IN THIS TWO DIFFERENT MATERIALS AVAILABLE

12-7-13

UNIT-II SATELLITE SUBSYSTEMS

* Satellite subsystems:-

In order to support the communication system, the satellite must provide a stable platform onto which we mount the antenna, electric power for the communication system and also provide a controlled temperature environment.

The major satellite subsystems required on the satellite are:

1) Altitude & orbit control system (AOCS):- This subsystem consists of rocket motors that are used to move the satellite back to the correct orbit, when external forces acting on it and gasjets are used to control the altitude of the satellite.

2). Telemetry tracking Command & Monitoring (TTC&M):- This systems are partly on the satellite and partly on the controlling earth station. The telemetry system sense data derived from many sensors on the satellite via a telemetry link to the controlling earth station. The tracking system is located at earth station, and provides information on the range, elevation and azimuthal angles of the satellite. Based on the telemetry data, received from the satellite and orbital data obtained from tracking system, the control system used to correct the position and altitude of the satellite.

3) Power Systems:- All communications subsystem derive their electric power from solarcells. This power is mainly used in the transmitters, receivers, and other electrical systems on the satellite.

4) Communication subsystem:- The communication subsystem usually composed of set of transmitters and receivers and one or more antennas. Here the set of Txers & Rxers are known as transponders.

5) Satellite Antennas:- The satellite antenna system is very complex and produces beams with shapes to match the areas on the earth's surface. Most satellite antennas operate in a single frequency band. In order to use multiple frequency bands, we need four or more antennas.

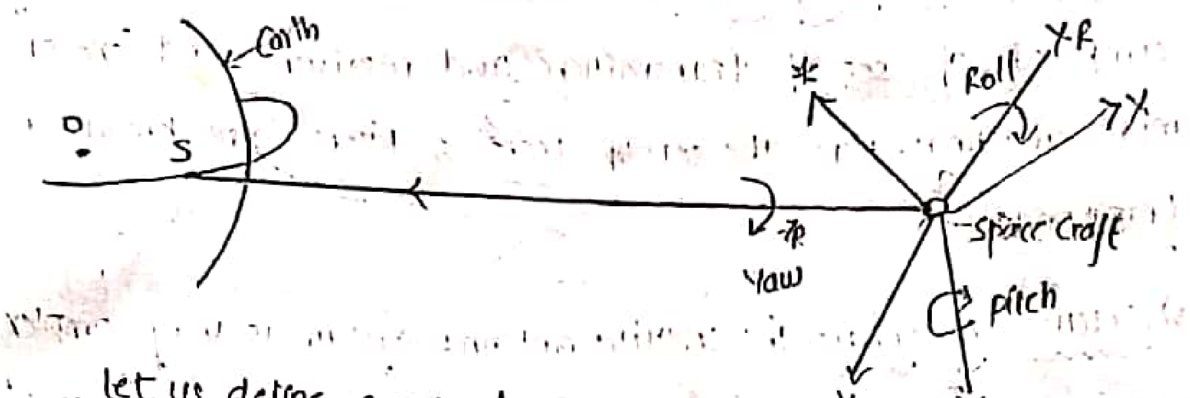
1.3 ATTITUDE AND ORBIT CONTROL SYSTEM (AOCS):-

There are several forces acting on a orbiting satellite that tend to change its attitude and orbit. The most important are the gravitational fields of the sun and the moon, irregularities in the earth's gravitational field, solar pressure from the sun and variations in the earth's magnetic field.

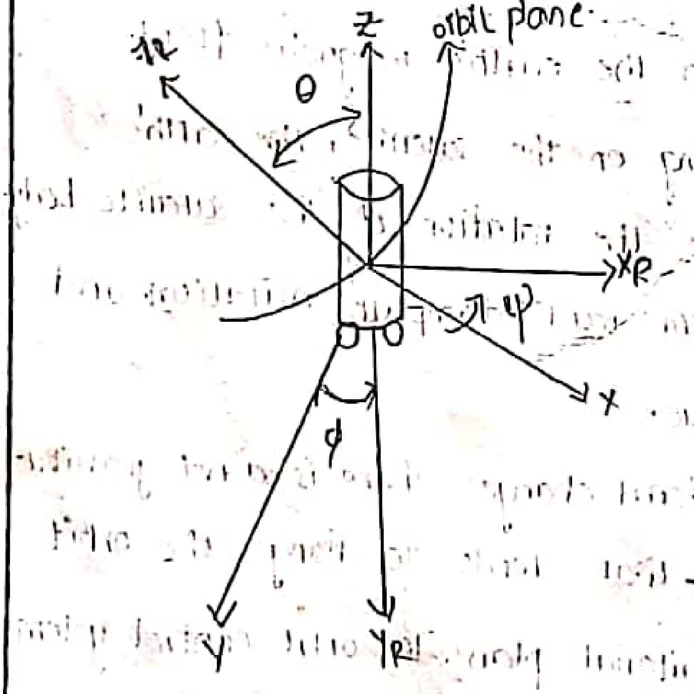
Solar pressure acting on the satellite, the earth's magnetic field tend to change the rotation of the satellite body. Now, the attitude control system must dampout this nutation and counter any rotational torque.

Due to the inclinational changes, there is a net gravitational pull on the satellite that tends to change the orbit of the satellite from its equitorial plane. The orbit control system of a satellite must be able to move the satellite back into the equitorial plane, before the orbital inclination becomes excessive.

ATTITUDE CONTROL SYSTEM :-



let us define a set of reference co-ordinate system i.e., X_R, Y_R, Z_R with the satellite at the origin as shown in the diagram. The Z_R axis is directed towards the center of the earth and X_R axis is tangent to the orbital plane. Y_R axis is perpendicular to the orbital plane. The rotation about the X_R, Y_R and Z_R axis is defined as roll about x-axis, pitch about y-axis, Yaw about z-axis. The satellite must be stabilised with respect to the reference axis to maintain accurate pointings of its antenna beams.



changes in the satellite attitudes cause the angles θ, φ & ψ. The location of z-axis intercept defines the pointings of satellite antenna, due to this rotation, the z-axis intercept point may be moved to repoint all the antenna beams, the attitude control system is used.

There are 2 ways to make a satellite stable in the orbit.

(1) The body of the satellite is rotated typically at the rate of 30- 100 rotations perminute, to create a gyrostopic force, that provides stability of the spin axis, such satellites are known as spinner satellites.

(2) The satellite can be stabilised by one or more momentum of wheels. This type of satellites are known as three-axis stabilized satellites.

12-7-17

* SPINNER SATELLITES:-

In this spinner satellites, satellite consists of cylindrical drum which is covered with solar cells, power systems and rocket motors. Usually for spinner satellite, the axis of rotation is in Y-axis, which is perpendicular to the orbital plane. Pitch correction is required only in 'Despun' antenna system and this can be done by varying the speed of the despun motors. Yaw & Roll are controlled by radially mounted jets.

* 3-AXIS STABILIZED SATELLITES:-

Attitude control of 3-axis stabilized satellites requires an increase or decrease in the speed of the momentum of wheels. If a constant torque exists about one axis of the satellite, a continuous increase or decrease in momentum of wheelspeed is necessary to maintain correct attitude.

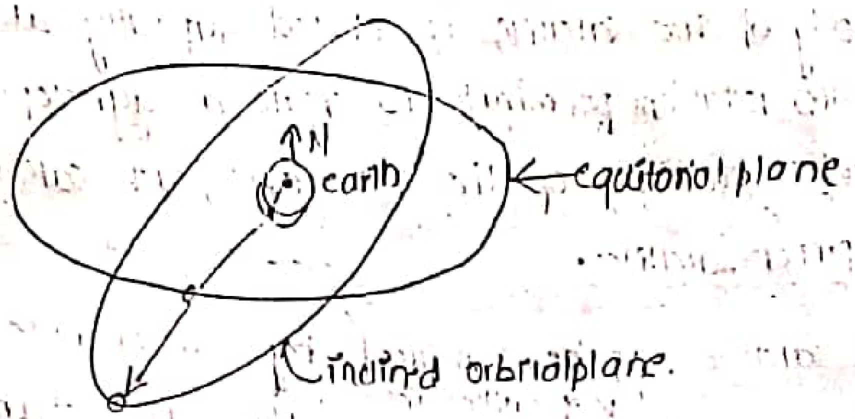
13-7-17

* ORBIT CONTROL SYSTEM:-

For the satellite to be in truly geo-synchronous earth orbit, the orbit must be: (1) in the equitorial plane.

(2) It should be circular.

(3) It must be at a correct altitude.



This cannot be done with momentum of wheels. So we need linear acceleration, to correct the orbit of the satellite. For this purpose, we use gasjets.

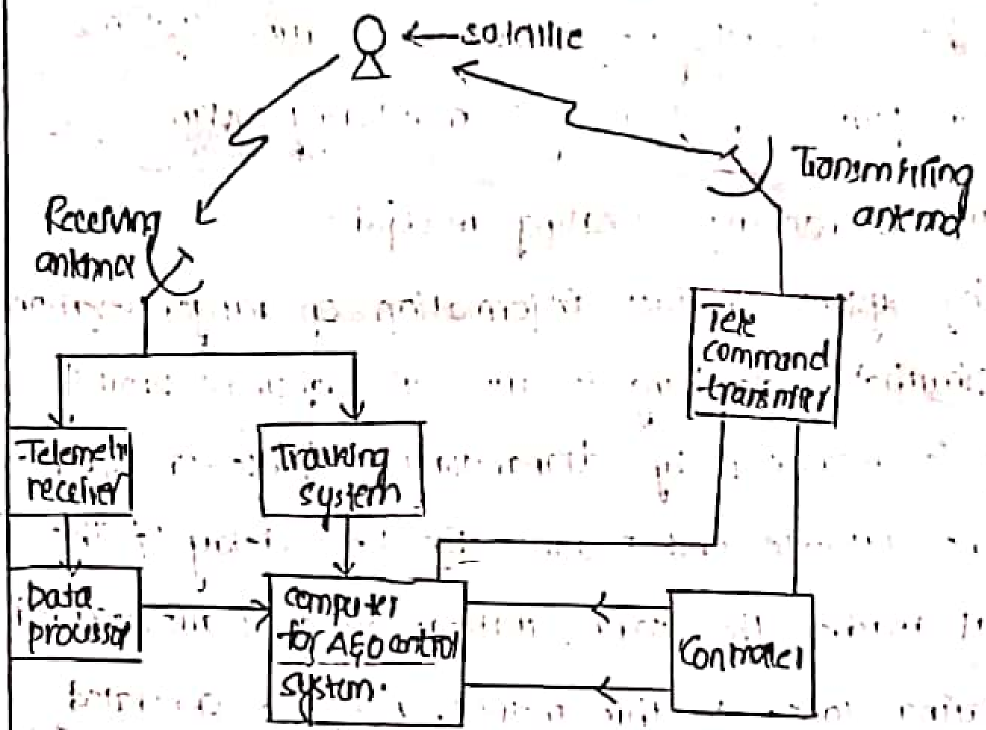
If the orbit is not circular, the velocity increase or decrease will have to be made along the x-axis. For spinning satellite, this is acheived by pulsing radially jets, along the x-axis direction. For a 3-axis stabilised satellites, we use two pairs of radially jets which are acting in opposite direction.

The inclination of the orbit of the satellite increases at an average rate of 0.85° per year, with an initial rate of change of inclination in an equitorial orbit between 0.75° to 0.94° per year.

For practically, the corrections are made using N-S no station keeping maneuvers & E-W station keeping maneuvers. It has become normal to split E-W and N-S maneuvers, so that at intervals of 2 weeks, the E-W corrections are made west-first and after 2 more weeks, N-S corrections are made.

Correcting the inclination of the satellite requires more fuel than any other orbital correction.

TELEMETRY TRACKING COMMAND & MONITORING SYSTEMS:-



TTC&M are used for is essential for the successful operation of the communication satellite. It is the part of the satellite management task. Satellite management used to control attitude & orbit of the satellite, monitor all the sensors of the satellite and control ON and OFF sections of communication satellite. TTC&M are owned and operated by the satellite owners or it gets from the third party on contract basis.

Telemetry & Monitoring system:-

It collects the data from the sensors of the satellite and sends to the earth station via telemetry link. This monitors

1) pressure in the fuel tanks &
2) voltages & currents in the power conditioning unit.
3) currents drawn from each subsystem.
4) critical currents & voltages in communication satellites.

This data is digitalized by PSK using TDM technique.

Computer at the earth station decode this information to determine the status of the sensors, subsystems and communication systems. This is the main purpose of telemetry & monitoring system.

Tracking systems:- Tracking → locating an object.

Tracking system provides information on range, elevation angle and azimuthal angle. Range is used to determine orbital elements. Range is measured by transmitting a pulse or sequence of pulses to the satellite and measure the time delay of the pulse before it reaches the earth station. Range is also measured by using ranging tones. In this method, a carrier generated at the satellite is modulated with series of sine waves and it is compared at the earth station.

Command system:-

A command system used to make changes in attitude and correction to the orbit, and also it controls the communication system. During launch, it is used to control the firing of the apogee kick motor.

The command structure contains safeguards against unauthorised attempts to make changes to the satellite operation. Encryption of commands & responses are used to provide security in the communication system. The control (code) word is converted into command word, which is sent to the satellite. After checking the validity in the satellite, the word is sent back to the control station via telemetry link, where it is checked again in the computer. If it is found the data received correctly and, execute instruction will be sent to the satellite, so that the command word is executive.

18-11

* Power systems:-

All the communication satellites obtain their electrical power from solar cells, which convert sunlight into electrical energy. Previously, space planetary research satellites used thermonuclear generators, to supply electrical power to the satellites. But, because of the danger to the people on the earth, if the launch should fail and nuclear fuel to spread over a inhabitated area.

Most of the power comes from the sun. In geostationary altitude, the radiation falling on the satellite has an intensity of $1.39\ KW/m^2$. All the power from the incident energy is not converted into the electrical energy. Their efficiency is typically 20-25% at beginning of life, and their efficiency increases by 15% at the end of life.

For spinner stabilised satellite, as it is in cylindrical body covered in solar cells, only half of the cells are illuminated and the edges of the illum other half of is illuminated. Because of this low angle of incidence to the other half, little electrical power is generated.

For 3-axis stabilised satellite, this satellite can make better use of its solar cells area since, the cells are arranged on flat panels, that can be rotated to maintain normal incidence of the sunlight. Therefore more power is generated in 3-axis stabilised satellite when compared to spinner stabilised satellite.

the satellite must carry batteries to power the subsystem during the eclipse, and during launch. Eclipse occurs twice an year, around the spring & fall equinox i.e., at March 21 and September 21. The duration of the eclipse is 70min. To avoid the need for the large and heavy batteries, most of the communication system may be shutdown for voice and data communication. For TV broadcasting, we use batteries, usually of the Ni-Hydrogen type with good reliability and good lifetime and can be safely discharged to 70% of their capacity. Sensors on the batteries, power conditioning unit and solar cells monitor temperature, voltage and current and supply this data to the controlling earth station via the telemetry link.

