UNIT-IV
EARTH STATION TECHNOLOGY

INTRODUCTION

Earth station is a vital element in any satellite communication network. The function of an earth station is to receive information from or transmit information to, the satellite network in the most cost-effective and reliable manner while retaining the desired signal quality. The design of earth station configuration depends upon many factors and its location. But it is fundamentally governed by its location which are listed below,

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

The factors are

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

EARTH STATION CONFIGURATION

Any earth station consists of four major subsystems

- Transmitter
- Receiver
- Antenna
- Tracking equipment

Two other important subsystems are

- Terrestrial interface equipment
- Power supply.

The earth station depends on the following parameters

- Transmitter power
- Choice of frequency
- Gain of antenna
- Antenna efficiency
- Antenna pointing accuracy
- Noise temperature
- Local conditions such as wind, weather etc,
- Polarization
- Propagation losses

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

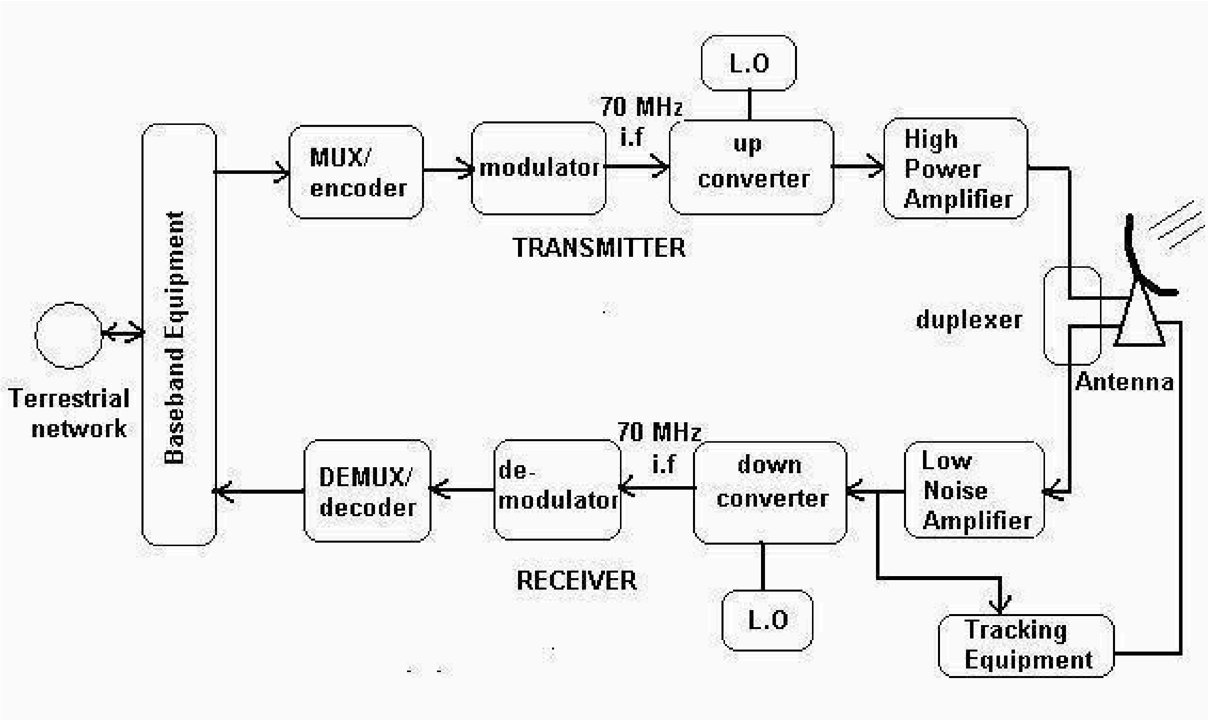


Fig- General Configuration of an Earth Station

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

- The encoder performs error correction coding to reduce the error rate, by introducing extra digits into digital stream generated by the base band equipment. The extra digits carry information. The presence of noise and non-ideal nature of any communication channel produces error rate is established above which the received information is not stable.
- The function of the modulator is to accept the symbol stream from the encoder and use it to modulate an intermediate frequency (I.F) carrier. In satellite communication, I.F carrier frequency is chosen at 70 MHz for communication using a 36 MHz transponder bandwidth and at 140 MHz for a transponder bandwidth of 54 or 72 MHz. The I.F is needed because it is difficult to design a modulator that works at the uplink frequency of 6 GHz (or 14GHz) directly.
