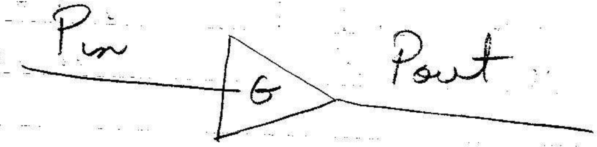
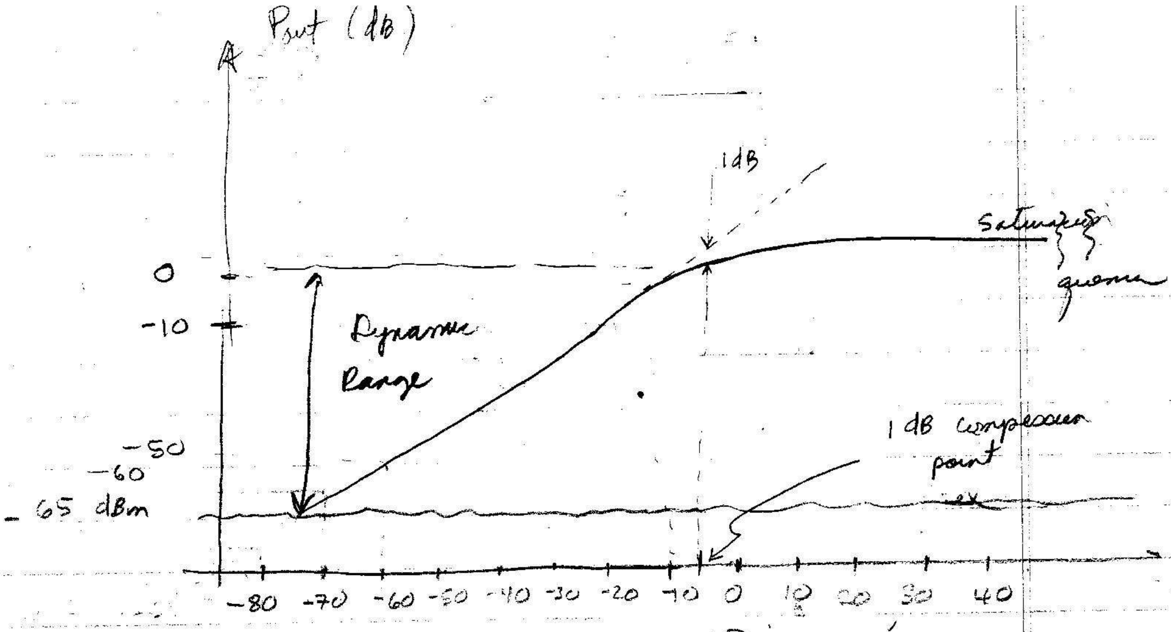
Ruido en sistemas de microondas:
(Vibraciones de electrones en conductores)
→ se puede generar fuera ó dentro del sistema

nivel de ruido → límite de energía mínima que se puede detectar

→ deseamos minimizar ruido

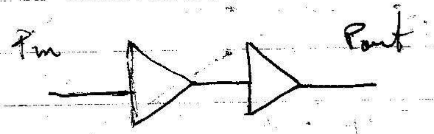
→ radiometro → distingue entre el potencia de ruido recibido y la generada en el sistema.

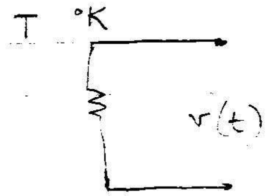


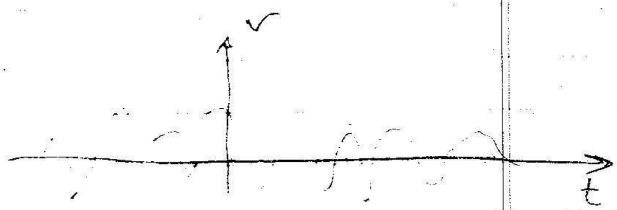


$G = 10\,dB$ $\qquad$ $P_{out} = 10\,P_{in}$

1dB CP → Pout esta 1dB por debajo de amplificador ideal







$\langle v \rangle = 0 \qquad v_{RMS} = v_n \neq 0$

Para microondas

$$v_n = \sqrt{4kTBR}$$

no depende de F ("white noise")

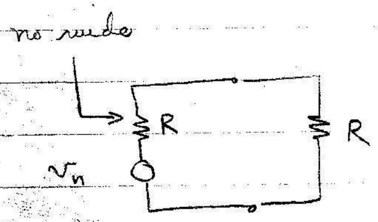
$k \rightarrow$ constante Boltzmann $= 1.380 \times 10^{-23}$ J/°K

