the pitch axis, parallel to the earth’s N-S axis.

overall effect is that the spin rate will decrease, and the direction of the angular spin axis will change. Impulse-type thrusters, or jets, can be used to increase the spin rate again and to shift the axis back to its correct N-S orientation.

Nutation, which is a form of wobbling, can occur as a result of the disturbance torques and/or from misalignment or unbalance of the control jets. This nutation must be damped out by means of energy absorbers known as *nutation dampers*.

The antenna feeds can therefore be connected directly to the transponders without the need for radio frequency (RF) rotary joints, while the complete platform is de-spun. Of course, control signals and power must be transferred to the de-spun section, and a mechanical bearing must be provided.

The complete assembly for this is known as the *bearing and power transfer assembly* (BAPTA). Certain dual-spin spacecraft obtain spin stabilization from a spinning fly- wheel rather than by spinning the satellite itself. These flywheels are termed *momentum wheels,* and their average momentum is referred to as *momentum bias.*

Sub-systems of a satellite

The bus or payload platform consists of the subsystems that support the payload. These subsystems typically include:

Structures subsystem**:** the physical structure of the spacecraft, to which all electronics boxes, thrusters, sensors, propellant tanks, and other components are mounted;

Electric power/distribution subsystem (EPS or EPDS): the hard- and software used to generate and distribute electrical power to the spacecraft, including solar arrays, batteries, solar-array controllers, power converters, electrical harnesses, battery-charge-control electronics, and other components;

Telemetry, tracking, and command subsystem (TT&C): The electronics used to track, monitor, and communicate with the spacecraft from the ground. TT&C equipment generally includes receivers, transmitters, antennas, tape recorders, and state-of-health sensors for parameters such as temperature, electrical current, voltage, propellant tank pressure, enable/disable status for various components, etc.;

Propulsion subsystem: Liquid and solid rockets or compressed-gas jets and associated hardware used for changing satellite attitude, velocity, or spin rate. Solid rockets are usually used for placing a satellite in its final orbit after separation from the launch vehicle. The liquid engines (along with associated plumbing lines, valves, and tanks) may be used for attitude control and orbit adjustments as well as final orbit insertion after launch;

Power supply: The primary electrical power for operating electronic equipment is obtained from solar cells. Individual cells can generate small amounts of power, and therefore array of cells in series-parallel connection are required. Cylindrical solar arrays are used with spinning satellites, thus the array are only partially in sunshine at any given time. Another type of solar panel is the rectangular array or solar sail. solar sail must be folded during the launch phase and extended when in geo-stationary orbit. Since the full component of solar cells are exposed to sun light ,and since the Sail rotate to track, the sun , they capable of greater power output than cylindrical arrays having a comparable number of cells. To maintain service during an eclipse, storage batteries must be provided.

Attitude control: The attitude of a satellite refers to its Orientation in space. Much of equipment carried abroad a satellite is there for the purpose of controlling its attitude. Attitude control is necessary, for example, to ensure that directional antennas point in the proper directions. In the case of earth environmental satellites the earth-sensing instrument must cover the required regions of the earth, which also requires attitude control. A number of forces, referred to as disturbance forces can alter attitude, some examples being the gravitational forces of earth and moon, solar radiation, and meteorite impacts.

Station keeping: A satellite that is normally in geo-stationary will also drift in latitude, the main perturbing forces being the gravitational pull of the sun and the moon. The force causes the inclination to change at the rate of about 0.85 deg/year. If left uncorrected, the drift would result in a cycle change in the inclination going 0 to 14.67deg in 26.6 years and back to zero, when the cycle is repeated. To prevent the shift in inclination from exceeding specified limits, jets may be pulled at the appropriate time to return the inclination to zero. Counteracting jets must be pulsed when the inclination is at zero to halt that change in inclination.

The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.
To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks.
These manoeuvres are termed *east-west station-keeping manoeuvres*.
Satellites in the 6/4-GHz band must be kept within 0.1° of the designated longitude, and in the 14/12-GHz band, within 0.05°.

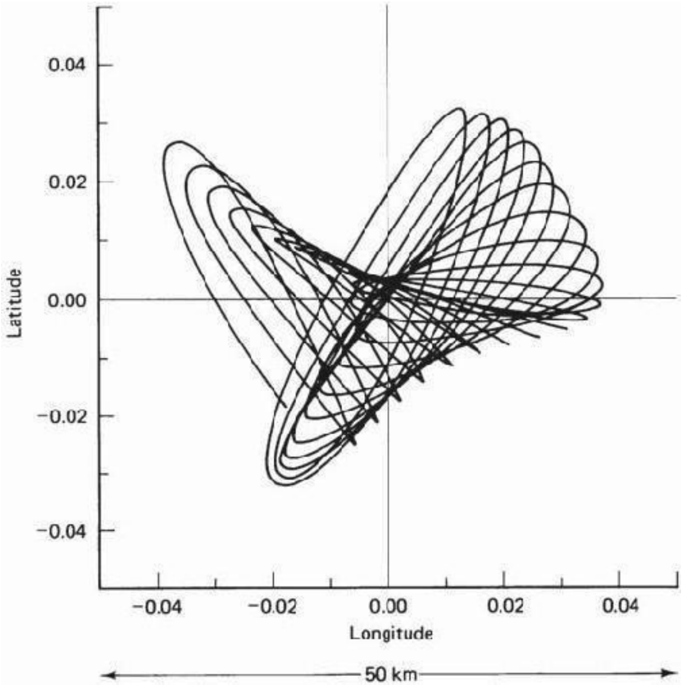

Figure 2.3: Typical satellite motion.(*Courtesy of Telesat,Canada,1983.*)

Thermal control: Satellites are subject to large thermal gradients, receiving the sun radiation on one side while the other side faces into space. In addition, thermal radiation from the earth, and the earth's abedo, which is the fraction on the radiation falling on the earth which is reflected can be sight for low altitude, earth-orbiting satellites, although it is negligible for geo-stationary satellites. Equipment in the satellite also generates heat which has to be removed. The most important consideration is that the satellite's equipment should operate as near as possible in a stable temperature environment. Various steps are taken to achieve this. Thermal blankets and shields may be used to provide insulation. Radiation mirrors are often used to remove heat from communication payload. These mirrored drums surrounded the communication equipment shelves in each case and provide good radiation paths for the generated heat to escape in to surround space. To maintain constant-temperature conditions, heaters may be switched on to make up for the hearts may be switched on to make reduction that occurs when transponders are switched off.

Telemetric Tracking And Command Subsystem The main functions of TT&C are:

1) Monitor the performance of all the satellite sub-systems and transmit the monitored data to the satellite control center.
2) Support the determination of orbital parameters.
3) Provide a source earth station for tracking.
4) Receive commands from the control center for performing various functions of the satellite.

