1- A two-port network has a standard temperature noise figure of 2.0 dB, a gain of 16 dB and a noise effective bandwidth of 2.5 kHz. What is the available noise power output in dBm? How much noise power is added by the amplifier in dBm? What is the noise equivalent temperature of the network?

$$F = 2\,\text{dB} = 1.584,\ G = 16\,\text{dB} = 39.81$$
$$N_0 = kT_0BFG_A = (1.38\times10^{-23})(290)(2.5\times10^{3})(1.584)(39.81) = 6.313\times10^{-16}\ \text{W} = -122\,\text{dBm}$$
$$P_{added} = (F-1)kT_0BG_A = 2.329\times10^{-16}\,\text{W} = -126.3\,\text{dBm}$$
$$T_e = (F-1)T_0 = 169.6°\text{K}$$

1- The noise figure of an amplifier is 3.2 dB at an ambient temperature of 297 K. What is the noise temperature of the amplifier?

$$NF = 3.2\,\text{dB} = 2.09\ \text{W/W}$$
$$T_a = (NF-1)T_o = (2.09-1)(297\ \text{K}) = 323\,\text{K}$$

3- Aşağıdaki sistemde merkez frekans 20 GHz olup bant genişliği 1 GHz ve sistemin sıcaklığı T = 300 K.'dir

a) Gürültü kaynağının eşdeğer sıcaklığı nedir?

b) Kuvvetlendiricinin gürültü faktörü nedir?

c) Kuvvetlendiricinin ve iletim hattının kaskat bağlanmasının gürültü faktörü nedir?

d) Gürültü kaynağı bağlandığında sistemin çıkışındaki gücü dBm olarak bulun.

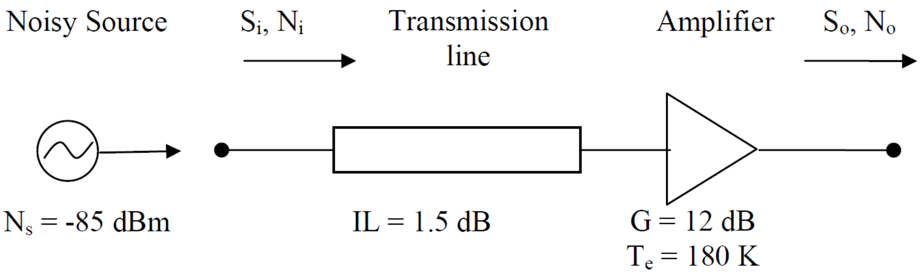
3- Consider the microwave system below, where the bandwidth is 1 GHz centered at 20 GHz, and the physical temperature of the system is T = 300 K.

a) What is the equivalent noise temperature of the source?

b) What is the noise figure of the amplifier, in dB?

c) What is the noise figure of the cascaded transmission line and amplifier, in dB?

d) When the noisy source is connected to the system, what is the total noise power output of the amplifier, in dBm?



$$B = 1\,\text{GHz}, G_1 = \tfrac{1}{1.41}, G_2 = 15.8$$

$$\text{a) } T_{es} = \frac{N_s}{kB} = \frac{(10^{-85/100}\,\text{mW})(1\,\text{W}/1000\,\text{mW})}{(1.38\times10^{-23})(1\,\text{GHz})} = 229.15\,\text{K}$$

$$\text{b) } F_2 = 1 + \frac{T_e}{T_0} = 1 + \frac{180}{290} = 1.62 = 2.1\,\text{dB}$$

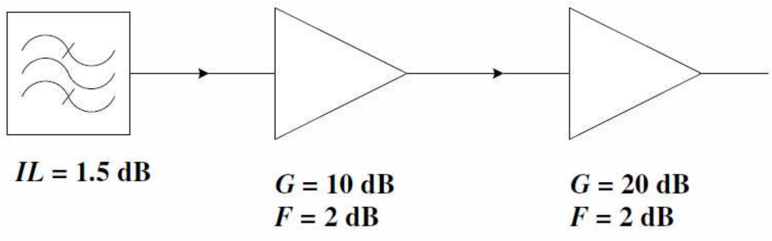
$$\text{c) } F_1 = 1 + (L-1)\frac{T}{T_0} = 1 + (1.41-1)\frac{300}{290} = 1.424$$

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} = 1.424 + (1.62-1)1.41 = 2.3 = 3.6\,\text{dB}$$

$$\text{d) } T_{ecas} = (F_{cas}-1)290 = 377\,\text{K} \Rightarrow N_0 = kBG_1G_2(T_{es}+T_{ecas}) = 9.37\times10^{-11} = -70.3\,\text{dBm}$$

1- Consider the WLAN receiver front-end shown below, where the bandwidth of the bandpass filter is 100 MHz centered at 2.4 GHz. If the system is at room temperature, find the overall noise figure. What is the resulting signal-to-noise ratio at the output if the input signal power level is -90 dBm? Can the components be rearranged to give a better noise figure?

1- 2.4 GHz'te 100 MHz bant genişliğine sahip WLAN alıcı devresi aşağıda verilmektedir. Sistemin oda sıcaklığındaki toplam gürültü faktorünü bulun. Girişe -90 dBm sinyal seviyesi uygulandığında çıkıştaki sinyal/gürültü oranı ne olur? Aşağıdaki sistem nasıl dizilmelidir ki toplam gürültü seviyesi en az olsun.



$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 1.44 + \frac{1.58 - 1}{1/1.41} + \frac{1.41 - 1}{10} = 2.3 = 3.64\,\text{dB}$$

$$S_i = -90\,\text{dBm} \Rightarrow S_o = S_i I_L G_1 G_2 \to S_o(\text{dBm}) = -90 - 1.5 + 10 + 20 = -61.5\,\text{dBm},$$

$$G_{cas} = -IL + G_1 + G_2 = 28.5\,\text{dB} = 707.946$$

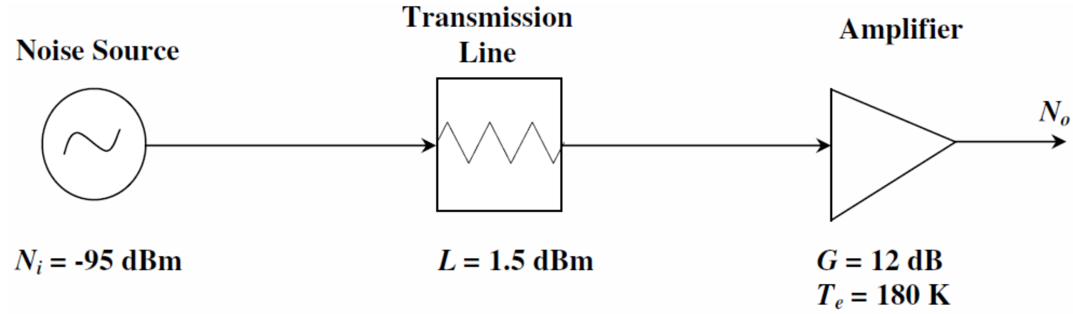
$$N_o = kT_{cas} B G_{cas} = k(F_{cas} - 1)T_0 B G_{cas} = 1.38 \times 10^{-23}(2.3 - 1)(290)(100 \times 10^6)(708)$$

$$= 3.71 \times 10^{-10}\ \text{W} = -64.3\,\text{dBm} \to S_o/N_o = -61.5 + 64.3 = 2.8\,\text{dB}$$

The best NF can be achieved when the element with highest G appear at the front and highest loss at the end.