Communication sub-system:-

→ A communication satellite exists & provides a platform in geostationary orbit for the relaying of voice, video and data communications. All other subsystems on the satellite exist solely to support the communication system.

→ Since it is the communication system that earns the revenue for the system operator, communications satellite are designed to provide the largest traffic capacity possible.

→ The satellite transponders have limited output power and the earth stations are atleast 36,000 kms away from a GEO satellite, so the received power level, even with large aperture, earth station antennas are very small.

→ For the system to perform satisfactorily, the signal power must exceed the power of the noise generated in the receiver by b/w 5 and 25db, depending on the bandwidth of the transmitted signal and modulation scheme used.

→ Early communication satellites were fitted with transponders of 250 or 500MHz bandwidth, but had low gain antennas and transmitter of 1or 2W o/p.

→ Later generations of communication satellites have transponders with greatly increased o/p power, upto 200w for DBS-TV satellites and have steadily improved in bandwidth utilisation efficiency.

→ The total channel capacity of a satellite that uses a 500MHz band at 6/4 GHz can be increased only if the bandwidth can be increased or reused.

→ The trend in high capacity satellites has been to reuse the available bands by employing several beams at the same frequency (spatial frequency reuse) and orthognal polarizations at the same frequency (polarization frequency reuse). Large GEO satellites also use both 6/4 GHz & 14/11 GHz bands to obtain more bandwidth.

Eg: Some GEO satellites have acheived an effective bandwidth of 2200MHz within a 500MHz band at 6/4 GHz and a 250MHz band at 14/11 GHz by a combination of spatial & polarization frequency reuse.

→ The designer of a satellite communication system is not free to select any frequency and bandwidth. International agreements restrict the frequencies that may be used for particular services, and regulations are administered by the appropriate agency in each country.

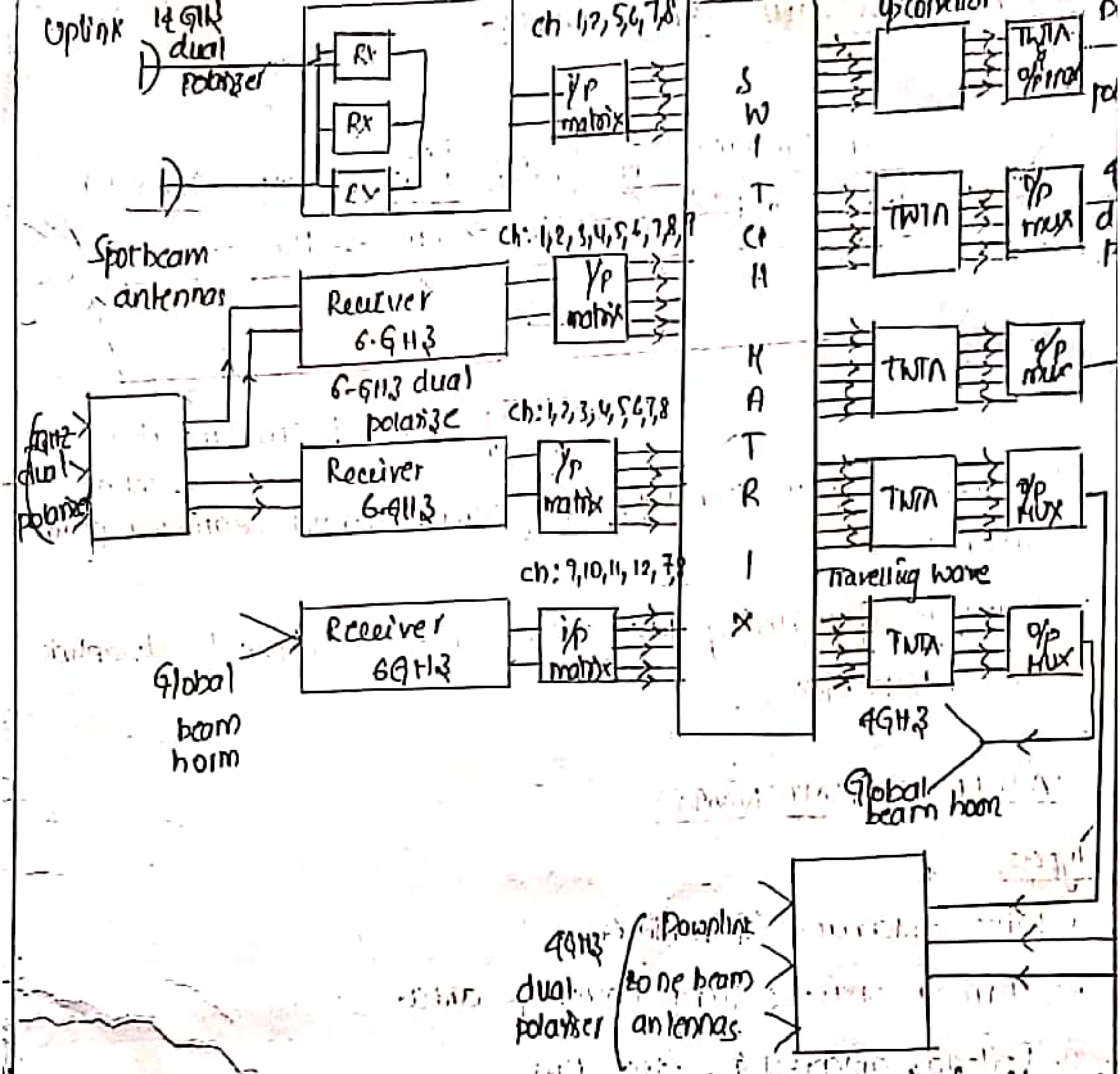
- The federal communication commission (FCC) in the United states.

→ The bands currently used for the majority of services are 6/4 GHz, 14/11 GHz & 30/20 GHz.

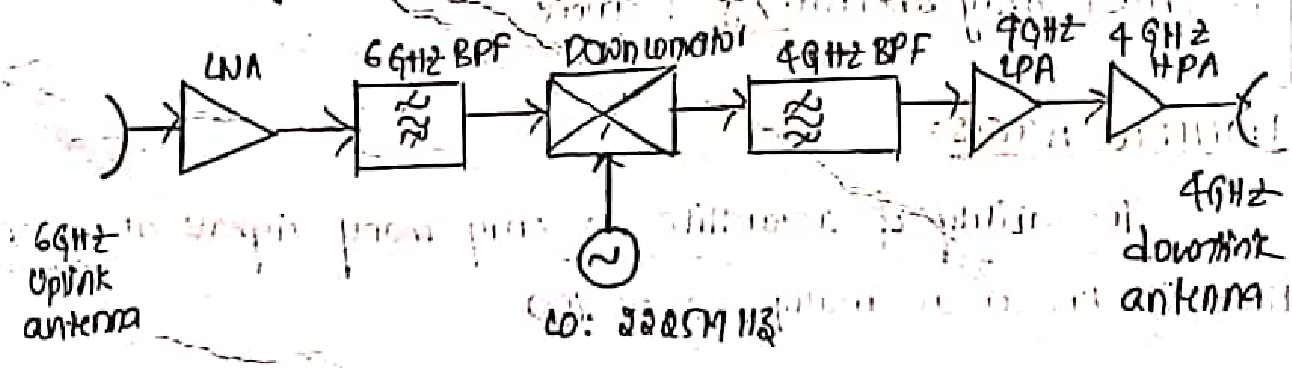
→ The 500MHz bands originally allocated for 6/4 and 14/11 GHz, satellite communication have become very congested. Extension of the bands to 1000MHz will eventually provide greater capacity as the new frequencies come into use. Many systems now use 14/11 GHz for TV broadcast & distribution and 30/20 GHz systems are introducing internet-like services from GEO.

→ Satellite systems designed for ku band (14/11 GHz) & Ka band (30/20 GHz) have narrow antenna beams and better control of coverage patterns than satellites using Cband (6/4 GHz).

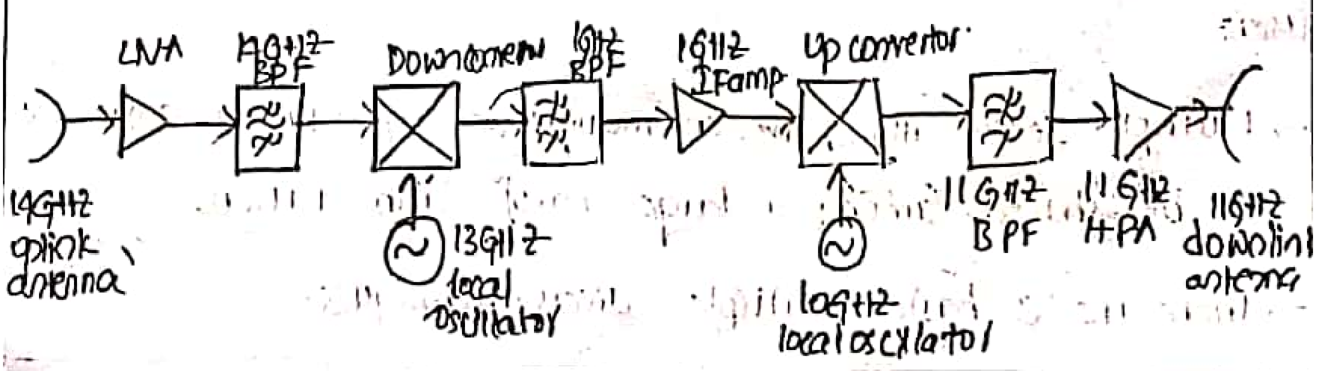
TRANSPONDER :-



<u>Simplified single conversion transponder (bent pipe) for 6/4 GHz</u>



<u>Double conversion transponder:-</u>



C

On board controller → reduces error in uplink & downlink

- Uses switched beam technology, to generate narrow beam for earth station.
- advantage of switching b/w uplink access technique to downlink access technique.

SATELLITE ANTENNAS:-

Types:-

1. Wire antennas :- Transmitter...
2. Horn antennas :- large coverage area.
3. Reflector antennas :- App:- DTH
4. Phased array antennas. App:- Telephone.

MULTIPLE ACCESS:-

The ability of a satellite to carry many signals at a same time is known as multiple access. (or)

The ability of a service to be accessable by different users

→ Multiple access allow the communication capacity of a satellite to be shared among a large no. of earth stations.

→ There are 3 basic multiple access techniques.

1. FDMA :- All users share the satellite at same time and each user transmit at unique allocated frequency.

2. TDMA :- Each user is allocated a unique timeslot at satellite.

3. CDMA :- All users transmit to satellite on same frequency & at same time.

→ The assigning of a transponder depends on many factors:

1) Percentage of utilisation,
2) Type of information and
3) Economy in terms of users.

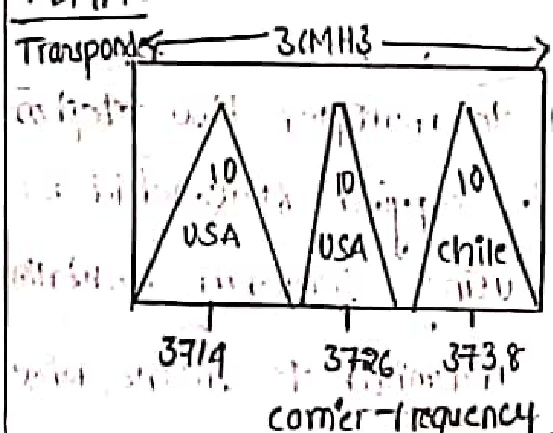
Pre-assigned Multiple Access / Fixed-assigned Multiple Access (PAMA/FAMA)
:- The transponder leased out permenently either for lifetime of satellite. No other earth stations can use this.

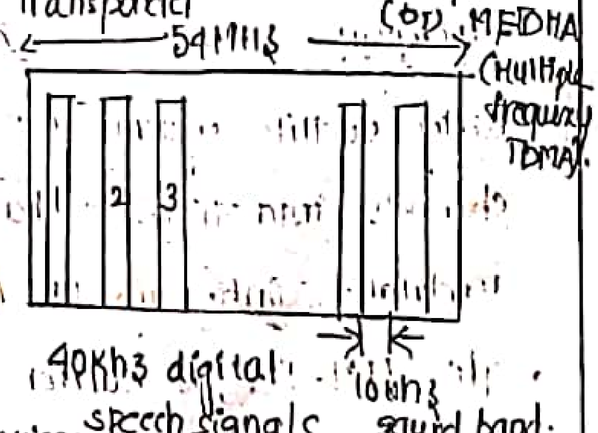
Demand Access Multiple Access :- It resource is allocated as needed depending on changing traffic conditions. efficiency is quite high.

Random Multiple Access :- Any earth station will can try to occupy a transponder and use it for short durations. It requires different level of control signals and a special equipment.

→ Some satellite systems will have both TDMA & FDMA that is called hybrid Multiple Access (or) MFDMA (Multiple frequency TDMA).

FDMA :-





frequency range - 300 to 3400 hz.

12 channels - 60 to 108 khz (basic group), 60 channels - 60 to 300 khz (supergroup)

Types of FDMA:- FDMA are defined with baseband and the type of modulation

1) FDM - FM - FDMA.

2) PCM - PSK - FDMA.

3) PCM - TDM - FDMA.

4) PCM - SCPC - MAD - FDMA (SPADE).

SCPC : single channel per carrier.

MAD: Multiple access for demand.

- FDMA is the first multiple access used in satellite in 1960's for telephony.
- All the signals are analog and a analog multiplexing is used to combine large no of channels to a single baseband that could modulated on single RF carrier.
- The process begins by limiting individual telephone channels to a frequency range of 300-3400 hz and then frequency shifting 12 channels to a freq. range of 60-108 khz. These 12 channels are called as basic group. 5 basic groups can be shifted to a range of 60-300khz to make a 60 channel supergroup.
- Early satellite systems use FDM to multiplex 1800 telephone channels into a wide baseband, occupying 8MHz, which was modulated onto an RF carrier using frequency modulation.
- The FDM-FM, RF carrier was transmitted to satellite where

It share a transponder with other carriers using FDMA.

