Unit -III

Satellite Link Design

Satellite link gives the estimate power that a satellite will receive from the Transmitting E S and power received by the Receiving E.S from the satellite repeater.

The factor effecting the link design are discussed earlier.

The major factor in the link design is the frequency of uplink and downlink [6/4 GHz)

The satellite link may be

1. point to point
2. point to ~~Many~~ Multipoint

(Network operation Center (NOC)

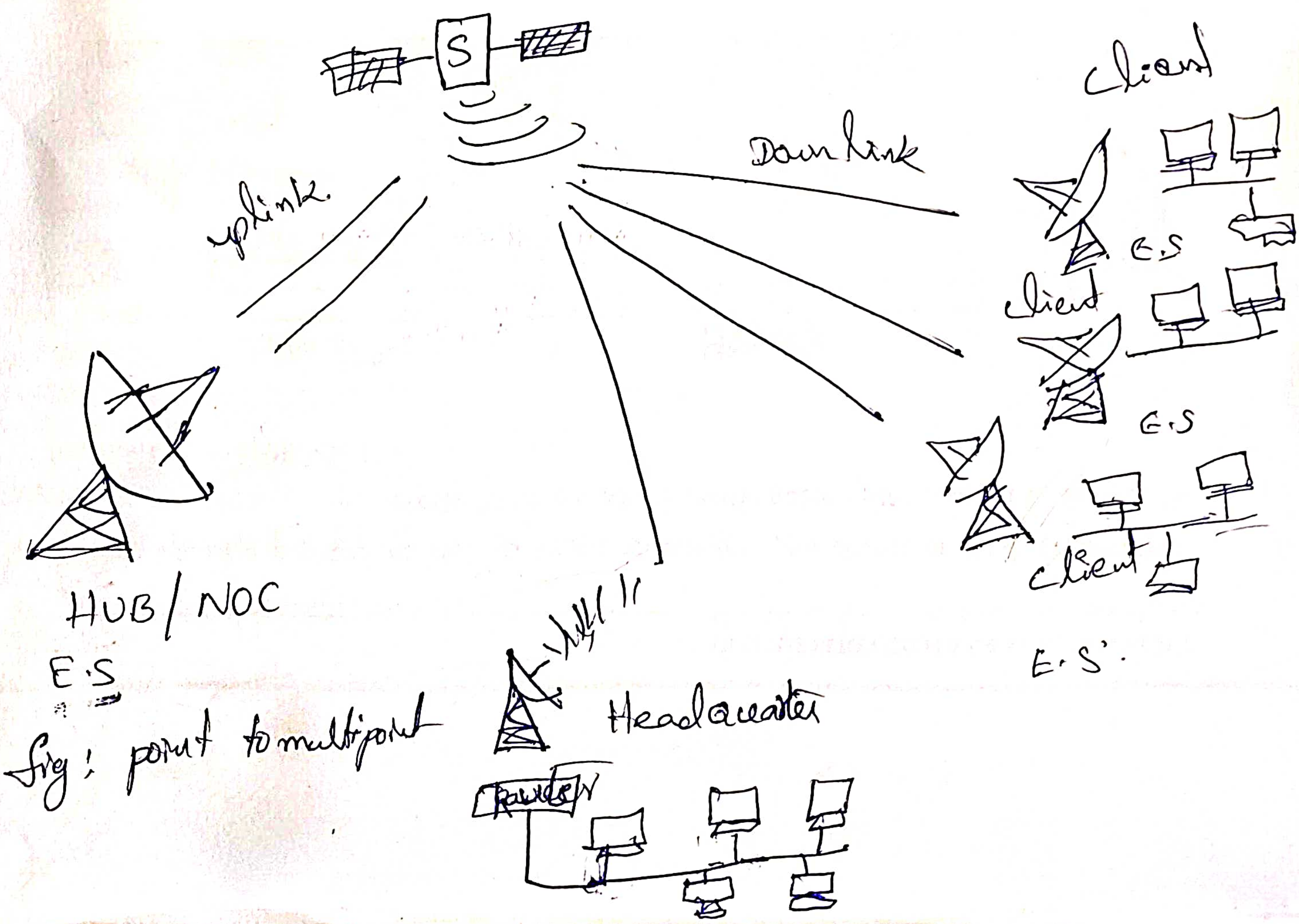
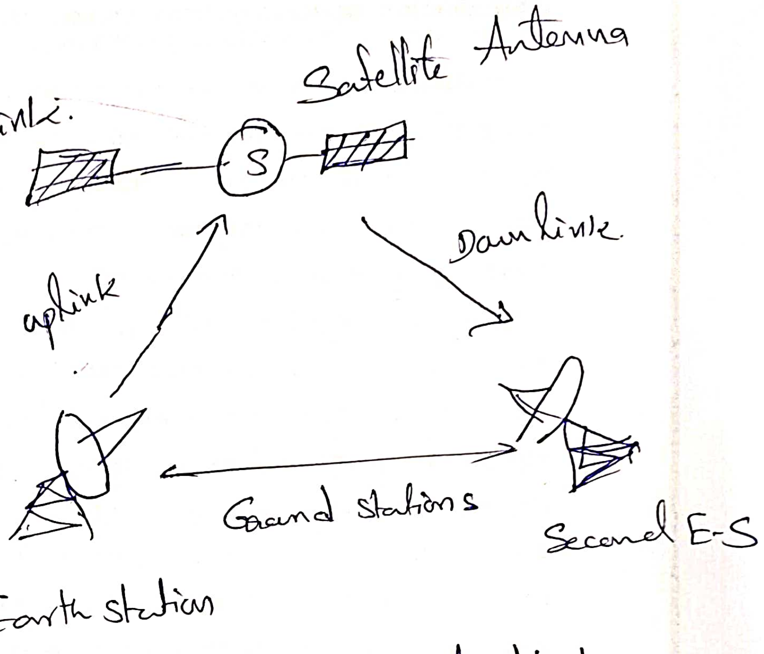


