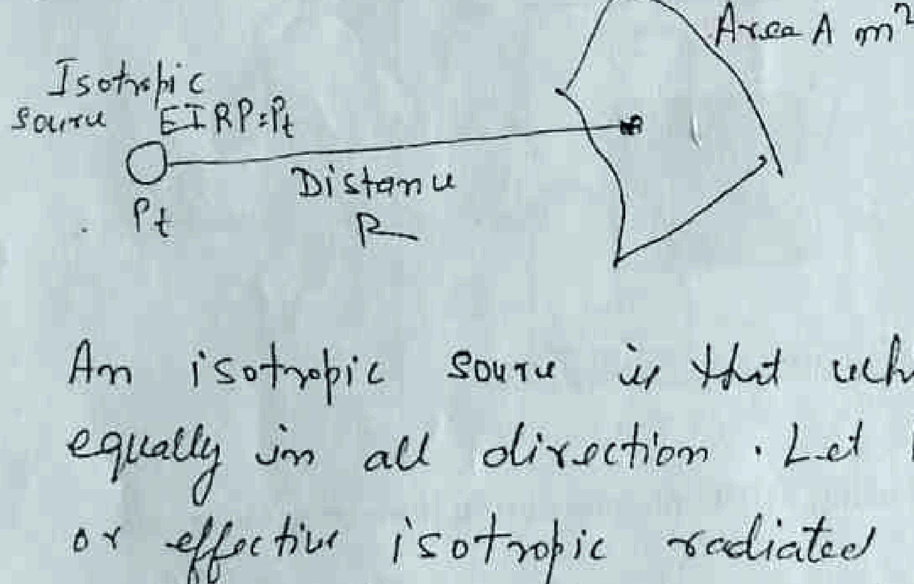
Satellite Link (1) Design

Satellite link consists of an uplink and Downlink. The uplink is the path from earth station to the satellite and the downlink is the path from satellite to earth station. If the transmission is in digital form then our aim is to minimise BER (Bit error rate) or C/N ratio in the case of Analog transmission. Hence to design the uplink and downlinks we need to know the propagation characteristics of the frequencies used in communication.

Basic Transmission Theory



An isotropic source is that which radiates equally in all direction. Let P_t = EIRP or effective isotropic radiated Power and this radiation be received at a distance R on an antenna at a distance R.

(2)

Flux density F at a distance R from the source is

$$F = \frac{P_t G_t}{4\pi R^2} \ w/m^2$$

and the Power collected by the area A

is $P_r = F \times A$.

Taking into account some energy is reflected by the antenna and also some loss due to spill over, the effective Area $A_e = \eta_A A_r$

where A_e = effective area taking into account the losses, η_A = efficiency of the antenna and A_r is the area of the receive antenna. η_A is between 50% to 75%.

$$\text{Hence } P_r = \frac{P_t G A_e}{4\pi R^2}$$

From antenna theory, the relationship between gain and area of antenna

$$G = \frac{4\pi A_e}{\lambda^2}, \quad \lambda = \text{wave length}$$

$$\text{or } G_R = \frac{4\pi A_e}{\lambda^2} \qquad A_e = \frac{G_R \lambda^2}{4\pi}$$

$$\text{Hence } P_r = \frac{P_t G_t G_R \lambda^2}{4\pi R^2 \times 4\pi}$$

$P_r = P_t G_t G_R$

This expression is called the <u>Link Equation</u> and from this we can get the Power received by the antenna for any radio link

From the above equation we can write

$$\text{Power Received} = \frac{\text{EIRP} \times \text{Receive ant gain}}{\text{Path Loss}}$$