- The fixed assignment FDM-FM-FDMA also makes inefficient use of transponder bandwidth. The estimate of average utilization in INTELSAT using fixed assignment was 15%. By demand assignment and single channel per carrier allows higher utilization.
- Gaurd bands are essential in FDMA system to allow the filters to select individual channels, without excessive interference from adjacent channels.
- These gaurd bands of 10-25% of channel bandwidth are needed to minimize adjacent channel interference.
- "Most satellite transponders use high power amplifiers, which are driven close to saturation, causing non-linear operation. & a transponders using travelling wave tube amplifiers, is more prone to non-linearity than highpower amplifiers."

III FDMA cont---)

- At receiving earthstation, the highspeed bitstream must first be recovered which requires a demodulation of RF carrier, generation of a bitclock.
- The synchronization bits in packets or frames must be found so that highspeed bitstream can split into original lower speed signals.
- The framelength is usually constant, and the clock frequency for bitstream is fixed. The packet lengths can vary. The entire process requires considerable storage of bits, so that original signal can be rebuild and leading to delay in transmission.

as a burst at specific time. At satellite, the burst from each earth stations arrive sequentially.

- The TDMA transmission, the burst is assembled at transmitting earthstation, so that it will correctly fit in a TDMA frame.
- The TDMA frame has a length from 125μs to many milliseconds.
- A time overlap of two RF signals is called collision & it results in data, and in both signals being lost. Collision must not be allowed to occur in TDMA system.

(FDMA cont....)

Voice Band channel:- A channel that is suitable for transmission of speech or analog data and it has the maximum usable frequency range of 300-3400 hz is called voice band channel.

* FDMA can be performed in two ways:-

1. Fixed Demand Multiple Access (FAMA):- The subchannels assignments are of fixed allotment. Ideal for broadcast satellite communication.

2. Demand-assignment Multiple Access (DAMA):- The sub-channel allotment changes based on demand. Ideal for point to point communication (centralised control and distributed control).

* SPADE - DAMA system (single channel per carrier PCM multiple Access Demand assignment equipment).

- SPADE is an example for DAMA uses distributed control).

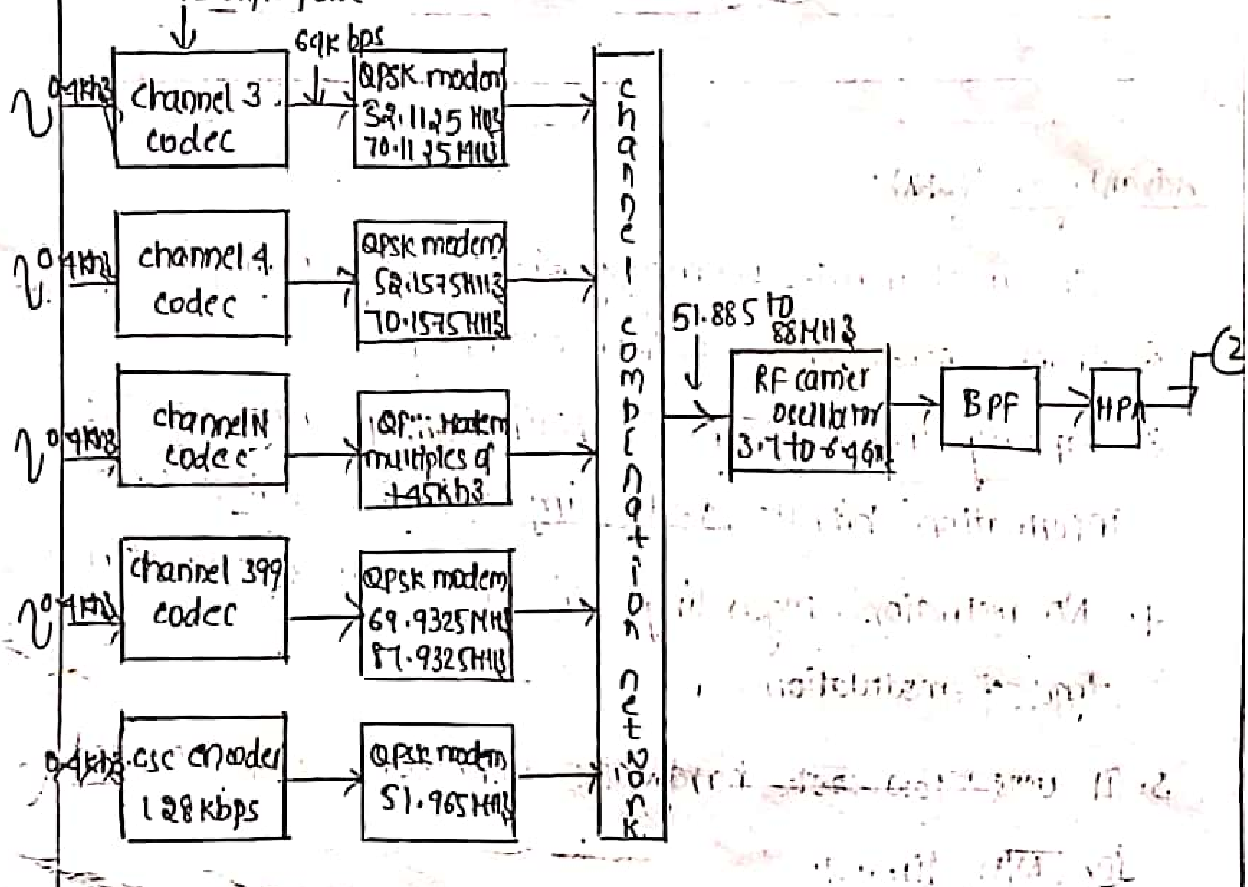
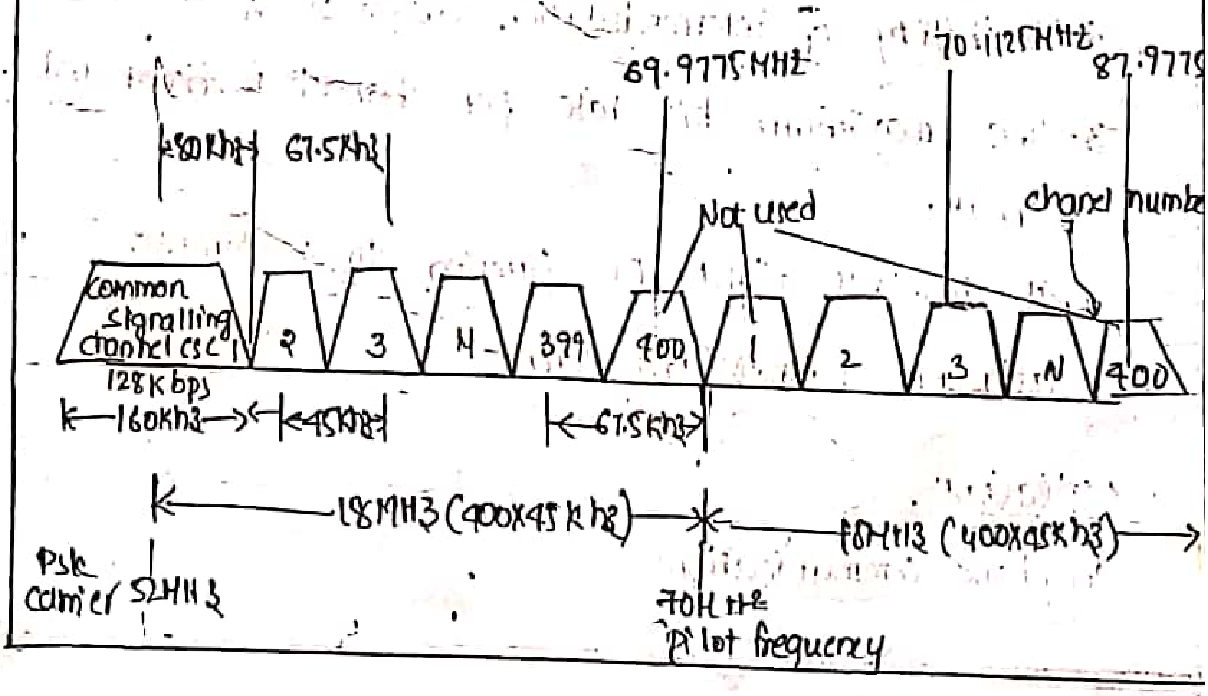
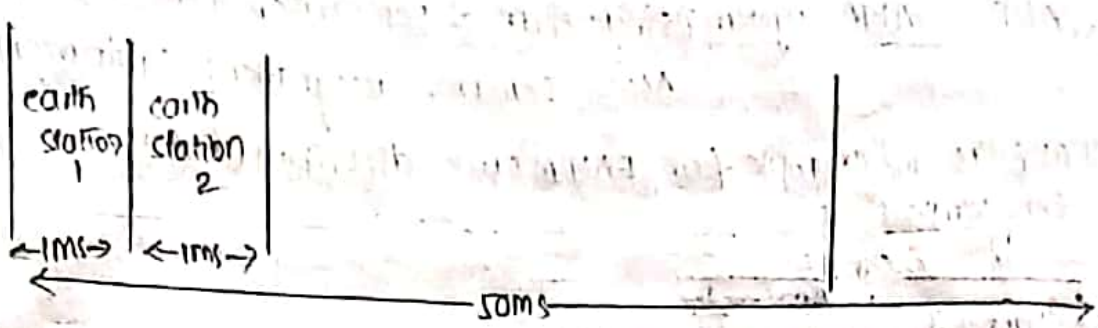


fig FDMA, SPADE EARTH STATION TRANSMITTER

* Carrier frequency assignments for the INTELSAT single channel per carrier-per multiple access demand - assignment equipment [SPADE]





* **Advantages (FDMA):-**

1. Users can transmit continuously without any interruption.
2. Channel bandwidth is utilized efficiently.
3. Capacity increase can be obtained by reducing the information bitrate and using efficient digital codes.
4. No restriction regarding the type of baseband (or) type of modulation.
5. It uses low cost hardware technology and no need for N/w timing.

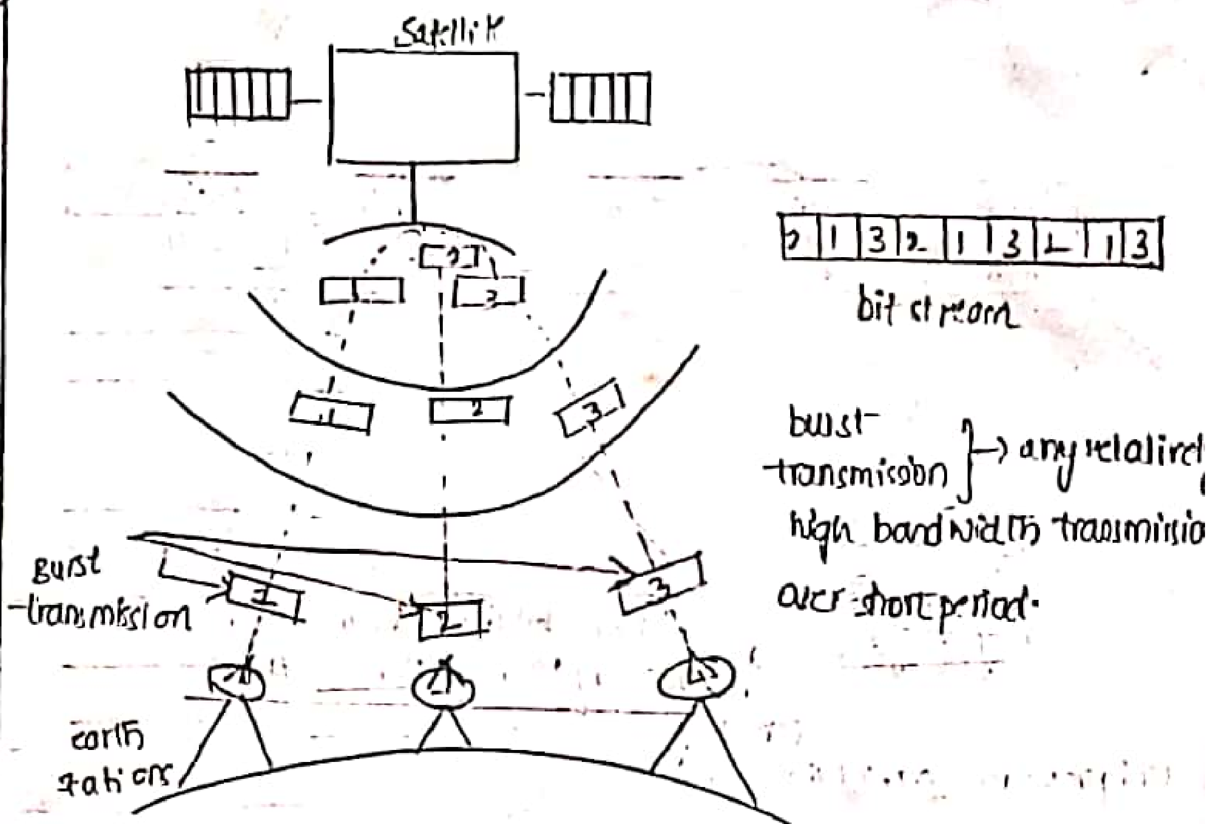
* **Disadvantages:-**

1. Extra gaurd bands are required to avoid inter channel.
2. Possibility of intermodulation distortion of transponder.
3. The maximum bit rate per channel is fixed and small.
4. It requires right RF filtering to minimize adjacent channel interference.

