Introduction :-

* The collection of equipment on the surface of the earth for communicating with the satellite is called an earth station.
* Earth stations can be used in the general case to transmit to and receive from the satellite, but in special applications only to receive or only to transmit.
* Receive-only stations are of interest for broadcast tx'ions from a satellite and transmit-only stations for the still much less developed application of data gathering.
* The below figure shows the general block diagram of an earth station capable of tx'ion, Rx'ion and a/a tracking.

Transmitter :-

There may be one or many transmit chains, dependin on the no.of seperate carrier frequencies and satellites with which the station must operate simultaneously.

Receiver :-

There may be one or many receiver/down converter chains, depending on the no.of seperate frequencies and satellites to be received and various operating consideratior

Antenna :-

usually one a/a serves for both tx'ion and Rx'ion, bu not necessarily. with in the antenna subsystem are the a/c proper, typically a reflector and feed; seperate feed syster to permit automatic tracking; and a duplex and multiplex

Unit 5

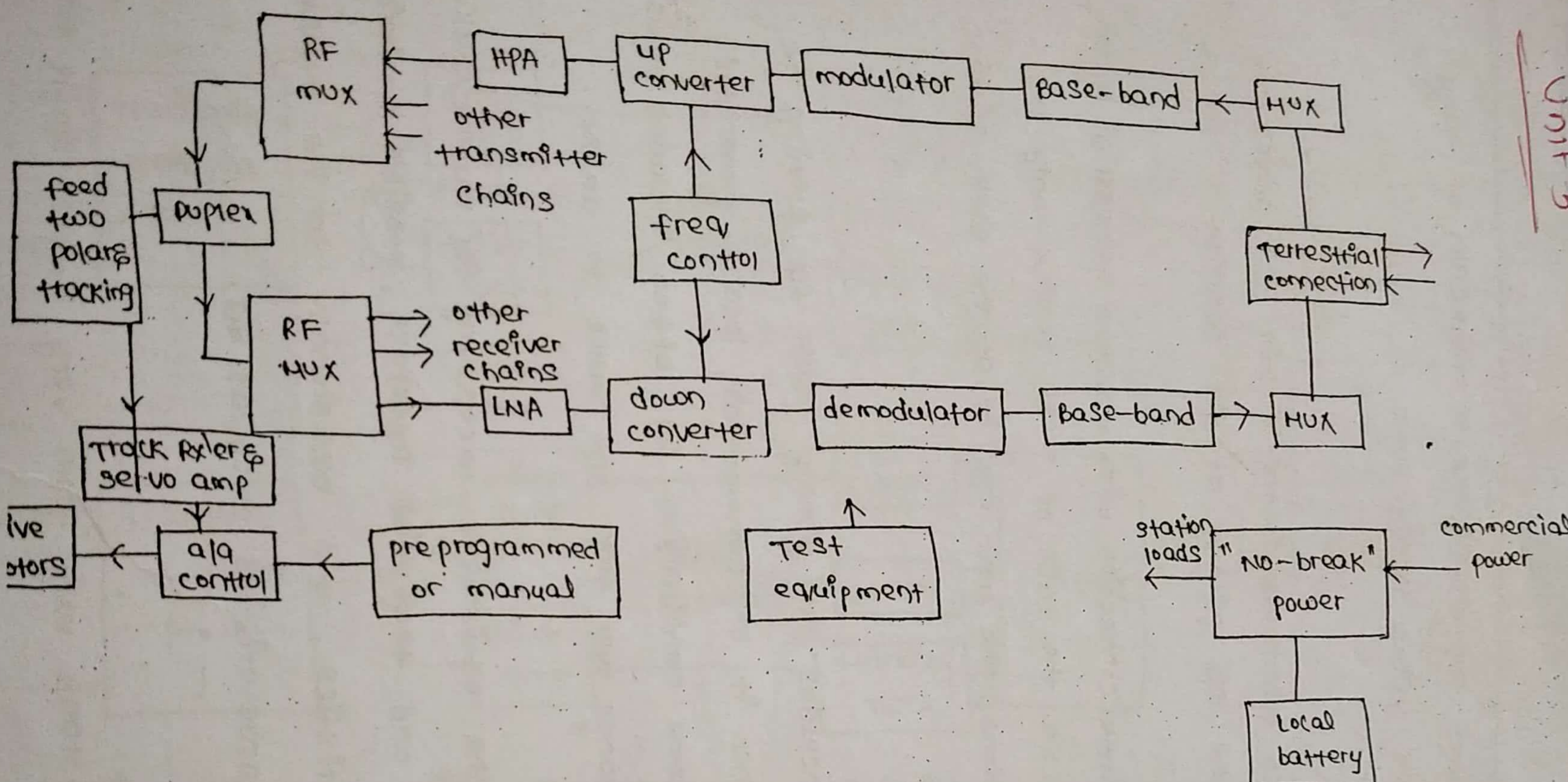

fig: General earth station

angement to permit the simultaneous connection of many
ansmit and receive chains to the same a/a.

acking system :-

This comprises whatever control circuit and drives are essary to keep the a/a pointed at the satellite.

estrial interface :-

This is the interconnection with whatever terrestrial syster any is involved. In the case of small receive-only (or) nsmit-only stations, the user may be at the earth station self.

mary power :-

This system includes the primary power for running the th station, whether it be commercial, locally generated, tery supplied or some combination. It often includes provis for 'no break' change over from one source to another.

t equipment :-

This includes the equipment necessary for routine checkir the earth station and terrestrial interface, possible monitorir satellite characteristics, and occasionally for the measure ent of special characteristics such as G/T.

— o —

ransmitters :-

Transmitter sub systems vary from very simple single tx'er of just a few watts for data-gathering purposes to multi channel tx'ers using 10-kW amplifiers.

* when multiple tx'er chains are required, common wide band travelling - wave tube amplifiers can be used (or) each channel can use a seperate high power amp typically a klystron

* Two - for - one redundancy switching is shown with the TWTAS.

* The common wide band amplifier is the more usual type, and it is suffering from the problem of intermodulation when nonlinear amplifiers handle more than one carrier simultaneously.