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 1.58 + \frac{1.58 - 1}{100} + \frac{1.41 - 1}{1000} = 1.586 = 2.0\,\text{dB}$$

2- A PCS cellular receiver front-end is shown below. The operating frequency is 1805-1880 MHz, and the physical temperature of the system is 300 K. A noise source with noise power N_i = -95 dBm is applied to the receiver input.



a) What is the equivalent noise temperature of the source over the operating bandwidth?
b) What is the noise figure (in dB) of the amplifier?
c) What is the noise figure (in dB) of the cascaded transmission line and amplifier?
d)What is the total noise power (in dBm) of the receiver output over the operating bandwidth?

a) $T_e = \frac{N_i}{kB} = \frac{3.16 \times 10^{-6}}{1.38 \times 10^{-23} \times 75 \times 10^{6}} = 305.3\,\mathrm{K}$

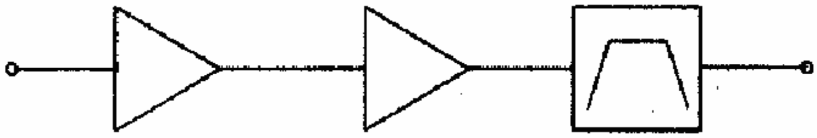
b) $F_{amp} = 1 + \frac{T_e}{T_0} = 1 + \frac{180}{290} = 1.62 = 2\,\mathrm{dB}$

c) $F_{line} = 1 + (L-1)T/T_0\,,\ F_{cas} = F_1 + \frac{F_2 - 1}{G_1} = 1.42 + \frac{1.62 - 1}{1/1.41} = 2.28 = 3.58\,\mathrm{dB}$

c) $T_{cas} = (F_{cas} - 1)T_0 = (2.28 - 1)290 = 378\,\mathrm{K},\ G_{cas} = G_{amp}G_{line} = 15.8/1.41 = 11.2 = 10.5\,\mathrm{dB}$

$\rightarrow N_o = k(T_{cas} + T_e)BG_{cas} = 1.38 \times 10^{-23}(378 + 305)75 \times 10^{6} \times 11.2 = 7.9 \times^{-12}\ \mathrm{W} = -81\,\mathrm{dBm}$

1- The equivalent temperature of a low noise amplifier is 50 K. A second stage amplifier has a noise figure of 2 dB. Both amplifiers have 15 dB gain and 1 dB compression points of 10 dBm, and the system bandwidth is 1 MHz. Following the amplifiers is a 100 foot length of coaxial cable with a 6 dB loss at the band center frequency (1 GHz).



$T = 50\,\mathrm{K}$ $\quad F = 2\,\mathrm{dB}$ $\quad 100\,\mathrm{ft\ cable}$

$G = 15\,\mathrm{dB}$ $\quad G = 15\,\mathrm{dB}$ $\quad 6\,\mathrm{dB\ \ loss\ at\ } f = 1\,\mathrm{GHz}$

(a) Find the noise figure and equivalent noise temperature of this system.

$$F_1 = 1 + \frac{50}{290} = 1.1724,\ F_2 = 10^{2/10} = 1.5849,\ F_3 = L = 10^{6/10} = 3.9811$$

$$G_1 = 10^{15/10} = 31.623,\ G_2 = 31.623,\ G_3 = 10^{-6/10} = 0.2512$$

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 1.194 = 0.770\,\mathrm{dB} \rightarrow T_{e,cas} = (F_{cas} - 1)T_0 = 56.2\,\mathrm{K}$$

(b) What is the input signal power in dBm/Hz that leads to an SNR of unity at the output?
(b) The output is connected to a detector that requires a signal at least 3 dB above the noise floor. What is the input signal power in dBm/Hz that leads to an SNR of 3 dB at the output?

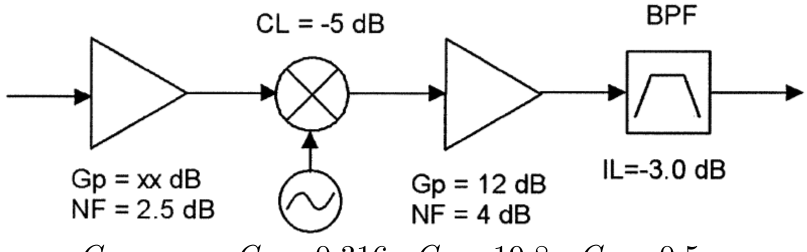
$$\mathrm{From\ the\ SNR\ statement,} S_0 = N_0,\ G_{cas} = \frac{S_0}{S_i} = \frac{N_0}{S_i} \rightarrow S_i = \frac{N_0}{G_{cas}} = \frac{G_{cas} k_B T_{e,cas} B}{G_{cas}} \rightarrow$$

$$\frac{S_i}{B} = k_B T_{e,cas} = 1.38 \times 10^{-23} \times 56.2 = 7.7556 \times 10^{-19}\,\frac{\mathrm{mW}}{\mathrm{Hz}} = -181.1\frac{\mathrm{dBm}}{\mathrm{Hz}}$$

(c) What is the dynamic range of the system?

$$N_o = G_{cas} k_B T_{e,cas} B = -97.1\,\mathrm{dBm} \rightarrow DR = 10\,\mathrm{dBm} - (-97.1\,\mathrm{dBm}) = 107.1\,\mathrm{dBm}$$

2- Determine the required gain for the first amplifier below so that the overall Noise Figure for the system is 2.817 dB.

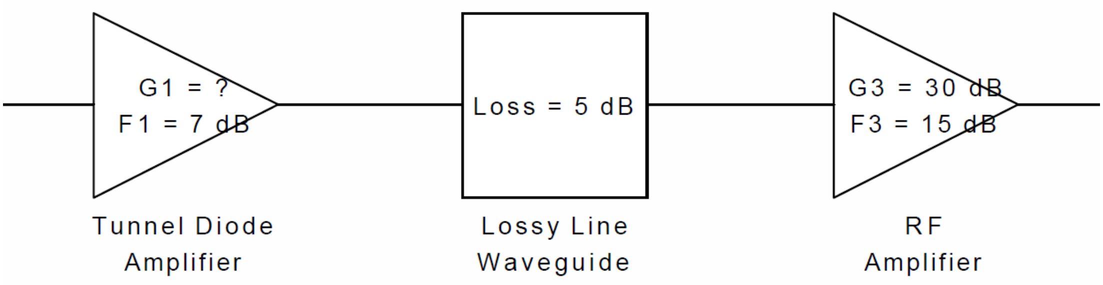


$G_1 = x \quad G_2 = 0.316 \quad G_3 = 19.8 \quad G_4 = 0.5$

$F_1 = 1.77 \quad F_2 = 3.16 \quad F_3 = 2.51 \quad F_4 = 2.0$

$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} = 1.91 = 1.77 + \frac{3.16-1}{x} + \frac{2.51-1}{x0.316} + \frac{2.0-1}{x0.316\times 19.8} \rightarrow x = 50.9 = 17\,\mathrm{dB}$$

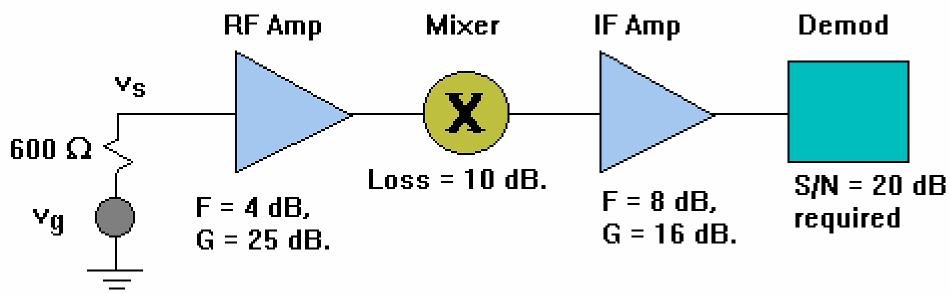
3- The front end of an RF receiver is shown in the following figure, where the elements are perfectly matched. How much power gain must the tunnel diode amplifier have to produce a front-end noise figure of 10 dB?



$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = F_1 + \frac{\frac{1}{L_2} - 1}{G_1} + \frac{F_3 - 1}{G_1 L_2} \rightarrow F_{total} - F_1 = \frac{\left(\frac{1}{L_2} - 1\right) + \frac{F_3 - 1}{L_2}}{G_1}$$

$$G_1 = \frac{\frac{F_3}{L_2} - 1}{F_{total} - F_1} = \frac{\frac{10^{15/10}}{10^{-5/10}} - 1}{10^{10/10} - 10^{7/10}} = \frac{10^2 - 1}{10 - 10^{7/10}} = \frac{99}{4.99} \approx 20 \rightarrow G_1 = 13\,\text{dB}$$

1- Consider the following system:



a) What is the noise figure of the receiver (RF Amp, Mixer, IF Amp) shown below? The system has 600 ohm impedances matched input and output.