* **Applications:-**

Telephone communications

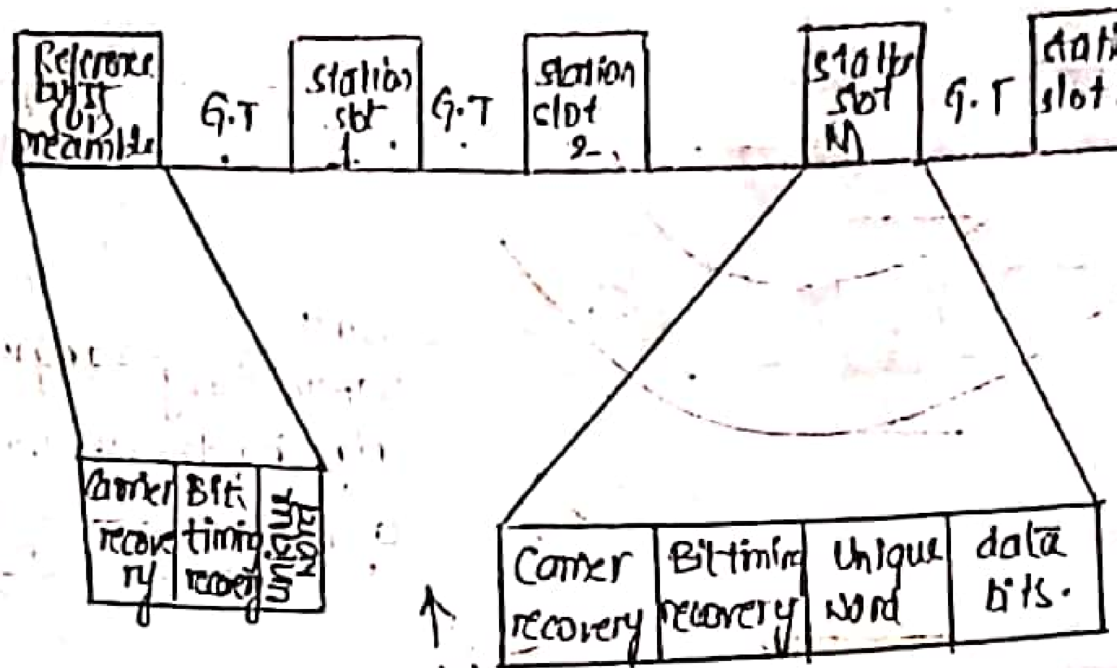
* TDMA (Time division Multiple Access):-



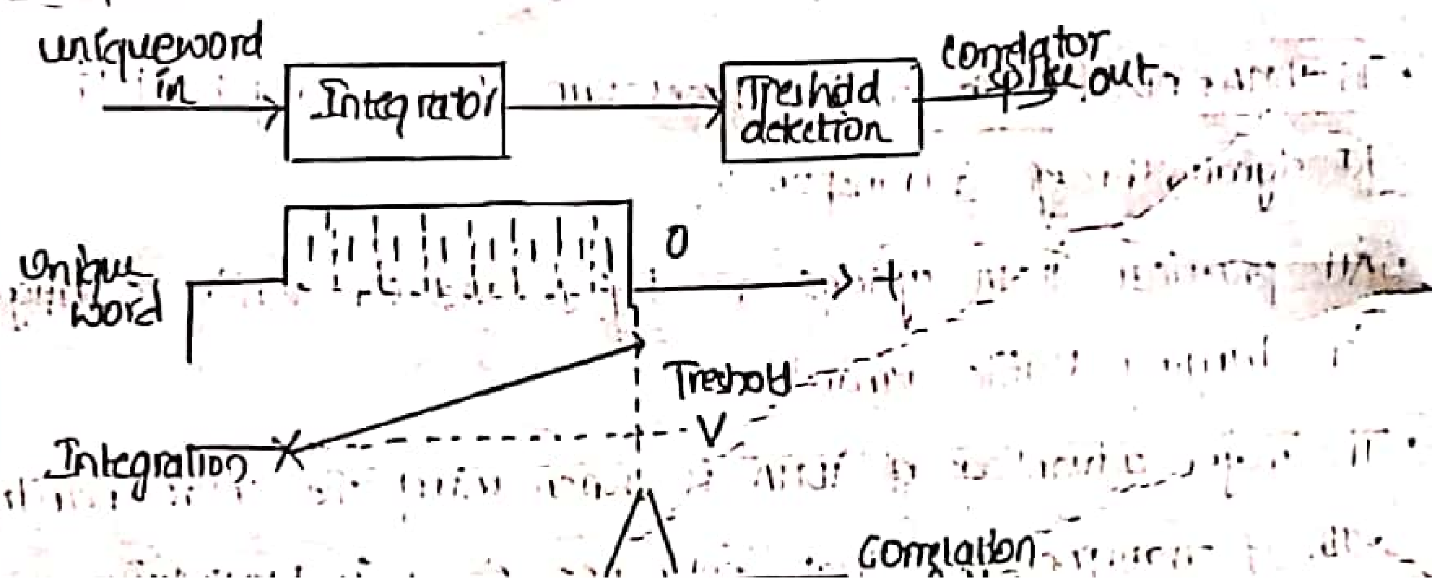
- In TDMA, no. of earth stations takes turns transmitting burst of RF signals, through a transponder.
- All practical TDMA systems are digital and can easily reconfigure for changing traffic demands.
- The major advantage of TDMA is when using the entire bandwidth of transponder, is that only one signal is present in transponder at one time.
- However using all of transponder bandwidth requires every earth station to transmit high bitrate, which requires high transmission power.
- Group of bits taken from each bitstream taken from and formed in baseband packets or frames, that also contains synchronous bits and identification bits.

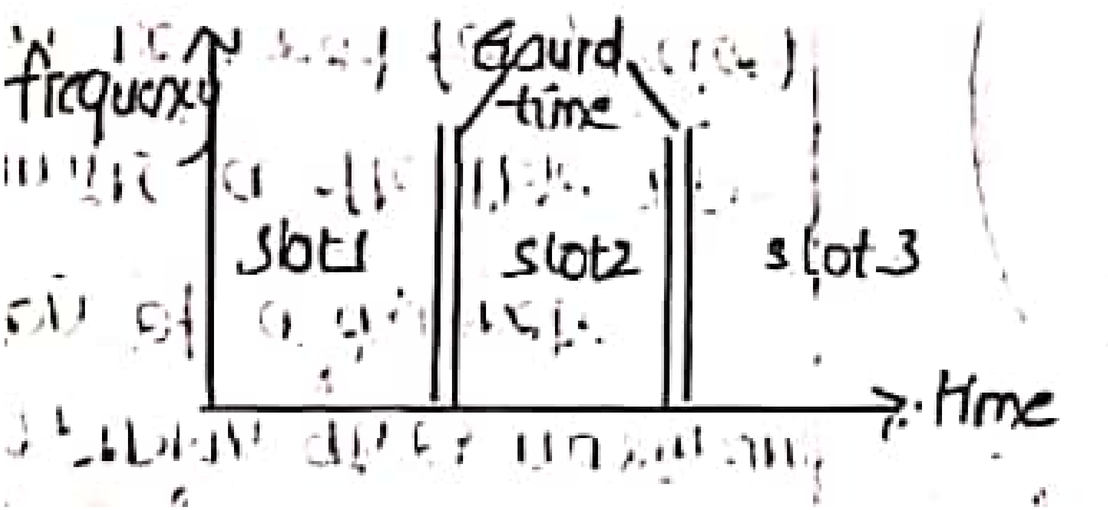
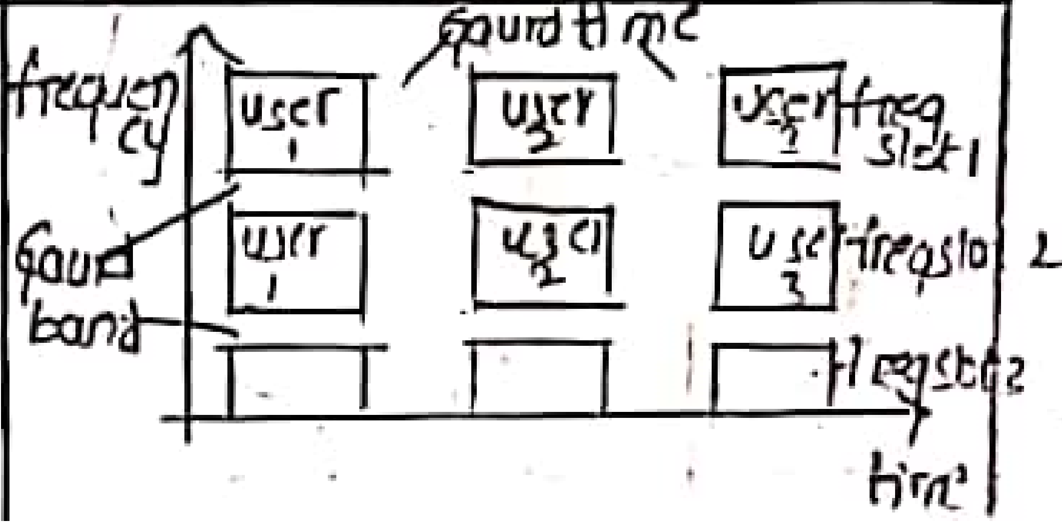
← Prev page

TDMA – frame structure:



Uniqueword correlator – spike



TDMA (Time division multiple access)	CDMA (code division multiple access) (spread spectrum)
1. In this, the time of the channel is shared by multiple users	1. In this, the time as well as bandwidth of a channel is shared by multiple users.
	

Parameters	FDMA (freq division multiple access)	TDMA (Time division multiple access)	CDMA (code division multiple access)
6. Gaurd band and Gaurd time	6. Gaurd band is required.	6. Gaurd times are required.	6. Gaurd bands & times are required.
7. Synchronisation	7. No synchronisation is required	7. Time synchronisation is essential	7. No synchronization is required.
8. Advantages	a. The users can transmit continu-ously without any interruption b. The channel bandwidth is utilized more efficiently. c. A capacity increase can be obtained by reducing the information bit rate & using efficient digital codes. d. No restriction regarding the type of baseband or the type of modulation e. Uses low cost H/W technology	a. Users get full bandwidth of channel in a particular timeslot b. For burst signals, such as voice or speech, TDMA gives maximum utilization of a channel. c. It permits a flexible bit rate and no need for precised narrowband filters, and it permits utilization of all advantages of digital techniques. d. Gaurd time b/w timeslots allows to reduce the impact of	a. Maximum utilization of a channel takes place. b. Synchronization is not necessary e.

	and no need for network timing.	g. Users get full band width of clock instability, transmission time delay.	
9. Disadvantages	a. Extra gaurd bands are required to avoid interchannel interference. b. Possibility of intermodulation distortion at transponder. c. The maximum bit rate per channel is fixed and small. d. It requires right RF filtering to minimize adjacent channel interference	a. It is not much suitable for continuous signals. b. extra gaurdtimes are necessary. c. It requires signal processing for matched filtering & correlation detection. d. It demands high peak power on uplink, in transmit mode.	a. chances of data collision because of overlap. b Protocalls are necessary to avoid collisions.
10. Application	a. Telephone communications	It is used for voice and data transmission.	Cellular mobile communications.

Random Access:-

Random Access is widely used in satellite multiple access technique where the traffic density from individual users is low.

The users can share the transponder space without any control (or) allocation of time or frequency, provided the average activity level is sufficiently low.

In a true Random Access network, a user can transmit packets whenever they are available and the packet has a destination address and source address. All stations receive the packet and the station with correct address only store the data contained in packet. All other earth stations ignore the packet, until it is designated as a broadcast packet with information for all stations. Early work on Random Access technique for radio channels are done at University of HAWAII. The system is called ALOHA and was known by a generic term, Packet Radios.

"Random Access cannot be used when traffic density exceeds 18% and therefore makes inefficient use of bandwidth available in transponder."

DEMAND ACCESS MULTIPLE ACCESS:-

Demand access can be used in any satellite communication link where traffic from earth's station is intermittent.

Telephone voice users communication at Random times for a period ranging from less than a minute to several minutes, as a percentage of total time, the individual user uses telephone, may be as little one person. Demand access allow a satellite channel to be allocated to user on a demand rather than continuously, which greatly increases the no. of simultaneous users, who can be served by the system. Most SCPC – FDMA systems, use demand access to ensure that available bandwidth in a transponder is used as fully as possible.

Demand access system requires two different types of channels. 1) common signalling channel and 2) communication channel. The user wishing to communication network first calls the controller earth station using communication signal channel (CSC). Packet transmission techniques are widely used in demand access systems because of need for address to determine the source & destination of signals. Bent pipe transponders are often used in Demand Access technique.

Unit-2 SATELLITE SUBSYSTEM

Attitude and orbit control system, telemetry, tracking, command and monitoring, power systems, communication subsystems, Satellite antenna Equipment reliability and Space qualification.

The major subsystems required on the satellite are given below

Attitude and orbit control system :-

This subsystem consists of rocket motors that are are used to move satellite back to the correct orbit when the external forces cause it to drift off station and gas (or) internal devices that control the attitude of the satellite

Telemetry, Tracking, command and monitoring

These systems are partly on the satellite and partly at controlling earth station. The telemetry system sends data derived from many sensors on the satellite, which monitor the satellites health via a telemetry link to the controlling earth station

The tracking system is located at this earth station and provides information on the range and the elevation and azimuth angles of the satellite.

on telemetry data received from the satellite at orbital data obtained from the tracking system, the control system is used to correct the position and attitude of satellite.

* It is also used to control the antenna pointing and commu system configuration to suit current traffic requirements, an to operate switches on the satellite

Power System

All communications satellite derive their electrical power from sol cel's. The power is used by the communications system, mainly in th transmitters and also by all other electrical systems on the satelli

Communications subsystem :-

* The communications subsystem is the major component c a communications satellite, the communications equipment is on a small part of the weight and volume of the whole satellite. It usually composed of one or more antennas, which receive and tr over wide bandwidths at microwave frequencies, and a set of receivers and transmitters that amplify and retransmit the incoming signals.

* The receiver - transmitter units are known as transponder. These are two types of transponder in use on satellites the linear (or) bent pipe transponders that amplifies the received s and retransmits it at a different, usually lower, frequency and the baseband processing transponder which is used only with digita signals, that converts the received signal to baseband process it and then retransmits a digital signal.

Satellite Antennas :-

(2)

* Although these form part of the Complete Communication System, they can be Considered Seperately from the transponders. On large GEO Satellites the antenna Systems are Very Complex and produce beams with shapes carefully tailored to match the areas on the earth's Surface Served by the Satellite.

* Most Satellite antennas are designed to operate in a Single frequency bands for example, C band (or) ku-band. A Satellite which uses multiple frequency bands usually has four (or) more antennas.

(1)

Attitude and orbit Control System (AOCS) :- 3(a)

* The earth is not quite a perfect sphere. At the equator, there are bulges of about 65m at longitudes 162°E and 348°E, with the result that a Satellite is accelerated toward one of two stable Points in the GEO orbit at longitude 75°E and 252°E, To maintain accurate station keeping, the satellite must be periodically accelerated in the opposite direction to the forces acting on it.

* There are two ways to make a satellite stable in orbit, when it weightless. The body of the satellite can be rotated typically at a rate between 30 and 100rpm, to Create a gyroscopic force that provides Stability are known as Spinners

* Alternatively, the Satellite Can be Stabilized by one or more wheels momentum wheels.

* The momentum wheel is usually a solid metal disk driven by an electric motor.

* The momentum wheel is usually a solid metal disk driven by an electric motor. Either there must be one momentum wheel for each of the three axes of the satellite (or) single momentum wheel can be mounted on gimbals and to provide a rotational force about any of the three axis.

* Increasing the speed of the momentum wheel causes the satellite to process in the opposite direction, according the principle of ... of angular momentum.