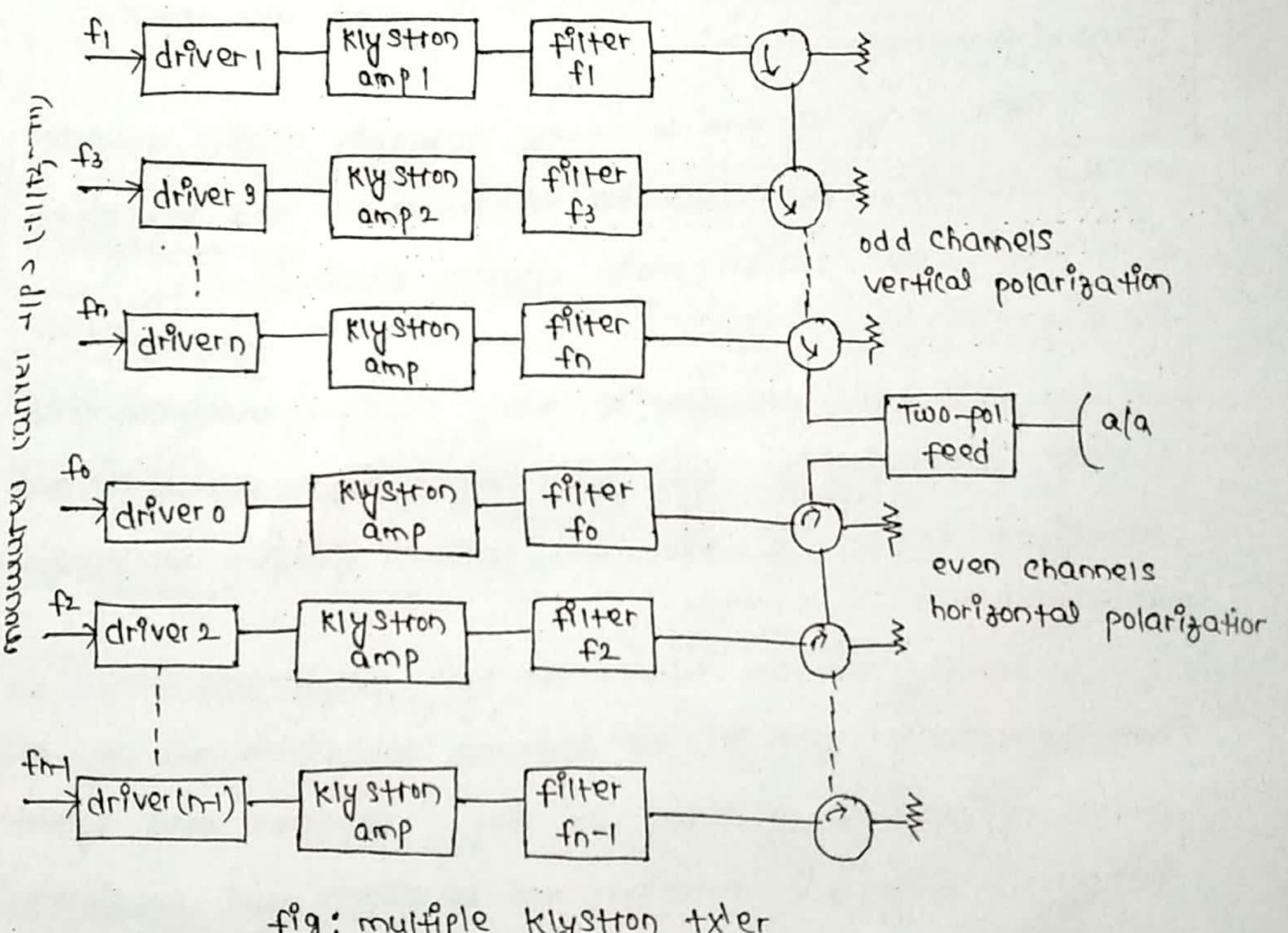

fig: multiple klystron tx'er

* system using feed back to reduce the nonlinearity effect are coming into use and allow greater power o/p.

performance in high power amplifiers uses predistort this method, a low level non linear amplifier of characteristics similar to the high power amp.

* The alternative of using seperate amplifiers is less flexible in operation.
* usually seperate amplifiers are narrowband and require retuning to change freq's.
* A few typical high power amplifier specifications is shown below.

	TWTA	TWTA	TWTA	SSPA	SSPA
freq band	C	Ku	Ka	C	Ku
power (W)	600	300	100	25	16
efficiency (%)	25	22	18	15	5
B.W (MHz)	500+	500+	2500	500	500
gain (dB)	50	70	50	50	50
Noise fig (dB)	25	28	35	6	12
Third-order intercept (dBm)	10	10	10	20	20
AM-PM	2°/dB	2°/dB	2°/dB	0.5°/dB	0.5°/dB
mean time to fail (MTTF) hrs	15-30,000	15-30,000	15-30000	150 000	150000

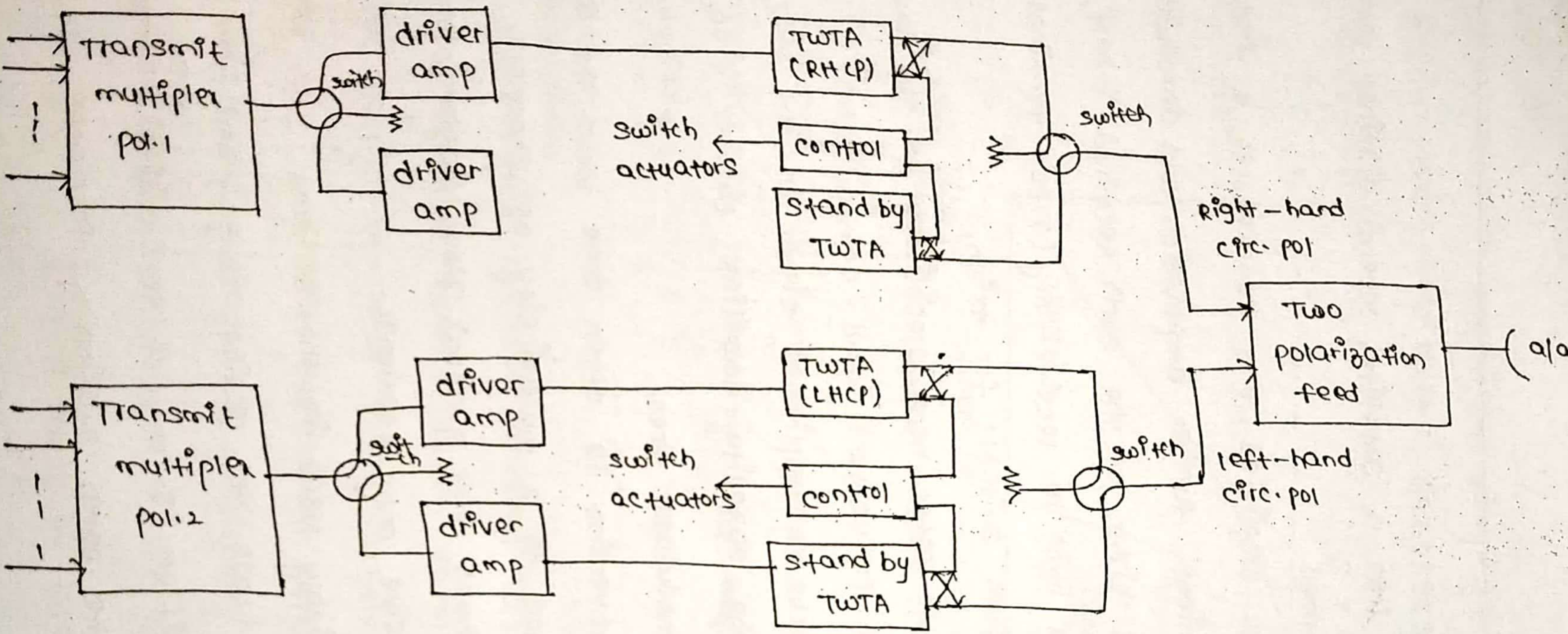

fig: common TWTA transmitted with redundancy (two polarizations)

— o —

Rx :

To receive a signal from a satellite, several distinct operations must be performed.

The sig must first be amplified then reduced to a freq, low enough for convenient further amplification and demodulation.

The sig may be used either at the earth terminal itself, as in the case of a home TV receive-only (TVRO) terminal, or converted into a form suitable for txion.

In receiver chain, we refer here specifically to the low-noise amplifiers, down converters and demodulators.

Down conversion can be accomplished either in one step, going directly from the satellite downlink carrier freq to the intermediate demodulator freq.

Two-stage down conversion is often done when the same Rxler is to be tuned to a multiplicity of channels.

The below figure shows the general block diagram for a video and audio receive only stations.

Such stations are widely used in the SC and such Rxlers are used in cable heads to receive TV programs from sat.

The low-noise amplifier is one of the critical element in determining the earth station performance.