$T \rightarrow$ Temperatura (°K)

$B \rightarrow$ ancho de banda del sistema [Hz]

$R \rightarrow$ Resistencia (Ω)

Modelo



Potencia de ruido

$$P_n = i^2 R = \left(\frac{v_n}{2R}\right)^2 R$$

$$= \frac{v_n^2}{4R} = \frac{\cancel{4}kTB\cancel{R}}{\cancel{4R}} = \underline{\underline{kTB}}$$

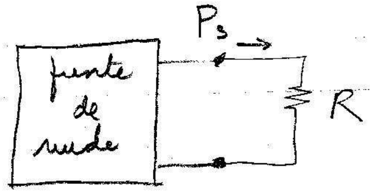
$B \to 0$ $P_n \to 0$ (Recoge menos ruido)

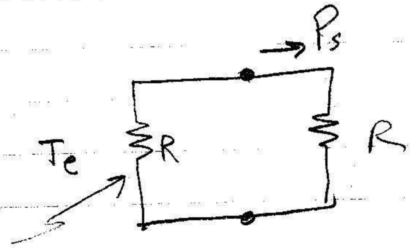
~~$T \to 0$ $P_n \to 0$ (más frío ... menos ruido)~~

$B \to \infty$ $P_n \to \infty$ (no ocurre)

eq. no valida

Potencia de ruido (termal) se puede modelar con temperatura equivalente de ruido (T_e).





$T_e \to$ temperatura que produce misma potencia (P_s) generada por fuente de ruido

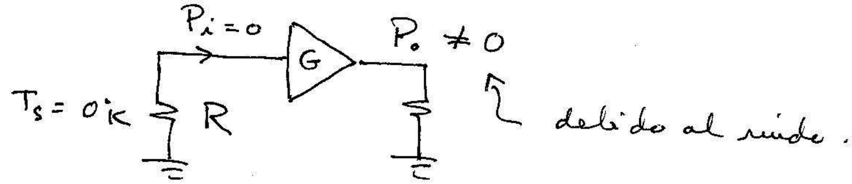
$$P = kTB$$

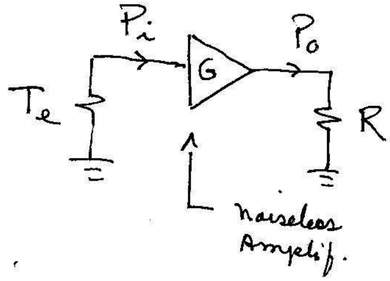
$$P_s = kT_eB \Rightarrow T_e = \frac{P_s}{kB}$$

1se clase, potencia de ruido $P_n = kTB$.

El ruido que se genera en un amplificador lo podemos caracterizar con T_e, temperatura equivalente de ruido:

Considerar:

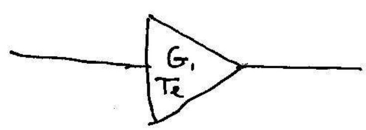




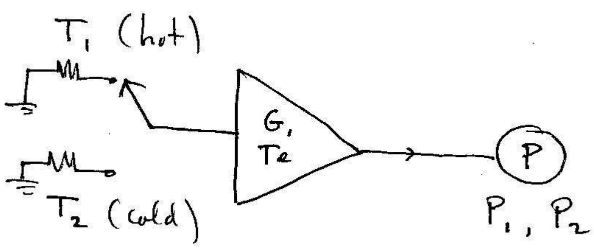
$$P_o = G P_i = G k T_e B$$

$$\therefore T_e = \frac{P_o}{G k B}$$

Ruido en amplificador se representa con T_e.



Metodo "factor - Y" para medir T_e del amplificador



$$P_2 = kT_2BG + kT_eBG$$

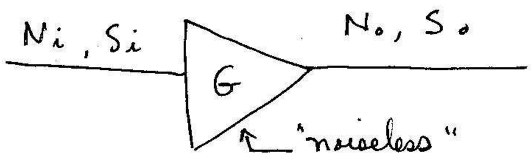
$$Y = \frac{P_1}{P_2} = \frac{T_1 + T_e}{T_2 + T_e} \Longrightarrow$$ P_1 y P_2 son medidos ∴ conozco Y.

$$Y(T_2 + T_e) = T_1 + T_e \longrightarrow T_e = \frac{T_1 - YT_2}{(Y - 1)}$$

Figura de ruido ("Noise Figure") – F → medida que caracteriza ruido en componentes (amplificador, sistema, subsistemas, etc...). Compara ruido entre entrada y salida del sistema.