Expressed in db watts

$$P_r = EIRP + G_r - L_p \text{ dBW}$$

$$EIRP = 10 \log_{10} P_t G_t \text{ dbw}$$

$$G_r = 10 \log_{10}\left(\frac{4\pi A_e}{\lambda^2}\right) \text{dbw}$$

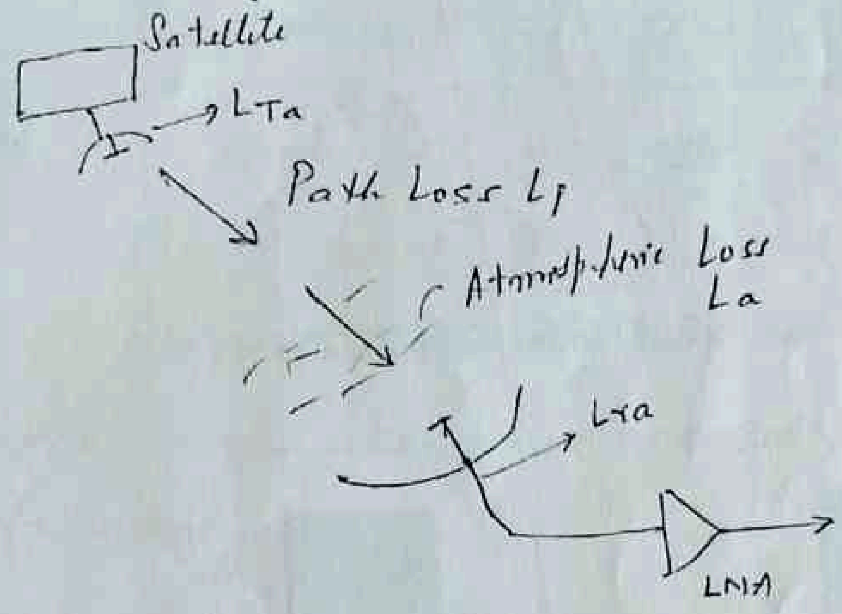
$$\text{Path Loss} = 10 \log_{10}\left(\frac{4\pi R}{\lambda}\right)^2 = 20 \log_{10}\left(\frac{4\pi R}{\lambda}\right) \text{dB}$$

The above equation does not consider losses in atmosphere due to moisture, losses in the transmitting antenna, loss due to receiving antenna. Taking these into account these factors, the received power is

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

~~System Noise Temp~~

Satellite Link showing various Losses



System Noise Temperature

Noise Temperature

- Noise temp is a useful concept in communication receiver
- It determines the thermal noise by active and passive devices in receiving systems

Noise Power is given by

$$P_n = K T_P B_n$$

$\underline{KT_P}$ is called the Noise Power spectral density.

(2)

Available noise power will be delivered only to a load when impedance is matched to the noise source.

Unit of Noise Temp is Kelvins

For an amplifier we find that

Noise temp of 30k at 4 GHz

Noise Temp of 100k at 11 GHz

Hence noise temp increases with frequency

Total thermal noise power is used to determine the performance of a receiving system

Noise Power at De-modulator ~~output~~ input is $P_{no} = k T_s B_n G_{rx}$ watts