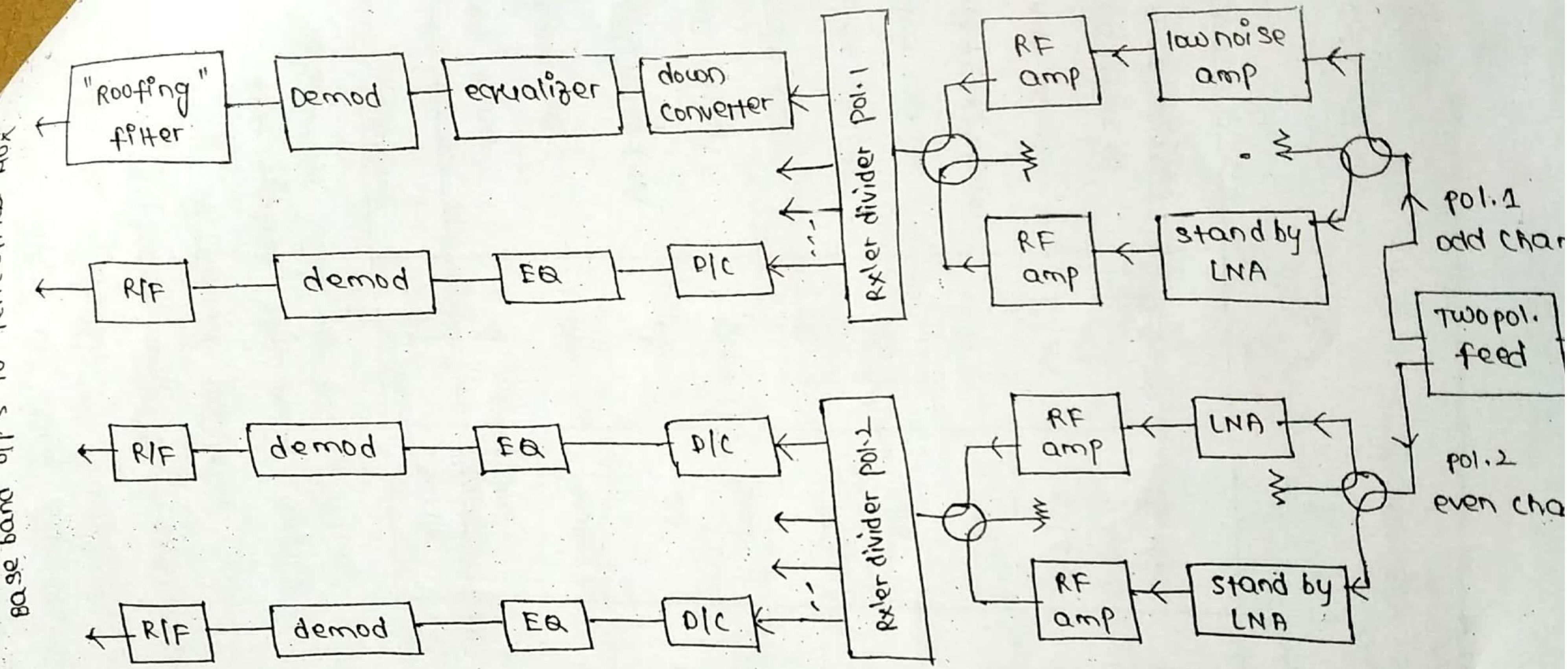

fig: Receive subsystem for multicarrier earth station

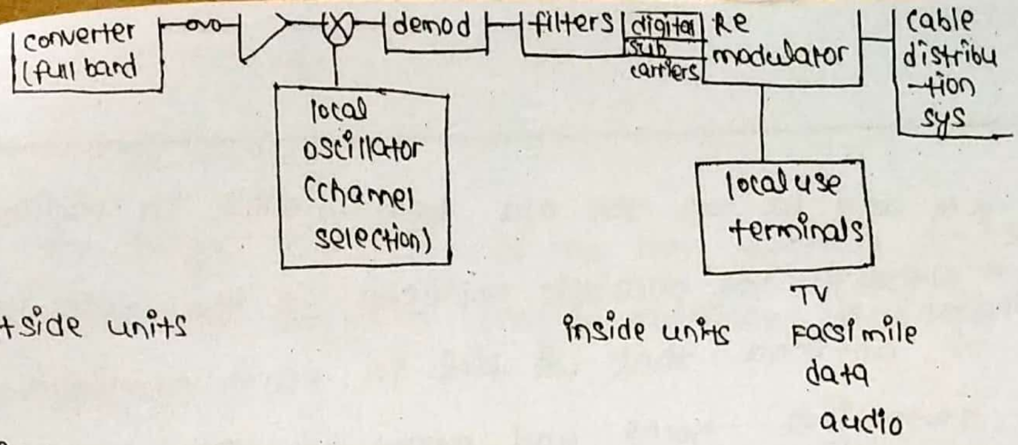

fig: General TVRO station – direct reception or cable distribution

$$T_S = T_a + (L-1)T_0 + LT_R + \frac{L(F-1)}{G_R} T_0$$

* It is not difficult to derive an expression for carrier-to-third-order modulation products. The result is

$$\left(\frac{C}{I}\right)_3 = 2(P_x - P_0)$$

here P_0 – saturated o/p power

P_x – intercept point

	L-band	C-band	X-band	K_u-band	Ka-band
cooling	uncooled	uncooled/cooled	uncooled/cooled	uncooled/cooled	uncooled/cooled
recr range (GHz)	1.5–2.5	3.0–5.0	7.0–10.0	10–14	11–20
B.W (MHz)	50–100	500	500–1000	1000	1000
noise temp (K)	40–60	35–60	55–75	65–130	200–300
Gain (dB)	45–60	50–60	50–55	50–60	20–25
I/P at 1.0 dB compression (dBm)	13	13	13	13	10
Intercept dB above o/p	10–13	10–13	10–13	10	10
AM–PM (°/dB)	0.03–0.5	0.03–0.50	0.03–0.50	0.113–0.50	0.03–0.50

the LNA.

* Most low-noise amplifiers today (1992) use gallium arseni field- effect transistors, GaASFETS or HEMTS.

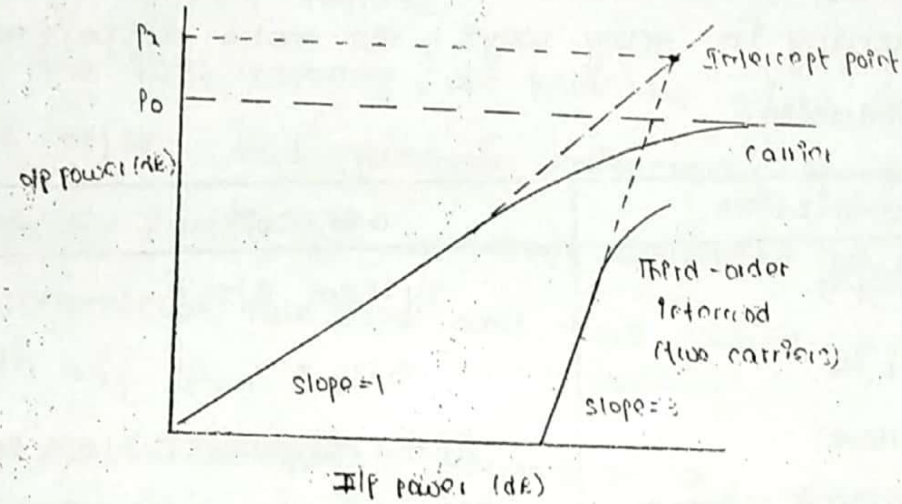

fig: Intercept point as a measure of third-order intermodulati level

* Intercept point and AM-PM conversion are two simple measures of non linearity that help in comparing diffe amplifiers.

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Antennas :-

* The parabolic reflector antenna has become the symbo for a satellite communication earth terminal.