Telemetry system

The telemetry, tracking, and command (TT&C) subsystem performs several routine functions abroad a spacecraft. The telemetry or "tele-metering" function could be interpreted as "measurement at a distance". Specifically, it refers to the overall operation of generating an electrical signal proportional to the quantity being measured, and encoding and transmitting this to a distant station, which for satellite is one of the earth stations, which for the satellite is one of the earth stations.

Data that are transmitted as telemetry signals include attribute information such as obtained from sun earth sensors; environmental information such as magnetic field intensity and direction; the frequency of meteorite impact and so on ;and spacecraft information such as temperatures and power supply voltages, and stored fuel pressure.

Summary of the parameters monitored by the Telemetry system are:

1) Voltage, current and temperature of all major sub-systems.
2) Switch status of communication transponders.
3) Pressure of the propulsion tanks
4) Outputs from altitude sensors.
5) Reaction wheel speed

Command systems

Command system receives instructions from ground system of satellite and decodes the instruction and sends commends to other systems as per the instruction.

Example of commands are:

1) Transponder switching
2) Switch matrix configuration
3) Antenna pointing control
4) Controlling direction and speed of solar array drive
5) Battery reconditioning
6) Beacon switching
7) Thruster firing
8) Switching heaters of the various sub-systems

Tracking

Tracking of the satellite is accomplished by having the satellite is accomplished by having the satellite transmit beacon signals which are received at the TT&C earth stations. Tracking is obviously important during the transmitter and drift orbital phases of the satellite launch.

When on-station, a geo-stationary satellite will tend to shifted as a result of the various distributing forces, as described previously. Therefore it is necessary to be able to track the satellites movements and send correction signals as required. Satellite range is also required for time to time. This can be determined by measurement of propagation delay of signals specially transmitted for ranging purposes.

Communication Sub-Systems

The major module of the communication system made up of transponders. A transponder is capable of:

- Receiving uplinked radio signals from earth satellite transmission stations (antennas).□ □
- Amplifying received radio signals□ □
- Sorting the input signals and directing the output signals through input/output signal multiplexers to the proper downlink antennas for retransmission to earth satellite receiving stations (antennas).

Transponders:

A transponder is the series of interconnected units which forms a single communications channel between the receiver and transmit antennas in a communications satellite.

Some of the units utilized by a transponder in a given channel may be common to a number of transponders. Thus, although reference may be made to a specific transponder, this must be thought of as an equipment *channel* rather than a single item of equipment.

Before describing in detail the various units of a transponder, the overall frequency arrangement of a typical C-band communications satellite will be examined briefly. The bandwidth allocated for C-band service is 500 MHz, and this is divided into sub bands, one transponder.

A typical transponder bandwidth is 36 MHz, and allowing for a 4-MHz guard band between transponders, 12 such transponders can be accommodated in the 500-MHz bandwidth.