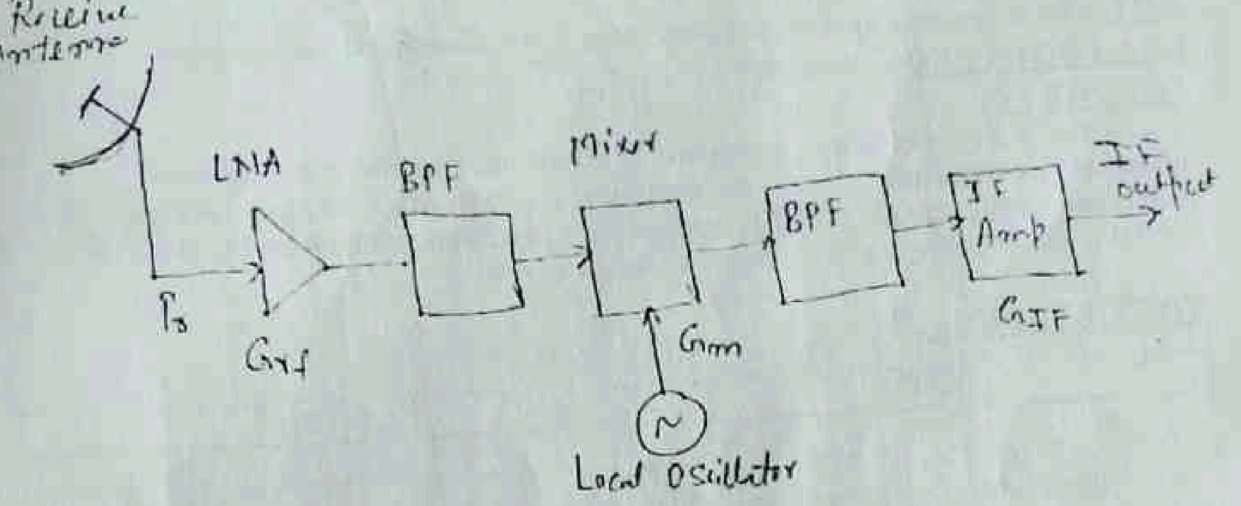
G_{rx}: gain of RX

Carrier to noise ratio at the de-modulator is given by

$$\frac{C}{N} = \frac{P_r G_{rx}}{k T_s B_n G_{rx}} = \frac{P_r}{k T_s B_n}$$

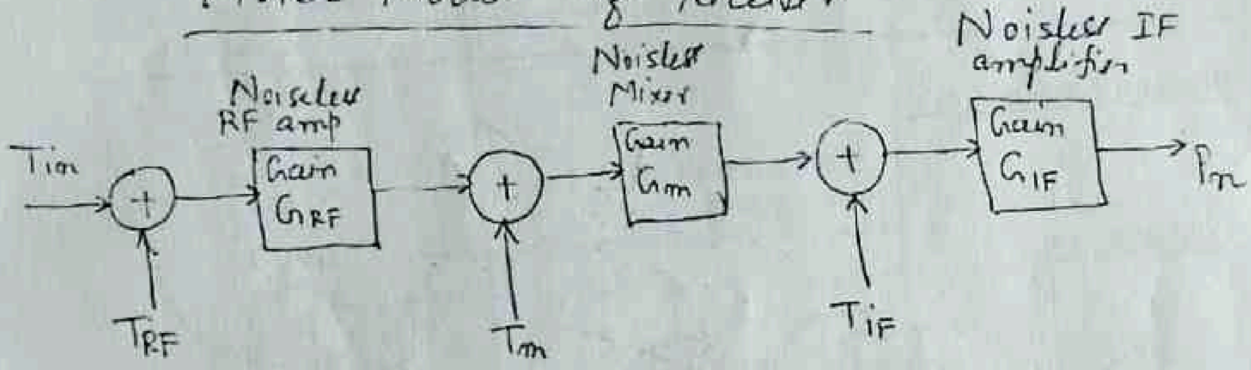
or $\boxed{\frac{C}{N} = \frac{P_r}{k T_s B_n}}$

Calculation of System Noise Temp



Earth Station Receiver

Noise Model of Receiver



The total noise power at the output

$$P_n = G_{IF} k T_{IF} B_n + G_{IF} G_m k T_m B_n + G_{IF} G_m G_{RF} k B_n (T_{RF} + T_{in})$$

where G_{IF}, G_m and G_{RF} are gain of IF amp, mixer, RF amp and

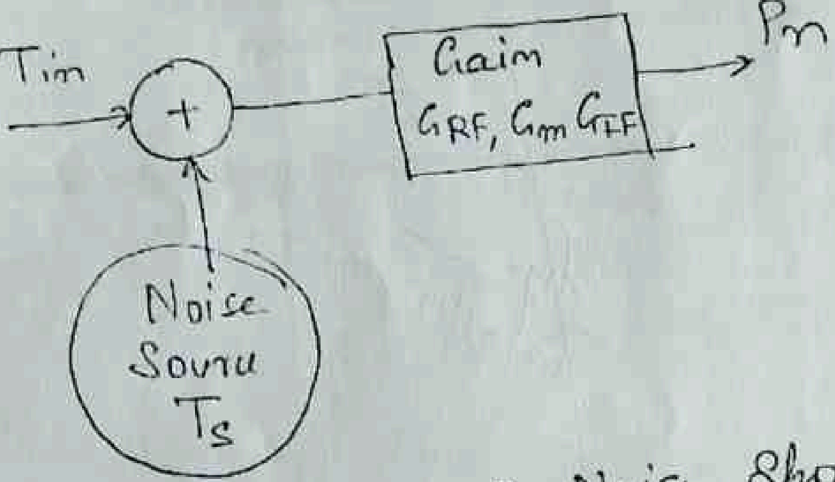
T_{IF}, T_m, T_{RF} are their equivalent