* The carrier-to-noise ratios acheivable on uplink and link, given directly determined fixed tx'er power an geographical coverages are directly determined by the physical size of the earth station a/a.

antennas at K band must be larger than those at band This is because as the min attenuation

The antenna electrical performance is involved in the system planning in many ways; the most important are the following.

characteristics	affects
overall gain, G	system G/T_S
a/a temp, T_a	G/T_S
side lobe level	Interference (C/I), a/a temp
cross - polarized response	C/I and C/N for entire sys
Beam width	Geographical coverage (satellite ak tracking requirement

for system planning, a generalized antenna pattern is often useful. A good pair of equ's for such use is

on main lobe : $$\frac{G}{G_m} = \left[\frac{\sin 1.39(\theta/\theta_0)}{1.39(\theta_0/\theta_0)}\right]^r$$

far from main lobe : $$\frac{G}{G_m} = \frac{1}{1+(\theta/\theta_0)^{2.5}}$$

where θ_0 is half the half - power beam width.

Gain is defined as the ratio of radiation intensity in a given direction to that the total radiated power to be radiated isotropically.

$$G \simeq \frac{4\pi}{\theta_1\theta_2} \simeq K\frac{41253}{\theta_1^\circ\theta_2^\circ}$$

where K is a factor to allow for energy not in the main beam.

* θ_1 and θ_2 are the a/a beamwidths in radians or degr

* Although the parabolic reflector is the most important kind of antenna that we find in earth stations and on the satellites. horns and array are also important.
* horns are widely used as primary feeds for reflectors and occasionally as principal radiators themselves.
* Two other kinds are ocasionally seen in spacecraft. They are lenses (either the dielectric or waveguide type) and phased arrays.
* The array is controlled by varying the phase and amplitude of the individual elements.

Horn antenna :-

* Horn antennas are commonly used as primary radiators in reflector system.
* we find horn antennas on board the satellite to provide earth coverage beam.
* The angle is about 18° from geostationary orbit and simply acheived with horns.
* There are two kinds of horns.
* primary horn as an extension of roctangular waveguide and conical horn as an extension of circular waveguide.

The following equations are applicable for those horn that are compared to wavelength.

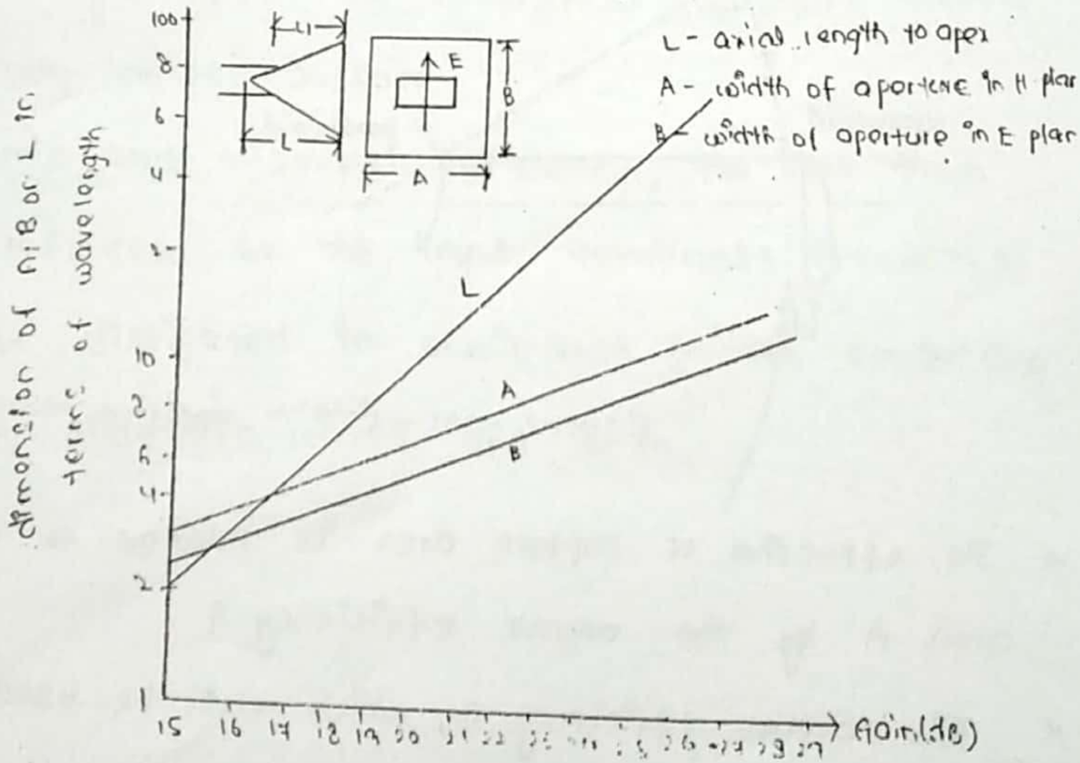
$$\theta_E = 51\frac{\lambda}{B}$$

$$\theta_H = 70\frac{\lambda}{A}$$

here A is the longer dimension of the horn aperture. It is desired to have the shortest length possible, that length L_1 is given by

$$L_1 = L\left(1-\frac{a}{2A}-\frac{b}{2B}\right)$$

* conical horns, which are natural extension of circular wave guides, are used typically higher-mode propagation
* The TM_{11} and TE_{11} modes circular wave guides are super imposed on each other with suitable control of the relative amplitude and phase.
* The variation of the horn feed very much used in primary feeds for big earth station is a hybrid-mode horn.



* we divide the reflector antennas broadly into two categ
those using a single reflector and horn feed and th
using multiple reflectors.
* In the first category, we have the prime focus feed
the offset - fed parabolic reflectors; in the second
have a family of antennas developed by analogy to
astronomical telescope and thus called Newtonian, ca
-grain and Gregorian.
* The later categories depend on the whether the subre
is plane, hyperbolic or ellipsoidal.

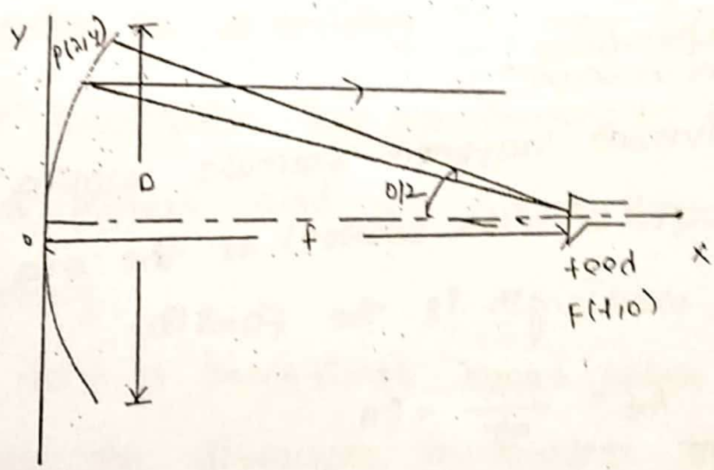


fig: Basic geometry; prime - focus - feed parabolic ref

* An important effect of the secondary reflector on a cassegrainian or Gregorian a/a is to increase the apparent focal length of the a/a. This increase called magnification.

The equivalent focal length of the cassegrainian reflector system is given by

$$f_e = mf = \frac{e+1}{e-1} f$$

- If several horn feeds with emerging beams at diff angles are to be use a main reflector that is circular in the cross section and parabolic in the other.

