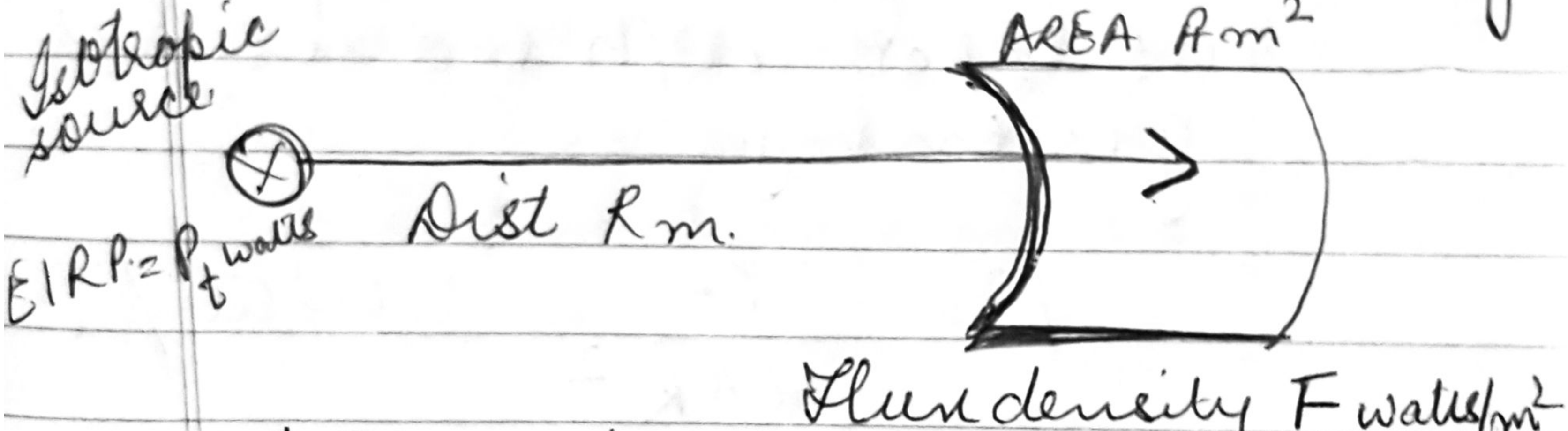
5/10/ P. Baslon

Basic Transmission Theory.



"FLUX density produced by isotropic source"

Let a transmitting source in free space, radiating a total power P_t watts uniformly in all directions as shown in figure.

Such type of isotropic source can't be physically realised because it couldn't create transverse em wave.

At a dist R mts from source the flux density crossing the surface of sphere w/h radius R is given by

$$F = \frac{P_t}{4\pi R^2} \quad Watt/m^2$$

now Tx with output P_t watts driving a lossless N/w whose gain G_t. The flux density in direction of antenna at distance R meters is

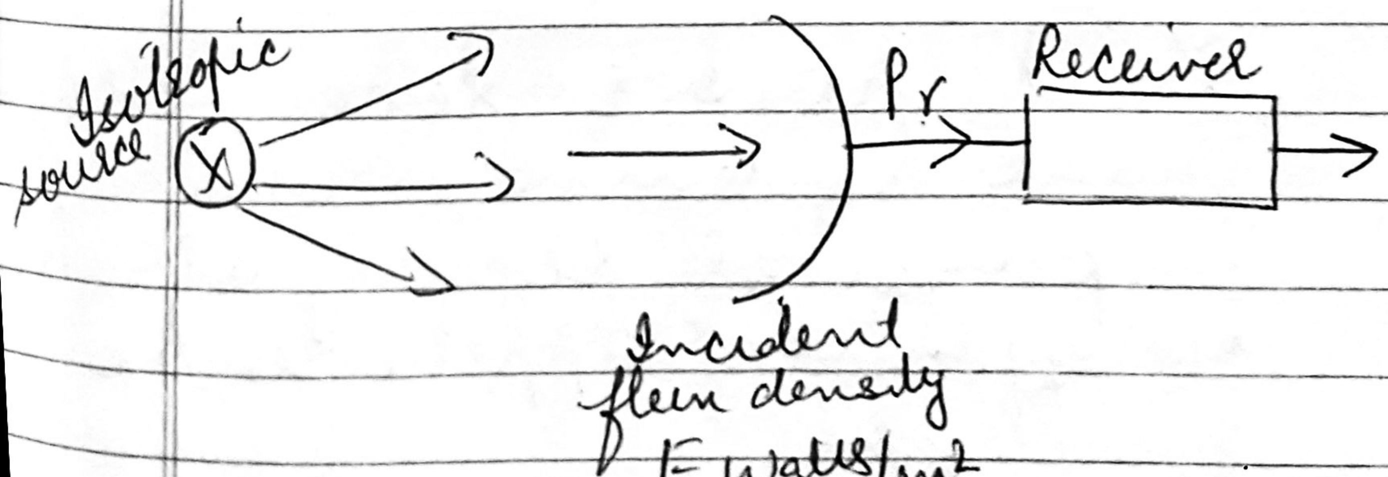
$$F = \frac{P_t G_t}{4\pi R^2} \quad W/m^2.$$