The above equation (1) can be re-written as

$$P_n = G_{IF} G_m G_{RF} \left[(k T_{IF} B_n)/(G_m G_{RF}) + (k T_m B_n)/G_{RF} + (T_{RF} + T_{in}) \right]$$

or $$P_n = G_{IF} G_m G_{RF} k B_n \left[T_{RF} + T_{in} + T_m/G_{RF} + T_{IF}/G_m G_{RF} \right] \quad \text{— (A)}$$

The noise model of the receiver can now be shown as below



The single source of Noise shown in the above figure with noise temp T_s generates the same noise power P_n at its output if $P_n = G_{IF} G_m G_{RF} k T_s B_n$ — (B)

Comparing equation (A) and (B)

$$T_s = \left[T_{RF} + T_m/G_{RF} + T_{IF}/(G_m G_{RF}) \right]$$

The noise model for an equivalent output noise source

8

$$\boxed{T_{mc} = T_p(1 - G_1)}$$

Noise Figure and Noise Temp

- Noise Figure is frequently used to specify the noise generated within a device.
- The operational N.F is defined by the formula

$$NF = \frac{(S/N)_{in}}{(S/N)_{out}}$$

The relationship between N.F. and noise temp $\boxed{T = T_0(NF - 1)}$ T_0 = reference temp

The link equation can be re-written in terms of (C/N) at the earth station

$$\boxed{\frac{C}{N} = \left[\frac{P_t G_t G_r}{K T_s B_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2 = \left[\frac{P_t G_t}{K B_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2\left[\frac{G_r}{T_s}\right]}$$

$\frac{G_r}{T_s}$ specifies the quality of a receiving earth station or satellite receiving syst...

Design of Downlinks (9)

The design of any Satellite communication is based on two objectives

1. Meeting a minimum C/N ratio for a specified percentage of time

2. Carrying the maximum revenue earning traffic at minimum cost

A Satellite link can be designed with a very Large Antenna to achieve high C/N ratio under all condition. But the cost in this case increases. All Satellite links are effected by rain attenuation

6/4 GHz — Small
14/11 GHz — More
30/20 GHz — Even More

} Rain attenuation

C-links Rain Attenuation 1 or 2 db

Ka links Rain attenuation 10 or 20 db

For telephone traffic C or Ku band is used

For Internet Transmission : Ka band is used

Calculation of C/N in a satellite is based on two equations

1. Received Signal Power
2. Receiver Noise Power

Received carrier Power $P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra}$ dbw

$EIRP = 10 \log_{10}(P_t G_t)$ dbw

$G_r = 10 \log_{10}(4\pi A_e / \lambda^2)$ db

Path loss $L_p = 10 \log_{10}\left(\frac{4\pi R}{\lambda^2}\right)$

L_a: Attenuation in atmosphere

L_{ta} - Losses associated with transmitting antenna.

L_{ra} - Losses associated with receive antenna

The noise Power P_n referred to the output terminal of the antenna where

$P_n = k T_s B_n$ T_s = System noise temp

Satellite Communication

Sem: 8 Branch ECE

Assignment unit - IV

Q1 Mention and explain the two segments of basic Satellite communication.

Q2 Define and explain Signal to noise Ratio in the case of satellite communication.

Q3 What is Antenna Loss?

Q4 Explain Noise Figure and Noise Temperature for satellite receiver

Q5 With the help of Block diagram explain noise Model of a receiver.