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 2.51 + \frac{10 - 1}{316.23} + \frac{6.31 - 1}{(316.23)(0.1)} = 2.71 = 4.33\ \text{dB}$$

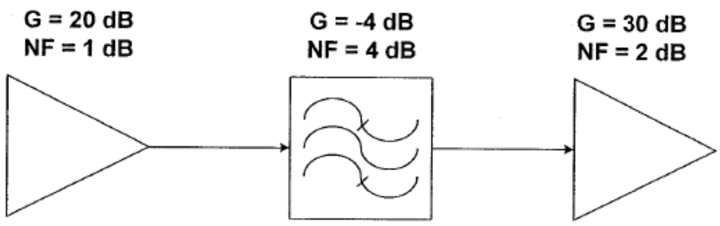
b) What minimum signal voltage will give the output S/N of 20 dB? The BW=25 KHz, assume a temperature of 300 Deg. K.

$$\frac{S_i}{N_i} = \frac{S_o}{N_o} F \Rightarrow \frac{V_s^2}{4kRTB} = \frac{S_o}{N_o} F$$

$$V_s^2 = 4kTBR_s F(S_o/N_o) = 4(1.38\times10^{-23})(300)(25\times10^3)(600)(2.71)(100) = 6.73\times10^{-11}$$

$$V_s = 8.2\ \mu\text{V} \rightarrow V_g = 8.2\times2 = 16.4\ \mu\text{V}$$

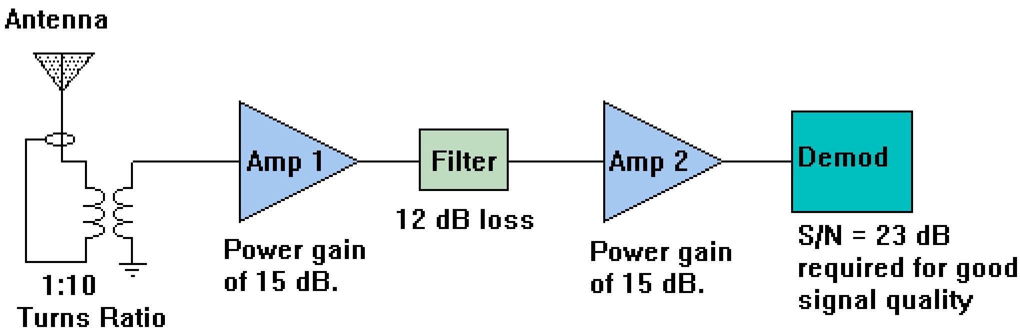
3- Aşağidaki alıcının toplam gürültü figürünü bulun.
3- Determine the noise figure of the following system.



$$G_1 = 100, F_1 = 1.259, G_2 = 0.398, F_2 = 2.512,\ G_3 = 1000,\ F_3 = 1.585$$

$$F_T = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 1.259 + \tfrac{2.512-1}{100} + \tfrac{1.585-1}{100(0.398)} == 1.298 = 1.33\,\mathrm{dB}$$

3- The system below has 50 ohm matched impedances at each stage. The first amplifier adds noise equivalent to 200 ohm, and the second noise equivalent to 300 ohm. The BW=25 KHz.



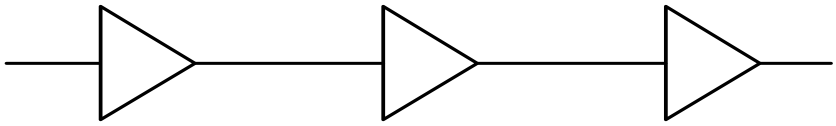
a) What is the noise figure of each stage, and of the receiver?

Amp 2 noise figure, neglecting any output contribution, is; $F_2 = 350/50 = 7 = 8.45$ dB.
Amp 1 noise figure, neglecting any output contribution, is; $F_1 = 250/50 = 5 = 7$ dB.
Total noise figure at the filter input is $8.45 + 12 = 20.45$ dB $= 111$.
Receiver noise figure is $F_R = 5 + (111-1)/31.62 = 8.5 = 9.3$ dB.

b) What minimum antenna voltage will give the outopu S/N of 23 dB?

At Amp 1 input $V_s^2 = 4kTBR_sF(S_o/N_o)$; $(S_o/N_o) = 23$ dB $= 200$, $F_R = 8.5$, $R_s = 50\ \Omega$
$V_s^2 = 4kTBR_sF(S_o/N_o) = 4(1.38\times10^{-23})(298)(25\times10^3)(50)(8.5)(200) = 3.5\times10^{-11} \rightarrow V_s = 5.9\ \mu\mathrm{V}$
With the input matched, transformer secondary must be twice the input voltage, or $11.8\ \mu\mathrm{V}$.
Primary voltage is $V_{antenna} = 1.2\ \mu\mathrm{V}$.

4- Given three cascaded amplifiers having the following parameters:



$Z_{in} = Z_{out} = 50\,\Omega$
$S_i = 1.5\,\mu\mathrm{W}$
$N_i = 0.01\,\mu\mathrm{W}$
$N_{amp} = 0.03\,\mu\mathrm{W}$
$G_1 = 20\,\mathrm{dB}$

$Z_{in} = Z_{out} = 50\,\Omega$
$F_2 = 11$
$G_2 = 1000$

$Z_{in} = Z_{out} = 50\,\Omega$
$N_o = 0.03\,\mu\mathrm{W}$
$F_3 = 9.8\,\mathrm{dB}$
$G_3 = 35\,\mathrm{dB}$

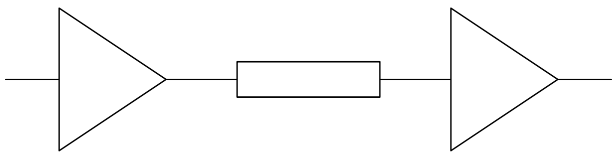
a) Determine S_o / N_o of stage 1.

$$S_o / N_o = GS_i / N_o = GS_i / (GN_i + N_{amp}) = 145.6 = 21.63\,\mathrm{dB}$$

b) Determine F1 and F3 and Fcas.

$$F_1 = 1.03,\; F_3 = 9.55, \quad F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 1.13 = 0.53\,\mathrm{dB}$$

2- Calculate the overall noise figure of the following system.
2- Aşağıdaki devrenin toplam gürültüsünü hesaplayın.

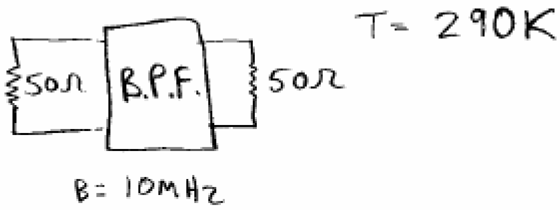


F_1 = 4 dB Loss = 8 dB F_3 = 6 dB
G_1= 12 dB

F_1 = 2.51 = 4 dB	F_2= 6.31 = 8 dB	F_3 = 3.98 = 6 dB
G_1= 15.85 = 12 dB	G_2 = 0.16 = -8 dB	G_3 = 39.81 = 16 dB

F = F_1 + (F_2 – 1)/G_1 + (F_3 –1)/G_1G_2
F = 2.51 + (6.31 – 1)/15.85 + (3.98 –1)/(15.85)(0.16) = 4.02 = 6.04 dB

8- A 50 ohm resistor at room temperature is connected to the input of a lossless bandpass fitler with passband with 10 MHz. The filter output is connected to a 50 ohm load.



(a) Find the time average noise power dissipated by the load in Watts/Hz.

$$P_n = k_B T B \qquad \frac{P_n}{B} = k_B T = \boxed{3.77\times 10^{-21}\ \frac{W}{Hz}}$$

(b) Find the power in dBm/Hz.

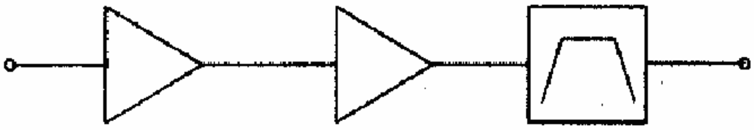
$$\frac{P_n}{B}\ (\text{dBm/Hz}) = 10\log\left(\frac{k_B T}{1\,\text{mW}}\right) = -174\ \text{dBm/Hz}$$

(c) Find the RMS noise voltage across the load.

$$P_n = \frac{\overline{v_n}^2}{4R} \qquad \overline{v_n} = \sqrt{4RP_n} = 2\sqrt{Rk_BTB}$$

$$= \boxed{2.75\ \mu V}$$

9- Consider the system below. Calculate the overall noise figure in dB for this system.