- The modulated I.F carrier is fed to the up-converter and frequency-translated to the uplink r-f frequency.
- This modulated R.F carrier is then amplified by the high power amplifier (HPA) to a suitable level for transmission and radiation by the antenna to the satellite.
- On the receive side, the earth station antenna receives the low-level modulated R.F carrier in the downlink frequency spectrum.

- The low noise amplifier (LNA) is used to amplify the weak received signals and improve the signal to Noise ratio (SNR). The error rate requirements can be met more easily.
- R.F is to be reconverted to I.F at 70 or 140 MHz because it is easier design a demodulation to work at these frequencies than 4 or 12 GHz.
- The demodulator estimate which of the possible symbols was transmitted based on observation of the received if carrier.
- The decoder performs a function opposite that of the encoder. Because the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and recover information-bearing digits.
- The information stream is fed to the base-band equipment for processing for delivery to the terrestrial network.
- The tracking equipments track the satellite and align the beam towards it to facilitate communication.

ANTENNA SUBSYSTEM

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

i)Axi-Symmetric Configuration

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

- **Primary Feed**

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

- **Cassegrain**

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

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

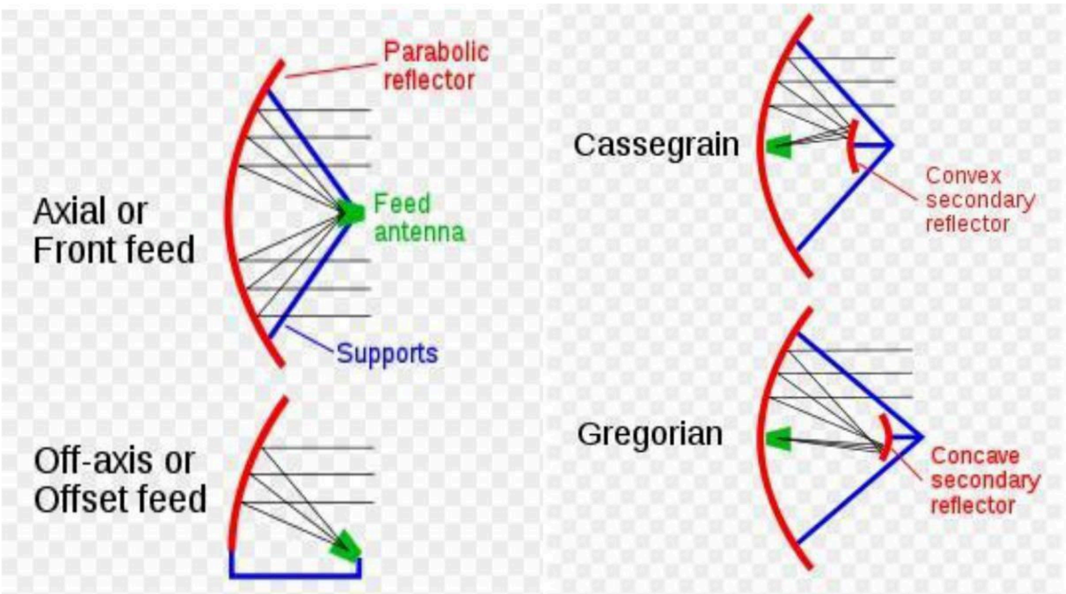
- **Gregorian**

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



ANTENNA REFLECTOR

Mostly parabolic reflectors are used as the main antenna for the earth stations because of the high gain available from the reflector and the ability of focusing a parallel beam into a point at the focus where the feed, i.e., the receiving/radiating element is located .For large antenna system more than one reflector surfaces may be used in as in the cassegrain antenna system.