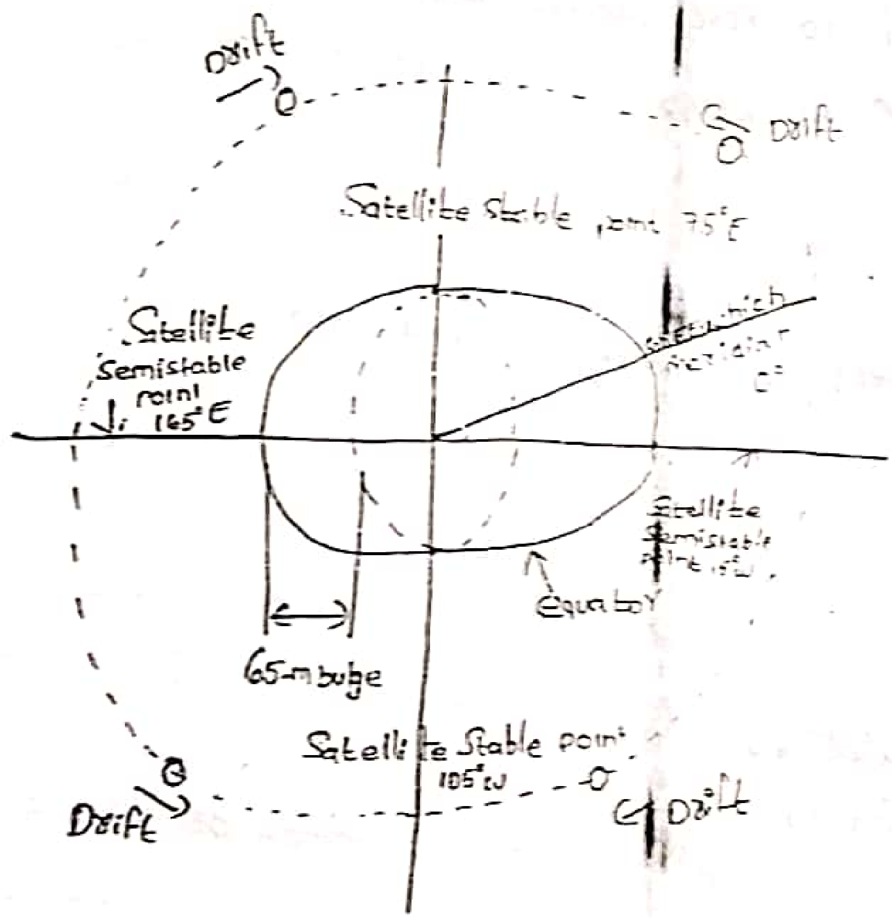


Figure: forces on a Synchronous Satellite

* The Spinner design of satellite is typified by many built by the Hughes Aircraft Corporation for domestic Communication Systems

* There are two types of rocket motors used on satellites. The traditional bio-propellent thruster described above, and arc jets (or) ion thrusters. The fuel that is stored on a GEO satellite is used for two purposes. to fire the apogee kick motor that injects the satellite into its final orbit.
* If the launch is highly accurate, a minimum amount of fuel is used to attain the final orbit. If the launch is less accurate more accurate, ~~more~~ minimum more fuel must be used to attain the final orbit.

3(a) (2

II

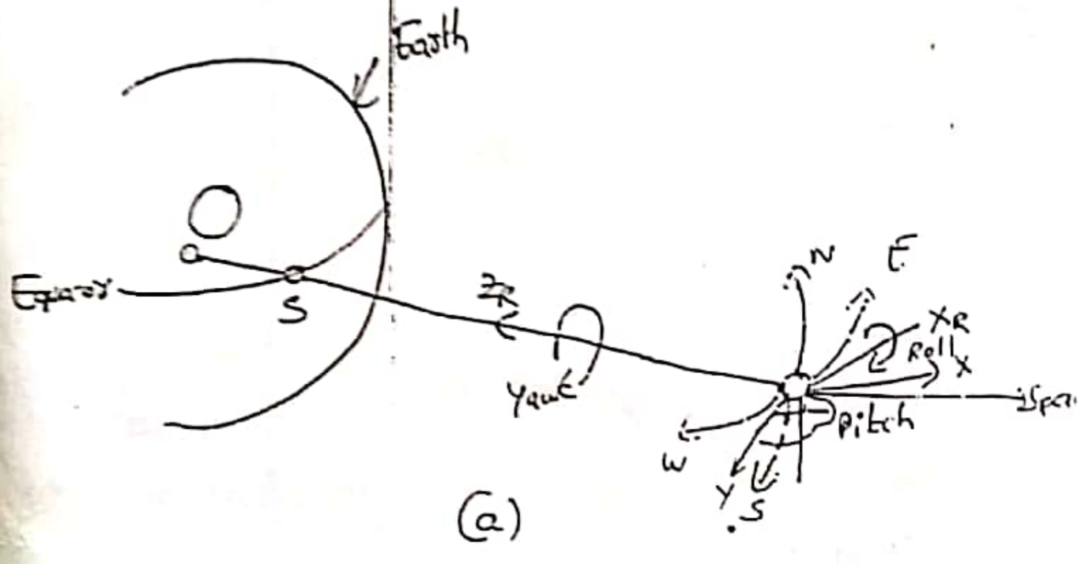
* Arc jets or ion thrusters are mainly used for north-south station keeping, which is where the greatest use of fuel is required for station keeping maneuvers, and become operational on the Hughes 600 series of satellite buses. Arc jets or ion thrusters lack the total thrust required to move satellites quickly but a small continous thrust is adequate to maintain N-S and E-W position keeping.

* In a three-axis stabilized, one pair of gas jets is needed for each axis to provide for rotation in both directions of pitch, roll and yaw.
* An additional set of controls allowing only one jet on a given axis is to be operated, provides for velocity increments in the x, y, and z-directions

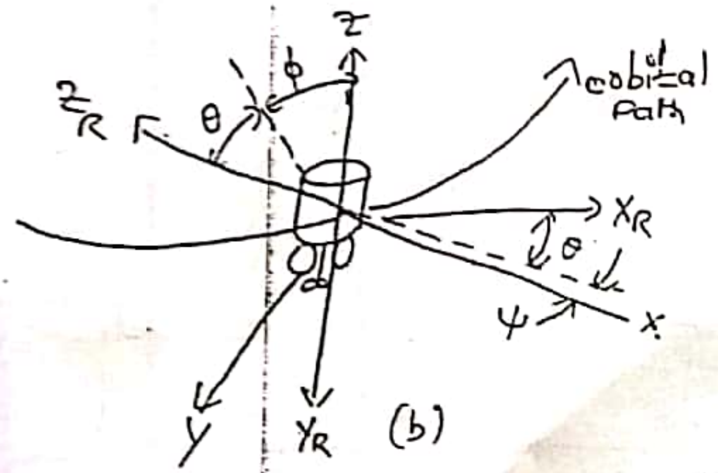
* Let us define a set of reference Cartesian axes (x_R, y_R, z_R) with the satellite at the origin as shown in figure. The z_R axis is directed toward the center of the earth and is in the plane of the satellite orbit. The x_R axis is tangent to the orbital plane and lies in the orbital plane.

Serving the Northern Hemisphere, the directions of x_R and Y_R are nominally east and South.

* Rotation about the x_R, Y_R and z_R axes is defined as roll about X_R axis, pitch about Y_R axis and yaw about the z_R in exactly the same ways as for an aircraft (or) ship travel in the x-direction.



(a)



(b)

Figure : (a) forces on a Satellite (b) Relationship b axes of satellite

④

* In a Spinner-type Satellite, the axis of rotation is usually the y-axis, which is maintained close to the Y_R axis, Perpendicular to the orbital plane.

* Pitch correction is required only on the despun antenna system can be obtained by varying the speed of the despin motor.
* yaw and roll are controlled by pulsing radially mounted jets at the appropriate instant as the body of satellite rotates.

* Attitude control of a three-axis stabilized satellite requires an increase (or) decrease in the speed of the interia wheel. If a constant torque exist about an axis of satellite, a continual increase (or) decrease in momentum wheel speed is necessary to maintain the correct attitude

3(a

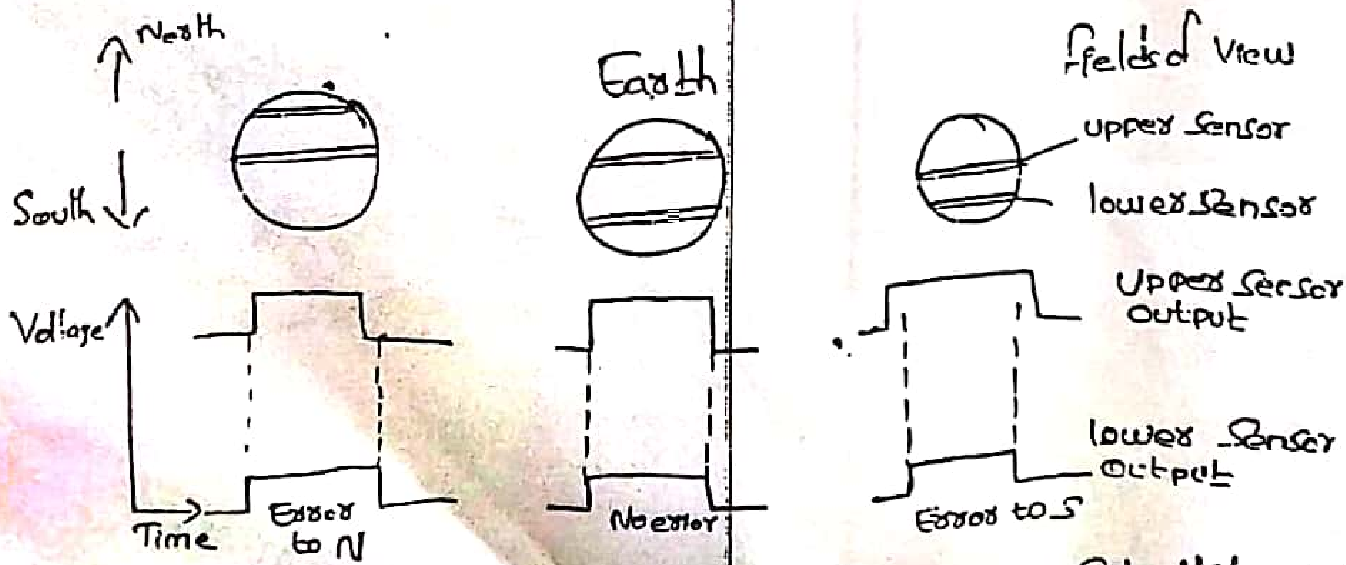
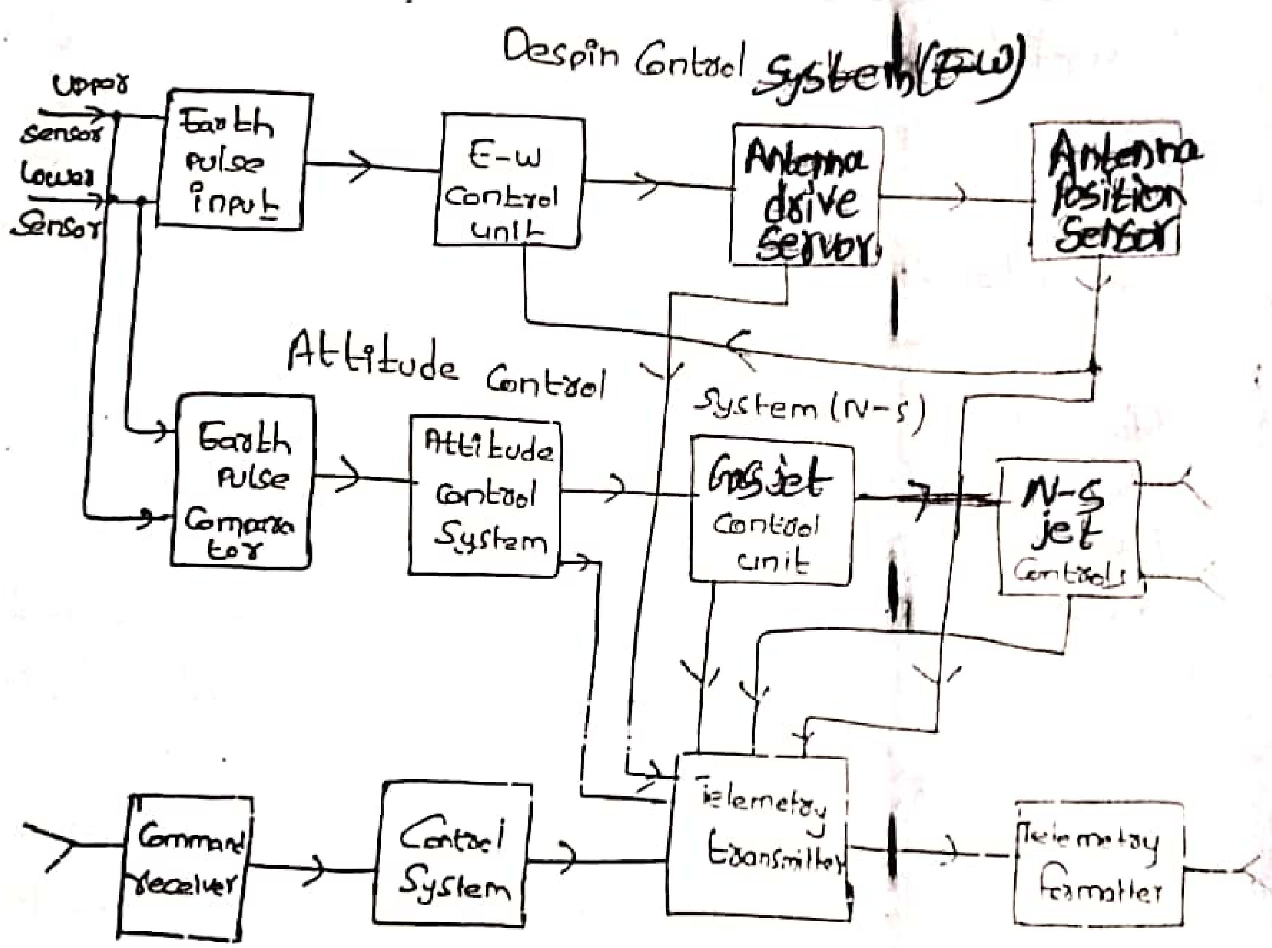


figure: Principle of N-S Control of a spinner satellite using infrared Earth station.