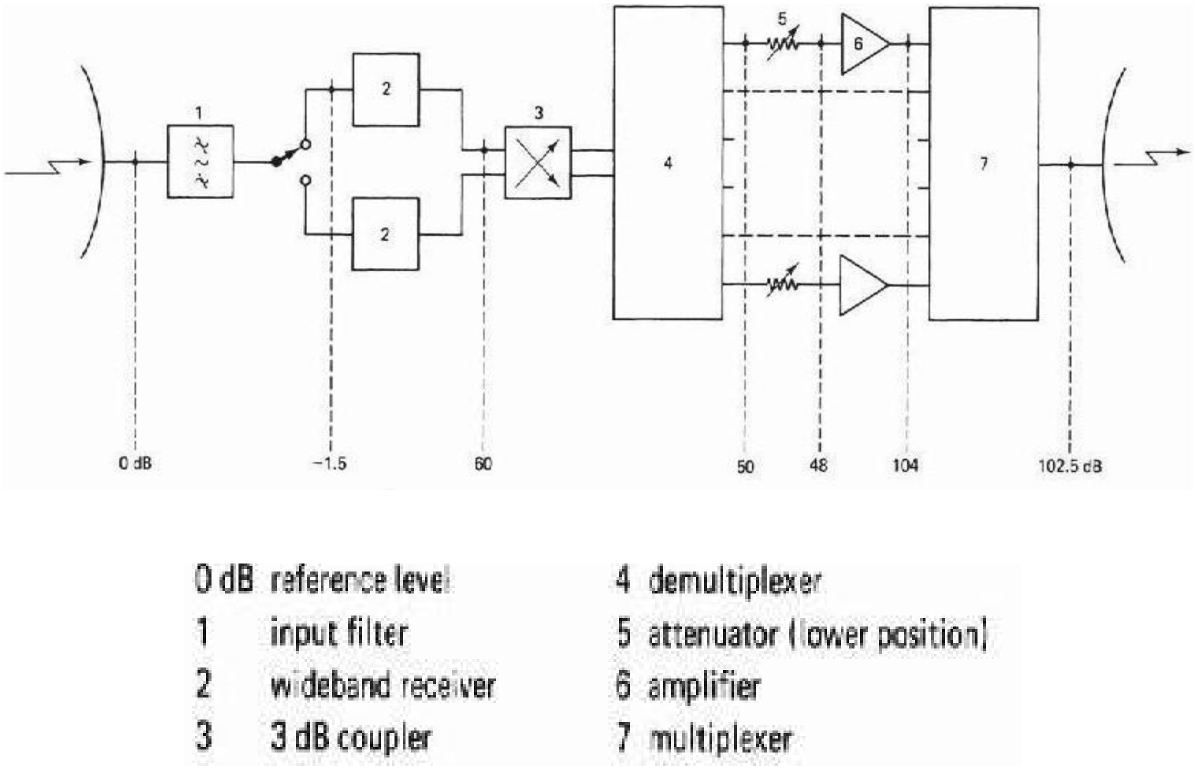

Fig 2.4: Communication Sub System

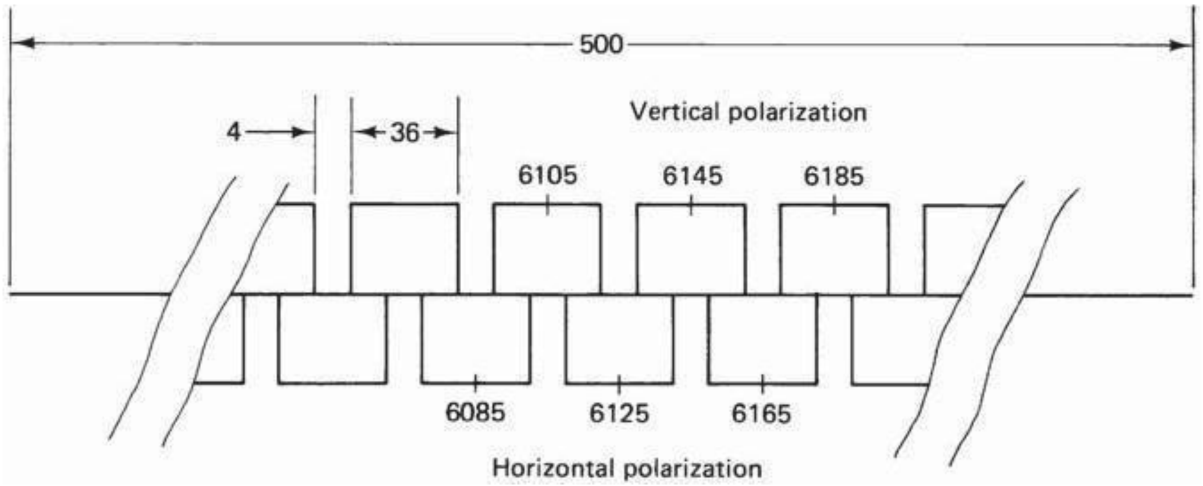

Fig 2.5: Polarisation Plan for a C-band Satellite

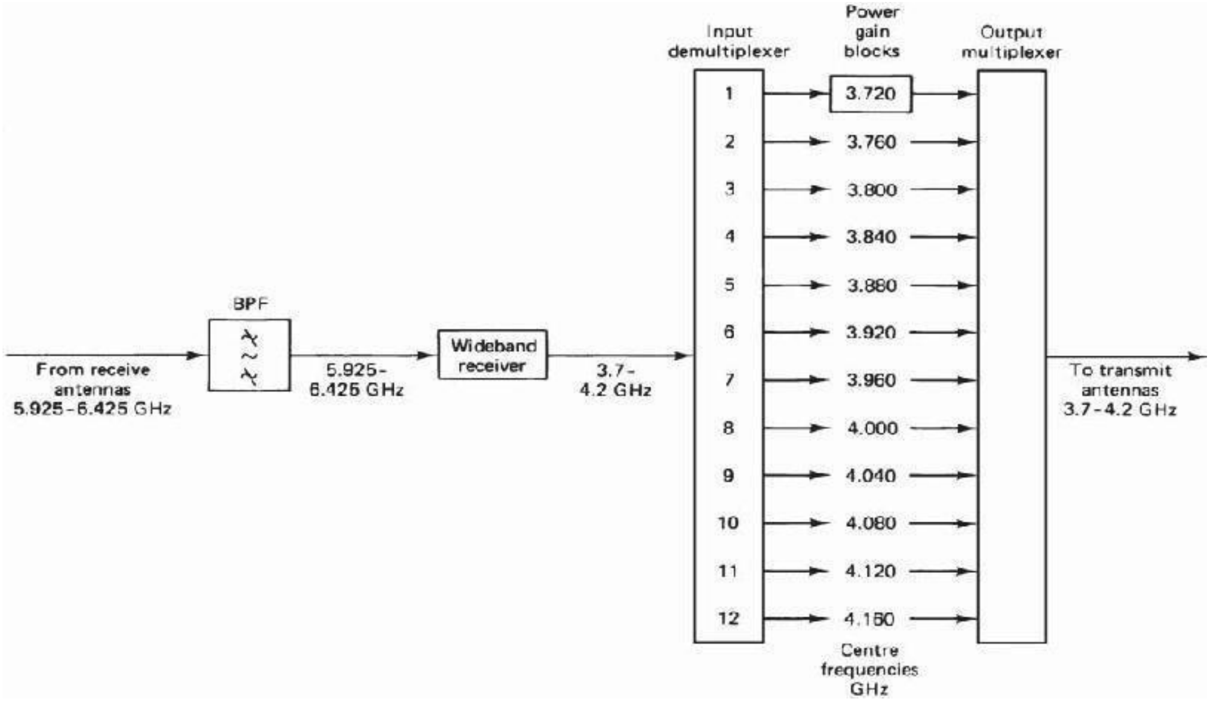

Figure 2.6: Satellite transponder channels

The wideband receiver

The wideband receiver is shown in more detail in Fig. 2.7. A duplicate receiver is provided so that if one fails, the other is automatically switched in. The combination is referred to as a *redundant receiver*, meaning that although two are provided, only one is in use at a given time.

The first stage in the receiver is a *low-noise amplifier* (LNA). This amplifier adds little noise to the carrier being amplified, and at the same time it provides sufficient amplification for the carrier to override the higher noise level present in the following mixer stage.

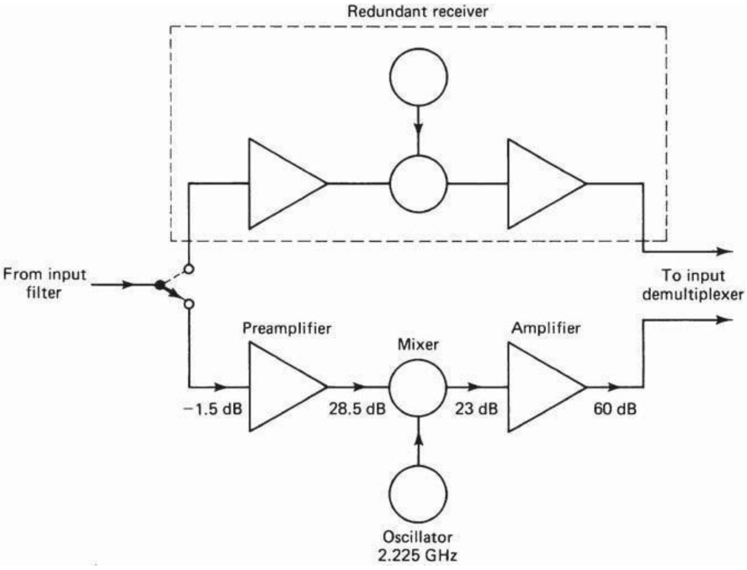

Figure 2.7 Satellite Wideband Receiver.

In a well-designed receiver, the equivalent noise temperature referred to the LNA input is basically that of the LNA alone. The overall noise temperature must take into account the noise added from the antenna. The equivalent noise temperature of a satellite receiver may be on the order of a few hundred kelvins.

The LNA feeds into a mixer stage, which also requires a *local oscillator* (LO) signal for the frequency-conversion process.

With advances in *field-effect transistor* (FET) technology, FET amplifiers, which offer equal or better performance, are now available for both bands. Diode mixer stages are used.
The amplifier following the mixer may utilize *bipolar junction transistors* (BJTs) at 4 GHz and FETs at 12 GHz, or FETs may in fact be used in both bands.

The input demultiplexer

The input demultiplexer separates the broadband input, covering the frequency range 3.7 to 4.2 GHz, into the transponder frequency channels. This provides greater frequency separation between adjacent channels in a group, which reduces adjacent channel interference. The output from the receiver is fed to a power splitter, which in turn feeds the two separate chains of circulators.