Earth stations are also classified on the basis of services for example:
1.Two way TV ,Telephony and data
1. Two way TV
2. TV receive only and two way telephony
and data 4.Two way data

From the classifications it is obvious that the technology of earth station will vary considerably on the performance and the service requirements of earth station.
For mechanical design of parabolic reflector the following parameters are required to be considered:

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

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

$$\text{Gain}= (\eta 4\Pi A_{eff})/ \lambda^2$$

Where Aeff is the aperture
λ is wave length
η is efficiency of antenna system
For a parabolic antenna with circular aperture diameter D, the gain of the antenna is :

$$\text{Gain}= (\eta 4\Pi/ \lambda^2)(\Pi D^2/4)$$

$$= \eta (\Pi D/ \lambda)^2$$

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

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

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

ANTENNA MOUNT

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

i) The Azimuth –elevation mount

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

ii) The X-Y mount.

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

INPUT BACK-OFF

In order to reduce the intermodulation distortion, the operating point of the TWT must be shifted closer to the linear portion of the curve, the reduction in input power being referred to as input backoff . The input backoff is the difference in decibels between the carrier input at the operating point and the saturation input which would be required for single-carrier operation.

HIGH POWER AMPLIFIER

Amplifier may work with signals of all level, depending on where they are in the signal chain. One type of Amplifier takes low power signals and increases them greatly in order to send the signal over a wire or from a dish. This is often called as high power amplifier, typical hardware used for earth station HPAs is similar to that used aboard the satellite for the transponders, but they typically operate at much higher powers.

Two most commonly used high power amplifier are TWT and klystron. TWT amplifier can offer bandwidths of the order of 500Mhz and are capable of providing powers of up to 10kW.

Klystrons are narrowband devices typically offering bandwidths of the order 40Mhz ,tunable over the entire 500 Mhz bandwidth. Maximum power rate of the order of 3kW.

The configuration of high power amplifiers depends on the type of application. For multi-carrier operation; two types of configuration are used depending on the stage where the carrier are combined. in a single amplifier configuration all the carriers are combined before the amplifier and therefore only one HPA is used as shown in the below figure.

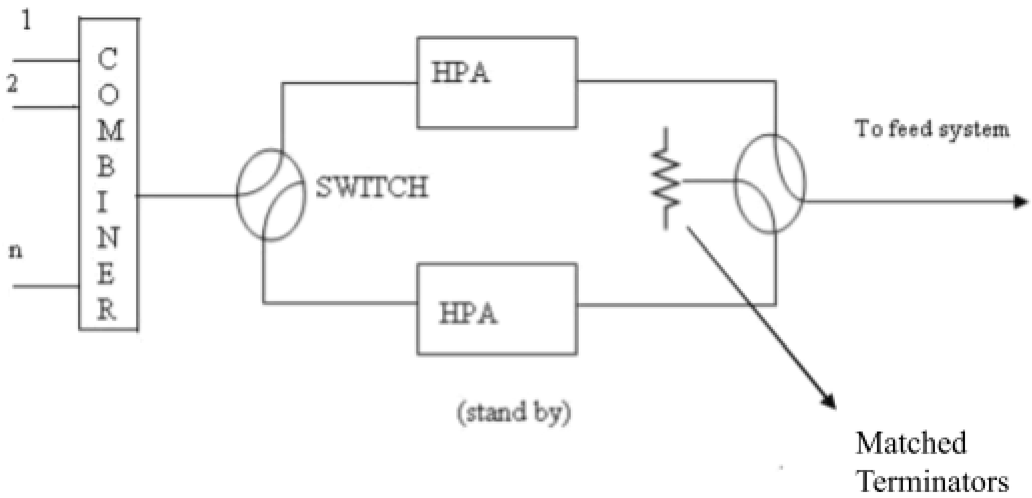


Fig-single stage HPA

In a multiple amplifier configuration each HPA amplifies one or a few of the total carriers. All the amplified signals are then combined at the output of the HPAs as shown in below figure.