$$\frac{S_i/N_i}{S_o/N_o} \geq 1$$

$S/N \Longrightarrow$ "signal-to-noise" ratio $\Longrightarrow$ razón de señal deseable (S) entre potencia de ruido (N)



$S_o = GS_i$

$N_o = GN_i$

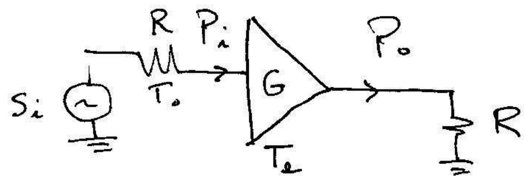
$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i/N_i}{\cancel{G}S_i/\cancel{G}N_i} = \underline{1}$$ No noise!!

$$F = \frac{\cdots}{GS_i / GN_i + \Delta N} > 1$$

Noisy !

Para medir F, usaremos por definición $N_i = kT_oB$

$T_o = 290^\circ K$



$$P_i = N_i + S_i \quad ; \quad P_o = N_o + S_o$$

$$P_o = GS_i + \underbrace{GN_i + GkT_eB}_{N_o}$$

$$\Longrightarrow \quad N_o = GN_i + GkT_eB = GkT_oB + GkT_eB$$

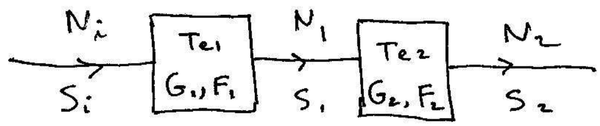
$$N_o = GkB\,(T_o + T_e)$$

$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i}{N_i} \cdot \frac{N_o}{S_o} = \frac{\cancel{S_i}}{\cancel{k}T_oB} \cdot \frac{\cancel{G}\cancel{k}\cancel{B}(T_o + T_e)}{\cancel{G}\cancel{S_i}}$$

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

$$\boxed{F = 1 + \frac{T_e}{T_o}} \qquad \boxed{T_e = (F-1)\,T_o}$$

Cascade configuration:



$$G_{TOT} = G_1 G_2$$

$$N_2 = G_{TOT}\, k B T_0 + G_{TOT}\, k B T_{casc.} \qquad \text{——(1)}$$

$$N_1 = G_1 k T_0 B + G_1 k T_{e1} B$$

$$N_2 = N_1 G_2 + G_2 k T_{e2} B$$

$$= G_1 G_2 k T_0 B + G_1 G_2 k T_{e1} B + G_2 k T_{e2} B$$

$$= G_1 G_2 k B \left(T_0 + T_{e1} + \frac{T_{e2}}{G_1} \right)$$

Comparando con (1):

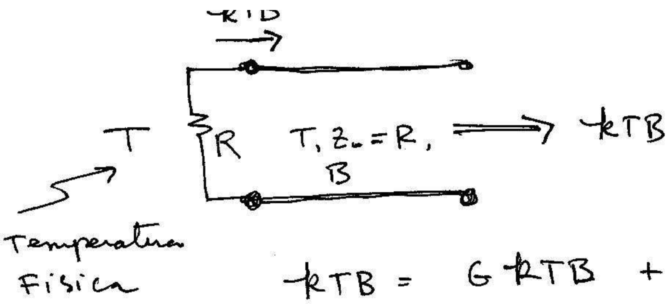
$$T_{cas} = T_{e1} + \frac{T_{e2}}{G_1}$$

$$F_{cas} = 1 + \frac{T_{cas}}{T_0} = F_1 + \frac{(F_2 - 1)}{G_1}$$

En general:

$$T_{cas} = T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \cdots$$

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots$$



$$kTB = G\,kTB + G\,N_{add}$$

$$G \rightarrow \text{losses} \rightarrow \quad G < 1 \longrightarrow L = \frac{1}{G}$$

$$\therefore \; G < 1 \;\; ; \quad L > 1$$

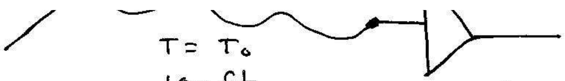
$$N_{add} = \frac{kTB\,(1-G)}{G} = kT_eB$$

$$T_e = \frac{T\,(1-G)}{G} = T\,(L-1)$$

Since $F = 1 + \frac{T_e}{T_0} \Longrightarrow F = 1 + \frac{T}{T_0}(L-1)$

Si $T = T_0 \Longrightarrow F = L$

Por ejemplo: un atenuador de 3 dB a $T = T_0$ tiene Figura de ruido $\underline{\underline{F = 3\text{ dB}}}$