This kind of toroidal antenna was first used in large early-warning radars to permit rapid beam scanning

Antenna performance :-

The universal antenna formula relating the effective area (or capture cross section) of the a/a Aeff and its gain and wavelength is the familiar

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

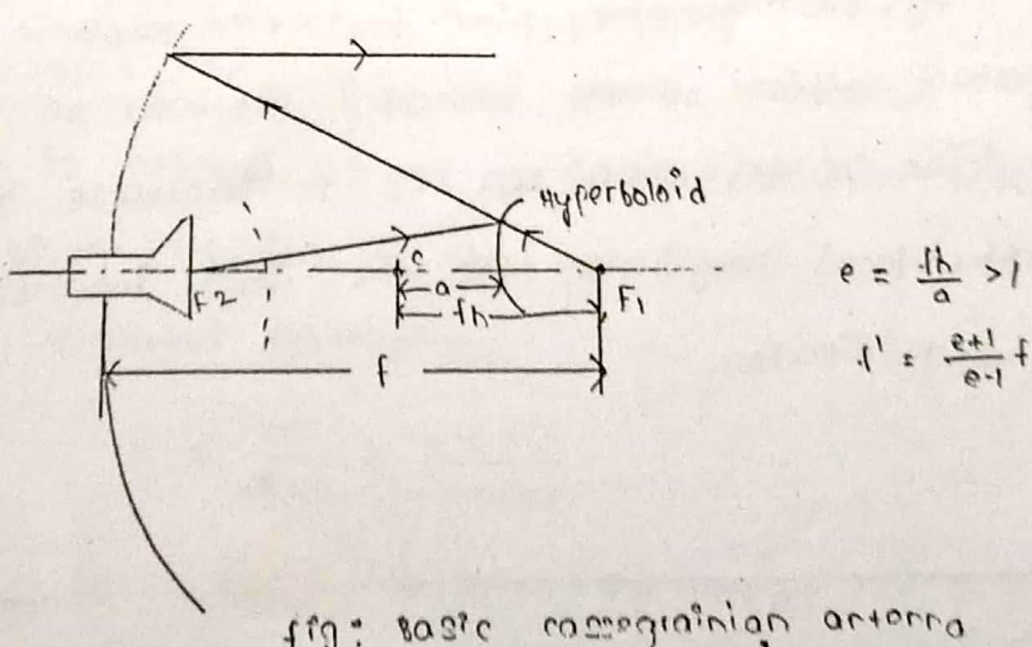
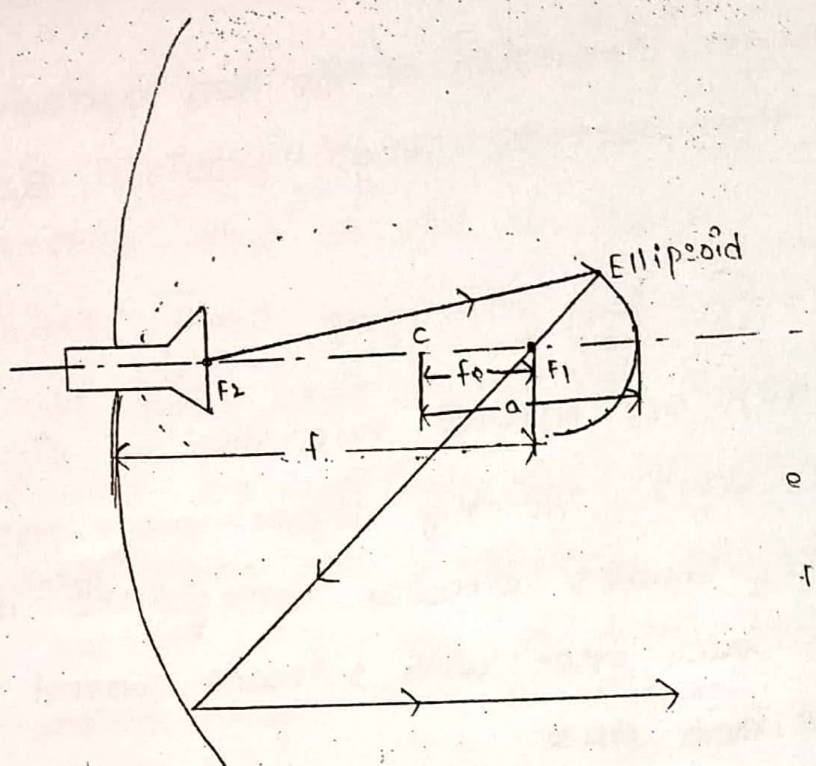


fig: Basic cassegrainian antenna



$$e = \frac{f_o}{a} < 1$$

$$f' = \frac{1+e}{1-e}$$

fig: Basic Gregorian antenna

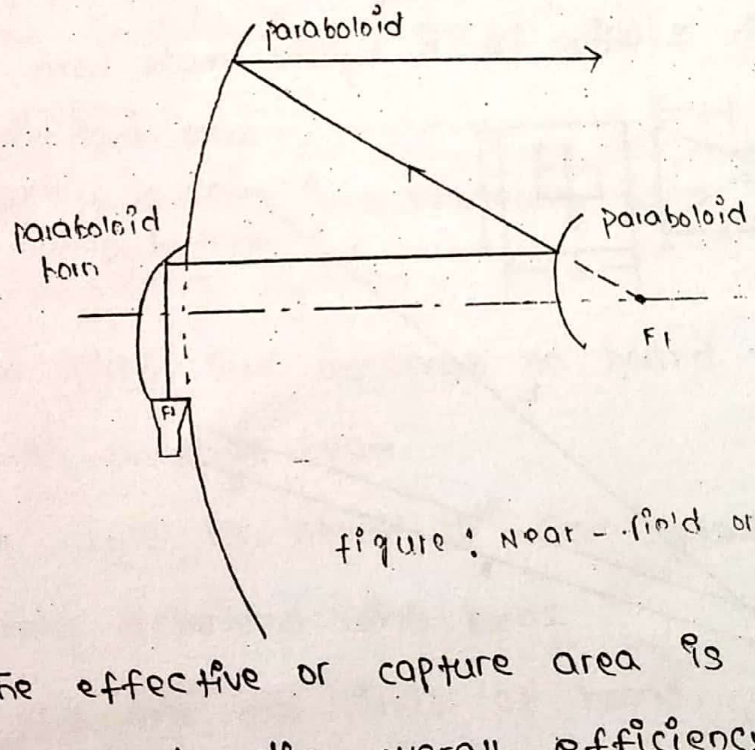


figure : Near-field or modified cassegrainian an

* The effective or capture area is related to the physical area A by the overall efficiency η.
* This overall efficiency η, which must be used in calcula-ng received carrier level.

$$\eta = \eta_a \eta_b \eta_s \eta_p \eta_e \eta_L$$

phase errors and so on; it increases as the side lobe level increases.

η_b = blockage efficiency, resulting from blockage of main reflector by the subreflector or feeds

η_s = spilover efficiency, the loss of energy because the subreflectors and main reflectors do not intercept all the energy directed toward them.

η_p = cross - polarization efficiency, the loss of energy due to energy coupled into the polarization orthogonal to that desired.