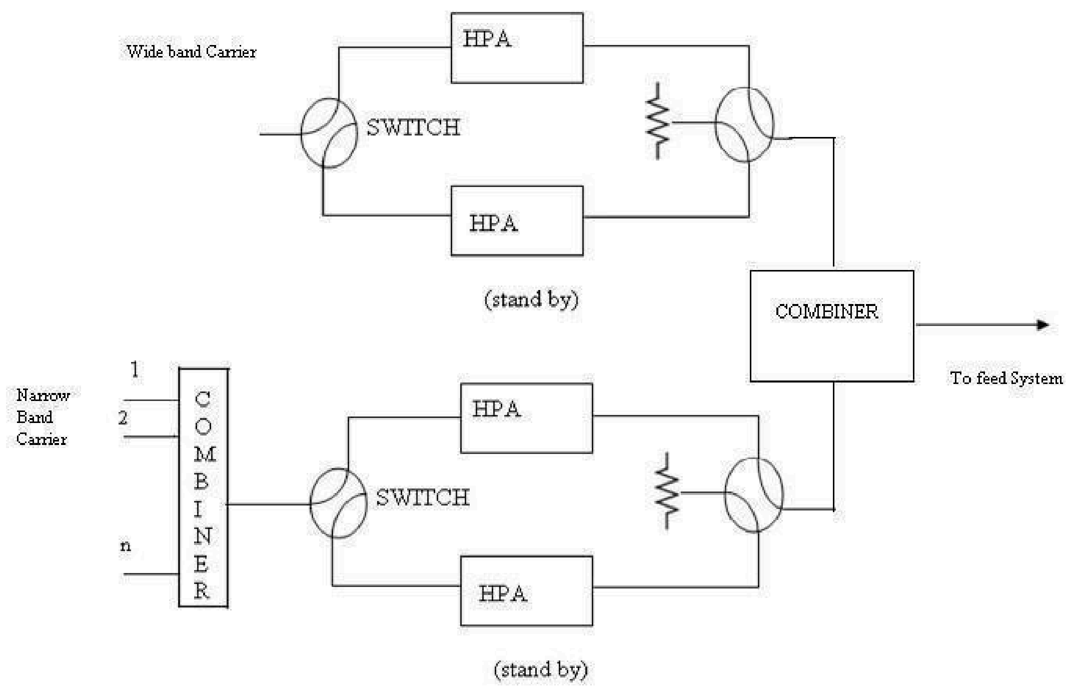


Fig-multi stage HPA

The high power amplifier (HPA) in an earth station facility provides the RF carrier power to the input terminals of the antenna that, when combined with the antenna gain, yields the equivalent isotropic radiated power (EIRP) required for the uplink to the satellite. The

Waveguide loss between the HPA and the antenna must be accounted for in the calculation of the EIRP.

An earth station HPA can be one of three types: a klystron power amplifier (KPA), a traveling wave tube amplifier (TWTA), or a solid state power amplifier (SSPA). The KPA and TWTA achieve amplification by modulating the flow of electrons through a vacuum tube. Solid state power amplifiers use gallium arsenide (GaAs) field effect transistors (FETs) that are configured using power combining techniques. The klystron is a narrowband, high power device, while TWTAs and SSPAs have wide bandwidths and operate over a range of low, medium, and high powers.

The principal technical parameters characterizing an amplifier are its frequency, and width, output power, gain, linearity, efficiency, and reliability. Size, weight, cabinet design, ease of maintenance, and safety are additional considerations. Cost factors include the cost of installation and the long term cost of ownership.

LOW NOISE AMPLIFIER

The low-noise amplifier (LNA) 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. In calculations involving noise, it is usually more convenient to refer all noise levels to the LNA input, where the total receiver noise may be expressed in terms of an equivalent noise temperature.

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.

Types of LNA in common use today include:

- Uncooled Field-Effect Transistor (FET) amplifiers which have a noise temperature of 55 to 75K at 4 GHz or around 200K at 11 GHz
- Amplifiers cooled by thermoelectric diodes which have a noise temperature of 35K to 45K at 4 GHz and around 120K at 11 GHz