$T = T_0$
100 ft
$.03 \frac{dB}{ft}$

$G = 15\,dB$
$B = 100\,MHz$
$T_e = 150^\circ K$

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1}$$

a) Since $T = T_0 \implies F_1 =$ attenuation

$$\text{Attenuation} = .03 \frac{dB}{ft} \cdot 100 = 3\,dB$$

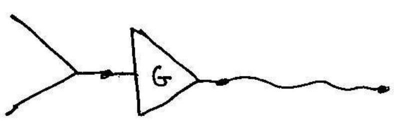
$$F_1 = 3\,dB \implies G_1 = 0.5 \;;\; L = 2$$

$$F_1 = 1 + \frac{T}{T_0}(L-1) = 1 + \frac{\cancel{T_0}}{\cancel{T_0}}(2-1) = 2$$

$$F_{amp} = 1 + \frac{T_e}{T_0} = 1 + \frac{150}{290} = 1.52$$

$$F_{cas} = 2 + \frac{1.52 - 1}{0.5} = 3.04 = \underline{4.82\,dB}$$

b)



$$F_{cas} = 1.52 + \frac{2-1}{31.62} = 1.55$$

$$= 1.9\,dB$$

$$G = 15\,dB \implies 10^{1.5} = 31.62$$

From $F_a = 4.82\,dB \implies F_b = \underline{1.9\,dB}$

$BW = 150\times10^6\ Hz$

$F = 4\ dB = 2.51$

$$F_{casc} = F_1 + \frac{F_2-1}{G_1} = 2.51 + \frac{4.10-1}{15.8} = 2.71 = 4.3\,dB$$

10.7

$$T_e = \frac{P_s}{kB} = \frac{(10^{-85/10})(10^{-3})}{(1.38\times10^{-23})(1\times10^9)} = 229\ ^\circ K$$

$$F_{AMP} = 1 + \frac{T_e}{T_0} = 1 + \frac{180}{290} = 1.62 = 2.1\ dB$$

$$F_{line} = 1 + (L-1)\frac{T}{T_0} = 1 + (1.41-1)\frac{300}{290} = 1.43$$

notar: $L > 1$

$$F_{cas} = F_1 + \frac{1}{G_1}(F_2-1) = F_1 + L(F_2-1) = 1.43 + (1.41)(1.62-1) = 2.3 = 3.6\,dB$$

$P_{noise} = P_{due\ input} + P_{due\ system}$

$P_{d.input} = -85\,dBm - 1.5\,dB + 12\,dB = -74.5\,dBm = 3.55\times10^{-11}$

$G_{cas} = 12 - 1.5\,dB = 10.5\,dB$

$$P_{d.system} = kT_{e_{cas}}BG_{cas} = k(F_{cas}-1)T_0BG_{cas} = k(2.3-1)(1\times10^9)(10^{1.05})(290) = 5.84\times10^{-11}\,W$$

$$P_{noise} = 5.84\times10^{-11} + 3.55\times10^{-11}\,W = 9.39\times10^{-11}\,W = -70.3\,dBm$$

10.8

$$F_{cas} = F_1 + \frac{F_2-1}{G_1} + \frac{F_3-1}{G_1G_2} = 1.41 + (1.41)(1.58-1) + \frac{1.41}{10}(1.58-1) = 2.31 = 3.64\,dB$$

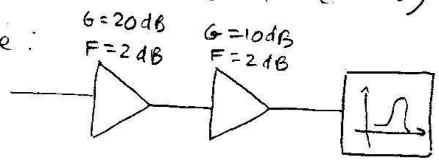
If $P_{in} = -90\,dBm$ $\quad P_{out} = -90 - 1.5 + 10 + 20 = -61.5\ dBm$

$$P_n = G_{cas}\,k\,T_{e_{cas}}B = k(F_{cas}-1)T_0BG_{cas}$$

$$= 1.38\times10^{-23}(2.31-1)(290)(10^8)(10^{28.5/10}) = 3.71\times10^{-10}\,W = -64.3\,dBm$$

$$\left(\frac{S_0}{N_0}\right)_{dB} = S_{0\,dB} - N_{0\,dB} = -61.5-(-64.3) = \underline{2.8\,dB}$$

Best noise Figure:



$$F_{cas} = 1.58 + \frac{(1.58-1)}{100} + \frac{(1.41-1)}{1000} = 1.586 = \underline{2\,dB}$$