$P_t G_t = EIRP$

$$F = \frac{EIRP}{4\pi R^2} \ W/m^2$$

If we had an ideal receiving antenna with an aperture area A mts then power collected at radiated power is given as

$$P_r = F \times A$$



For a practical antenna w/n physical apperture area $A_r m^2$

Then effective aperture is defined as Ae

$$A_e = \eta A_r$$

$\eta \rightarrow$ apperture efficency accounts for all loss between incident wavefront & antenna o/p port

Thus power received by real antenna with a physical receiving area A_r & effective apperture A_e ie

$$P_r = \frac{P_t G_t A_e}{4 \pi R^2}$$

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

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

$$P_r = \frac{(P_t G_t) G_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$$

$\lambda \rightarrow$ wavelength (mtr) at freq of operation

$$\text{Power Received} = \frac{(\text{EIRP})(\text{Receiving ant gain})}{\text{Path loss}}$$

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

$$EIRP = 10 \log P_t G_t$$

$$G_r = 10 \log \frac{4\pi A_e}{\lambda^2}$$

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

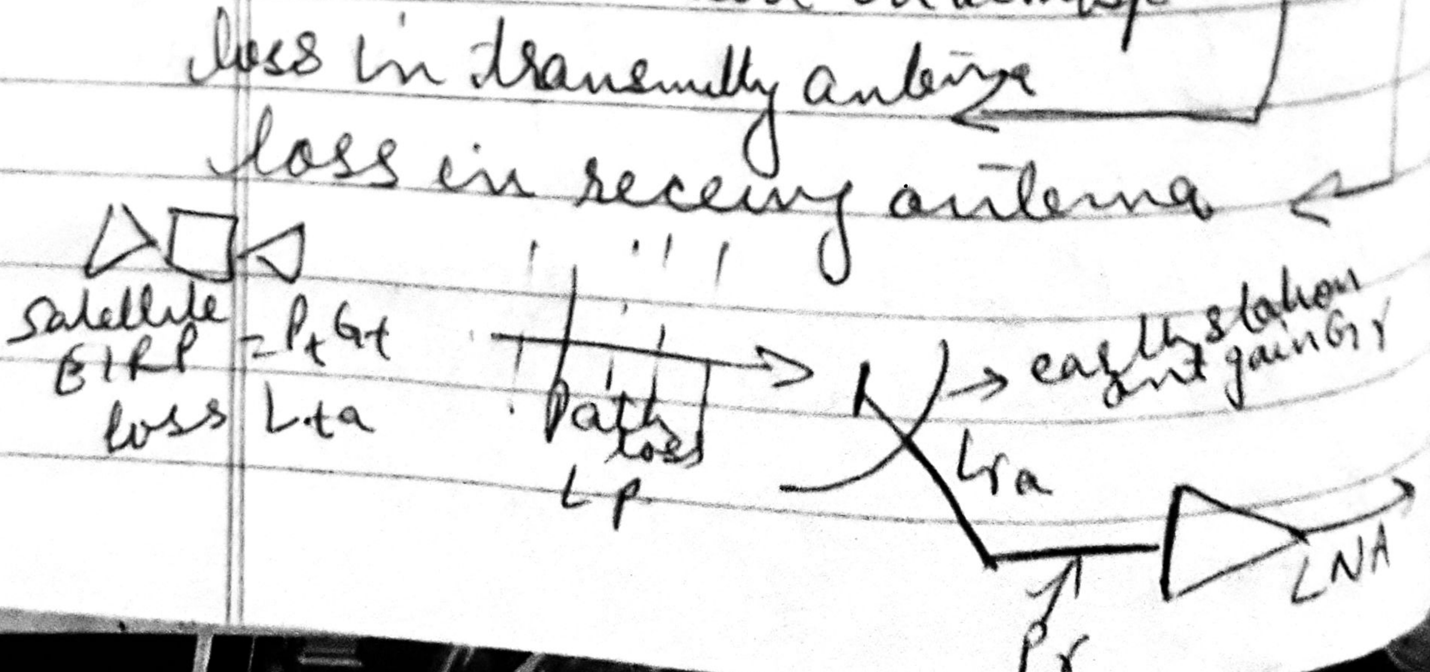
The above eq holds for ideal case in wk there no additional losses in link. It describes transmission b/w 2 ideal antennas in empty space but practically we need to take account of losses in atmosphere, in ante