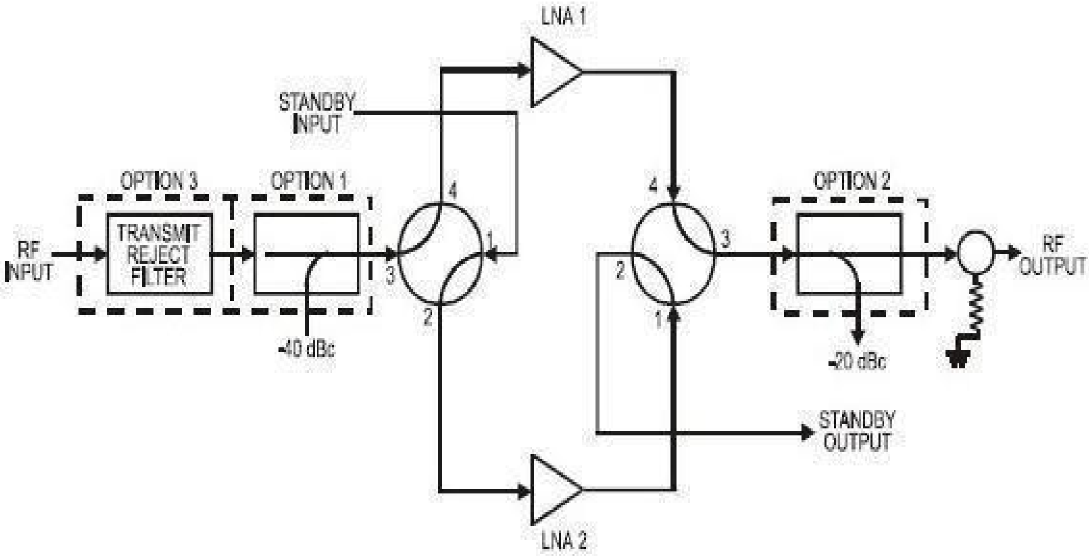


Fig-multi stage LNA

There are two variations of LNA they are :

A low noise block-downconverter (or LNB) is the receiving device of a parabolic satellite dish antenna of the type commonly used for satellite TV reception. The device is sometimes called an LNA (for low noise amplifier), LNC (for low noise converter) or even LND (for low noise downconverter) but as block-downconversion is the principal function of the device, LNB is the preferred term, although this acronym is often incorrectly expanded to the incomplete descript ions, low noise block or low noise block converter.

It is functionally equivalent to the dipole antenna used for most terrestrial TV reception, although it is actually waveguide based. Inside the LNB waveguide a metal pin, or probe, protrudes into the waveguide at right angles to the axis and this acts as an aerial, collecting the signal travelling down the waveguide.

The LNB is usually fixed on the satellite dish framework, at the focus of the reflector, and it derives its power from the connected receiver. This power is sent "up" the same cable that carries the received signals "down" to the receiver. The corresponding component in the transmit link uplink to a satellite is called a Block upconverter (BUC).

EARTH STATION TRACKING SYSTEM

Tracking is essential when the satellite drift, as seen by an earth station antenna is a significant fraction of an earth station's antenna beam width. An earth station's tracking system is required to perform some of the functions such as

i) Satellite acquisition ii)Automatic tracking iii)Manual tracking iv)Program tracking.

a)Satellite Acquisition

Before communication can be established it is necessary to acquire a satellite. One method is to program the antenna to perform a scan around the predicted position of the satellite. The automatic tacking is switched on when the receiver signal strength is sufficient to lock the tracking receiver to the beacon.

b)Automatic Tracking:

After acquisition a satellite needs to be tracked continuously. This function is performed by the automatic tracking system .Auto-tack systems are closed-loop control systems and are therefore highly accurate. This tracking mode is the preferred configuration when accuracy is the dominant criterion.