fig: point to multipoint

range of temperatures. Besides there a backup or redundant unit will be provided to avoid the failure of different components.

fig 6 point to point link.

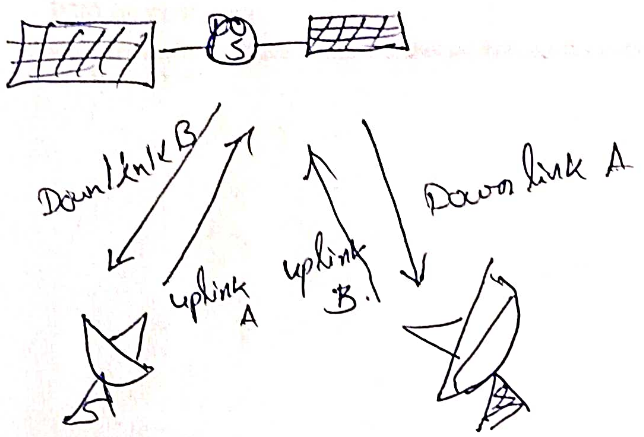


HUB :- Another name of HUB is
1. Ethernet Hub
2. Repeater Hub
3. Active Hub
4. Network Hub

It is Similar to switch but are not as 'Smart'

"HUB is a Computer network is used for connecting multiple computers or Segments of a LAN. It is used for peer to peer small Home Network.

Two way Communication :



Basic Transmission Theory :

The calculation of power received by an GS from a Satellite Tx'er is very important in satellite Communication link design.

Consider ~~the~~ a transmitting Source to be located in free space and Supposed to radiate a power P_T watt uniformly in all directions. Such a Source is called isotropic and ideally it is not possible because it could not create transverse polarized E.M waves.

Normally we use directive antenna to limit our Tx'ed power to be radiated primarily in one direction and its directivity is represented by a finite beam of width θ.

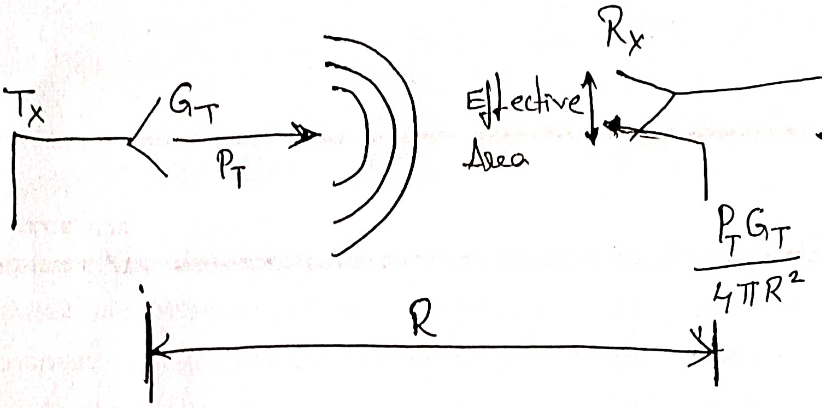


fig (a) Link budget Calculation.