$$P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra}$$

L_a ↳ attenuation in atmosp

L_{ta} loss in transmitting antenna

L_{ra} loss in receiving antenna



BACKOFF LOSS:- L_{bo}

H.P. Ampr's used in earth stat T^r's & TWT used in satellite are non linear devices. To reduce the amt of intermodulation distortion due to non linear amplification of HPA, the I/P power must be reduced (backed off) by several dB. This allows HPA to operate in a more linear region.

The amount of O/P level is backed off from rated levels is eqt to a loss w/c is called as Back OFF LOSS (L_{bo})

Transmit power & Bit Energy:

Carrier Pr / Transmit Power = P_t watts or Joules

Energy perbit = E_b.

$$\boxed{E_b = P_t T_b}$$

E_b → energy of a single bit
unit → Joules perbit

P_t → Total saturated O/P power
Total carrier power
unit (watts or Joules/sec)

T_b → Time of single bit (sec/bit)

$$T_b = \frac{1}{f_b}$$

$f_b \rightarrow$ bit rate in bits/sec

$$E_b = \frac{P_t}{f_b} = \frac{J/s}{b/s} = \frac{Joule}{bit}$$

Ques :- For a total transmit power P_t of 1000W, determine the energy per bit (E_b) for a transmission rate of 50 Mbps

$$T_b = \frac{1}{f_b} = \frac{1}{50 \times 10^6 \text{ bps}}$$

$$T_b = 2 \times 10^{-8} \text{ (seconds/bit)}$$

$P_t = 1000$ Watts or J/sec

$E_b = P_t T_b$

$= 1000 \times 2 \times 10^{-8}$

$= 20 \times 10^{-6}$ Joules / bit

$E_b = 20 \mu J$

↳ is itself energy per bit
∴ only joules

$E_b|_{dB} = 10 \log_{10} (20 \times 10^{-6})$

$= -46.98$ dB Joules

$E_b = -47$ dB Joules.

EIRP :— Effective isotropic radiated power. is defined as an equivalent transmitted power & is expressed mathematically as.

Equivalent or

$$\boxed{EIRP = P_{in} A_t}$$

EIRP → Eff iso rad power (watts)

$P_r \rightarrow P_{in} \rightarrow$ Input antenna power (watts)

$A_t \rightarrow$ transmit antenna gain (unitless

$$(EIRP)_{dBWatt} = P_{in_{dBW}} + A_{t\,dB}$$

$$P_r = P_{in} = P_t - L_{bo} - L_{bf}$$

$$\boxed{EIRP = P_t - L_{bo} - L_{bf} + A_t}$$

~~Ques~~

P_{in} → antenna I/P power (dBW per watt)

P_t → actual power of T^r (dBWatt/w)

L_{bo} → back off losses of HPA (dB)

L_{bf} → total branching & feeder losses (dB)

A_t → transmit antenna gain (dB)

Q/ For an earth station T^r w/s an antenna I/P power of 40dBW (10,000 Watt) a backoff loss of 3dB, a total branching & feeder loss of 3dB & a transmit antenna gain of 40dB Determine EIRP.