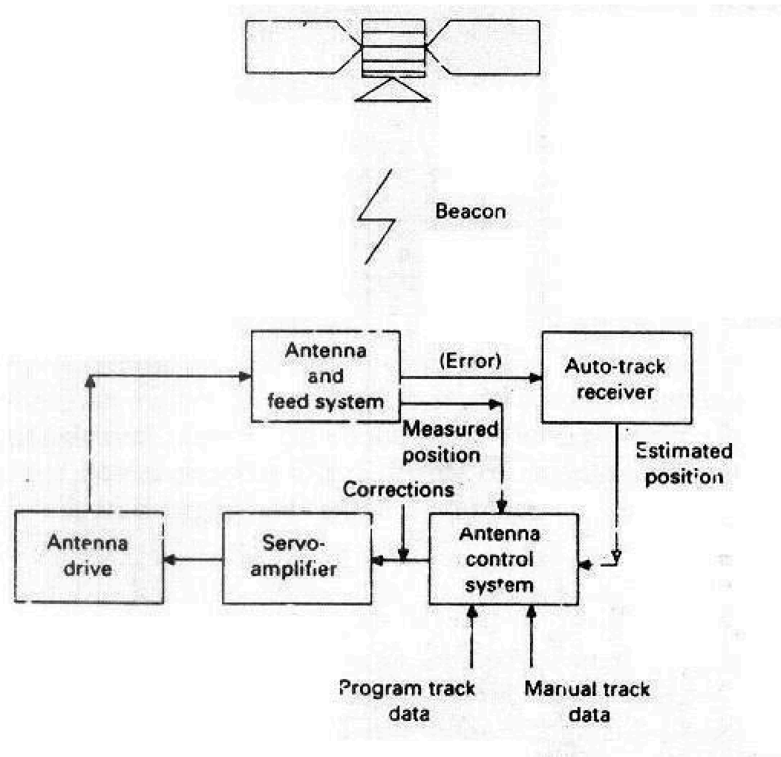
c)Manual track:

To avoid a total loss of communication due to a failure in the tracking system, earth stations generally also have manual mode. In this mode an antenna is moved through manual commands.

d)Program Track:

In this tracking mode the antenna is driven to the predicted satellite position by a computer. The satellite position predictions are usually supplied by the satellite operators. It may be noted that since a program track system is an open-loop control system, its accuracy is mainly governed by the accuracy of the prediction data.

MAIN ELEMENTS OF A SATELLITE TRACKING SYSTEM



Communication satellites transmit a beacon which is used by earth stations for tracking. The received beacon signal is fed into the auto-track receiver where tracking corrections or, in some auto-track systems estimated positions of the satellite are derived. In other auto-track techniques the feed system provides the required components of error signals. The outputs of the auto-track receivers are processed and used to drive each axis of the antenna to the estimated satellite position.

In the manual mode, an operator sets the desired angles for each axis on a control console. This position is compared with the actual antenna position, obtained through shaft encoders, and the difference signal is used to drive the antenna.

In the program track mode the desired antenna position is obtained from a computer. The difference in the desired antenna positions constitutes the error and is used to drive the antenna.

Auto Track system:

There are three main types of auto-track system which have been commonly used for satellite tracking;

i)conical scan; ii)monopulse ; iii)step-track.

i)CONICAL SCAN

The conical scan technique has evolved from the lobing technique used in the RADARS (Radio detection and ranging).In this technique an antenna beam is switched between two positions. When an approaching target is at the centre of these beams the echoes from each beam are equal in magnitude, but at other positions unequal. The antenna position is adjusted such that the amplitudes of echoes are equalized.

This concept was extended to a continuous rotation of a beam around a target ,giving rise to the conical scan technique .

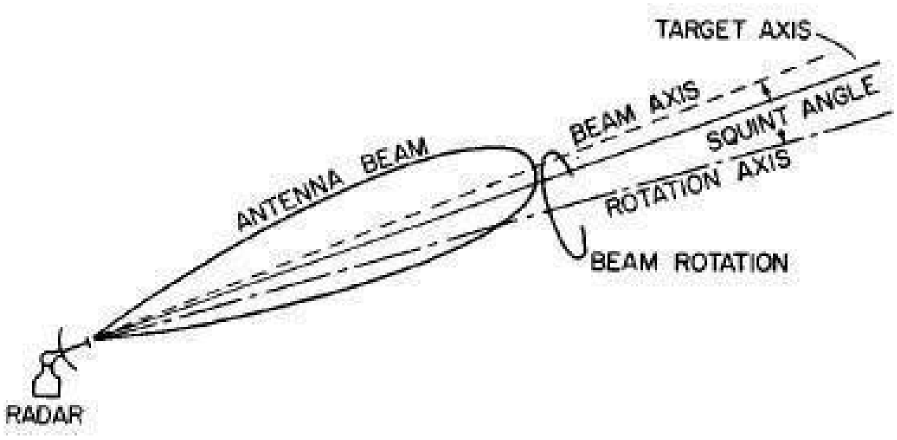


Figure shows the principle of this technique .An antenna beam is rotated around an axis (rotation axis) which is offset from the beam axis by a small squint angle .Whenever the satellite is off the target axis, the envelope of the received beacon is modulated at the rate of beam rotation.