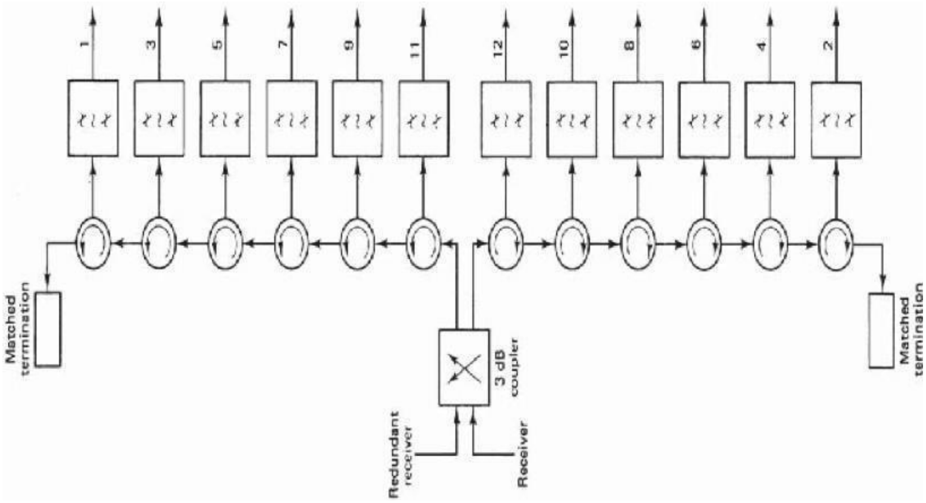

Figure 2.8: Satellite input multiplexer

The full broadband signal is transmitted along each chain, and the channelizing is achieved by means of channel filters connected to each circulator,

Each filter has a bandwidth of 36 MHz and is tuned to the appropriate center frequency, as shown in Fig. 2.5.

Although there are considerable losses in the demultiplexer, these are easily made up in the overall gain for the transponder channels.

The power amplifier

The fixed attenuation is needed to balance out variations in the input attenuation so that each transponder channel has the same nominal attenuation, the necessary adjustments being made during assembly.

The variable attenuation is needed to set the level as required for different types of service (an example being the requirement for input power back-off discussed later). Because this variable attenuator adjustment is an operational requirement, it must be under the control of the ground TT&C station.

Traveling-wave tube amplifiers (TWTAs) are widely used in transponders to provide the final output power required to the transmit antenna.

Nonlinear Characteristics of TWT Amplifier

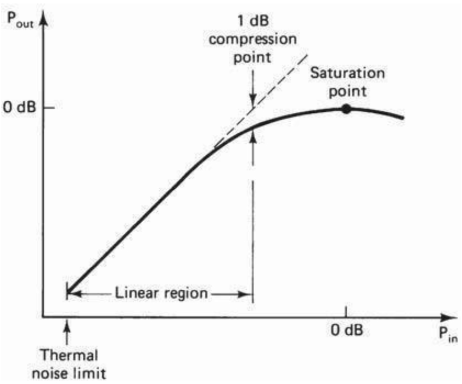

Figure 2.9: Power transfer characteristics of a TWT. The saturation point is used as 0-dB reference for both input and output.

At low-input powers, the output-input power relationship is linear; that is, a given decibel change in input power will produce the same decibel change in output power. At higher power inputs, the output power saturates, the point of maximum power output being known as the *saturation point*.

The saturation point is a very convenient reference point, and input and output quantities are usually referred to it. The linear region of the TWT is defined as the region bound by the thermal noise limit at the low end and by what is termed the *1-dB compression point* at the upper end. This is the point where the actual transfer curve drops

Satellite Antenna Equipment

The basic structure of a parabolic reflector antenna is as shown in Fig 2.10 below. It consists of a feed antenna poited towards a parabolic reflector and is located at its focal point. The feed antenna is often a horn antenna with a circular aperture.

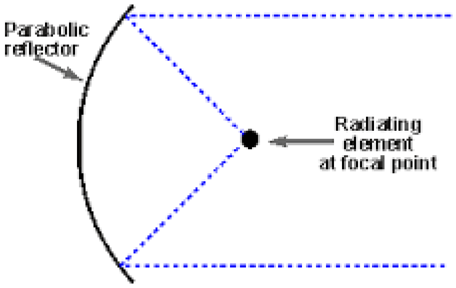

Fig 2.10: Parabolic reflector antenna

Advantages

The following are the advantages of Parabolic reflector antenna −

- Reduction of minor lobes
- Wastage of power is reduced
- Equivalent focal length is achieved
- Feed can be placed in any location, according to our convenience
- Adjustment of beam (narrowing or widening) is done by adjusting the reflecting surfaces

Disadvantage

The following is the disadvantage of a Parabolic reflector antenna −

- Some of the power that gets reflected from the parabolic reflector is obstructed. This becomes a problem with small dimension paraboloid.

Applications

The following are the applications of Parabolic reflector antenna −

- The cassegrain feed parabolic reflector is mainly used in satellite communications.
- Also used in wireless telecommunication systems.

Parabolic Reflector Antennae are used for satellites for communication.

The antenna system consist of

- Feed System
- Antenna Reflector

- Mount
- Antenna tracking System

Feed System

The feed along with the reflector is the radiating/receiving element of electromagnetic waves. The reciprocity property of the feed element makes the earth station antenna system suitable for transmission and reception of electromagnetic waves.

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

i) Axi-Symmetric Configuration
ii) Asymmetric Configuration

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

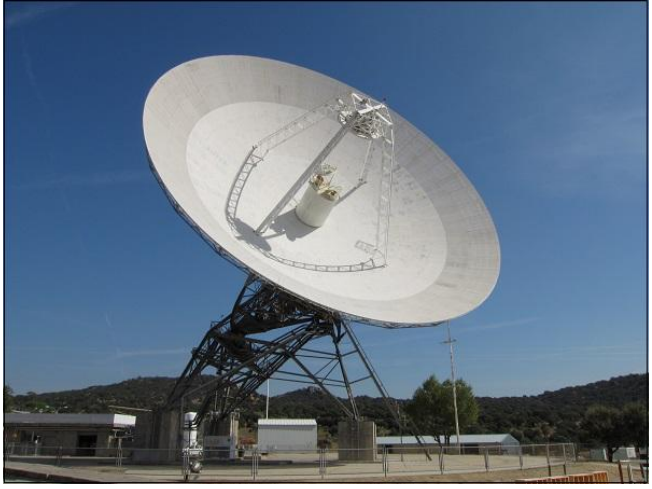

Fig 2.10: Earth Station Antenna

$$G = \frac{4\pi A_e}{\lambda^2}$$

Where G is the Gain of the antenna, A_e is the Effective Aperture, λ is the wavelength, D is the diameter of reflector.