Ans. $EIRP = P_{in} - L_{bo} - L_{bf} + A_t$

$= 40 - 3 - 3 + 40$

$EIRP = 74\,dB\,watt$ [always give ans in dB if in Ques they are in ratio then convert to dB]

EQUIVALENT NOISE TEMPERATURE

Noise temperature is a way of determining how much thermal noise is generated by active & passive

devices in the receiving system
At μwave freqs, a black body with a physical temp T (degree Kelvin) generates electrical noise over a Bandwidth

Total noise power N or P_N

P_N $\boxed{N = KTB}$

$N \rightarrow$ total noise power (watts)
$K \rightarrow$ Boltzman's constant ~~(Joules)~~ (Joules/Kelvin)
$K = 1.38 \times 10^{-23}$ J/K or dBW/K/Hz

T = Temp of environment (Kelvin)
$B \rightarrow$ Bandwidth (Hz)

F (Noise factor)

$$F = 1 + \frac{T_e}{T}$$

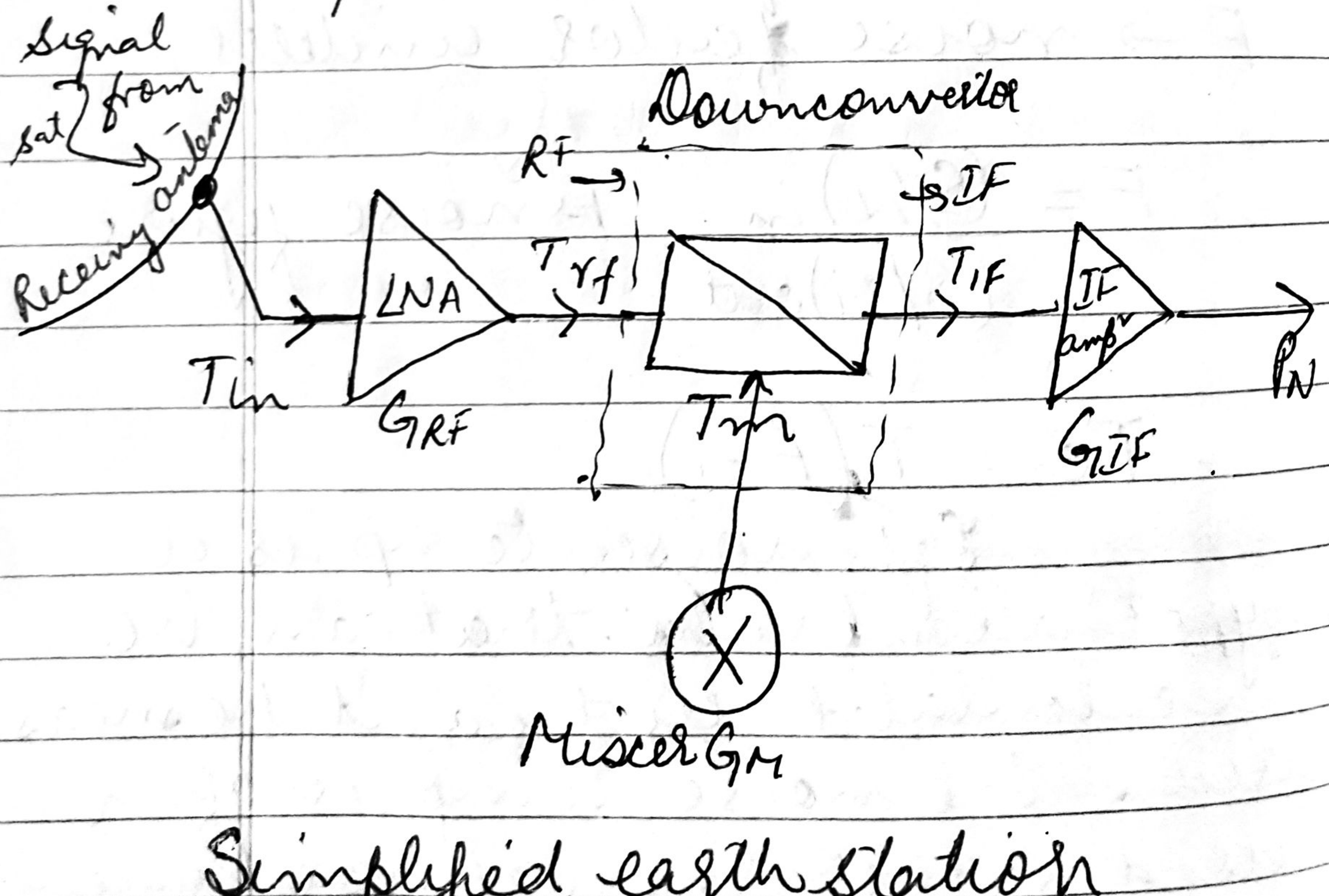
$T_e \rightarrow$ eqt noise temperature(K)
$F \rightarrow$ noise factor unitless