The Distance between a T_x'er and R_x'er is 'R'.

For a Transmitter with P_T watt driving a lossless Antenna with Gain G_T, the flux density in the direction of Antenna at distance R metre is

$$\boxed{F = \frac{P_T G_T}{4\pi R^2} \ w/m^2} \quad \text{——— (1)}$$

The product P_T G_T is called Effective isotropic radiated power (EIRP). It gives a measure of power flux. If the aperture area of ideal receiving antenna is A_R m^2, as shown in given fig (b), we would correct Received power P_R is given by

$$\boxed{P_R = F \cdot A_R} \quad \text{——— (2)}$$

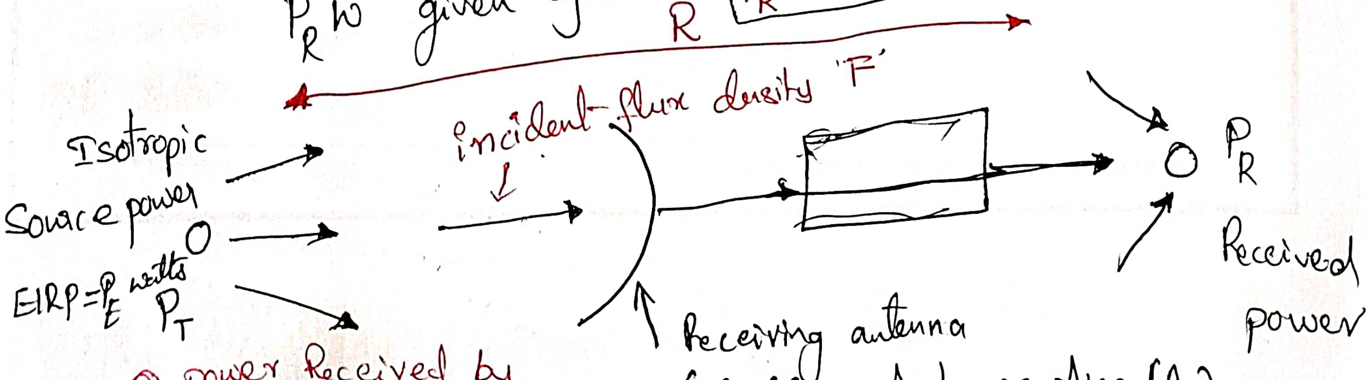


fig: (b) power Received by antenna with Area 'A_R'

In practical Antenna with effective Area $A_R . m^2$, Some of the energy incident on the aperture is reflected away from the antenna, and some is absorbed by lossy components. This reduced efficiency is described by an effective operature A_e, where

$$\boxed{A_e = \eta . A_R} \quad \text{—— (3)}$$

where η = Aperature efficiency of the Antenna and it is because of all the losses between the incident wave -front and antenna output port.

For paraboloidal Refector Antenna η is typically 50 to 75 % in range and for Horn Antennas it approaches 90 %. So the power received by an real antenna with physical receiving area A_R and Effective aperture area $A_e . m^2$ is

$$\boxed{P_R = \frac{P_T G_T A_e}{4 \pi R^2}} \quad \text{—— (4)}$$

The receiving Antenna Gain 'G_R' is related to its

Effective Area A_R by the Relationship

$$\boxed{G_R = \frac{4\pi A_e}{\lambda^2}} \quad \text{———} \quad (5)$$

Substituting eq (5) into eq. (4) we get

$$P_R = \frac{P_T G_T G_R}{\left[\frac{4\pi R}{\lambda}\right]^2} \text{ watts}$$

$$P_R = P_T G_T G_R \left[\frac{\lambda}{4\pi R}\right]^2 \quad \text{———} \quad (6)$$

This expression is known as the "Friis transmission equation." and it is very important in calculation of power received in any radio link.

The term $\left[\frac{4\pi R}{\lambda}\right]^2$ is known as path loss or Free space loss (L_{FS}).