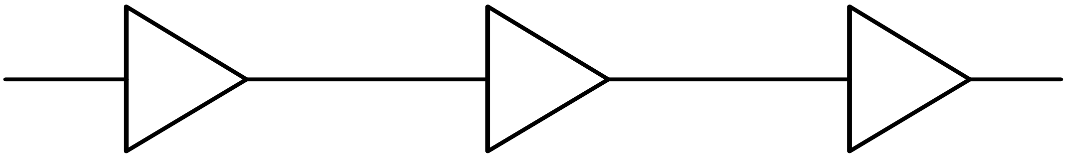
$G_1 = 15\,\text{dB}$ $\quad G_2 = 10\,\text{dB}$ $\quad \text{Loss} = -3\,\text{dB}$

$NF = 3\,\text{dB}$ $\quad NF = 4\,\text{dB}$

$$G_1 = 31.6, F_1 = 2, G_2 = 10, F_2 = 2.51, G_3 = 0.5, F_3 = 2$$

$$F_T = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} = 2 + \frac{2.512-1}{31.6} + \frac{2-1}{31.6(10)} = 2.051 = 3.12\,\text{dB}$$

5- Consider the following system.



Z_i=Z_o=50 ohm	Z_i=Z_o=50 ohm	Z_i=Z_o=50 ohm
G=20dB	G=30 dB	G=35 dB
N_i=0.01 μV	F=12	F=9.3 dB
S_o/N_o=120		

a) Determine F_1

F1=3.067

b) Determine S_i for stage 1

S_i=3.68 μV

c) Determine F_2

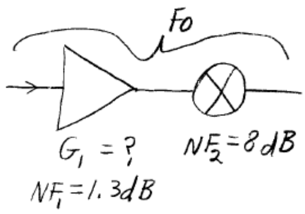
F2=10.79

d) Determine noise added by the amplifier in stage1 in μV

$$S_o/N_o = \frac{S_i G_1}{N_i G_1 + N_{amp}} \quad \rightarrow \quad N_{amp}=2.07\ \mu V$$

4- A superhet receiver has a mixer with a noise figure of NF = 8 dB. However, the designer needs an overall noise figure of 3 dB for his application. He decides to place a low noise amplifier in front of the mixer having a NF = 1.3 dB. What must the gain of the amplifier be to realize his design goal?

4- Superheterodin bir alıcının mikseri için NF = 8 dB'dir. Fakat alıcı için toplam NF = 3 dB olması isteniyor. Bunun için mikserin önüne NF = 1.3 dB olan bir kuvvetlendirici konuyor. Bu hedefe ulaşmak için kuvvetlendiricinin kazancı ne olmalıdır?



$$NF_{overall} = 10\log(F_o) = 3dB$$

$$F_0 = 10^{3/10} = 1.9953 \qquad NF_2 = 8dB$$

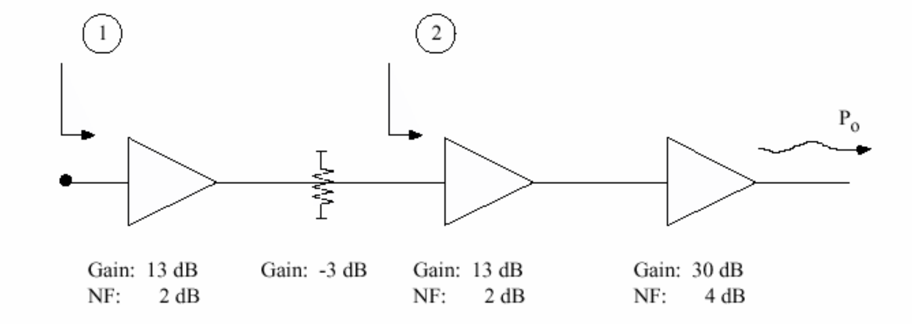
$$F_0 = F_1 + \frac{(F_2-1)}{G_1} \qquad F_2 = 10^{8/10} = 6.3096$$

$$F_1 = 10^{\frac{1.3}{10}} = 1.3490$$

$$F_0 = F_1 + \frac{(F_2-1)}{G_1} \qquad G_1 = \frac{(F_2-1)}{F_0 - F_1} = \frac{6.3096-1}{1.9953-1.3490}$$

$$G_1 = 8.22 \text{ or } 10\log(8.22) = 9.15dB$$

1- (a) Calculate the gain, noise figure and effective noise temperature as seen from the reference plane labeled on the figures. The filters act like attenuators at room temperature To = 290 K.

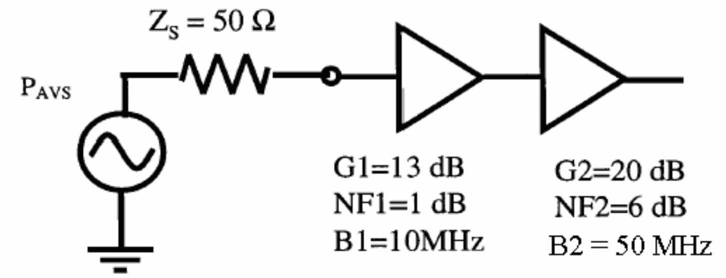


G_2 = 43 dB $F_2 = F_3 + (F_4 - 1)/G_3 = 1.66 = 2.2$ dB $T_2 = (F_2-1)T_0 =$ 191.5 K
G_1 = 53 dB $F_1 = F_1 + (F_2 - 1)/G_1 + (F_3 - 1)/G_1G_2 = 1.70 = 2.29$ dB $T_1 = (F_1-1)T_0 =$ 201.8 K

b) calculate the output power, Po, in a 100 MHz BW if a matched resistor at 300K is attached to the input.

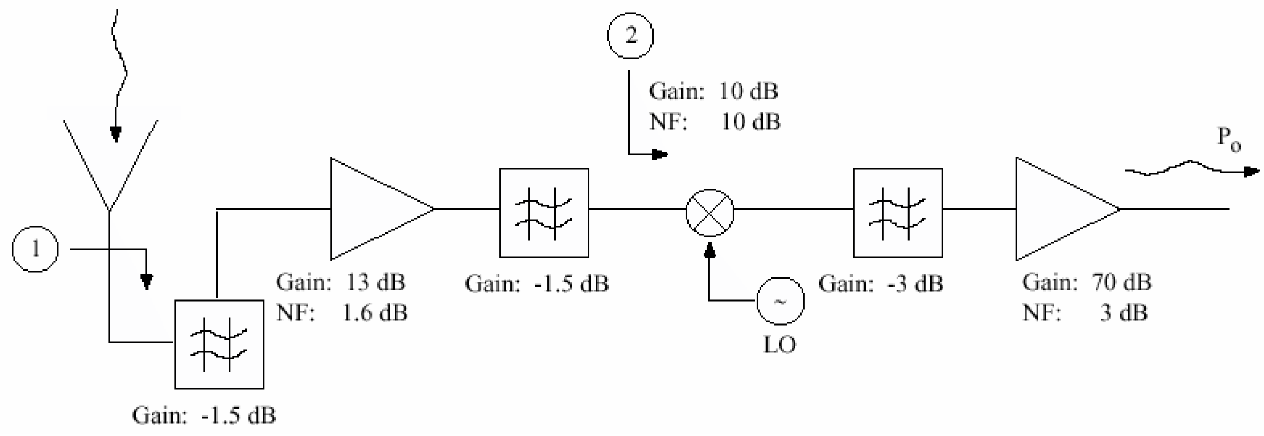
$P_o = (T_R + T_1)\, kBG_1 = (300+201.8)\, k\, (100\text{x}10^6)\, (200\ 000) = 138.6$ nW = –38.6 dBm

2- The available source power driving this amplifier chain is 1 pW. Determine (SNR)out of the chain.