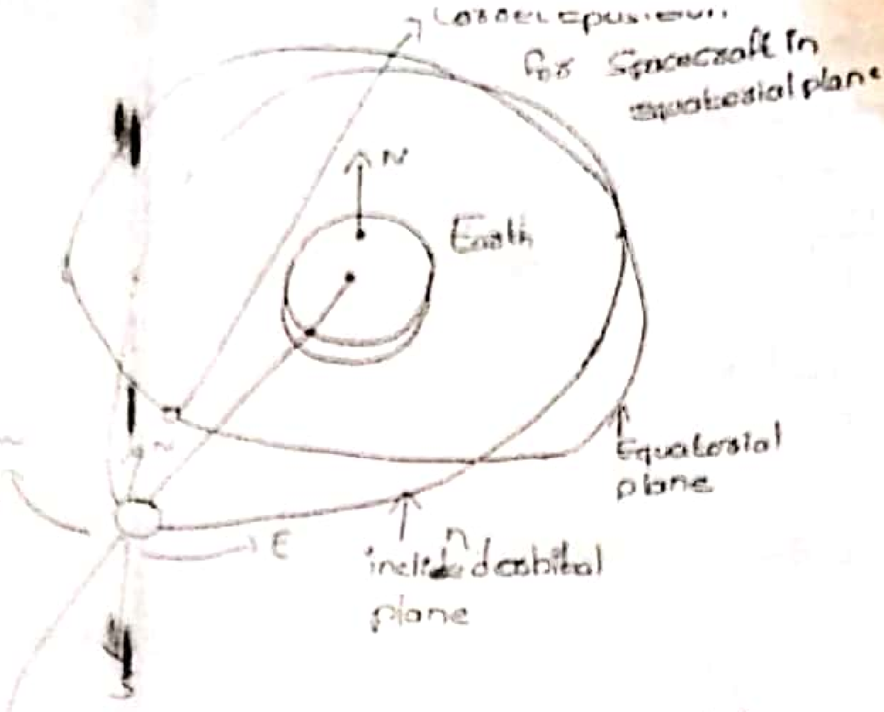
figure illustrates how an infrared sensor on the spinning of a satellite can be used to control pointing toward the earth.



Command and telemetry system

figure : Typical onboard control system for spinner satellite.

Above figure shows a typical control system using the technique. The control system will be complex for a three axes stabilized satellite and may on computer to process the sensor data and commands.



Spacecraft position in inclined orbital plane

3(a)(4)

Above figure shows a diagram of an inclined orbital plane close to the geostationary orbit. for the orbit to be truly geostationary it must lie in the equatorial plane, be circular and have the correct altitude

If the orbit is not circular, a velocity increase or decrease will have to be made along the orbit, in the x-axis direction

The orbit of a geostationary satellite remains approximately circular for long periods of time and does not need frequent velocity corrections to maintain circularity.

The inclination of orbit of a satellite that starts out in a geostationary orbit increases at an average rate of about 0.85° per year, with an inclination for satellite in an

* Most GEO Satellites are specified to remain w box of $\pm 0.05^\circ$ and so, in practice corrections, called South station keeping maneuver are made every to keep the error small.

* East-west station keeping is effected by the use jets of satellite. for a satellite located away from the at 75°E and 252°E, a slow drift toward these point

* Low earth orbit and medium earth orbit satellite AOC systems to maintain the correct orbit and atti continous communication.

* Because of much stronger gravitational force of in LEO orbit, attitude stabilization is often accompl rigid gravity gradient boom.

Telemetry, Tracking Command and monitoring :- ⑥

5(b) (i)

* On large geostationary Satellites, Some repointing of individual antennas may be possible, under the Command of TTC & M System.

Telemetry and Monitoring System :-

* The monitoring system Collects data from many Sensors with in the Satellite and Sends these data to the Controlling earth station.
* There may Several hundreds sensors located on the Satellite to monitor Pressure in the fuel tanks, Voltage and Current in the power Conditioning unit, current drawn by each system Subsystem, and critical Voltages and Currents in the Communications electronics.
* Telemetry data are usually digitized and transmitted a phase shift keying of low power telemetry Carrier using time divison techniques.
* A low data rate is normally used to allow the receiver at the earth station to have a narrow bandwidth band they maintain a high Carrier to noise ratio.
* The entire TDM frame may Contain thousands of bits of data and take Several seconds to transmit. At the Controlling earth Station a Computer Can be used to monitor, store, and decode the telemetry data so that the Status of any System or Sensor on the Satellite Can be determined immediately by the Controller on the earth.

(i) Tracking :-

* A number of techniques can be used to determine the correct orbit of a satellite. Velocity and acceleration sensors on the satellite can be used to establish the change in orbit from the last known position, by integration of the data

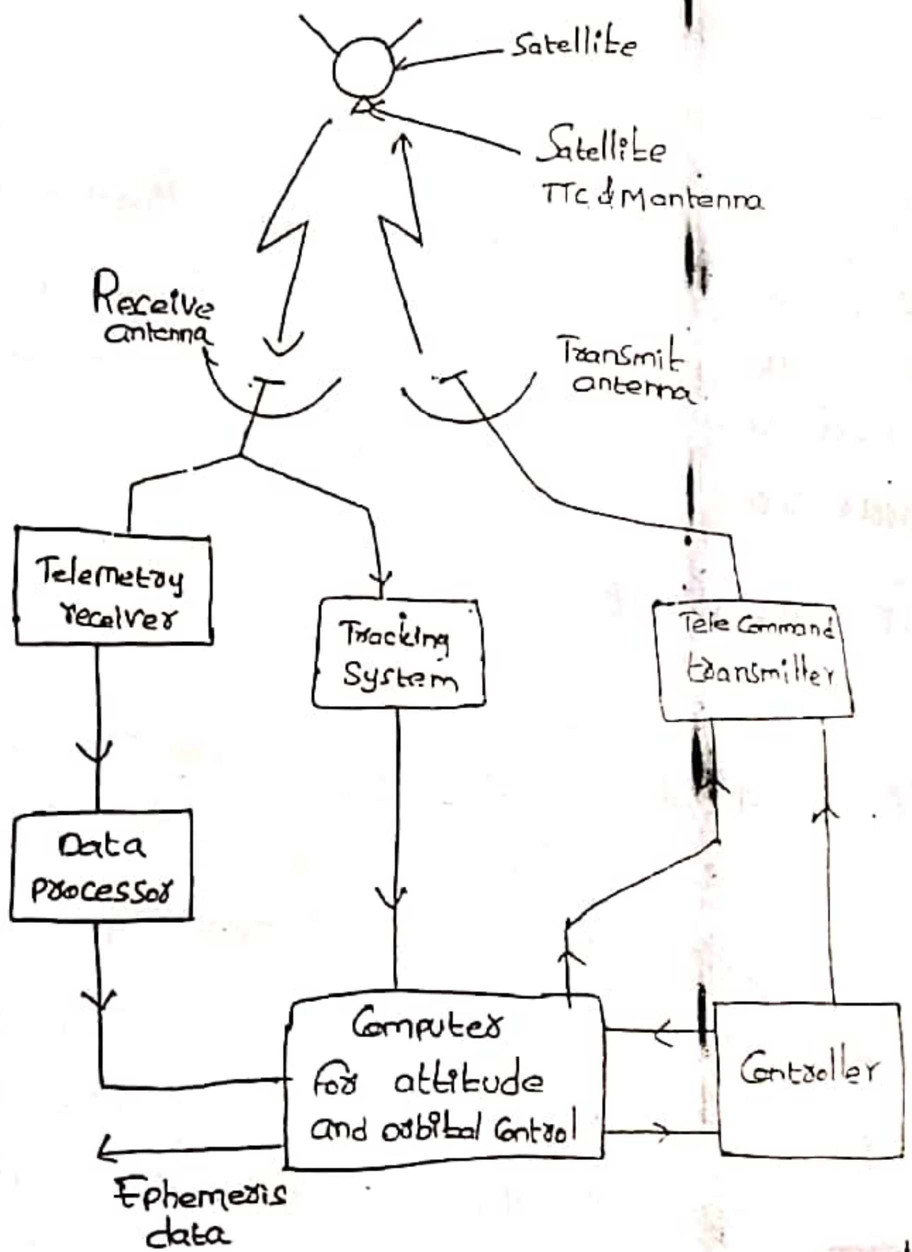


Figure : Typical tracking, telemetry Command and monitoring System

The earth station controlling the satellite can observe the Doppler shift of the telemetry carrier or beacon transmitter carrier to determine the rate at which range is changing. 3(b)

Ranging tones are also used for range measurement. A carrier generated on board the satellite is modulated with a series of sine wave frequency, usually harmonically related.

The phase of the sine wave modulation components is compared at an earth station, and the number of wavelengths of each frequency is calculated

Ambiguities in the numbers are resolved by reference to lower frequencies and prior knowledge of approximate range of the satellite

If sufficiently high frequencies are used, perhaps even the carrier frequency, range can be measured to millimeter accuracy

ommand :-

The command system is used to make changes in attitude and corrections to the orbit and to control the communication system. During launch, it is used to control the firing of the apogee kick motor and to spin up a spinner or extend the solar sails and antennas of a three-axis stabilized satellite

* The Command structure must possess safeguards against unauthorized attempts to make changes to the satellites operati and also against inadvertent operation of a control due to errors in a received command.

2)

* The control code is converted into a command word which is se in a TDM frame to the satellite. After checking for validit in the satellite, the word is sent back to the control statio via the telemetry link where it is checked again in the computer.

* If it is found to have been received correctly, an executi instruction will be sent to the satellite so that the com. is executed. The entire process may take 5 or 10s, but minimize risk of erroneous commands causing a satellite malfunction.

* The command and telemetry links are usually seperate from communication system; although they may operate in the sa frequency band (6 and 4 GHz). Two levels of command syst are used in the Intelsat satellite: the main system oper in the 6GHz band, in a gap between the communication c frequencies

* The main telemetry system uses a similar gap in th 4GHz band. These are earth-coverage horns, so the main system can be used only after correct attitude of the satellite is achieved.

Power Systems :-

* The Sun is a powerful Source of an energy. In the total Vaccum of outer space, at geostationary altitude, the radiation failing on a satellite has intensity of 1.39kw/m². Solar cells do not convert all this incident energy into electrical power; their efficiency is typically 20 to 25% at beginning of life (BOL) but falls with time because of aging of cells and etching of the surface by micrometer impacts.

* A Spin-stabilized Satellite usually has a cylindrical body covered in solar cells. Because the Solar cells are on a cylindrical surface, half of the cells are not illuminated at all, and at the edges of the illuminated half, the low angle of incidence results in little electrical power being generated

* A three axis stabilized Satellite can make better use of its cells area, since the cells can be arranged on flat panels that can be rotated to maintain normal incidence of the Sun light. only one third of the total area of solar cells is needed relative to a spinner with some saving in weight.

* Solar sails must be rotated by an electric motor once per 24h to keep the cells in full sunlight. This causes the cells to heat up, typically to 50°C to 80°C, which causes a drop in output voltage.

* The Satellite must carry batteries to power the subsystems during launch and during eclipse. Eclipses occur twice per year, around the spring and fall equinoxes, when the earth's the satellite.

* TV broadcast satellites may not carry sufficient capacity to supply their high power transmitters during eclipse and may shut down. By locating the satellite w of the longitude of service area, the eclipse will occur after 1 A local time for the service area when the shut down is more acceptable.

3(b)(3)

*

Communications Subsystem :

Description of the Communications system

* A Communications satellite exists to provide a platform geostationary orbit for the relaying of voice, video and data unications.

* All other subsystems on the satellite exist solely to support the Communications System, although this may represent only small part of the volume, weight and cost of satellite in orbit

* Since it is the Communications System that earns the real for the system operator, Communications Satellites are designed to provide the largest traffic capacity possible

* Successive satellites have become larger heavier and more but rate at which traffic capacity has increased has been resulting in a lower cost per telephone circuit (or) channel bit with each succeeding generation of satellite

* The Satellite transponders have limited out put power and earth st are atleast 36,000km away from a GEO Satellite, So the received level even with large aperture earth station antennas, is very sm and rarely exceeds 10^{-10} W.

* For the system to perform satisfactorily, the signal power mu exceeds the power of the noise generated in the receiver b between 5 and 25 dB, depending on the bandwidth of transmitt signal and modulation scheme used

* Early Communications Satellites were fitted with transponde 250 (or) 500 MHz band width but had low gain antennas and tran of 1 or 2 W out put power.

* The earth station receiver could not achieve an adequa signal to noise ratio when the full bandwidth was used with result the system was power limited.

* The 500-MHz bands originally allocated for 6/4 and 14/1 satellite communications have become very congested and are n completely filled for some segments of geostationary orbit.

* Many systems now use 14/11 GHz for TV broadcast and dist and 30/20 GHz systems are introducing Internet-like services f GEO.

* The standard spacing between GEO Satellites was originally se 3°, but under regulations covering North America and much of rest of the world, the spacing has been reduced to 2°.

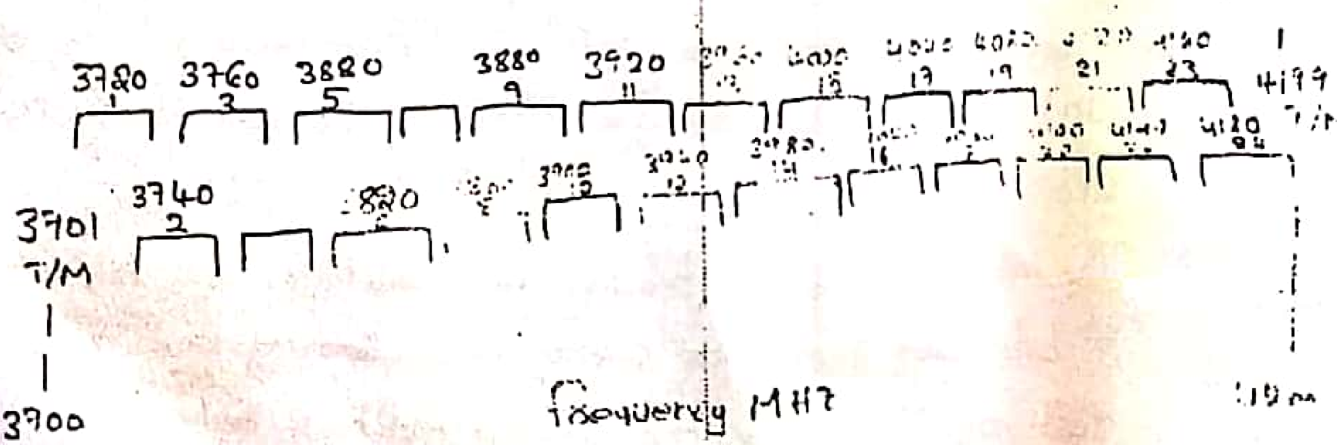
Transponders :-

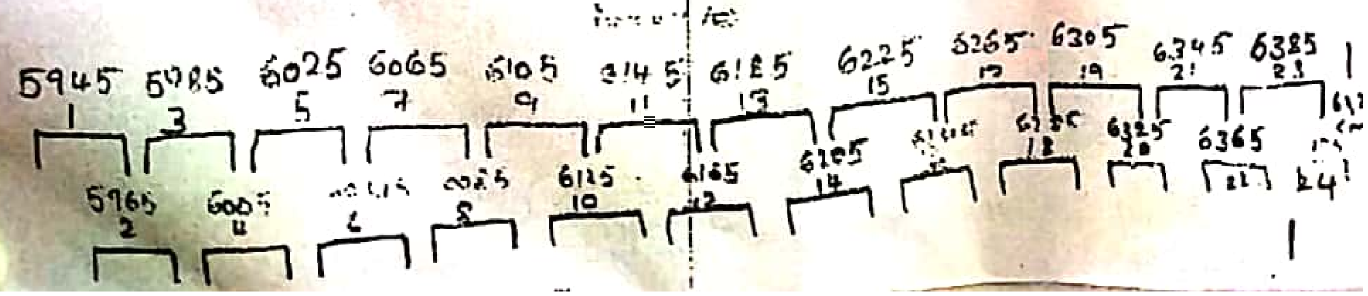
Signals transmitted by an earth station are received at the satellite by either a zone beam (or) a spot beam antenna. Zone beams can receive from transmitters any where with in the coverage zone, where as spot beams have limited coverage.