η_e = surface efficiency, the loss in gain resulting from surface irregularities, the statistical departure from a theoritically correct surface

η_L = ohmic and mismatch efficiency, the loss from energy reflected at the input terminals (VSWR>1.0) and that dissipated in ohmic loss in the conducting surfaces, dielectric lenses and so on,

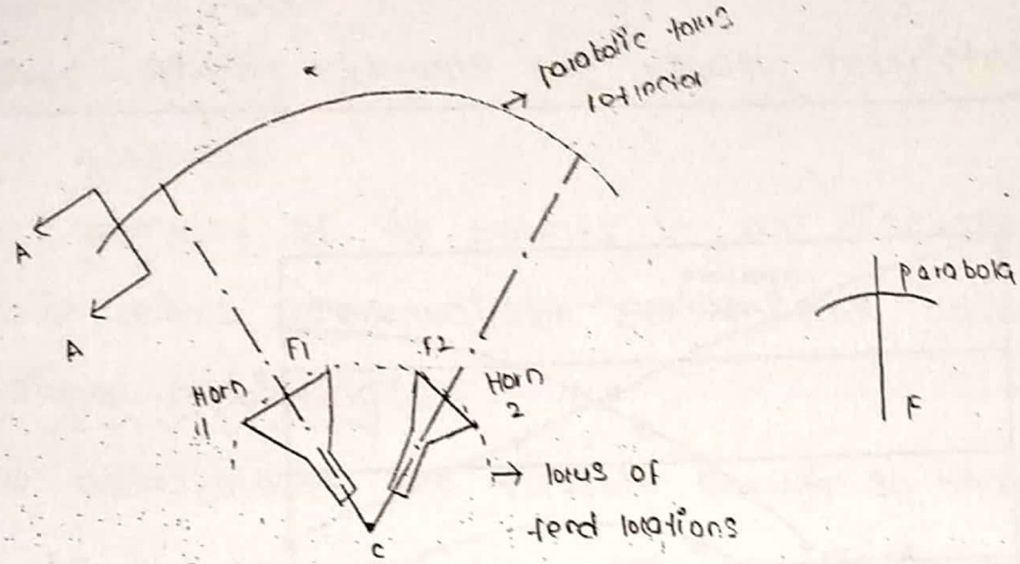


fig: multifeed toroidal antenna

* The aperture efficiency η_a is equal to unity for an aperture that is illuminated uniformly in amplitude phase, in which the directivity is max for given a
* The reflector illumination has two components: one due the horn feed pattern and one due to the inherent reflector geometry.
* The second term is sometimes called space attenua and is simply the difference in inverse square - la loss b/w the edge and centre of the aperture.
* from the geometry of the parabola, it can be show that this loss is given by

$$\text{space attenuation} = \left(\frac{R}{f}\right)^2 = \sec^2\theta/4$$

where θ is the full angle subtended by the reflector

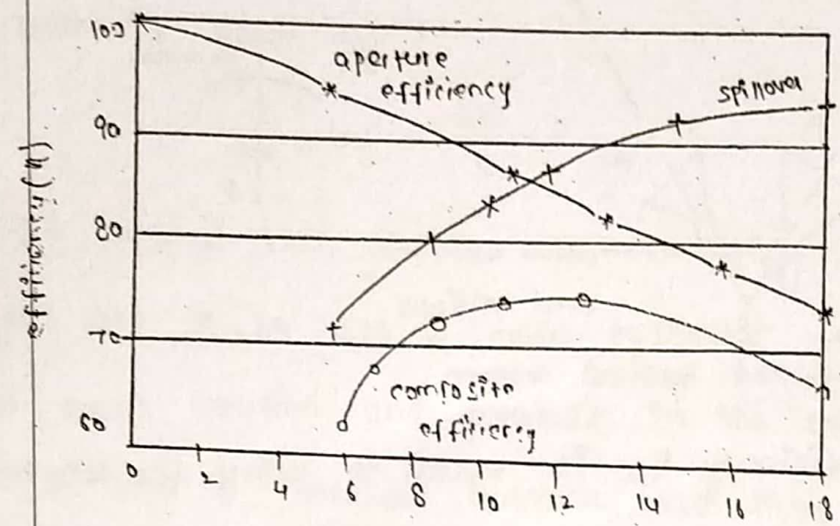


fig: Typical spillover and aperture efficiencies as a function of illumination taper

A good approximation to a cosine horn pattern is simply $(\theta / \beta_{10})^2$. where β_{10} is the horn beam width at the tenth power point.

The net edge taper is

$$T = 10 \log \sec^4 \frac{\theta}{4} + 10\left(\frac{\theta}{\beta_{10}}\right)^2$$

aperture blockage is a significant problem especially in cassegrainian and Gregorian antennas.

The related efficiency η_b is given by $[1 - 2a(A_B/A)^2]$, where A_B is the blocked area and A is the total aperture area.

cross - polarization efficiency η_p is another important problem in satellite antennas.

* There is always a fundamental loss in efficiency because of random surface irregularities.

* Ruze (1952) in a classic paper developed the following equation for the effect of surface variation:

$$\eta_e = \frac{G}{G_0} = e^{-K(4\pi\delta/\lambda)^2}$$

$$K = \frac{1}{1+(D/4f)^2} \simeq 1$$

* These equations hold for gaussian distribution of phase errors due to surface imperfections.

here δ is the mass surface deviation

G_0 is the gain of a perfect surface reflector general, nongeostationary orbits require more tracking than geostationary.

* For instance, messaging systems for ground mobile service from low earth orbit often use hemispherical coverage a/a's, aeronautical and many marine terminals and require no tracking.
* on the other hand, there are successful mbl services to vehicles using ku band with the narrow beams and trackir because of vehicular motion.
* we identify a hierarchy of pointing and tracking categol -es as follows.

1. No tracking is necessary and only initial fixed-pointing adjustment is required.
2. Repointing of the a/a is needed to switch from one satellite. to another and possibly to correct for satellite motion. This repointing can be needed rarely (or) frequently
3. Tracking is required, but it is satisfactory to drive the a/a in two axes and to preprogram this drive in accordance with the calculated satellite motion.
4. Automatic tracking is necessary but can be achieved by a simple step tracking system.
5. Fully automatic continuous tracking is necessary.

* fixed - pointing systems are usually restricted to beam antennas.
* The geometry of the mounts is as discussed - in screw drives are available for initial adjustmer

occasional repointing :-

* The adjustments are flexible enough so that they can be changed manually with out difficulty.
* simple motor drives may be added to do it remo.

preprogrammed :-

* once motor drives are available for one - or two axis control, both automatic and preprogrammed can be
* If the a/a beamwidth is wide relative to the predi error, it can be preprogrammed to track open loop.
* often the principal apparent GEO satellite motion is due to imperfect inclination control.
* This motion, for small inclinations and otherwise pe orbits, is a figure eight with a period of one s real day.
* It's vertical height is twice the orbital inclinatio and it's width is only a small fraction of th value.
* If the orbit has zero inclination but has a sm

centricity e, the amplitude of the maximum longitudinx *

parture is 2e radians.

ep tracking :-

Step tracking uses a primitive servomechanism in ich the a/a is moved a discrete amount and if e signal level increases, it is moved again in is direction. *

As soon as the signal level does not increase, it eturns to the previous position.

This method obviously depends on the size of the step.

lly automatic :-

fully automatic tracking can be provided using method iginally developed for the pointing of radar a/a's.

The most common is the monopulse or simultaneous lobing system, in which four beams are generated n an auxilary feed and combinations of the signals om these four beams provide left-right and up-down ror signals.

These error signals are detected, amplified and used to generate control signals for driving the a/a.

It is possible to derive the error signals either with multiple horn ~~feed~~ systems or by the use of higher

* The multiple - horn feeds use four horns grouped toge[ther]
(or) sometimes four horns grouped around a single larger horn.
* where as the higher - mode error- determining signals use circular wave guide modes such as TM_{01} or TE_{01}, which have no field component on the axis.

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.
* The operating devices such as TV Rx'ers, telephones, data sets and so on are used at earth station.
* at other extreme, we find the interface equipment necessary in a large commercial satellite system fo[r] 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 eith[er] frequency (or) time division multiplex methods.
* The signals must be changed from those formats into suitable formats for satellite tx'ion.