Useful approximate formula for the Half Power Beam Width (HPBW) and the beam Width between the first nulls (BWFN) are

$$\text{HPBW} = 70\,\frac{\lambda}{D}$$

$$\text{BWFN} = 2\ \text{HPBW}$$

Primary Feed

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

Cassegrain

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

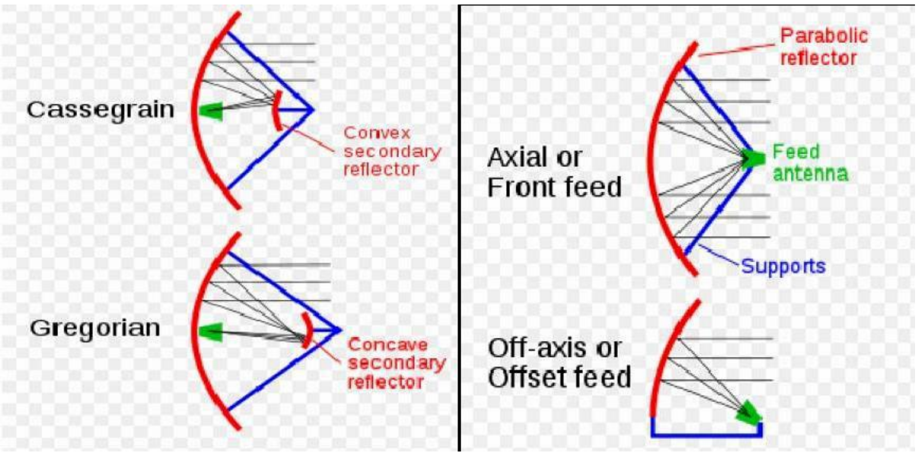

Fig 2.11: Feed Systems

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

Gregorian Antenna

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

ii) Asymmetric Configuration

Offset or Off-axis feed

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

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

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

Basic Transmission Theory

The calculation of power received by an earth station from a satellite transmitter is fundamental to the understanding of satellite communications. In this section we shall discuss two approaches to this calculation: the use of flux density and the link equation.

Consider a transmitting source, in free space, radiating a total power of P_t watts uniformly in all directions. Such a source is called isotropic: it is an idealization that cannot be realized physically. At a distance of R meters from the hypothetical isotropic source transmitting RF power P_t watts, the flux density 'F' crossing the surface of a sphere with radius R is given by

$$F = \frac{\boldsymbol{P_t}}{\boldsymbol{4\pi}R^2} \quad W/m^2$$

All real antennas are directional and radiate more power in some directions than in others. Any real antenna has a gain G(θ), defined as the ration of power per unit solid angle radiated in a direction θ to the average power radiated per unit solid angle.

$$G(\theta) = \frac{P(\theta)}{Po\,/4\boldsymbol{\pi}}$$

Where P(θ) is the power radiated per unit solid angle by the antenna
Po is the total power radiated by the antenna
G(θ) is the gain of the antenna at an angle θ

The reference for the angle θ is usually taken to be the direction in which maximum power is radiated, often called the bore sight direction of the antenna. The again of the antenna is then the value of G(θ) at angle $\theta = 0^o$, and is a measure of the increase in flux density radiated by the antenna over that from an ideal isotropic antenna radiating the same total power. For a transmitter with output P_t watts driving a lossless antenna with gain G_t, the flux density in the direction of the antenna bore sight at a distance R meters is

$$F = \frac{\boldsymbol{P_t\,G_t}}{\boldsymbol{4\pi}R^2} \quad W/m^2$$

The Product P_tG_t is often called the Effective Isotropically Radiated Power or EIRP, and it describes the combination of transmitter power and antenna gain in terms of an equivalent isotropic source with power P_tG_t watts, radiating uniformly in all directions.

If we has an ideal receiving antenna with an effective aperture area of A_e m^2, the power collected by the antenna is

$$P_r = F \text{ x } A_e \text{ watts} = \frac{\boldsymbol{P_t\,G_t\,A_e}}{\boldsymbol{4\pi}R^2} \quad \text{watts}$$

The fundamental relationship in antenna theory is that the gain and area of an antenna are related by

$$G = \frac{4\pi A_e}{\lambda^2}$$

Where λ is the wavelength of the signal,

$$P_r = \frac{P_t\, G_t\, \lambda^2\, G_r}{4\pi R^2} \text{ watts}$$

The above expression is known as the link equation, and it is essential in the calculation of power received any radio link. The above equation can be written as

$$\text{Power Received} = \frac{\text{EIRP X Receiving Antenna Gain}}{\text{Path Loss}} \text{ watts}$$

In communication systems decibel quantities are commonly used to simplify equations, the above equation in dB Watts can be written as

$P_r = EIRP + G_r - L_p$ dBW
Where $EIRP = 10 \log_{10}(P_t G_t)$ dBW
$G_r = 10 \log_{10} \{\frac{4\pi Ae}{\lambda^2}\}$ dBW
$Lp = 20 \log_{10} \{\frac{4\pi R}{\lambda}\}$ dBW

The above equation represents an idealized case, in which there are no additional losses in the link. It describes transmission between two ideal antennas in otherwise empty space. In practice, we will need to take into account of other losses such as attenuation due to rain, water vapour, Losses in the antennas at each end of the link, and possible reduction in antenna gain due to mis pointing. In such case received power can be expressed as

$$P_r = EIRP + G_r - L_p - L_s - L_{ta} - L_{ra} \quad \text{dBW}$$

Where
L_s = Attenuation in atmosphere
L_{ta} = Losses associated with transmitting antenna
L_{ra} = Losses associated with receiving antenna

Noise temperature

Noise temperature is a useful concept in communications recivers, since it provides way of determining how much thermal noise is generated by active and passive devices in the reciving system. At microwave frequencies, a black body with a physical temperature, T_p degrees Kelvin, generates electrical noise over a wide bandwidth. The noise power is given by

Therefore $P_n = k\, T_p\, B_n$

Where

k = Boltzmann's constant = $1.39 \text{ X } 10^{-23}$ J/K = -228.6 dBW/K/Hz
T_p = Physical temperature of source in Kelvin degrees
B_n = Noise Bandwidth in which the noise power is measured, in Hz

P_n is the available noise power and will be delivered only to a load that is impedance matched to the noise source. The term kT_p is a noise power spectral density, in watts per hertz. The density is constant for all radio frequencies upto 300 G Hz.

In satellite communications systems we are always working with weak signals and must make the noise level as low as possible to meet C/N (Carrier to Noise Ratio) requirements. This is done by making the bandwidth in the receiver usually set by IF amplifier stages, to be just large enough to allow the signal to pass unrestricted, while keeping the noise power to the lowest value possible.

To determine performance of receiving system we need to able to find the total thermal noise power against which the signal must be demodulated. We do this by determining the system noise temperature, Ts. Ts is the noise temperature of a noise source, located at the input of a noiseless receiver, which gives the same noise power as the original receiver, measured at the output of the receiver and usually includes noise from the antenna.

If the overall end-to-end gain of the receiver is G_{rx} (G_{rx} is the ratio, not in decibels and its narrowest bandwidth is B_n Hz, the noise power at the demodulator input is

$$P_{no} = k\,T_p\,B_n\,G_{rx}\ \text{Watts}$$

Where G_{rx} is the gain of the receiver, from RF input to demodulator input.