$F = F_1 + (F_2 - 1) / G_1 = 1.26 + 3 / 20 = 1.41 = 1.51$ dB
(S/N)in = Pavs / kTB_1
Pavs = – 90 dBm
kTB_1 = – 174 dBm + $10\log 10^7$ = –104 dBm
(S/N)in = – 90 – (– 104) = 14 dB
(S/N)out (dB) = (S/N)in – NF (dB) =12.5 dB

2- Consider the following system.



a) Calculate the gain, noise figure and effective noise temperature as seen from the reference plane labeled on the figures. The filters act like attenuators at room temperature To= 290 K.

$$G_2 = 77\ dB,\ F_2 = F_4 + \frac{F_5 - 1}{G_4} + \frac{F_6 - 1}{G_4 G_5} = 10.8 = 10.12\ \text{dB} \rightarrow T_2 = (F_2 - 1)T_0 = 2697\ K$$

$$G_1 = 87\ dB,\ F_1 = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} = 3.0 = 4.76\ dB \rightarrow T_1 = (F_1 - 1)T_0 = 580\ K$$

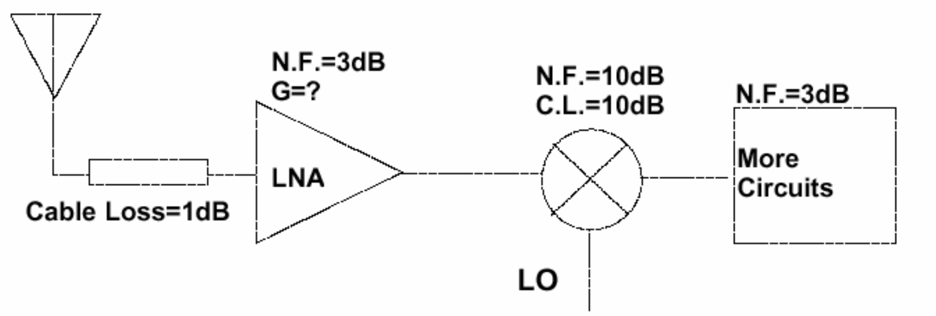
b) calculate the output power, Po, if a –98 dBm signal is input at the antenna.

Po = –98 dBm + 87 dB = –11 dBm = 79.4 uW

c) Calculate the output noise power, Po, in a 60 kHz bandwidth, if a 300 K matched resistor is attached in place of the antenna (the antenna effectively looks like a atched room-temperature resistor). What is the S/N ratio?

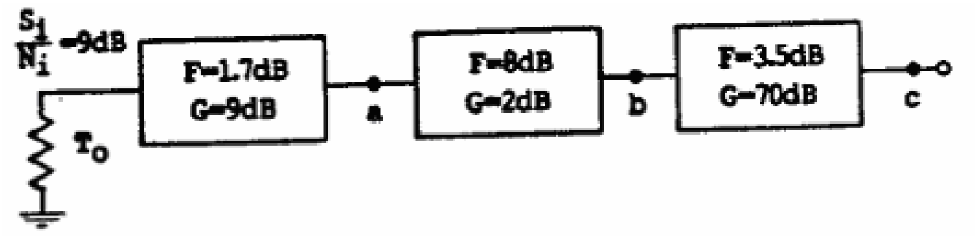
Pn = (T_1 + T_R) k (60×10^3) $10^{(87/10)}$ = 365 nW = –34.4 dBm
SNR = 79.4 μW / 365 nW = 217.5 = 23.4 dB or –11 dBm – (–34.4 dBm) = 23.4 dB

3- You are designing a receiver as shown below. Calculate the minimum required LNA gain, such that the overall NF of the receiver is 6 dB. Note that the electronics following the mixer have a composite noise figure of 3 dB.



$F = F_1 + (F_2 - 1) / G_1 + (F_3 - 1) / (G_1G_2) + (F_4 - 1) / (G_1G_2G_3)$
$F = 3.981$, $F_1 = 1.2589$, $F_2 = 1.99526$, $F_3 = 10$, $F_4 = 1.99526$
$G_1 = 10^{-0.1}$, $G_2 = ?$, $G_3 = 10^{-1}$
$G_2 = 16.24 = 12.1$ dB minimum LNA gain

4- For the following receiving system, find the signal to noise ratio at points a, b, and c. Assume a matched resistive termination at T_o at the input.



$F_1 = 1.48$	$F_2 = 6.31$	$F_3 = 2.24$
$G_1 = 7.94$	$G_2 = 1.58$	$G_3 = 10^7$

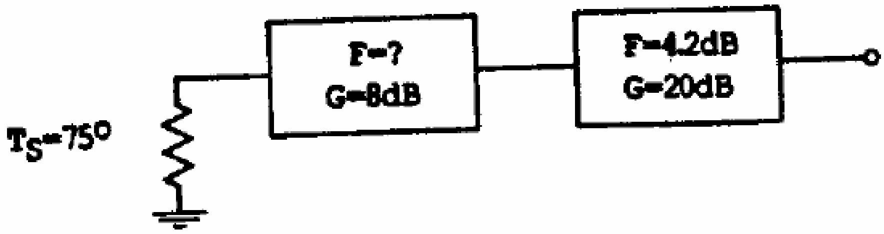
$(S/N)_i = 7.94$

At point a:
$(S/N)_a = (S/N)_i$
$(1/F_1) = 5.36 = 7.3$ dB

At point b:
$F_{12} = F_1 + (F_2 - 1) / G_1 = 2.15$,
$(S/N)_b = (S/N)_i \ (1/F_{12}) = 3.69 = 5.7$ dB

At point c:
$F_{13} = F_1 + (F_2 - 1) / G_1 + (F_3 - 1) / (G_1G_2) = 2.25$,
$(S/N)_c = (S/N)_i \ (1/F_{13}) = 3.53 = 5.5$ dB .

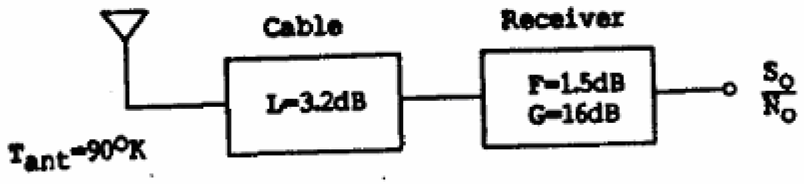
5- The following receiver has an actual F=4.7 dB. Find the noise figure of the first stage.



F_1=? $F_2=10^{0..42} = 2.63$
$G_1=10^{0.8} = 6.31$ $G_2=10^2 = 100$

$F_{act}=10^{0..47} = 2.95$
$F_{act} = 1 + (F_{ov} – 1) (T_o /T_s)$
$F_{ov} = (F_{act} – 1) (T_s /T_o) +1 = (2.95 – 1) (75/290) +1 = 1.51$
$F_{ov} = F_1 + (F_2 – 1) / G_1$
$F_1 = F_{ov} – (F_2 – 1) / G_1 = 1.25 = 0.97$ dB

6- A receiver with a measured F=1.5 dB, is connected to anantenna with effective noise temperature, $T_{ant}=90^oK$ by a length of transmission line with a loss 3.2 dB. The noise effective BW is 6 kHz.



a) Find the S/N at the output of the receiving system if S/N at the antenna terminals is 6 dB.

$F_1=10^{0..32} = 2.09$ $G_1=10^{-0.32} = 0.479$
$F_2=10^{0..15} = 1.41$ $G_2=10^{1.6} = 39.8$

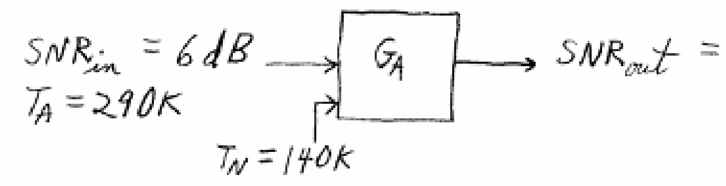
$F_{ov} = F_1 + (F_2 – 1) / G_1 = 2.95$
$F_{act} = 1 + (F_{ov} – 1) (T_o /T_{ant}) = 7.28$
$(S/N)_i = 10^{0.6} = 3.98$
$(S/N)_o = (S/N)_i\ (1/F) = 0.547 = -2.62$ dB

b) Find the minimum detectable input signal for this receiver if the S/N at the output of the receiver must be 8 dB.

$(S/N)_o = 10^{0.8} = 6.31$
$(S/N)_i = F_{act}(S/N)_o = 46$
$N_i = kT_{ant}B = (1.38x10^{-23}) (90) (6x10^3) =7.45x10^{-18}$ W
$S_i=N_i(S/N)_i = (7.45x10^{-18})(46) = 3.43x10^{-16}$ W = -125 dBm

1- Sıcaklığı 140 K olan bir kuvvetlendiricinin girişindeki SNR 6 dB dir. Bu kuvvetlendiricin çıkışındaki SNR ve F nedir?

1- The S/N at the input of an amplifier is 6 dB. If the amplifier has a noise temperature of 140K, what is the SNR at the output of the amplifier? What is the noise figure of the amplifier?



This problem requires that an antenna temperature, $T_A = 290\,K$, must be assumed.