The recieved signal is often taken to two low noise amplifiers and is recombined at their output to provide redundancy. If either amplifier fails, the other one can still carry all the traffic.

Since all carriers from one antenna must pass through a low noise amplifier, a failure at that point is catastrophic. Redundancy is provided wherever failure of one component will cause the loss of significant part of satellite's communication capacity.

Transmit





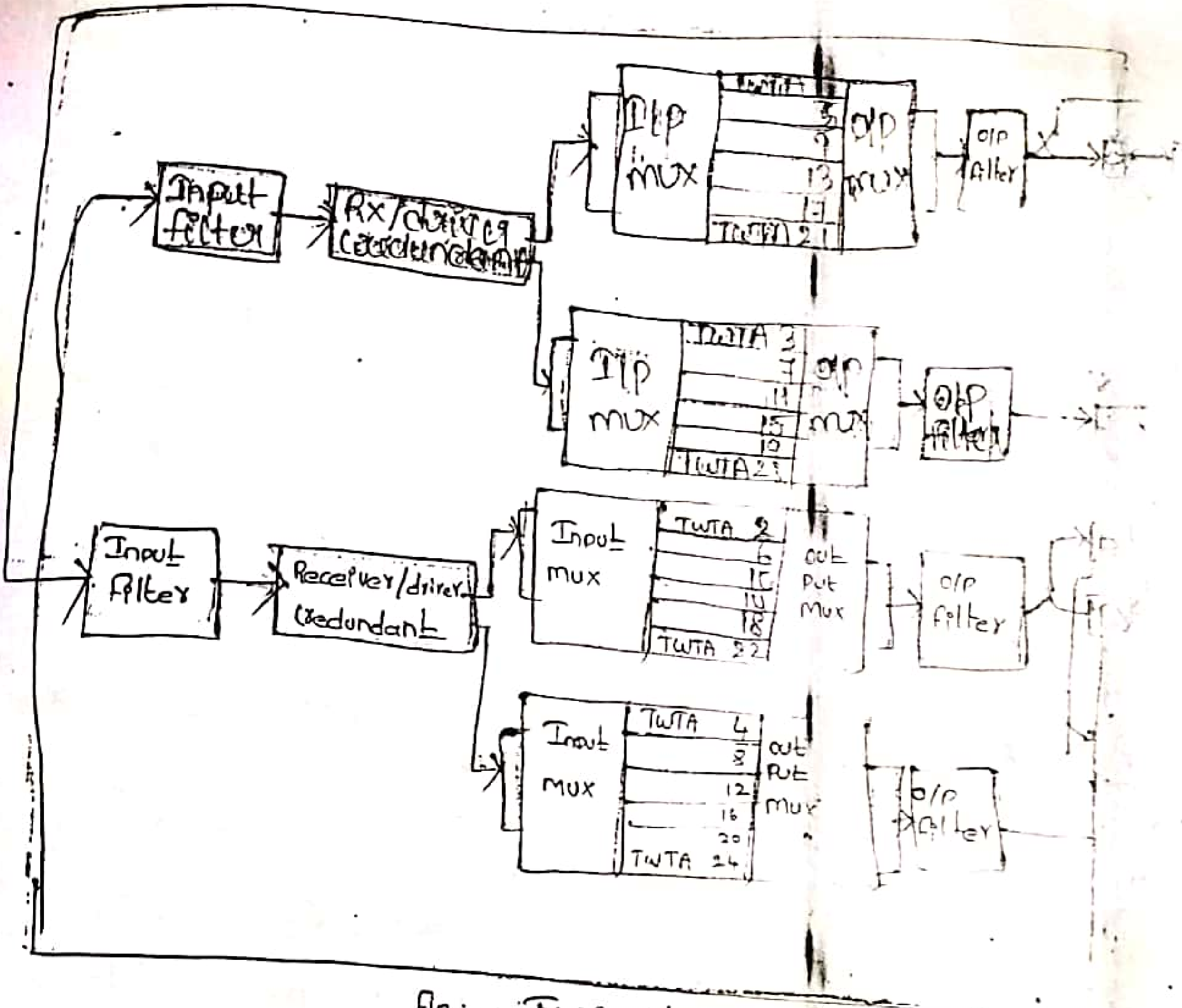


Fig :- Transponder

* Above figure shows a simplified block diagram of a satellite communication subsystem for the 6/4 GHz band. The 500 MHz bandwidth is divided up into channels, often 36 MHz wide, which is each handled by a seperate transponder.

A transponder consists of a band-pass filter to select the channels band of frequencies, a down converter to change and from 6GHz at the input to 4GHz at the output, and one amplifier.

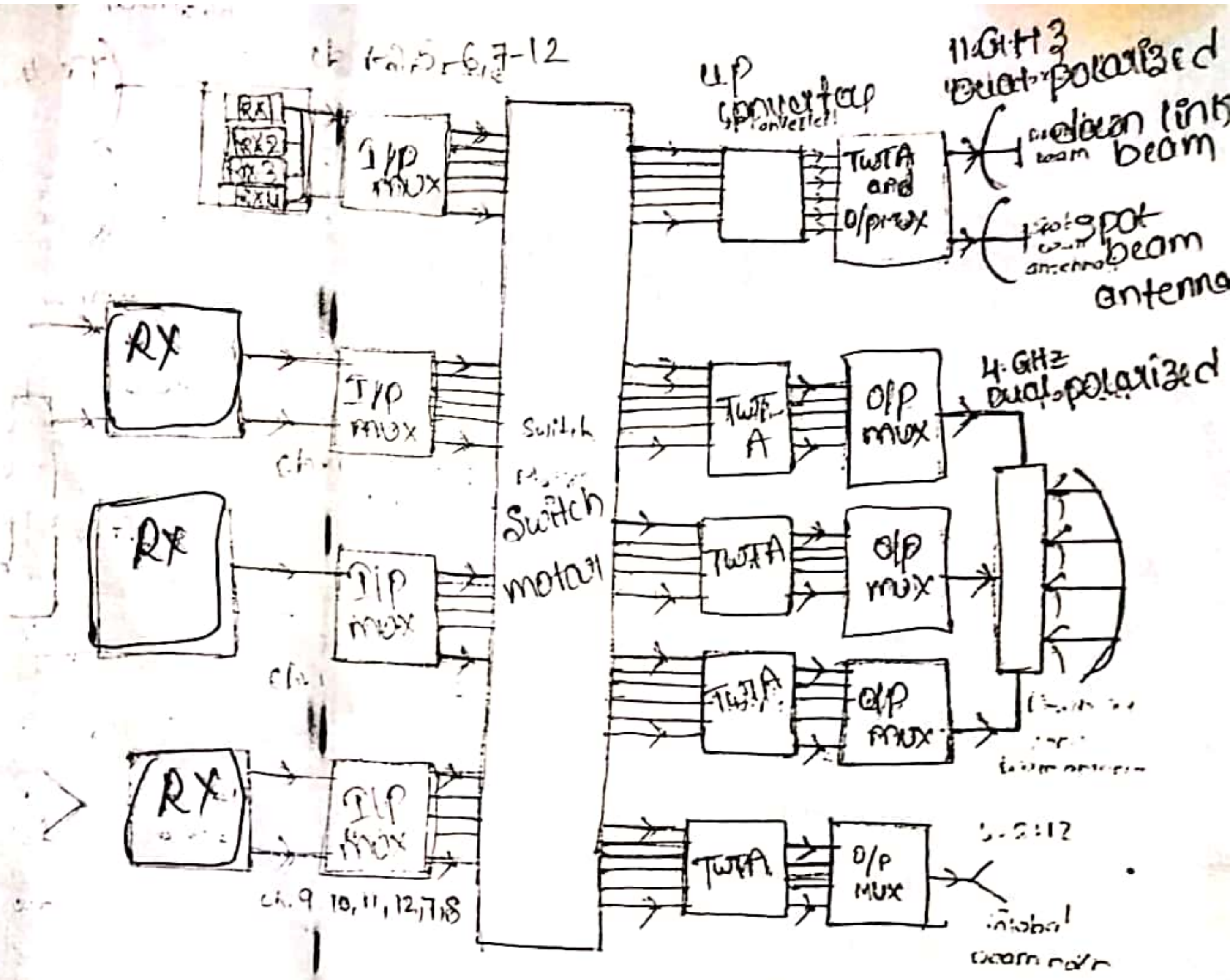


fig - Simplified block diagram of an INTELSAT V Communication System

Above figure shows a simplified diagram of the Communication System carried by INTELSAT V Satellites. The later Series of Intelsat Satellite use a Similar arrangement.

The bulk of the traffic is carried by 6/4 GHz Section, With total bandwidth of 2000 MHz available in frequency reuse. The Switch matrix allows a very large no. of Variations in connecting 6 GHz receivers to the 4 GHz transmitters.

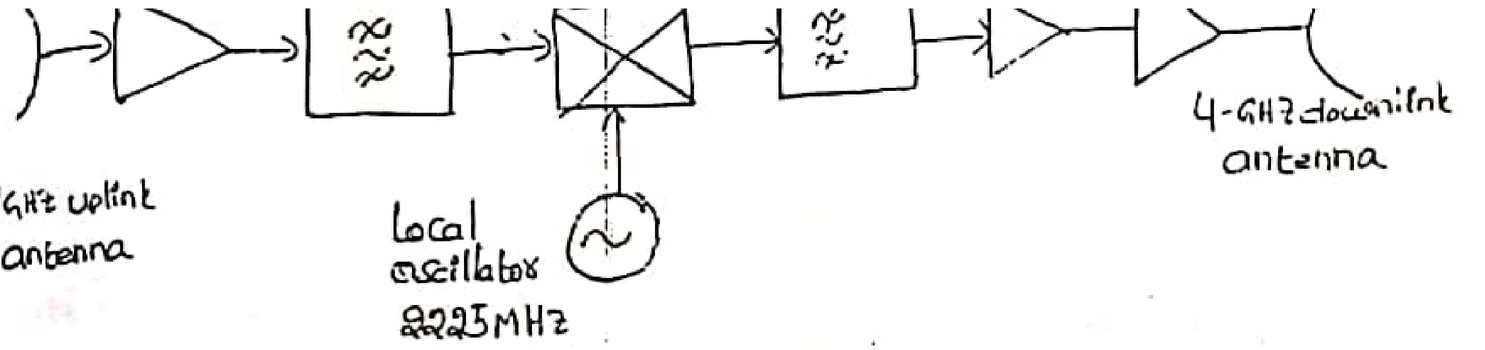


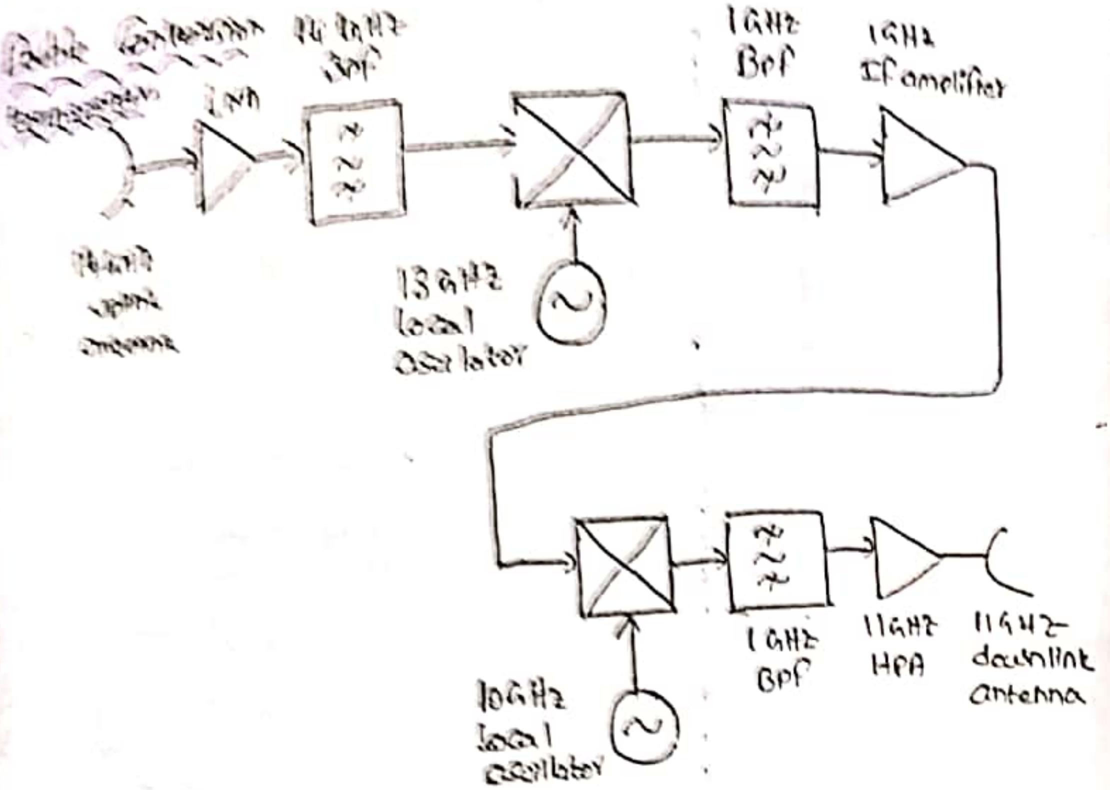
Figure: Simplified Single Conversion transpond (bent pipe) for 6/4 GH

* Above figure shows a typical single conversion bent pipe transponder of type used on many satellites for the 6/4 GHz band. The output RF amplifier is usually a solid state power amplifier (SSPA) unless a very output power is required, when a traveling wave tube amplifier would b

* The local oscillator is at 2225 MHz to provide the appropriate shi frequency from the 6-GHz uplink frequency to the 4-GHz down link frequency, and band-pass filter after the mixer removes unwanted f uency, and ncies resulting from down conversion operation.