Collecting the Various factors we can write

$$\boxed{\text{power Received} = \frac{\text{EIRP} \times \text{Receiving Antenna Gain}}{\text{path loss}}} \quad \text{—(7)}$$

In terms of decidel, we have

$$P_R = (EIRP + G_R - L_{FS})\ dBW \quad \text{—— (8)}$$

where, $EIRP = 10 \log_{10} (P_T G_T)\ dBW$

$$G_R = 10 \log_{10}\left(\frac{4\pi A_e}{\lambda^2}\right) dB$$

$$L_{FS} = \text{path Loss} = 20 \log_{10}\left[\frac{4\pi R}{\lambda}\right] dB$$

equation (8) represents an ideal case, in which there are no additional losses in the link. In real sense there would be a variety of losses so,

$$\boxed{L = L_{FS} * L_A} \quad \text{—— (9)}$$

where, L_A = Additional losses

the additional Losses is written as

$$\boxed{L_A = L_{ta} * L_{ra} * A_{AG} * A_{rain} * L_{point} * L_{POL}} \quad \text{—(10)}$$

where, L_{ta} = Losses Associated with Tx'ing Antenna

L_{ra} = Losses Associated with Rx'ing Antenna

- A_{AG} = Attenuation by the Atmosphere and Ionosphere

A_{rain} = Attenuation due to precipitations and clouds.

L_{POL} = Losses Caused by polarisation mismatch between the Transmitting and Rx'ing Antenna

L_{point} = Losses Caused by Antenna depointing

So the equation (10) Can be written as

$$\boxed{P_R = EIRP + G_R - L_{FS} - L_{ta} - L_{ra} - A_{AG} - A_{rain} - L_{POL} - L_{point}} \quad (11)$$

dBW

The power received P_R From eq (4) and (6) is known as carrier power (C) because most Satellite links use either frequency modulation (F.M) for Analog transmission (AM) or phase modulations (PM) for digital Systems.

In both modulation Systems when data are modulated on to carrier, the amplifier of the Carrier is not changed, So Carrier power 'C' is always equal to received power P_R.

System Noise Temperature and G/T Ratio :-

Noise Temperature :-

It is very important parameter Since it provides a way of determining thermal noise generated by the devices in the receiver System.

The most Important Source of noise in the receiver is the thermal noise in its pre-amplifier.

The Noise power P_N is the receiver is given by

$$\boxed{P_N = K \cdot T_n \cdot B} \quad \text{---} \; (i)$$

where, K = Boltzmann Constant (1.38×10^{-23})

T_n = Receiver Temperature

B = Bandwidth.

P_N = is the Available Noise power and will be delivered only to a device that is impedance matched to the Source.

Term, $K.T_n$ = Noise Spectral density (watts per hertz)

The performance of the receiver System is determined by System noise temperature T_S.

T_S is also called effective input noise temperature of the receiver and is defined as the noise temperature of a noise source located at the I/P of a noise less receiver.

In the Receiver before De-modulator a RF amp and IF amplifier exists. So if the overall Gain of the receiver is 'G' and bandwidth is B, the noise power at the De-modulator I/p is

$$\boxed{P_n = K.T_s.B.G} \quad \text{—— (2)}$$

If P_R is the signal power at the I/p to the receiver then the s/g power at the de-modulator I/p will be $P_R G$.

Hence the Carrier to noise ratio at the demodulated I/p is given by.

$$\boxed{\frac{C}{N} = \frac{P_R G}{K.T_s B G} = \frac{P_R}{K T_s B}} \quad \text{—— (3)}$$

Several sources of Noise in the receiver is replaced by single noise temperature (T_s).