$T_N = T_0(F-1), F = 1 + T_N/T_0 \Rightarrow F = 1 + \frac{140}{200} = 1.4828 = 1.71\,\text{dB}$

$SNR_{out} = SNR_{in} - NF = 4.29\,\text{dB}$

5- High quality TV requires a SNR at the input to the customer's TV of 50 dB. The TV has NF=2 dB and a noise effective bandwidth of 6 MHz. The cable TV company uses a 75 ohm line having attenuation of 1.25dB/100feet. If the cable run to the nearest line amplifier is 2 statute miles, what power must the amplifier provide to the meet the 50dB requirement?

5. The equivalent noise input to the receiver is $-174\,dBm + 10\log(6\cdot 10^6) + 2\,dB = -104.2\,dBm$

The required input signal, for a 50dB SNR is therefore $-104.2\,dBm + 50\,dB = -54.2\,dBm$

The line loss is $\frac{1.25\,dB}{100\,feet} \times 2\,mile \left(\frac{5280\,ft}{mile}\right) = 132\,dB$

The necessary power at the "head-end" is therefore

$P = -54.2\,dBm + 132\,dB = 77.7815\,dBm$
$= 60{,}000\text{ watts}$

(This is definitely not representative of a typical CATV system.

2- This problem illustrates the importance of antenna temperature when considering two amplifiers having only a slight difference in noise figure. Two TVRO low noise amplifiers are available to a purchaser. One is advertised as having NF=1.7 dB, the other as having NF=1.4 dB. The first amplifier costs $500, the second amplifier cost $800.

(a) If the antenna (sky) temperature were 290K, what is the difference, in dB, between the output SNR of the two amplifiers?

2. (a) $T_A = 290K$

	Amplifier A	Amplifier B
$SNR_{in} =$	3dB	3dB
$- NF =$	−1.7dB	−1.4dB
$SNR_{out} =$	$\boxed{1.3dB}$	$\boxed{1.6 dB}$

(b) The actual sky temperature is 4K. What is the difference, in dB, between the output SNR of the two amplifiers?

(b) $F = 10^{NF/10} = 10^{\frac{1.7}{10}} = 1.479$ $\qquad$ $F = 10^{NF/10} = 10^{\frac{1.4}{10}} = 1.38$

from eq.(3.67) $F_A = 1 + (F-1)\frac{T_0}{T_S}$

$F_A = 1 + (1.479-1)\frac{290}{4}$ $\qquad$ $F_A = 1 + (1.38-1)\frac{290}{4}$

$F_A = 35.73$ $\qquad$ $F_A = 28.55$

$NF_A = 10 \log 35.73$ $\qquad$ $NF_A = 10 \log 28.55$

$= 15.53 dB$ $\qquad$ $= 14.55 dB$

Thus the amplifier with NF = 1.4dB produces an output SNR that is 1dB better than the amplifier with a NF that is only 0.3dB worse.

3- High frequency radio signals, below about 30 Mhz, commonly travel far beyond the visible horizon to global distances, because of ionospheric bending of the signals. However, signals above 30 Mhz can not routinely be depended upon to travel beyond the radio horizon. The distance to the radio horizon is given by d = sqrt(2h), where h is the antenna height in feet and d is in statute miles. (A statute mile is 5280 feet; a nautical mile is 6076 feet). The radio horizon is based on an earth radius that is 4/3 times the actual radius, to allow for tropospheric bending effect, which always occurs. Two aircraft are each flying at 35,000 feet and communicating at 400 Mhz, using identical transceivers. Each uses an antenna having a gain of 1 dB. The transmission line loss between the transceiver and the antenna is 0.5 dB. The transceiver requires an input SNR of 12 dB for reliable communication. What minimum transmitter power in watts is necessary for communication? The noise effective bandwidth is 15 Khz.

3. The maximum possible line-of-sight distance between the two aircraft is twice the distance to the horizon for each aircraft, since they are both flying at 35,000 feet.

$$d = \sqrt{2h} = \sqrt{2 \cdot 35000} = 264.6 \text{ miles}$$

$$2d = 529.2 \text{ miles} = 851,667 \text{ m}$$

at 400 MHz, the path loss is

$$L(dB) = 20 \log\left(\frac{4\pi R f}{c}\right) = 20 \log\left(\frac{4\pi \cdot 851,667 \cdot 4 \cdot 10^{8}}{3 \cdot 10^{8}}\right)$$

$$= 143.1 \text{ dB}$$

The noise at the input to the receiver is

$$N_{in} = -174 \text{ dBm} + 10 \log(15,000) = -132.2 \text{ dBm}$$

Thus the signal at the input to the receiver must be $N_{in} + 12 \text{ dB} = -132.2 + 12 = -120.2 \text{ dBm}$

$$P_T - L_{line} + G_T - L + G_R - L_{line} = P_R = -120.2 \text{ dBm}$$

$$P_T = -120.2 \text{ dBm} + 2L_{line} - G_T - G_R + L$$

$$= -120.2 + 2(0.5) - 1 - 1 + 143.1 = 21.9 \text{ dBm}$$

$$P_T = 21.9 \text{ dBm} = 155.9 \text{ mW} = 0.156 \text{ W}$$

1- It is desired to receive information from a weather station situated on the planet Mars when it is at a distance of 125 x 10^6 km from the Earth. The weather station operates at a frequency of 8.5 GHz and has an antenna with 20 dB gain. On earth, the very large receiving antenna has a gain of 65 dB and an antenna temperature (Mars) of 75K. The very good receiver has a noise temperature of 5K. How much power does the transmitter on the weather station need in order to produce a SNR on the earth of 3 dB. The noise effective bandwidth of the system is 500 Hz and system losses are negligible. Determine the signal to noise level at the receiver.

$$N_i = \underbrace{kT_A B}_{\text{input noise}} + \underbrace{(F-1)kT_o B}_{\text{receiver noise}}$$

$$N_i = kT_A B + kT_N B \qquad (T_N = (F-1)T_o)$$

$$N_i = kB(T_A + T_N)$$

$$= (1.38\times10^{-23})(75+5) = 5.52\times10^{-19}\ W$$

$$P_R = 10^{3/10}\cdot N_i = 1.101\times10^{-18}\ W$$

$$P_R = P_T\left(\frac{\lambda}{4\pi R}\right)\frac{G_T G_R}{L} \qquad \text{Free-space gain}$$

$$P_T = P_R\left(\frac{4\pi R}{\lambda}\right)\frac{L}{G_T G_R}$$

$$P_T = (1.101\times10^{-18})\frac{(4\pi)(125\times10^9\ m)}{\frac{3\times10^8\ m/sec}{8.5\times10^9/sec}}\left(\frac{1}{(10^{\frac{10}{10}})(10^{\frac{65}{10}})}\right)$$

$$P_T = 6.889\ W$$

2- When connected to a 50-ohm source at standard temperature, an amplifier supplies a noise power of -120 dBm to a conjugately-matched termination. When connected to a noise diode having an ENR of 6 dB, the noise power delivered to the load is -116 dBm. What is the standard-temperature noise figure of the amplifier in dB?

Noise temperature of the noise diode

$$T_H = T_o(ENR+1)$$

$$T_H = (290)(10^{\frac{6}{10}}-1) = 1445\ K$$

$$T_C = T_o = 290$$

$$P_H = 0.001\cdot10^{\frac{-116}{10}} = 2.512\times10^{-15}\ W$$

$$P_C = 0.001\cdot10^{\frac{-120}{10}} = 1.0\times10^{-15}\ W$$

$$Y = \frac{P_H}{P_C} = 2.512$$

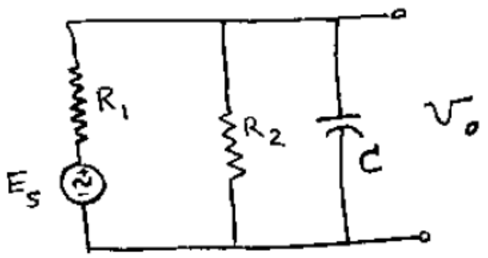
$$F = 1 + \frac{\frac{T_H}{T_o} - \frac{T_C}{T_o}Y}{Y-1} = 1 + \frac{\frac{1445}{290} - \frac{290}{290}(2.512)}{2.512-1}$$

$$F = 2.633$$

$$NF = 10\log(F) = \underline{4.21\ dB}$$

4- For the circuit below, determine noise voltage and signal to noise ratio at the output.