* The attenuator can be controlled via the uplink command system t set the gain of the transponder. Redundancy is provided for high power amplifiers (HPA) in each transponder by including a spare TWT (or) solid state amplifier (~~HPA~~) (SSPA) that can be switched into circuit if th primary power amplifier fails

12

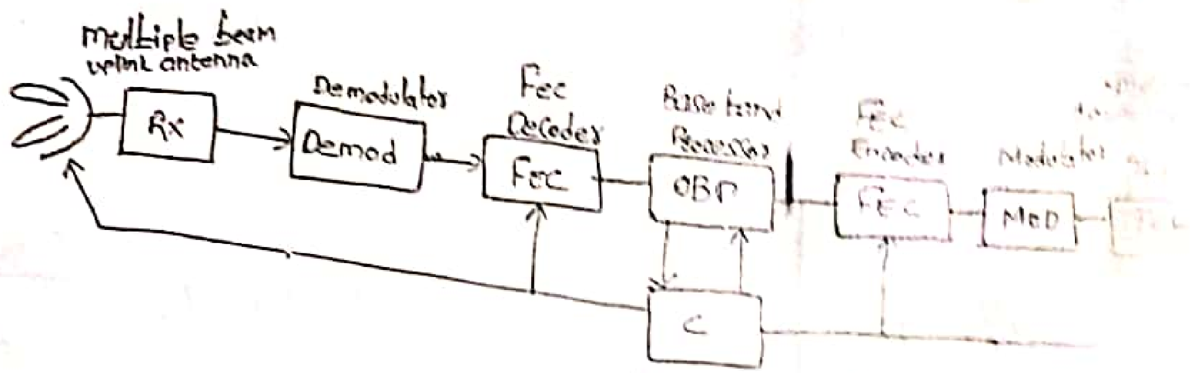


Simplified double conversion transponder for 14/11 GHz band.

* Transponders for use in the 14/11 GHz bands normally employ a double frequency conversion scheme. is shown in above figure.
* It is easier to make filters, amplifiers and equalizers at an intermediate frequency (IF) such as 1100 MHz than at 14 or 11 GHz, so the incoming 14-GHz carrier is translated to an IF of around 1 GHz. The amplification and filtering are performed at 1 GHz and relatively high-level carrier is translated back to 11 GHz for amplification by the HPA.

On board processing transponder :-

On board processing may also be used to advantage. to switch between the uplink access technique (eg MF-TDMA) and downlink access technique (eg TDM) so that small earth stations may access each other directly via the satellite.



* The processor can provide the data storage needed for switched beam system and also can perform error correction independently uplink and downlink.

Satellite ANTENNAS :-

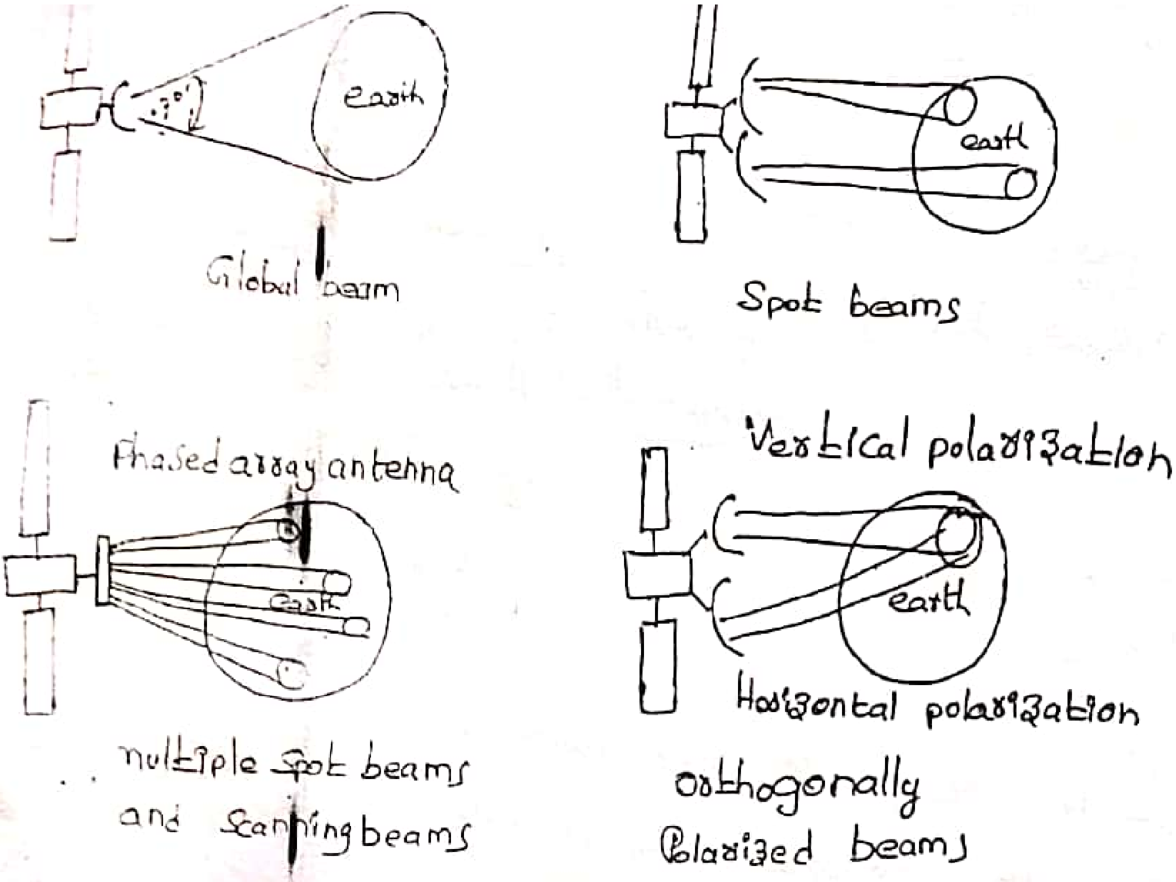
Basic antenna types are Relationships:

Four main types of antennas are used on satellites. These are

1. Wire antennas ; monopoles and dipoles
2. Horn antennas
3. Reflector antennas
4. Array antennas.

Wire antennas

Wire antennas are used primarily at VHF and UHF to provide action for the TTC & M systems. They are positioned with great on the body of the satellite in attempt to provide omni direct coverage. Most satellites measure only a few wave lengths are frequencies, which makes it difficult to get the required antenna and therefore tend to some orientations of the satellite in which sensitivity of the TTC & M system reduced by nulls in antenna



Typical Satellite antenna patterns and coverage zones.

Horn antennas :

Horn antennas are used at microwave frequencies when relatively wide beams are required, as for global coverage, A horn is flared section of waveguides that provides an aperture several wave lengths wide and a good match between the waveguide impedence and free space.

Horns are also used feeds for reflectors, either ~~slightly~~ singly or in clusters. Horns and reflectors are examples of aperture antennas that launch a wave into free space from wave guide.

It is difficult to obtain gains much greater than 23 dB or beam widths narrower than about 10° with horn antennas. for higher gains or narrow beamwidths a reflector antenna (or) array must be used.

* Reflector antennas are usually illuminated by one or mo horns and provide a large aperture than can be achieved with horn alone. For maximum gain, it is necessary to generate a plane wave in the aperture of the reflector.

* This is achieved by choosing a reflector profile that has e path lengths from the feed to aperture, so that all the rays radiated by the feed and reflected by the reflector reach the aperture with the same phase angle and creates a uni phase front.

The following approximate relationships will be used here to guide the selection of antennas for communications satellite

An aperture antenna has a gain G given by

$$G = \eta_A 4\pi A/\lambda^2 \quad \text{— (1)}$$

where A is the area of the antenna in meters

λ is the operating wavelength in meters.

η_A is the aperture efficiency of the antenna.

Horn antennas tend to have higher efficiencies than reflec antennas, typically range 65 to 80%. If the aperture is circu can be written as

$$G = \eta_A (\pi D/\lambda)^2 \quad \text{— (2)}$$

Where D is the diameter of the circular aperture in mete

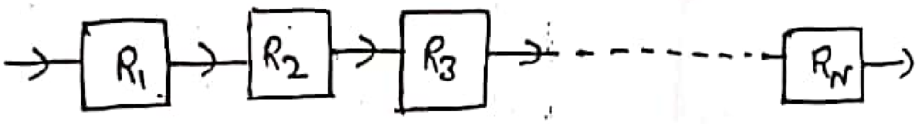
The 3dB beam width in a given plane for an antenna with di mension 'D' in that plane is

$$\theta_{3dB} \simeq 75\lambda/D \text{ degrees.} \quad \text{— (3)}$$

Redundancy:-

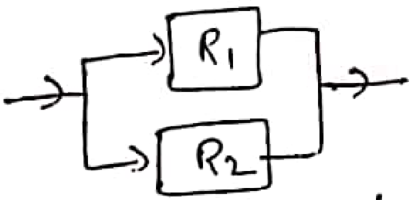
In a satellite, many devices are used, each with a different MTBF, and failure of one device may cause catastrophic failure of complete subsystem. If we incorporate redundant devices, the subsystem can continue to function correctly.

(a)



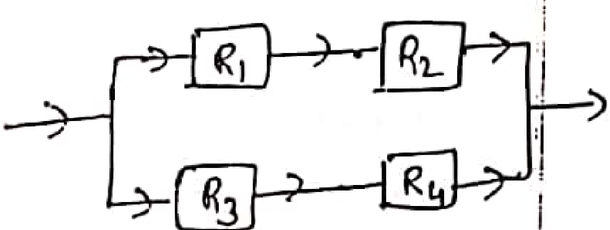
Series Connection

(b)

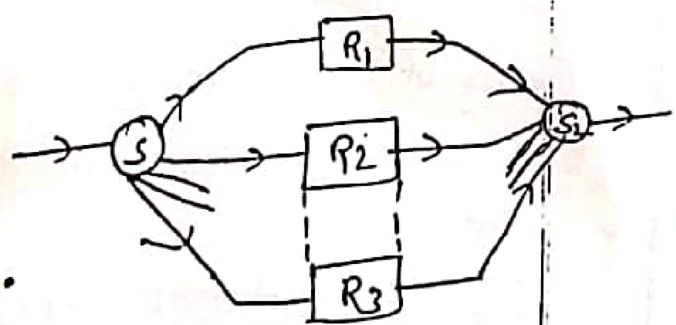


Parallel connection

(c)



Series/parallel Connection



(d) Switch connection.

(16)

The average failure rate λ, is the reciprocal of the MTBF, m. If we assume that λ is constant, then

$$\lambda = \frac{\text{Number of failures in given time}}{\text{Number of surviving Components}}$$

$$\lambda = \frac{1}{N_s}\frac{\Delta N_t}{\Delta t} = \frac{1}{N_s}\frac{dN_t}{dt} = \frac{1}{MTBF}$$

failure rate λ is often given as the average failure rate per 10^9h. The rate of failure, dN_f/dt is the negative of rate survival dN_s/dt, So we can ~~defined~~ redefined λ as

$$\lambda = -\frac{1}{N_s}\frac{dN_s}{dt}$$

The Reliability R is N_s/N_0 so

$$\lambda = \frac{-1}{N_0 R}\frac{d}{dt}(N_0 R)$$

$$= -\frac{1}{R}\frac{dR}{dt}$$

the $R = e^{-\lambda t}$

~~Thus the reliabil~~

However, end of useful life it is usually taken the time t_1 at which R falls to 0.37 (1/e

$$t_1 = 1/\lambda = m$$

The probability of a device failing, therefore has a relationship to the MTBF and is represented by the

Series Connection, used in Solar cells arrays, ... used to provide redundancy of the high power amplifiers in satell... transponders, and b switched connection often used to provide parallel paths with multiple transponders.

* The switched connection arrangement shown in figure is also referred to as ring redundancy since any component can be switched in for any other.
* The important point to note is that the active devices ($R_1, R_2 --- R_n$) have sufficient bandwidth, power output range etc to be able to handle any of channels that might be switched through to them.

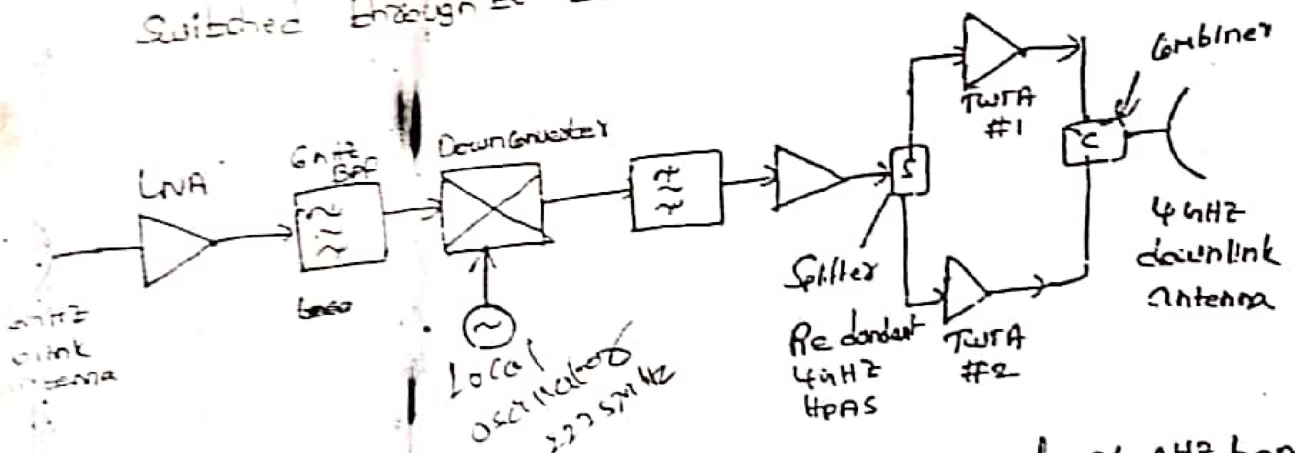


Figure: Redundant TWTA Configuration in HPA of 6/4 GHz band

* The parallel connection of two TWTs as shown in figure raises the reliability of amplifier stage to 0.60 at the MTBF period, assuming zero probability of a short circuit.