The tracking receiver in the conical scan technique uses the full received power for extracting errors and hence the sensitivity requirement of the auto track receiver is reduced .The accuracy of the system is affected by amplitude disturbances .moreover the maximum gain of the antenna is not realized because of the squint introduced into the main beam. As a result of these limitations conical systems are surpassed by other tracking techniques.

ii)MONOPULSE TECHNIQUE

In the mono pulse technique the errors for driving the antenna system are derived by simultaneous lobbing of the received beacon –hence the name Static-split or monopulse. The inherent susceptibility of the conical scan technique to amplitude fluctuations is eliminated since errors are derived from simultaneous measurements.

Several mono pulse schemes such as amplitude comparison, phase comparison or amplitude phase comparison are possible. The amplitude comparison technique is the simplest and commonly used for satellite tracking. The basic principle of its operation is understood from Figure

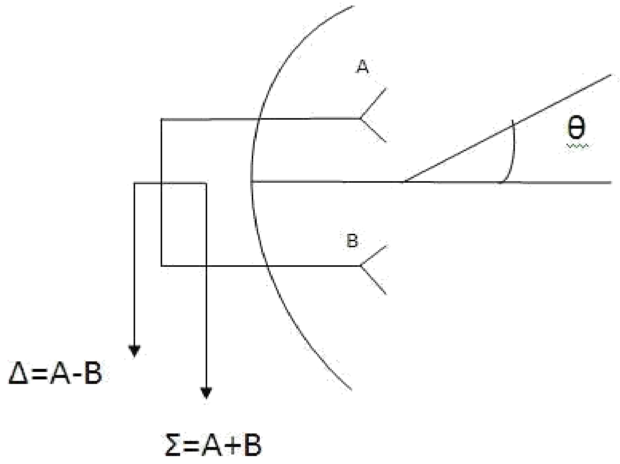


Fig: Mono pulse

Two horns are offset and mounted in a plane. Two types of patterns can be distinguished-a sum pattern Σ and a difference pattern . The difference pattern output with respect to sum pattern is zero when the satellite is centered, otherwise the output is proportional to the tracking error. It should be emphasized that the difference pattern must be detected with respect to the sum pattern to obtain the error. This can be achieved by a coherent detection process .That the difference pattern changes phase stability of the receiver be good.

Several techniques can be used to determine the sum and difference signals. One commonly used technique is used to use microwave circuits known as hybrids. Referring to fig1 a power from two horns A and B is fed into a microwave hybrid. A hybrid consists of two input arms ,A and B and two output arms the sum arm and the difference arm .The property of the hybrid is that the input powers appear as a sum in the 'Sum' arm and as a difference in the 'difference' arm.

iii) STEP –TRACK SYSTEM

In the step –track technique, error signals are derived from amplitude sensing. The operation is based on maximization of the received signal by moving the axes in small steps (hence the name step track) until a maximization is affected. The tracking accuracy of the technique depends on the step size and the signal to noise ratio. For high signal to noise ratios the standard deviation of tracking error approaches the step size.

Recent Tracking Techniques:

There have been some interesting recent developments in auto-track techniques which can potentially provide high accuracies at a low cost .In one proposed technique the sequential lobing technique has been I implemented by using rapid electronic switching of a s single beam which effectively approximates simultaneous lobing. The high rate of switching is achieved by the use of an electronically controlled feed. This technique, sometimes referred to as electronic beam squinting, requires a simple single channel receiver and has been reported to achieve a tracking accuracy approaching that of the auto-track technique.