... frequencies, ...ending on their source and put together with the corresponding outgoing circuit to make up a terristrical circuit.

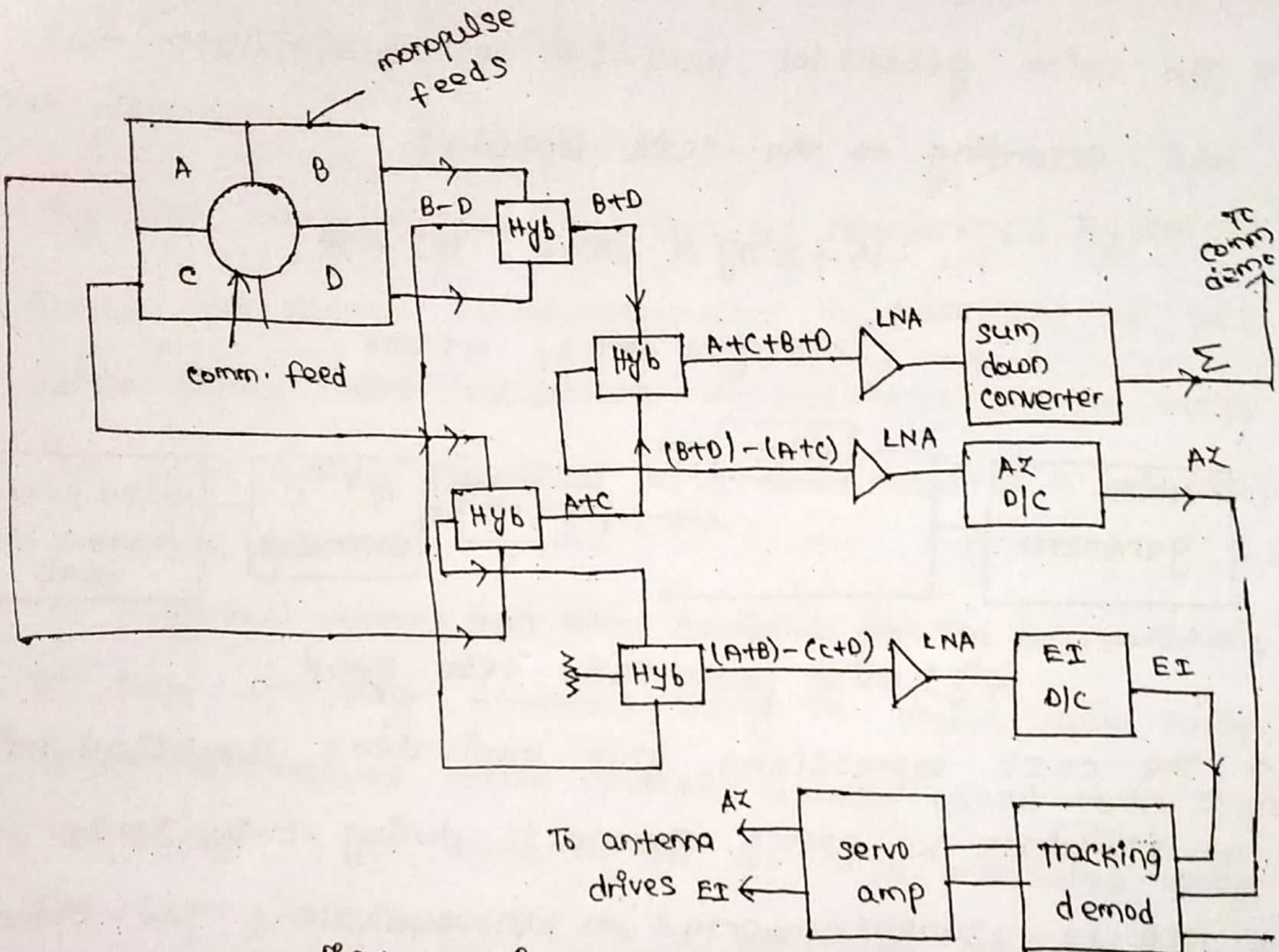


fig: Tracking system

* If the satellite tx'ion is single channel per carrier, it is necessary to bring each terrestrial carrier down to base band before remodulation.

The interfaces b/w terrestrial time division and satellite freq-division systems and vice-versa are complicated.

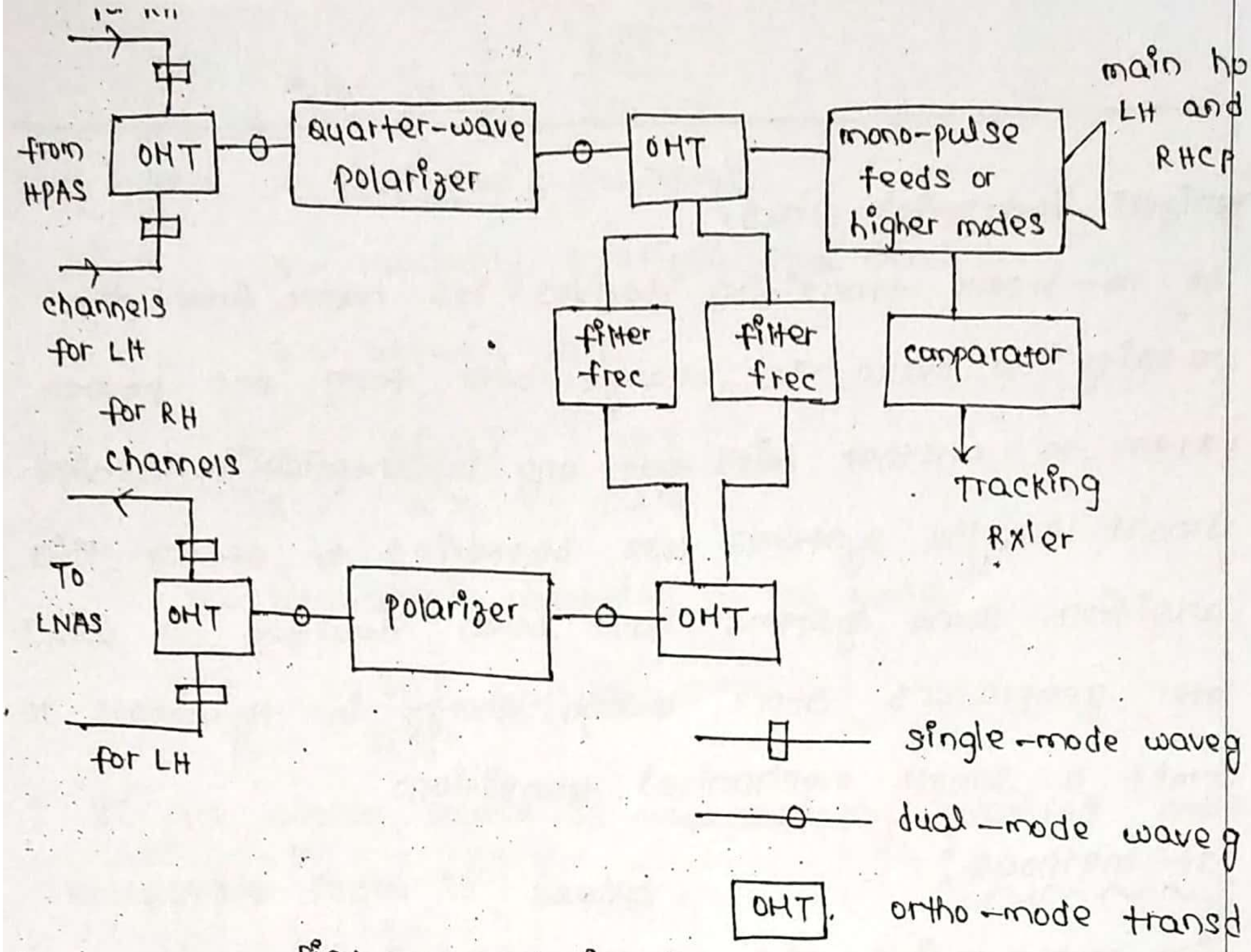


fig: Two-polarization horn-feed systems

primary power :—

* primary power systems vary from plain battery or sol -cell operated remote tx'ers for data gathering . huge, combined commercial power and diesel genera systems for large stations.