Calculation of System Noise Temperature :=

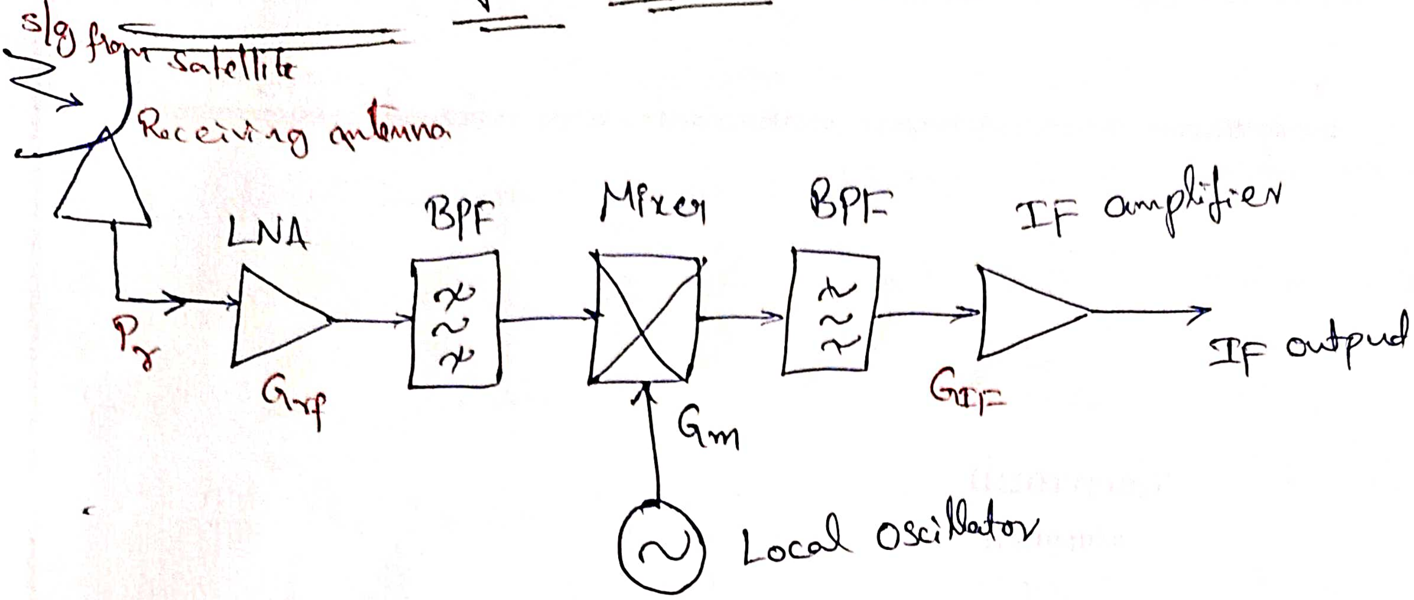
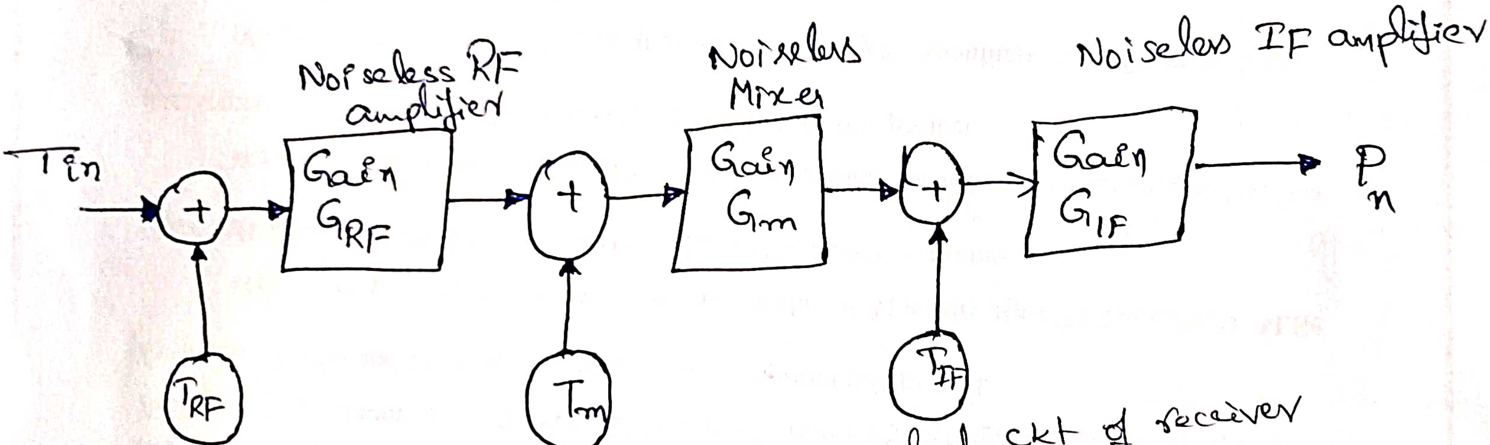
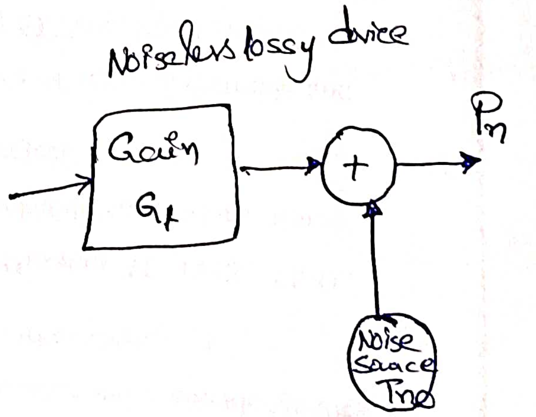