Let the antenna deliver a signal power Pr watts to the receiver RF input. The signal power at the demodulator input is P_rG_{rx} watts, representing the power contained in the carrier and sidebands after amplification and frequency conversion within the receiver. Hence, the Carrier-to-Noise ratio at the demodulator is given by

$$\frac{C}{N} = \frac{PrGrx}{k\ Tp\ Bn\ Grx} = \frac{Pr}{k\ Tp\ Bn}$$

The S***ystem noise temperature*** T_s, is defined as the effective noise temperature of the receiver system including the effects of antenna temperature $\boldsymbol{T_a}$ (It is also sometimes called the system operating noise temperature) if the receiver effective noise temperature is $\boldsymbol{T_e}$, then

$$T_s = T_a + T_e = T_o\,F_s$$

where $\mathbf{F_s}$ is the system noise-figure including the effect of antenna temperature.

$$F_n = 1 + T_e/T_o$$
$$T_e = (F_n - 1)/T_o$$

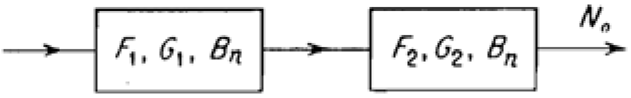

Fig 2.12: Two Networks in cascade

The effective noise temperature of a receiver consisting of a number of networks in cascade is

$$T_e = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \cdots$$

Where **T_i** and G_i are the effective noise temperature and gain of the ith network. The effective noise temperature and the noise figure both describe the same characteristic of a network. In general, the effective noise temperature has been preferred for describing low-noise devices, and the noise figure is preferred for conventional receivers. For radar receivers the noise figure is the more widely used term, and is what is used in this text.

G/T Ratio for Earth Stations

The link equation can be rewritten in terms of C/N at the earth station, by substituting for Pr from previous equations

$$\frac{C}{N} = \;=\; \frac{P_t G_t\;G_r}{\text{k Ts Bn}}\left[\frac{\lambda}{4\pi R^2}\right]^2 = \left[\frac{P_t G_t}{\text{k Ts Bn}}\right]\left[\frac{\lambda}{4\pi R^2}\right]^2\left[\frac{G_r}{\text{Ts}}\right]$$

$$=$$

Thus it can be seen from the above equation that C/N is proportional to G_r/T_s and the terms in the square brackets are all constants for a given satellite system. The ratio G_r/T_s which is usually quoted as simply G/T in decibels with units dB/K, can be used to specify the quality of a receiving earth station or a satellite receiving system, since increasing G/T increases C/N ratio.

Example 1: *An earth station antenna has a diameter of 30 m, has an overall efficiency of 68%, and is used to receive a signal at 4.15 GHz. At this frequency, the system noise temperature is 79 K when the antenna points at the satellite at an elevation angle of 28°. What is the earth station G/T ratio under those conditions? If heavy rain causes the sky temperature to increase so that the system noise temperature rises to 88° K. What is the new G/T value?*

Solution

Antenna efficiency $\eta = 0.68$

Signal Wavelength $\lambda = c/f = 0.0723$ m

Antenna Gain $G = \frac{\eta\, 4\pi A_e}{\lambda^2} = \eta\left[\frac{\pi D}{\lambda}\right]^2 = [0.68 \times \pi \times 30 / 0.0723]^2 = 1.16 \times 10^6 = 60.6$ dB

Noise Temperature in dB = 10 log 79 = 19.0 dBK

G/T = 60.6 – 19.0 = 41.6 dB/K

During heavy rain Ts = 88 K = 10 log 88 dBK = 19.4 dBK

G/T = 60.6 – 19.4 = 41.2 dB/K

Example 2: *A satellite downlink at 12 GHz operates with a transmit power of 6 W and an antenna gain of 48.2 dB. Calculate the EIRP in dBW.*

Solution

EIRP = 10 log 6 + 48.2 = 56 dBW

Example 3: *The range between a ground station and a satellite is 42000 km. Calculate the free space loss a frequency of 6 GHz.*

Solution

Lp = Free space loss = 32.4 + 20 log 42000 + 20 log 6000 = 200.4 dB

Example 4: *An antenna has a noise temperature of 35 K and it is matched into a receiver which has a noise temperature of 100 K. Calculate the noise power density and the noise power for a BW of 36 MHz.*

Solution

N_0(Noise Power Density) = (35 + 100) x 1.38 x 10^{-23} = 1.86 * 10^{-21}J

P N (Noise Power) = 1.86 x 10^{-21}x 36 x 10^6 = 0.067 pW

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Design of Downlinks

The design of any satellite communication is based on two objectives: meeting a minimum C/N ratio for a specified percentage of time, and carrying the maximum revenue earning traffic at minimum cost. There is an old saying “an engineer is a person who can do for a dollar shat any fool can do for one hundred dollars”. This applies to satellite communications too. Any satellite link can be designed with very large antennas to achieve high C/N ratios under all conditions, but the cost will be high. The art of good system design is to reach the best compromise of system parameters that meets the specification at the lowest cost. For example, if satellite link is designed with sufficient margin to overcome a 20-dB rain fade rather than a 3-dB fade, earth station antennas with seven times the diameter are required.

All satellite communications links are affected by rain attenuation. In the 6/4 GHz band the effect of rain on the links is small. In the 14/11 GHz (Ku) band, and even more so in the 30/20 GHz (Ka) band. Rain attenuation becomes all important. Satellite links are designed to achieve reliabilities of 99.5to99.99%, averaged over a long period of time. Typically a year .that means the C/N ration in the receiver will fall below the minimum permissible value for proper operation of the link for between 0.5and0.01%of the specified time: the link is then said suffer an outage. The time period over which the percentage of time is measured can be a month, sometimes the “worst month “in attenuation terms, or a year. Rain attenuation is very variable phenomenon, both with time and place.Chapter8discusses the prediction of path attenuation and provides ways to estimate the likely occurrence of outages on a given link. In this chapter we will simply assume certain rain attenuation statistics to use in examples of link design.

C-band links can be design to achieve 99.99% reliability because the rain attenuation rarely exceeds 1 or 2 dB. the time corresponding to 0.01% of a year is 52 min: at this level of probability the rain attenuation statistics are usually not stable and wide fluctuations occur from year to year. Outages occur in heavy rain. Usually in thunderstorms, and thunderstorm occurrence varies widely. link designed to have outages totalling 52min each year may well have outages of several hours one year and none the next. Most Ka band links cannot be designed to achieve 99.99% reliability because rain attenuation generally exceeds 10 dB, and often 20 dB, for 0.01% of the time. Outage times of 0.1 to 0.5% of a year (8t o 40h) are usually tolerated in Ka band links. The allowable outage time for a ink depends in part on the traffic carried. Telephone traffic needs real-time channels that are maintained for the duration of a call, so C band or Ku band is used for voice channels with sufficient link margin that outage times are small. Internet transmissions are less affected by short outages and generally do not require a real-time channel, making Ka band better suited for Internet access.