$R_1 = 12 M\Omega$
$R_2 = 6 M\Omega$
$C = 10 pF$
$E_s = 2 mV\ rms$
$T = 300^{\circ} K$



$E_n^2 = 4KTBR$, $R = R_1 \| R_2 = 4\,M\Omega$

To find the effective noise BW:

$f_c = \frac{1}{2\pi RC} = \underline{3979\ Hz}.$

Effective BW $= \frac{\pi}{2} \cdot f_c = \underline{6250}\ Hz$

With $K = 1.38 \times 10^{-23}$, $T = 300^{\circ}\ T$

$E_n^2 = 4.14 \times 10^{-10}$ volts^2.

$E_n = \sqrt{E_n^2} = \underline{\underline{20.35\ \mu V}}\ (rms)$

$E_s = 2\ mV\ (rms)$

$V_o = \frac{Z_2}{R_1 + Z_2} E_s$, $Z_2 = R_2 \| \left(\frac{1}{j 2\pi f C}\right)$

Assuming f_c is the highest signal frequency
Smallest signal output would be at f_c.

$f = f_c = \frac{1}{2\pi RC} = 3979\ Hz.$

$Z_2 = [R_2 \| (-j 4 \times 10^6)]$

$= (1.846 - j\,2.769)\ M\Omega.$

$|V_o| = \underline{471.4\ \mu V}\ (rms)$

$(S/N) = \frac{V_o^2}{E_n^2} = \underline{\underline{536.8}}$ or $\underline{\underline{27.3\ dBs}}$

1- Consider a satellite receiving system with a low noise amplifier (LNA) and a cable:
a) The insertion loss of a cable is 6.5 dB. What is the power gain (attenuation) and noise figure (NF) of the cable?

Cable insertion loss $= 6.5\,dB \Rightarrow (NR)_c = 10^{0.65} = \underline{4.47}$

$\therefore$ Cable attenuation$|_{dB} = -6.5\,dB$

Cable gain$|_{Power} = A_c$

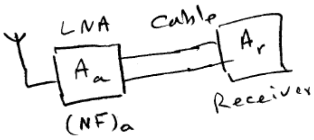
$10\log_{10}(A_c) = -6.5\,dB$

$\therefore A_c = (10)^{-0.65} = \underline{0.2239}$

Cable Noise figure $= (NF)_c =$ insertion loss $= 6.5\,dB$.

b) A satellite receiving system consists of a low noise amplifier (LNA) that has a gain of 47 dB and a noise temperature of 120 K (T_{ref} = 290 K), a cable with a loss of 6.5 dB, and a main receiver with a noise figure of 9 dB. Calculate the equivalent noise temperature of the overall system referred to the input for the following system connections:

i. The LNA at the input, followed by the cable connecting to the main receiver;
ii. The input direct to the cable, which then connects to the LNA, which in turn is connected directly to the main receiver.



$A_a|_{dBs} = 47$

$\therefore A_a = (10)^{4.7} = \underline{5.012\times10^4}$

$(NR)_a = 1 + \frac{T_a}{T_r}$, $T_r = \underline{290^\circ K}$ (given)

$(NR)_a = 1 + \frac{120}{290} = \underline{1.4134}$

$A_c = 0.2239$

$(NR)_c = 4.47$

$(NF)_r = 9\,dB \Rightarrow (NR)_r = 10^{0.9} = \underline{7.9433}$

(i) $(NR)_{sys} = (NR)_a + \frac{(NR)_c - 1}{A_a} + \frac{(NR)_r - 1}{A_a \cdot A_c}$

$= 1.4134 + \frac{3.47}{5.012\times10^4} + \frac{6.94}{(5.012\times10^4\times.2239)}$

$= \underline{1.4137}$

$(NR)_{sys} = 1 + \frac{T_{sys}}{T_r}$

$\therefore T_{sys} = [(NR)_{sys} - 1]T_r$

$= 0.4137\times290$

$\approx \underline{120^\circ K}$

(ii) $(NR)_{sys} = (NR)_c + \frac{(NR)_a - 1}{A_c} + \frac{(NR)_r - 1}{(A_c \cdot A_a)}$

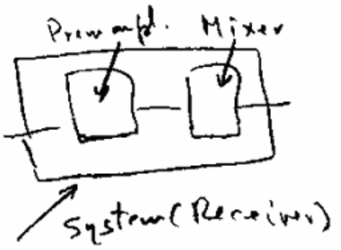
$= 4.47 + \frac{0.4134}{0.2239} + \frac{6.94}{(5.012\times10^4\times0.2239)}$

$= 6.317$

$\therefore T_{sys} = 5.317\times290$

$= \underline{1542^\circ}$!

5- A receiver consists of two stages: A preamplifier stage located at the input, followed by a stage mixer. The noise figure of the preamplifer is $NF_1 = 3$ dB, and that of the mixer is $NF_2 = 8$ dB. Determine the gain of the amplifier so that the overall system noise id $NF_S = 4$ dB.



$NF = 10\log_{10}(NR)$.

$\therefore NR = (10)^{(NF/10)}$

$\therefore NR_1 = (10)^{3/10} = 1.9953$

$NR_2 = (10)^{8/10} = 6.3096$

$$\text{System }(NR) = NR_1 + \frac{(NR_2 - 1)}{A_{P_1}}$$

$(NF)_{system} = 4 \Rightarrow (NR)_{system} = 10^{4/10} = 2.512$

$$\therefore \quad 2.512 = 1.9953 + \frac{5.3096}{A_{P_1}}$$

$\therefore A_{P_1} = 10.3$ Preamp Power gain

38. An FM receiver operates with an S/N of 30dB at its detector input and with m_f=10

(a) If the received signal has a voltage of 10mV, what is the amplitude of the noise voltage?

(b) (b) Find the maximum phase shift that could be given to the signal by the noise voltage.

(c) Calculate the S/N at the detector output, assuming the detector is completely insensitive to amplitude variations.

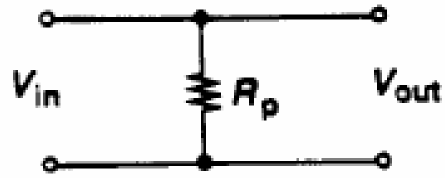
(a) Using S/N at receiver input

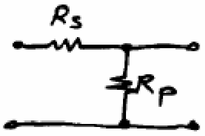
$$\left(\frac{S}{N}\right) = 20\log\frac{Es}{En} \Rightarrow \frac{Es}{En} = 10^{\frac{\left(\frac{S}{N}\right)}{20}} \Rightarrow En = \frac{Es}{10^{\frac{\left(\frac{S}{N}\right)}{20}}} = \frac{10mV}{10^{\frac{30}{20}}} = 316.23\mu V$$

(b) Maximum shift $\phi n \approx \frac{En}{Es} = \frac{316.23\times10^{-6}V}{10\times10^{-3}V} = 31.623\times10^{-3}rad = m_{fn}$

(c) $\left(\frac{Es}{En}\right)_o = \frac{\delta s}{\delta n} = \frac{m_{fs}\cdot fm}{m_{fn}\cdot fm} = \frac{m_{fs}}{m_{fn}} = \frac{10}{31.623\times10^{-3}} = 316.24 = 50dB$

7- (a) Calculate the noise figure of the following circuit with respect to a source resistance Rs. What value of Rp minimizes the noise figure?





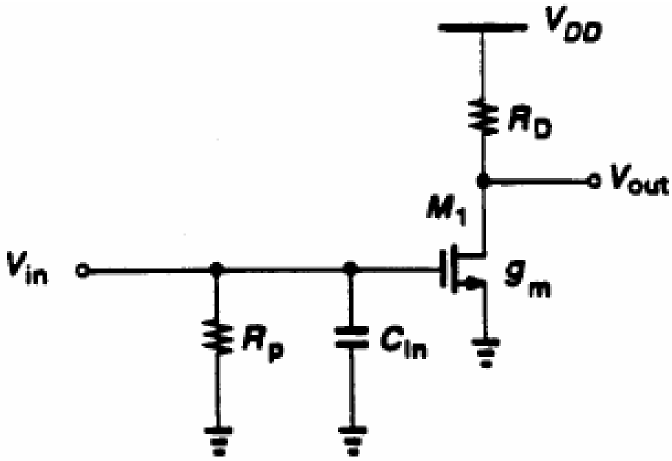
$$\overline{V_{n,out}^2} = 4kT(R_s \| R_p)$$

$$NF = \frac{1}{\left(\frac{R_p}{R_p+R_s}\right)^2}\cdot 4kT(R_s\|R_p)\cdot\frac{1}{4kTR_s}$$

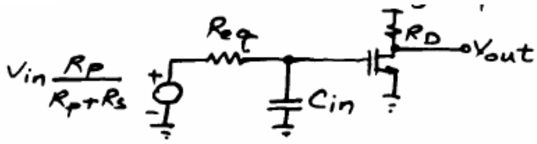
$$= 1+\frac{R_s}{R_p}$$

$NF \to 1$ if $R_p \to \infty$

b) Find the noise figure of the following circuit with respect to a source resistance Rs. Neglect all other parasitic capacitances. What is the noise figure for Cin=0?