fig: Simplified E.S receiver, BPF, B



(or) equivalent ckt of receiver

fig:(a) Equivalent Noise Sources



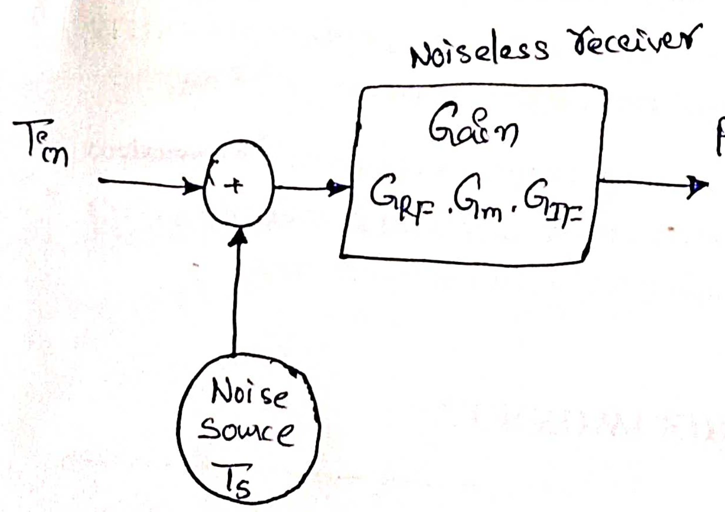


fig:(c) Noise model for a lossy device.

fig:(b) Noise model of receiver

The equivalent circuit used to represent this receiver is shown in fig ⓐ in which each device is replaced by single noise source with Temperature, T_s.

Let the gain of RF amplifier, down converter and IF amplifiers are G_{RF}, G_m, G_{IF} and their respective equivalent noise temperature are T_{RF}, T_m and T_{IF}.

If T_{in} is the I/p noise temperature then the "total noise power at the output of the IF amplifier" is given by

$$P_n = G_{IF} K.T_{IF} B + G_{IF} G_m K T_m B + G_{IF} G_m G_{RF} KB (T_{RF} + T_{in}) \quad (1)$$

$$= G_{IF} G_m G_{RF} \left[\frac{K T_{IF} B}{G_m G_{IF}} + \frac{K.T_m B}{G_{RF}} + KB (T_{RF} + T_{in}) \right]$$

$$\boxed{P_n = G_{IF} G_m G_{RF} KB \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]} \quad (2)$$

with the System noise temperature T_s, the noise power, P_n at the output of IF amplifier is given by

$$P_n = G_{IF} . G_m . G_{RF} K T_s B \quad (3)$$

from equation (2) and equation (3) we get,

$$K T_s B = KB \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$

(OR) $$\boxed{T_s = \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]} \quad \text{--- (4)}$$

Since the gain of each stage is added in the receiver

So the succeeding stages contribute less and less noise.

Noise figure and Noise Temperature:

Noise figure is used to specify the noise generated within a device. The operational Noise figure is defined as the ratio of I/p s/g to noise power to the o/p s/g to noise power.

It is given by

$$\text{Noise figure}(NF) = \frac{(S/N)_{in}}{(S/N)_{out}} \quad \text{--- (5)}$$

The Relationship between a noise Temperature and noise figure is given by

$$\boxed{T_d = T_0 (NF - 1)} \quad \text{--- (2)}$$

where T_0 = reference temperature ~~and~~ used to calculate the standard N.F

Usually noise Figure (N.F) is given in decibles.

G/T Ratio for Earth station :-

The link equation can be rewritten in terms of (C/N) at Earth station.

$$\frac{C}{N} = \frac{P_T G_T G_R}{K T_S R}\left[\frac{\lambda}{4\pi R}\right]^2$$

$$\frac{C}{N} = \left[\frac{P_T G_T}{KB}\right]\left[\frac{\lambda}{4\pi R}\right]^2\left[\frac{G_R}{T_S}\right] \quad \text{--- (1)}$$

Thus $\left(\frac{C}{N}\right) \propto \left(\frac{G_R}{T_S}\right)$ and for a given satellite λ and R will be constant.

$\frac{G_R}{T_S}$ ratio is widely used to specify the quality of an E.S and is known as $\frac{G}{T}$ ratio (or) the figure of merit.