Link Budgets

C/N ratio calculation is simplified by the use of link budget is a tabular method for evaluating the received power and noise power in ratio link. Link budgets invariably use decibel units for all quantities so that signal and noise powers can be calculated by addition and subtraction. Since it is usually impossible to design a satellite link at the first attempt, link budgets make the task much easier because, once a link budgets has been established, it is easy to change any of the parameters and recalculate that result. Tables 2.1 and 2.2 show a typical budget for a C-band downlink using a global beam on a GEO satellite and a 9 m earth station antenna.

The link budget must be calculate for an individual transponder, and must be repeated for each of the links. In a two –way satellite communication link there will be four separate links, each requiring a calculation of C/N ratio. When a bent pipe transponder is used the uplink and downlink C/N ratio must be combined to give an overall C/N In this section we will calculate the C/N ratio for a single link. Later examples in this chapter demonstrate the evaluation of a complete satellite communication system.

TABLE 2.1 C-Band GEO Satellite Down Link Budget in Clear Air

C –band satellite parameters		
	Transponder saturated output power	20 W
	Satellite Tx Antenna gain, on axis	20 dB
	Transponder bandwidth	36 MHz
	Downlink frequency band	3.7 - 4.2 GHz
Signal	FM-TV analog signal	
	FM-TV signal bandwidth	30MHz
	Minimum permitted overall C/N in receiver	9.5dB
Receiving C-band earth station		
	Downlink frequency	4.00 GHz
	Antenna gain, on axis, 4 GHz	49.7dB
	Receiver IF bandwidth	27 MHz
	Receiving system noise temperature	75 K
Downlink power budget		
	P_t =Satellite transponder output power, 20 W	13.0 dBW
	B_o =Transponder output back off	-2.0dB
	G_t =Satellite antenna gain, on axis	20.0 dB
	G_r = Earth station Rx antenna gain	49.7 dB
	L_p = Free space part loss at 4 GHz	-196.5 dB
	L_{ant} =Edge of beam loss for satellite antenna	-3.0 dB
	L_a =Clear air atmospheric loss	-0.2 dB
	L_m =Other losses	-0.5 dB
	Pr =Received noise power at earth station	**-119.5 dBW**
Downlink noise power budget in clear air		
	k = Boltzmann’s constant	- 228 .6 dBW/K/Hz
	T^s =System noise temperature,75 k	18.8 dBK
	B_n =Noise bandwidth, 27 MHz	74.3 dBHz
	N =Receiver noise power = k T_s B_n	**- 135.5dBW**
C/N ratio in receiver in clear air		
C/N = P_r - N = -119.5 dBW - (-135.5 dBW) = 16.0 dB		

Link budgets are usually calculated for a worst case, the one in which the link will have the lowest C/N ratio. Factors which contribute to a worst case scenario include: an earth station located at the edge of the satellite coverage zone where the received signal is typically 3dB lower than in the center of the zone because of the satellite antenna pattern, maximum path length from the satellite to the earth, a low elevation angle at the earth station giving the highest atmospheric path attenuation in clear air, and maximum rain attenuation on the link causing loss of received signal power and an increase in receiving system noise temperature. The edge of the coverage pattern of the satellite antenna and the longest path usually go together. However, when a satellite has a multiple beam antenna, this may not always be the case. Earth station antennas are assumed to be pointed directly at the satellite, and therefore operate at their on-axis gain. If the antenna is mispointed, a loss factor is included in the link budget to account for the reduction in antenna gain.

TABLE 2.2 C-Band Downlink Budget in rain

	P_{rca} = Received power at earth station in clear air	-119.5 dBW
	A = Rain attenuation	-1.0 dB
	P_{rain} =Received power at earth station in rain	-120.5 dBW
	N_{ca} =Receiver noise power in clear air	-135.5 dBW
	N_{rain} =Increase in noise temperature due to rain	2.3dB
	N rain =Receiver noise power in rain	-133.2 dBW
C/N ratio in receiver in rain		
C/N = P_{rain} –N_{rain} = - 120.5 dBW - (-133.2 dBW) =12.7dB		

TABLE 2.3 Ku-Band Downlink Budget for DTH

DTH TV Terminal received signal power		
	Transponder output power, 160 W	22.0 dBW
	Antenna beam on-axis gain	34.3 dB
	Path Loss at 12.2 GHz, 38,000m path	-205.7 dB
	Receiving antenna gain, on axis	33.5 dB
	Edge of beam loss (If the location is on periphery of contour)	-3.0 dB
	Clear sky atmospheric loss	-0.4 dB
	Miscellaneous losses	-0.4 dB
	Received Power	**-119.7 dBW**
DTH TV terminal receiver noise power		
	Boltzmann's constant k	-228.6 dBW/K/Hz
	System Noise Temperature, Clear Sky, 145 K	21.6 dBK
	Receiver noise bandwidth, 20 MHz	73.0 dBHz
	Noise Power, N	-134.0 dBW
DTH-TV terminal C/N in clear sky		
	Clear sky overall C/N	**14.3 dB**
	Minimum required C/N	8.6 dB
	Link margin over 8.6 dB threshold	5.7 dB
C/N ratio in receiver in rain		
Rain Attenuation 3 dB for 0.2% (15h) Rain Attenuation 6 dB for 0.01% (52min) average over the year in a given location		

Satellite Communication Link Design Procedure

The design procedure for a one-way satellite communication link can be summarized by the following 10 steps. The return link design follows the same procedure.

1. Determine the frequency band in which the system must operate. Comparative designs may be required to help make the selection.
2. Determine the communications parameters of the satellite. Estimate any values that are not known.
3. Determine the parameters of the transmitting and receiving earth stations.
4. Start at the transmitting earth station. Establish an uplink budget and a transponder noise power budget to find $(C/N)_{up}$ in the transponder.

5. Find the output power of the transponder based on transponder gain or output back-off.
6. Establish a downlink power and noise budget for the receiving earth station. Calculate $(C/N)_{dn}$ and $(C/N)_o$ for a station at the edge of the coverage zone (worst case).
7. Calculate S/N or BER in the baseband channel. Find the link margins.
8. Evaluate the result and compare with the specification requirements Change parameters of the system as required to obtain acceptable $(C/N)_o$ or S/N or BER values. This may require several trial designs.
9. Determine the propagation conditions under which the link must operate. Calculate outage times for the uplinks and downlinks.
10. Redesign the system by changing some parameters if the link margins are inadequate. Check that all parameters are reasonable, and that the design can be implemented within the expected budget

System Design Examples

The following samples system designs demonstrate how the ideas developed in this chapter can be applied to the design of satellite communication systems.