$$F = \frac{(S/N)_{in}}{(S/N)_{out}}$$ $F \rightarrow$ noise figure

$$T_e = T(F-1)$$

Eqt noise temp is a hypothetical value that can be calculated but can't be measured. Eqt noise temp is often used rather than noise figure. Eqt noise temp T_e represents noise power present at I/p to a device plus the noise added internally by that device

Derivation to calculate SYSTEM NOISE TEMPERATURE



Simplified earth station receiver.

$T_S \rightarrow$ Several sources of noise in receiver in the form of system noise temp

$T_{in} \rightarrow$ eqt noise temp at RF section

A simple communication receiver consists of 3 components

Sno.	Components	Eqt temp	Gain
1)	RF ampr or LNA	T_{rf}	G_{rf}
2)	Downconvertor (mixer + local osc)	T_m	G_m
3)	IF amplifier	T_{if}	G_{if}

Total noise power at o/p of IF amp^r of the R^r is given by (take gain in cascade)

eq ① ← $$P_N = (KT_{if}B)G_{if} + (KT_m B)G_{if}G_m + K(T_{in}+T_{rf})B\,G_{if}G_m G_{rf}$$

P_N is total noise power in terms of T_S (system noise temp)

eq ② ← $$P_N = [KT_S B]G_{if}G_m G_{rf}$$

from ① & ②

$$(KT_S B G_{if}G_m G_{rf}) = (KT_{if}B)G_{if} + (KT_m B)G_{if}G_m + K(T_{in}T_{rf})B G_{if}G_m G_{rf}$$

$$T_S \left[KBG_{if}G_mG_{rf} \right] = (KBG_{if}G_mG_{rf}) \left[\frac{T_{if}}{G_mG_{rf}} + \frac{T_m}{G_{rf}} + T_{in} + T_{rf} \right]$$

$$T_S = \frac{T_{if}}{G_mG_{rf}} + \frac{T_m}{G_{rf}} + T_{rf} + T_{in}$$

From the above expression of T_S we concluded that succeding stages of receiver contribute less & less noise to total system noise temp

Special Cases:—

Case I → If gain of RF amp^r is high then the noise contributed by IF amp^r & later stages can be ignored