* Host transmit and Receive earth stations require s kind of " no-break " power systems, that is emerger power to continue the comm's during commercial po outages.

* such power outages are frequent, even in highly

anized industrial areas.

The no-break transition derives its name from the cessity to make the change over from one power ystem to another with out any interruption in service. Almost all the systems use batteries to effect this ransition. Some systems have been devised in whict otor generators store enough energy in fly wheels to ermit a smooth mechanical transition.

---

est methods :-

oise power ratio (NPR) :-

earth stations are typically provided with complex est equipment, ranging from that necessary for outine measurements of voltage, power, temp and so or

The Noise power ratio (NPR) is the traditional meas ure of intermodulation noise for FDM systems in e comm's field.

The principle of NPR measurement involves loading he entire base band spectrum, save for the noise ne voice-freq channel slot, with noise.

NPR is measured by a set up as shown in below fig.

The noise generator band is limited by filters to the base band.

* The noise generator band is limited by

* The noise generator level is set to simulate full load according to the CCIR formulas.

$$P = -15 + 10\log N \text{ dBm0}, \quad N \geq 240$$

$$P = -1 + 4\log N \text{ dBm0}, \quad N < 240$$

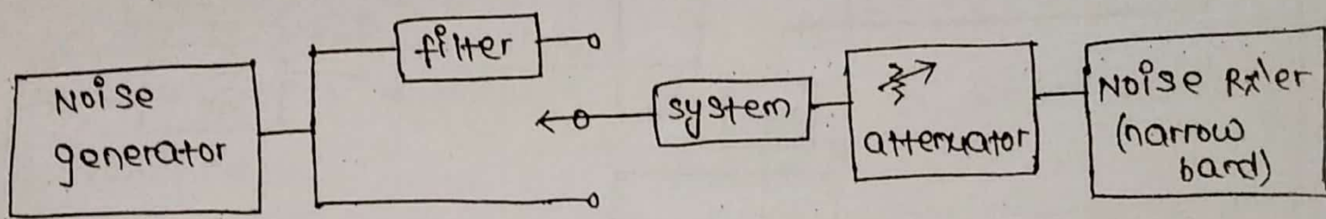


fig: Noise power ratio test setup

* The CCIR expressions give equivalent Gaussian noise to simulate N speech channels during busy hors.

* NPR is usually converted to an equivalent per-channel signal-to-noise-ratio.

$$BWR = 10\log \frac{\text{base band total B.W}}{\text{signal channel B.W}}$$

$$NLR = 10\log \frac{\text{base band noise test power}}{\text{test-one power per channel}}$$

$$= \text{dBm0 of loading calculation}$$

* The equivalent base band signal-to-noise ratio du to intermodulation is then

$$S/N = NPR + BWR - NLR$$

 Scanned by CamScanner

$B = 4028 - 60$

then $BWR = \frac{4028 - 60}{3} = 31.2\,dB$

$NLR = 10\log 960 - 15 - 14.8\ dBm0$

$(S/N)_{equiv} = 71.4\ dB$

The measurement of G/T: —

* System temperature T_s can be determined by conven-tional laboratory noise generator measurement of Rx'er noise figure and radiometric measurements of a/a temp.
* The basic system parameter G/T_s also requires a knowledge of antenna gain.
* An ingenious method has been developed for the measurement of G/T_s for large antennas using the known radio noise characteristics of stellar sources usually called radio stars.
* Y factor is the ratio of the o/p noise measured when the Rx'er is connected to a hot noise source (T_h), to the o/p noise measured when connected to a cold source(T
* excess noise T_c is related to the Y factor by

$$T_\omega = \frac{T_h - Y T_c}{Y - 1}$$

* If the cold source is the normal sky and the hot source the radio star, the operating system temperature T_s is

$$T_s = \frac{T_h - T_c}{Y - 1} = \frac{\Delta T_a}{Y - 1}$$

$$\Delta T_a = \frac{S}{2aK} \frac{G\lambda^{\gamma}}{4\pi}$$

Here K - Boltzman's constant

S - randomly polarized flux density

G - antenna gain

$$\frac{G}{T_S} = \frac{G(Y-1)}{\Delta T_a} = \frac{8\pi K}{S\lambda^{\gamma} a}(Y-1)$$

a - atmospheric absorption at the zenith

$$\frac{G}{T_S} = \frac{8\pi K}{S\lambda^{\gamma} a A}(Y-1)\sin\theta$$

* If the stellar source is not randomly polarized, anoth correction factor is needed.
* cassiopeia A is the most commonly used source.

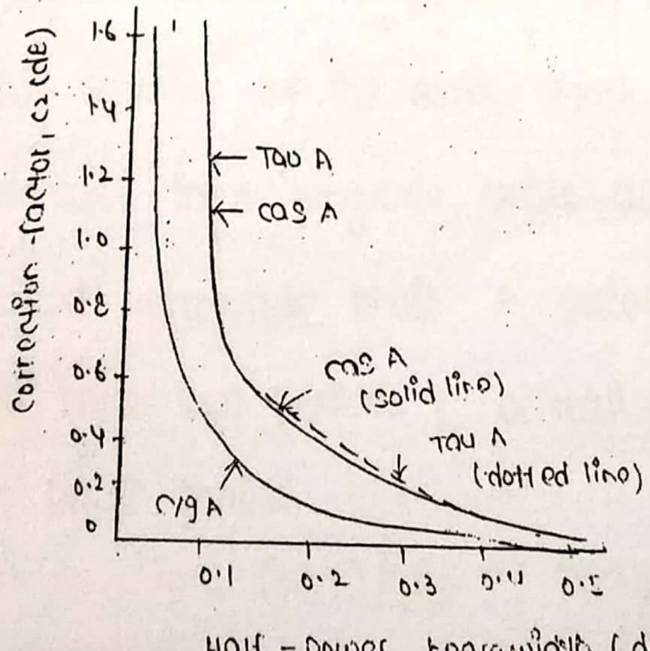


fig: correction factor for G/T measurement using extended sources ome further correction may be necessary if the beamwidth

: the a/a under test is narrow compared to the stellar radi

source.

) extended source of varying brightness can be considered

3 equivalent to a Rayleigh - Jeans black - body radiator.

The primary reason for the use of LEO was the generally small "throwmass" of the launchers.

→ Throw mass includes both payload and spacecraft bus syste also includes additional rocket motors and fuel.

→ LEO range is 500 km to 1500 km.

→ LEO and MEO are generally refered as Non-geo-stationary orbit -s mostly used for internet

→ NGSO satellites brought us the first communication satellite (SCORE), the first pictures of our cloud cover of weather forecasting (TIROS), the first Navigation aids in space (TRANSIT), the first live television pictures across oceans (TELSTAR) etc.

GEO stationary:

→ The reason for using GEO is "more bits can be sent per dollor of capital investment".

→ There are some specialized applications:

* Surveillance of earth's surface for military and gathering the earth resources.

* Providing global navigation such as GPS.

GPS uses 24 satellites in orbits with an altitude of 20,000 km and an inclination of 55°.

* For cellular telephone system.