TABLE 2.4 System and satellite Specification

Ku- band satellite parameters

Geostationary at 73^{0}W longitude, 28 Ku-band transponder Total RF output power	2.24 kW
Antenna gain, on axis (transmit and receive)	31 dB
Receive system noise temperature	500 K
Transponder saturated output power: Ku band 80 W	19.03 dBW
Transponder bandwidth: Ku band	54 MHz
Signal compressed digital video signals with transmitted symbol rate of 43.2 Msps Minimum permitted overall$(C/N)_0$ in receiver	9.5 dB
Transmitting Ku-band earth station	
Antenna diameter	5 m
Aperture efficiency	68%
Uplink frequency	14.15 GHz
Required C/N in Ku-band transponder	30 dB
Transponder HPA output back off	1 dB
Miscellaneous uplink losses	0.3 dB
Location: - 2 dB contour of satellite receiving antenna	
Receiving Ku-band earth station	
Downlink frequency	11.45 GHz
Receiver IF noise bandwidth	43.2 MHz
Antenna noise temperature	30 K
LNA noise temperature	110 K
Required overall$(C/N)_0$ in clear air	17 dB
Miscellaneous downlink losses	0.2 dB
Location: - 3 dB contour of satellite transmitting antenna	
Rain attenuation and propagation factors Ku-band clear air attenuation	
Uplink	0.7 dB
Downlink	0.5 dB
Rain attenuation	
Uplink	6.0 dB
Downlink	5.0 dB

System Design Example 4.8.1

This example examines the design of a satellite communication link using a Ku-band geo stationary satellite with bent pipe transponders to distribute digital TV signals from an earth station to many receiving station throughout the United States. The design requires that an overall C/N ratio of 9.5dB be met in the TV receive to ensure that the video signal on the TV screen is held to an acceptable level. The uplink transmitter power and the receiving antenna gain and diameter are determined for each system. The available link margins for each of the systems are found and the performance of the systems is an analyzed when rain attenuation occurs in the satellite –earth paths. The advantages and disadvantages of implementing uplink power control are considered.

In This example, the satellite is located at 73^0 W. However, for international registration of this satellite location would be denoted as 287^0 E. The link budgets developed in the examples below use decibel notation throughout. The satellite and earth stations are specified in Table 2.4 show an illustration of the satellite television distribution system.

Ku-Band Uplink Design

We must find the uplink transmitter power required to achieve $(C/N)_{UP}$ =30dB in clear air atmospheric conditions. We will first find the noise power in the transponder for 43.2MHz bandwidth and then add 30dB to find the transponder input power level.

Uplink Noise Power Budget

K = Boltzmann’s constant	-228.6 dBW/K/Hz
T_s = 500 K	27.0 dBK
B = 43.2MHz	76.4 dBHz
N = Transponder noise power	-125.2 dBW

The received power level at the transponder input must be 30 dB greater than the noise power .

P_t = Power at transponder input = -125 dBW + 30 dBW = - 95.2 dBW

The uplink antenna has a diameter of 5 m and an aperture efficiency of 68% at 14.15 GHz the wavelength is 2.120 m. The antenna gain is

$$Gt = 10 \log [0.68 \times (\pi D/\lambda)^2] = 55.7 \text{ dB}$$

The free space Path Loss is $Lp = 10 \log [(4\pi R/\lambda)^2] = 207.2$ dB

Uplink Power Budget

Pt = Earth station transmitter power	Pt dBW
Gt =Earth station antenna gain	55.7dB
Gr = satellite antenna gain	31.0dB
Lp = Free space path loss	-207.2dB
Lant =E/S on 2 dB contour	- 2.0dB
Lm = Other losses	-1.0dB
Pr =Received power at transponder	-123.5dB

The required power the transponder input to meet the $(C/N)_{up}$ =30dB

objective is - 95.2dBW. Hence

P_t -123.5 dB = 95.2 dBW

P_t =28.3 dBW or 675W

This is a relatively high transmit power so we would probably want to increase the transmitting antenna diameter to increase its gain, allowing a reduction in transmit power.

Ku-Band Downlink Design

The first step is to calculate the downlink $(C/N)_{dn}$ that will provide $(C/N)_0$ =17dB when $(C/N)_{\mathbf{up}}$ =30dB.from Eq.(4.43)

$$1/(C/N)_{dn}=1/(C/N)_0-1/(C/N)_{up} \quad \text{(not in dB)}$$

This

$$1/(C/N)_{dn}=1/50-1/100=0.019$$

$$(C/N)_{dn}=52.6=17.2dB$$

We must find the required receiver input power to give $(C/N)_{dn}$=17.2dB and then find the receiving antenna gain G_r

Downlink Noise Power Budget

K=Boltzmann's constant	-228.6dBW/ K/Hz
Ts=30+110k=140k	21.5dBK
Bn=43.2MHz	76.4dBHz
N=transponder noise power	-130.7dBW

The power level at the earth station receiver input must be 17.2dB greater than the noise power in clear air.

P_t = Power at earth station receiver input= -130.7 dBW +17.2 dB= -113.5 dBW

We need to calculate the path loss at 11.45GHz. At 14.15 GHz Path loss was 207.2 dB. At 11.45GHz path loss is

L_p=207.2 - 20log $_{10}$(14.15/11.45) = 205.4 dB

The transponder is operated with 1 dB output back off. So the output power is1dB below 80W (80W 19.0dBW) $\Longrightarrow$

Pt=19Dbw-1dB=18dBW

Downlink Power Budget

P_t= Satellite transponder output power	18.0dBW
G_t= Satellite antenna gain	31.0dB
G_r= Earth station antenna gain	G_r dB
L_p= Free space path loss	-205.4dB
L_a=E/S on -3 dB contour of satellite antenna	-3.0dB
L_m= Other losses	-0.8dB
P_r =Received power at transponder G_r	-160.2dB

The required power into the earth station receiver to meet the $(C/N)_{dn}$=17.2dB objective is

P_t = -120.1dB whence the receiving antenna must have a gain G_r where

$$G_r - 160.2 \text{ dB} = -113.5 \text{ dBW}$$

$$G_r = 46.7\text{dB}$$

The earth station antenna diameter, D is calculated from the formula for antenna gain G, with a circular aperture

$$G_r = 0.65x(\pi D/\lambda)^2 = 46.774$$

At 11.45 GHz, the wavelength is 0.0262 m. Evaluating the above equation to find D gives the required receiving antenna diameter as D =2.14 m

Exercise

1. Explain the phenomenon of scintillation.
2. What are atmospheric losses?
3. Explain the effects of clouds of electrons.
4. List various propagation concerns for satellite communication systems.
5. Explain ionosphere scintillation.
6. What is meant by rain attenuation? Derive an equation for the same.
7. Explain what is meant by effective path length in connection with rain attenuation.
8. Explain what is meant by rain rate. How this is related to specific attenuation.
9. Describe the major effect that ionosphere has on satellite signals losses?