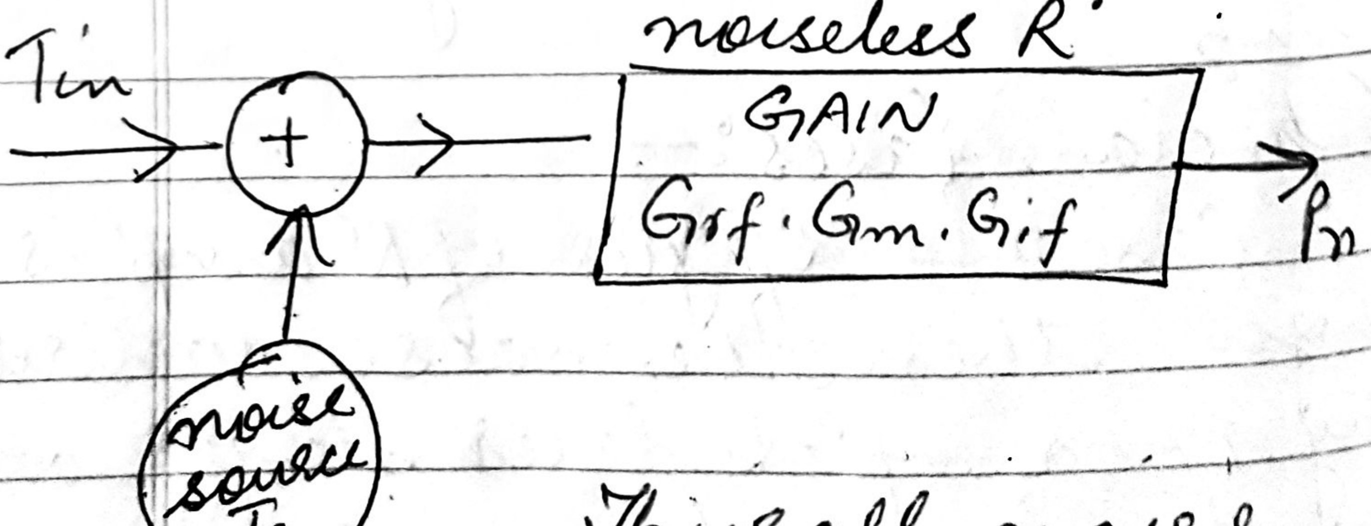
The T_S in this case is simply

$$T_S = T_{rf} + T_{in}$$

Sum of antenna noise temp & low noise amplifier noise temp

{Value for components gains is in ratio & not in dB}

Equivalent noise model



Thus all noise comes from antenna or is internally generated by R^x

Read Pg 110 Pratt $T_{no} = T[1 - G_l]$

$G_l \rightarrow$ linear gain not in dB
$G_l < 1$

Q For a small earth station R^x on 4GHz typical values of gain & noise temp are

$T_{in} = 50\,K$ $G_{rf} = 23\,dB\ (10^{2.3} = 199.52)$
$T_{rf} = 50\,K$ $G_m = 0\,dB$
$T_m = 500\,K$ $G_{IF} = 30\,dB\ (10^3 = 1000)$
$T_{if} = 1000\,K$

$$T_S = \frac{T_{if}}{G_m G_{rf}} + \frac{T_m}{G_{rf}} + T_{in} + T_{rf}$$

$$T_S = \frac{1000}{(1)(199.52)} + \frac{500}{199.52} + 50 + 50$$

$$T_S = 5.012 + 2.506 + 100$$

$$T_S = 107.51 \text{ Kelvin}$$

Ques $T_{in} = 25K$.
Pg 110

Cal T_S if $G_m = 0$ dB.
(2) Recalculate T_S w/n mixer has 10dB loss. How can noise temp of R' be minimized w/n mixer has 10dB loss

$$T_S = 25 + 50 + \frac{500}{199.52} + \frac{1000}{199.52}$$

$$\boxed{T_S = 82.51\,K}$$

(2) ∵ 10 dB loss to mixer ∴ gain down by 10 dB.

$$G_m = -10\,dB$$
$$10 \log G_m = -10\,dB.$$
$$G_m = 0.1$$

$$T_S = 25 + 50 + \frac{500}{199.52} + \frac{1000}{(199.52)(0.1)}$$

$$T_S = 127.62\,K.$$

Lowest sys noise temp is obtd by using high gain LNA

So Tse the LNA gain lete

$G_{RF} = 50\,dB$ then
$\cancel{100}\ 10^5$

$$T_S = 25 + 50 + \frac{500}{10^5} + \frac{1000}{10^4}$$

$$T_S = 75.105\,K$$

OR $T_S \approx T_{in} + T_{RF}$

$$T_S = 75\,K.$$

see Pratt pg 110
Eg 4.3.2