Radio Frequency Circuits & Antenna

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Homework: 6

May 18, 2022

Problem 1

0.1 Determine the equivalent noise temperature and noise figure of the receiver system (including the noise temperature of the antenna).

$$F_T = 1 + T_{tot}/T_0 \tag{1}$$

$$\begin{aligned} G_{rf} = 25[dB] \rightarrow 316.2 \quad &\wedge \quad F_{rf} = 3[dB] \rightarrow 2 \\ L = 7[dB] \rightarrow 5 \quad &\wedge \quad F_m = 8[dB] \rightarrow 6.31 \\ G_{if} = 40[dB] \rightarrow 10000 \quad &\wedge \quad F_{if} = 1[dB] \rightarrow 1.26 \end{aligned} \tag{2--4}$$

$$\begin{aligned} T_{rf} &= (F_{rf} - 1)T_0 = (2-1)300 = 300[K] \\ T_m &= (CL - 1)T_0 = (5-1)300 = 1200[K] \\ T_{if} &= (F_{if} - 1)T_0 = (1.26-1)300 = 77.6[K] \end{aligned} \tag{5--7}$$

$$\begin{aligned} T_{tot} &= T_{rf} + \frac{T_m}{G_{rf}} + \frac{T_{if}CL}{G_{rf}} \\ &= 300 + 1200/316.2 + 77.6 \cdot 5/316.2 \\ T_{tot} &= 305.02[K] \end{aligned} \tag{8--10}$$

$$\therefore F_T = 1 + 305.02/300 = 2.0167 \rightarrow 3.05[dB] \tag{11}$$

0.2 Determine the noise power at the output of receiver system if the bandwidth BW = 100 MHz.

$$N_{out} = KBG_{sys}(T_A + T_{tot}) \tag{12}$$

$$T_A = \eta T_{sky} + (1-\eta)T_{ant} = 0.8 \cdot 100 + (1-0.8) \cdot 300 = 140[K] \tag{13}$$

$$G_{sys} = G_{rf} + G_{if} - CL = 25 + 40 - 8 = 57[dB] \rightarrow 501187 \tag{14}$$

Thus, combining (13) & (14) into (12):

$$N_{out} = 1.38 \cdot 10^{-23} \cdot 100 \cdot 10^3 \cdot 501187 \cdot (140 + 305.02) \tag{15}$$
$$N_{out} = 3.078 \cdot 10^{-10} \rightarrow -95.11[dB] \tag{16}$$

0.3 The receiving antenna is a round plate with a radius a. Suppose that the effective area of the antenna is equal to 60% of the physical area of antenna aperture. Calculate the minimal value of a that provides $(S/N)_{out} \geq 20[dB]$.

$$S = \frac{P_t \cdot G}{4\pi r^2} = \frac{100 \cdot 10^3}{4\pi(36000 \cdot 10^3)^2} = 6.14 \cdot 10^{-12}[W/M^2] \tag{17}$$
$$A_{phys} = \frac{\lambda^2}{4\pi} \cdot \text{round plate area} = \frac{300/14}{4\pi} 4\pi a^2 = 21.42 \cdot a^2 \tag{18}$$
$$A_{eff} = e_a A_{phys} G_{sys} = 0.6 \cdot 21.42 \cdot a^2 \cdot 501187 = 6443835a^2 \tag{19}$$
$$P_{rec} = A_{eff} S = 3.956 \cdot a^2 \cdot 10^{-5} \rightarrow -44.02 + 20 \log a \tag{20}$$

$$-44.02 + 20 \log a - (-95.11) \geq 20 \tag{21}$$
$$20 \log a \geq -31.09 \tag{22}$$
$$\log a \geq -1.55 \tag{23}$$
$$a = 27.9[mm] \tag{24}$$

0.4 The second satellite has the same parameters as the first satellite and it transmits a signal that we wouldn't like to receive and so for us it is considered a noise. The gain of the receiving antenna in the direction of the second satellite is X dB lower than in the direction of the first satellite. Calculate the minimal value of X that guarantees a degradation of signal to noise ratio at the output of the receiver system by not more than 1 dB.

$$P_{noise} = -44.02 + 20 \log a + X \tag{25}$$

$$(S/N)_{normal} = 51.09 + 20 \log a \tag{26}$$

$$\begin{aligned} 51.09 + 20 \log a - (-44.02 + 20 \log a + X) &\leq 1 & (27) \\ X + 7.07 &\leq 1 & (28) \\ X &\leq -6.07 & (29) \end{aligned}$$

Problem 2

0.5 Find the gain G_{a1} of relay receiving antenna to obtain a 15 dB signal-to-noise ratio at the relay output marked as point 1 in the circle.

Calculating for noise:

$$N_{out} = KBG_{sys}(T_A + T_{tot}) \tag{30}$$

$$T_A = \eta T_{sky} + (1-\eta) T_{ant} = 0.9 \cdot 150 + (1 - 0.9) \cdot 300 = 165[K] \tag{31}$$

$$G_{sys} = G_1 + G_2 - CL = 30 + 30 - 7 = 53[dB] \rightarrow 199526 \tag{32}$$

$$\begin{aligned} G_1 = 30[dB] \rightarrow 1000 \quad &\wedge \quad F_1 = 2[dB] \rightarrow 1.58 && (33) \\ CL = 7[dB] \rightarrow 5 \quad &\wedge \quad F_m = 8[dB] \rightarrow 6.31 && (34) \\ G_2 = 30[dB] \rightarrow 1000 \quad &\wedge \quad F_2 = 2[dB] \rightarrow 1.58 && (35) \end{aligned}$$

$$\begin{aligned} T_1 &= (F_1 - 1)T_0 = (1.58 - 1)300 = 174[K] && (36) \\ T_m &= (CL - 1)T_0 = (5 - 1)300 = 1200[K] && (37) \\ T_2 &= (F_2 - 1)T_0 = (1.58 - 1)300 = 174[K] && (38) \end{aligned}$$

$$\begin{aligned} T_{tot} &= T_1 + \frac{T_m}{G_1} + \frac{T_2 CL}{G_1} && (39) \\ &= 174 + 1200/1000 + 174 \cdot 5/1000 && (40) \\ T_{tot} &= 176.07[K] && (41) \end{aligned}$$

Thus, combining (31), (32) and (41) into (30):

$$\begin{aligned} N_{out} &= 1.38 \cdot 10^{-23} \cdot 100 \cdot 10^3 \cdot 199526 \cdot (165 + 176.07) && (42) \\ N_{out} &= 9.4 \cdot 10^{-11} \rightarrow -100.27[dB] && (43) \end{aligned}$$

0.6 Find the gain G_r of the receiving antenna to obtain a 10 dB signal-to-noise ratio at the receiver output.