Radio Frequency Circuits & Antenna

Thomas Glezer
Tel Aviv University

—

Homework: 5

May 6, 2022

1 Complete the entries in the following table:

Remarks on general equations:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \Longleftrightarrow |\Gamma| = \left|\frac{1-VSWR}{1+VSWR}\right| \tag{1}$$

$$|\Gamma| = \sqrt{P_r/P_f} \tag{2}$$

$$T = \sqrt{1-|\Gamma|^2} \Longleftrightarrow |\Gamma| = \sqrt{1-T^2} \tag{3}$$

$$RL(dB) = 10\log_{10}\frac{P_i}{P_r} = -20\log_{10}|\Gamma| \Longleftrightarrow |\Gamma| = 10^{-RL/20} \tag{4}$$

$$IL(dB) = 10\log_{10}\frac{P_T}{P_R} = -20\log_{10}(|T|) \Longleftrightarrow |\Gamma| = \sqrt{1-10^{-IL/10}} \tag{5}$$

$VSWR$	$\|\Gamma\|$	$RL(dB)$	$\|T\|$	$IL(dB)$
1.02	0.01	40	0.99995	0.000434
1.1	0.05	26	0.99874	0.011
1.22	0.099	20.078	0.995	0.04286
1.49687	0.1989997	14.023	0.98	0.17547
1.86	0.3	10.5	0.954	0.41
2.337	0.40067	7.944	0.91622	0.76
3	0.5	6.02	0.866	1.249587
4	0.6	4.437	0.8	1.9382
9	0.8	1.9365	0.6	4.44

2 Complete the entries in the following table:

Remarks on general equations:

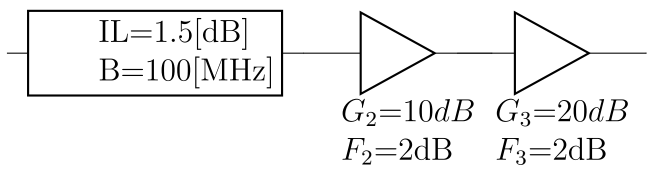
$$P[dBm] = 10\log_{10} P[mW] \tag{6}$$
$$P[W] = 10^3 P[mW] \tag{7}$$

$P[W]$	$P[mW]$	$P[dBm]$
10^{-4}	0.1	-10
10^{-3}	1	0
10^{-2}	10	10
0.015	15	11.76
0.02	20	13.01
0.1	100	20

3 An amplifier with a gain of $11[dB]$, a bandwidth of $150[MHz]$, and a noise figure of $3.8[dB]$ feeds a receiver with a noise temperature of $935[K]$. Find the noise figure of the overall system.

$$F_{tot} = F_1 + \frac{F_2 - 1}{G_1} \tag{8}$$
$$= 3.8[dB] + \frac{1 + T_e/T_o - 1}{11[dB]} \tag{9}$$
$$= 10^{0.38} + \frac{T_e}{10^{1.1}T_o} \tag{10}$$
$$= 2.4 + \frac{935}{12.59 \cdot 290} = 2.4 + 0.2561 \tag{11}$$
$$F_{tot} = 2.656 \rightarrow 4.242[dB] \tag{12}$$

4 Consider the wireless local area network (WLAN) receiver front-end shown below, where the bandwidth of the bandpass filter is $100[MHz]$ centered at $2.4[GHz]$. The system is at the room temperature.



a) Find the noise figure of the overall system.

$$L = 10^{1.5/10} = 1.41 \quad \wedge \quad G_1 = L^{-1} \tag{13}$$

$$F_2 = 10^{2/10} = 1.585 \quad \wedge \quad G_2 = 10^{10/10} = 10 \tag{14}$$

$$F_3 = 10^{2/10} = 1.585 \quad \wedge \quad G_3 = 10^{20/10} = 100 \tag{15}$$

$$F_{tot} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} \tag{16}$$

$$= 1.41 + \frac{1.585 - 1}{1/1.41} + \frac{1.585 - 1}{10/1.41} \tag{17}$$

$$F_{tot} = 2.317 \rightarrow 3.65[dB] \tag{18}$$

b) What is the resulting signal-to-noise ratio at the output, if the input signal power level is -86 dBm?

$$P_{in} = -86[dBm] = 2.512 \cdot 10^{-9} mW \tag{19}$$

$$P_{out} = (P_{in} + G_2 + G_3 - L)[dBm] = \tag{20}$$

$$= -86 + 10 + 20 - 1.5 \tag{21}$$

$$= -57.5[dBm] \tag{22}$$

$$= 1.78 \cdot 10^{-6} mW \tag{23}$$

Noise effect:

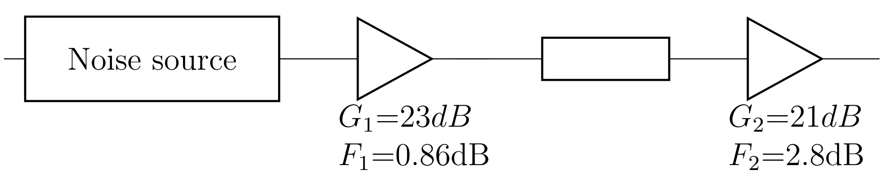
$$
\begin{aligned}
N &= G \cdot K \cdot T \cdot B && (24)\\
G &= -1.5 + 10 + 20 = 28.5[dB] \rightarrow 10^{2.85} = 707.95 && (25)\\
K &= 1.38 \cdot 10^{-23}[J/K] && (26)\\
T &= (F_{tot} - 1)T_0 = (2.317 - 1)290 = 381.9[K] && (27)\\
B &= 100[MHz] = 10^8[Hz] && (28)\\
\therefore N &= 707.95 \cdot 1.38 \cdot 10^{-23} \cdot 381.9 \cdot 10^8 && (29)\\
&= 3.73 \cdot 10^{-7}[mW] \rightarrow -64.3[dBm] && (30)
\end{aligned}
$$

$$
SNR = \frac{P_{out}}{N_{out}} = -57.5 - (-64.3) = 6.8[dB] \rightarrow 4.79 \qquad (31)
$$

c) Can the components be arranged to give a better noise figure?
Yes, by reversing the order of the system we would get:

$$
\begin{aligned}
F_{tot} &= F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} && (32)\\
&= 1.585 + \frac{1.585 - 1}{100} + \frac{1.41 - 1}{1000} && (33)\\
F_{tot} &= 1.59 \rightarrow 2.02[dB] && (34)
\end{aligned}
$$

5 Consider the next system:



a) Find the equivalent noise temperature and the noise figure of the system (without the noise of the source).

$$
\begin{aligned}
G_1 &= 23[dB] \rightarrow 199.5 \quad \wedge \quad F_1 = 0.86[dB] \rightarrow 1.22 && (35)\\
L &= 0.9[dB] \rightarrow 1.23 \quad \wedge \quad T = 315 && (36)\\
G_2 &= 21[dB] \rightarrow 125.9 \quad \wedge \quad F_2 = 2.8[dB] \rightarrow 1.91 && (37)
\end{aligned}
$$

$$T_1 = (F_1 - 1)T_0 = (1.22 - 1)290 = 63.8[K] \tag{38}$$
$$T_2 = (F_2 - 1)T_0 = (1.91 - 1)290 = 263.9[K] \tag{39}$$
$$T_L = (L - 1)T_0 = (1.23 - 1)315 = 72.45[K] \tag{40}$$

$$T_{tot} = T_1 + \frac{T_L}{G_1} + \frac{T_2 \cdot L}{G_1} \tag{41}$$
$$= 63.8 + \frac{72.45}{199.5} + \frac{263.9 \cdot 1.23}{199.5} \tag{42}$$
$$T_{tot} = 65.8[K] \tag{43}$$
$$F_T = 1 + T_{tot}/T_0 \tag{44}$$
$$= 1 + 65.8/290 = 1.23 \tag{45}$$
$$F_T = 0.89[dB] \tag{46}$$

b) Find the output noise power of the system, if it's bandpass is $103MHz$ and the noise power of the source is $N_i = -92[dBm]$.

$$N_{in} = -92[dBm] \tag{47}$$
$$= 10^{-9.2} \rightarrow 6.31 \cdot 10^{-10}[mW] \tag{48}$$

$$G_{tot} = (23 - 0.9 + 21)[dB] \tag{49}$$
$$= 43.1[dB] \rightarrow 10^{4.31} = 20417.38 \tag{50}$$

$$N_{out} = N_{in}G_{tot} + KBT_{tot}G_{tot} \tag{51}$$
$$= (N_{in} + KBT_{tot})G_{tot} \tag{52}$$
$$= (6.31 \cdot 10^{-10} + 1.38 \cdot 10^{-23} \cdot 103 \cdot 10^6 \cdot 65.8)20417.38 \tag{53}$$
$$= 1.34 \cdot 10^{-5} mW = 48.7[dBm] \tag{54}$$

6 A certain transmission line has a noise figured $F = 1.2[dB]$ at a temperature of $T_0 = 290[K]$. Calculate and plot in "Matlab" the noise figure of this line (in dB) as its physical temperature ranges from $T = 0 \rightarrow 1200[K]$.

$$F(T) = 1 + (L - 1)T/T_0 \tag{55}$$

$$F(T_0) = L = 1.2[dB] \rightarrow 1.318 \tag{56}$$