TERRESTRIAL INTERFACE:

The terrestrial interface comprises a wide variety of equipment. At one extreme, when the terminal is a mobile or receive -only station, there may be no terrestrial interface equipment at all. The operating devices, such as TV receivers, telephones, data sets, and so on, are used right at the earth station. At the other extreme, we find the interface equipment necessary in a large commercial satellite system for fixed service. In such cases, hundreds of telephone channels, together with data and video, are brought to the station by microwave and cable systems using either frequency- or time -division terrestrial multiplex methods. The signals must be changed from those formats into formats suitable for satellite transmission. In an easy case, frequency –division multiplex groups and supergroups, as brought in from terrestrial transmission facilities, can be transmitted directly or with simple translation in baseband frequency from the satellite after modulation and up -conversion, but in many cases it is necessary to reformat extensively for terrestrial circuits. Individual telephone channels, for instance, May all be transmitted on the same carrier, which is received by many earth stations in the network. The return channels for particular conversation circuits will be coming in on various carrier frequencies, depending on their source, and they must be tagged and put together with the corresponding outgoing circuit to make up a terrestrial circuit. This can be a complex process. The presence of video and data complicates matters further.

If the satellite transmission is single channel per carrier, it is necessary to bring each terrestrial carrier down to baseband before remodulation. The interfaces between terrestrial time –division and satellite frequency –division systems, and vice versa, are complicated and can be accomplished in a variety of ways. Television video signals must often be separated from order wire channels, program sound channels, cueing channels, and so on, and then matched up again at the proper point.

Usually, in the systems engineering and programming planning phase it is only necessary to be alert to the problems and possibilities, the detailed design can be saved until later in the program.

PRIMARY POWER

Primary power systems vary from plain battery- or solar -cell -operated remote transmitters for data gathering to huge, combined commercial power and diesel generator systems for large stations. Most transmit and receive earth stations require some kind of "no -break" power system, that is emergency power to continue the communications during commercial power outages.

Such power outages are frequent, even in highly organized industrial areas, if for no reason other than thunderstorms. The no –break transition derives its name from the necessity to make the change over from one power system to another without any interruption in service. Almost all systems today use batteries to effect this transition. Some systems have been devised in which motor generators store enough energy in flywheels to permit a smooth mechanical transition.

TEST METHODS

Noise Power Ratio (NPR)

Earth stations are typically provided with complex test equipment, ranging from that necessary for routine measurements of voltage, power, temperature, and soon, to sophisticated and specialized measurements unique to satellite communication. One of these is noise power ratio (NPR), the traditional measure of intermodulation noise for FDM systems in the communications field. The principle of NPR measurement involves loading the entire baseband spectrum, save for the one voice -frequency channel slot, with noise, simulating in total the loading of the system by actual voice traffic in all but that channel. Noise appearing in the unloaded slot is a manifestation of intermodulation. The ratio of that noise power to the per -channel loading noise power is the NPR. NPR is measured by a setup as shown in Figure. The system can be between any two points of interest. The noise generator band is limited by filters to the baseband, and the noise generator level is set to simulate full load according to the CCIR formulas

$$P = -15 + 10 \log N \text{ dBmO}, \qquad N \geq 240$$

$$P = -1 + 4 \log N \text{ dBmO}, \qquad N < 240$$

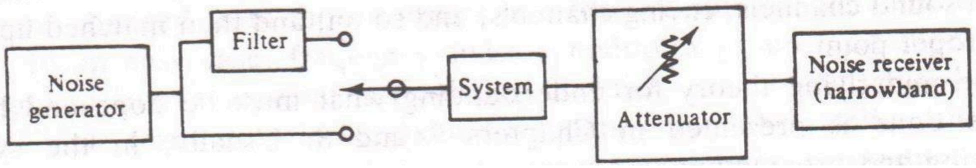


Figure Noise power ratio test setup.

The Measurement of G/T

System temperature Ts can be determined by conventional laboratory noise generator measurement of receiver noise figure and radiometric measurements of antenna temperature. The basic system parameter G/T s also requires a knowledge of antenna gain, and as the antennas get larger, this characteristic is not so easy to get. The gain of smaller antennas, say less than 7 or 8 m, can be found from pattern measurements on a range or by comparison to a gain standard, but these methods are cumbersome and may be impractical for larger antennas. Large earth stations, with antenna sizes up from 10 m, can sometimes use a carefully calibrated satellite signal to measure G/Ts.