(b)



$R_{eq} = R_p \| R_s$

$$\overline{V_{n,out}^2} = 4kTR_{eq}\frac{g_m^2R_D^2}{1+R_{eq}^2C_{in}^2\omega^2} + 4kT\frac{2}{3}g_mR_D^2 + 4kTR_D$$

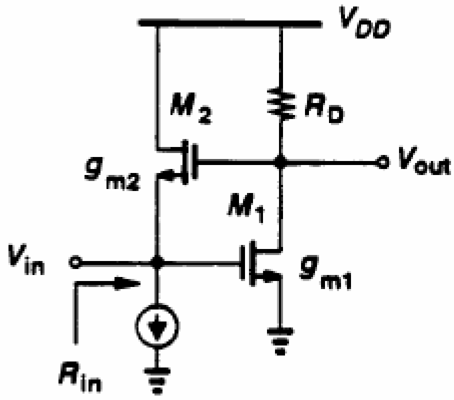
$$A_v^2 = \left(\frac{V_{out}}{V_{in}}\right)^2 = \left(\frac{R_p}{R_p+R_s}\right)^2\cdot\frac{g_m^2R_D}{1+R_{eq}^2C_{in}^2\omega^2}$$

$$\Rightarrow NF = \frac{\overline{V_{n,out}^2}}{A_v^2}\cdot\frac{1}{4kTR_s}$$

$$= 1+\frac{R_s}{R_p}+\frac{2}{3g_mR_s}\left(1+\frac{R_s}{R_p}\right)^2\left(1+R_{eq}^2C_{in}^2\omega^2\right)+\left(1+\frac{R_s}{R_p}\right)^2\frac{1+R_{eq}^2C_{in}^2\omega^2}{g_m^2R_sR_D}$$

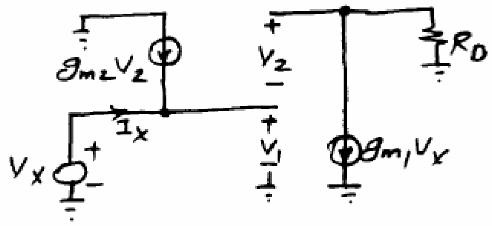
$$C_{in}=0 \Rightarrow NF = 1+\frac{R_s}{R_p}+\left(1+\frac{R_s}{R_p}\right)^2\left(\frac{2}{3g_mR_s}+\frac{1}{g_m^2R_sR_D}\right)$$

8- Consider the following circuit.



a) Neglecting the body effect and parasitic capaciatances, find the input resistance of the circuit.

(a)



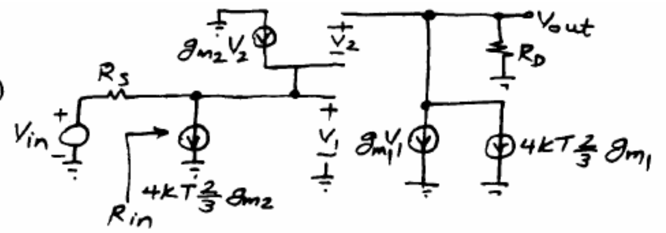
$$V_2 = -g_{m1} V_X R_D - V_X = -V_X(1+g_m R_D)$$

$$\Rightarrow I_X = -g_{m2} V_2 = g_{m2} \cdot V_X (1+g_m R_D)$$

$$\Rightarrow \frac{V_X}{I_X} = \frac{1}{g_{m2}} \cdot \frac{1}{1+g_{m1}R_D}$$

b) Find the noise figure with respect to a source resistance R_s. What is the NF if $R_{in}= R_s$?

(b)



$$\overline{V_{n,out}^2} = 4kTR_S \frac{R_{in}^2}{(R_{in}+R_S)^2} \cdot g_{m1}^2 R_D^2 + 4kT\frac{2}{3} g_{m2} \cdot (R_S \| R_{in})^2 \cdot g_{m1}^2 R_D^2$$

$$+ \ 4kT\frac{2}{3}g_{m1} \cdot R_D^2 + 4kTR_D$$

$$A_V = \frac{R_{in}}{R_S+R_{in}} \cdot g_{m1} R_D$$

$$\Rightarrow NF = \left[4kTR_S + 4kT\frac{2}{3}g_{m2}R_S^2 + \frac{4kT\frac{2}{3}(R_S+R_{in})^2}{g_{m1} R_{in}^2} + \frac{4kT(R_S+R_{in})^2}{g_{m1}^2 R_{in}^2 R_D}\right]\frac{1}{4kTR_S}$$

For $R_S = R_{in}$,

$$NF = 1 + \frac{2}{3}g_{m2}R_S + \frac{8}{3} \cdot \frac{1}{g_{m1}R_S} + \frac{4}{g_{m1}^2 R_S R_D}$$

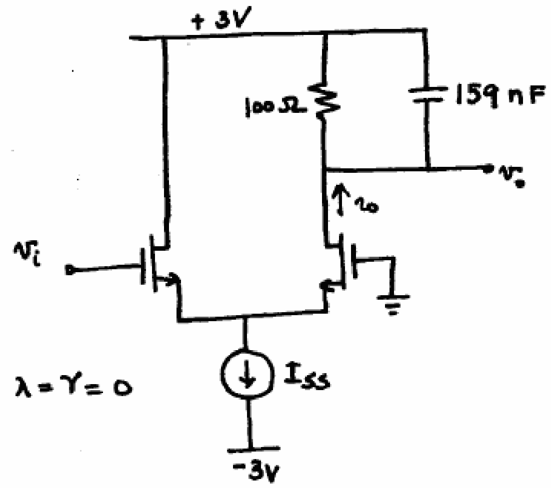
A more rigorous solution requires exact calculation of output impedance for noise of R_D & M_1 : $R_{out} = R_D \,\|\, \left[\frac{1}{g_{m1}} \cdot \left(1+\frac{1}{g_{m2}R_S}\right)\right]$.

20- Calculate the total output noise voltage for the SC-pair shown below. Assume the noise model for the MOSFET as shown. Ignore the noise contribution of the resistor. Take $4kT = 1.6\times10^{-20}$ J, and assume $g_m = 1\,\mathrm{mA/V}$ at the operating point.

For the SC pair $\overline{v_{eq}^2} = 2\overline{v_n^2}$

$i_o = \frac{g_m}{2} v_i$

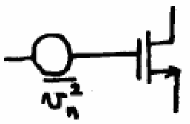
At low frequencies $v_o = \frac{g_m R}{2} v_i$



$\therefore$ Output noise PSD at low frequency $= \left(\frac{g_m R}{2}\right)^2 \cdot 2\frac{\overline{v_n^2}}{\Delta f}$

$= \frac{g_m^2 R^2}{2} \frac{\overline{v_n^2}}{\Delta f}$

$= \frac{g_m^{\cancel{2}} R^2}{\cancel{2}} \cdot 4KT\left(\frac{\cancel{2}}{3}\right)\frac{1}{\cancel{g_m}}$



$\overline{v_n^2} = 4KT\left(\frac{2}{3}\right)\frac{1}{g_m}\Delta f$

Since the output is a low pass filter the noise BW $= \frac{\pi}{2}\cdot\frac{1}{2\pi RC} = \frac{1}{4RC}$

$\therefore$ Total output noise power $= g_m R^2 \left(\frac{4KT}{3}\right)\frac{1}{4RC}$

$= \frac{g_m R}{3} \frac{KT}{C}$

$\Rightarrow$ output noise voltage $= \sqrt{\frac{g_m R}{3}\frac{KT}{C}} = \sqrt{\frac{10^{-3}\times100\times1.6\times10^{-20}}{3\times159\times10^{-9}\times4}}$

$\simeq 29\ \mathrm{nV}$