Analog Circuits for Biochip: exercise on lecture 10, antennas and antenna systems

Exercise 1

Consider an antenna having a gain of 28.5 dBi and a system noise temperature (antenna + LNA) of 100 K. How much will the overall G/T of this antenna increase if we decrease the losses of the cable connecting the antenna and the LNA by 0.1 dB ? We consider an ambient temperature of 20° corresponding to 293 K

Solution:

The G/T of the system with the cable will be equal to

$$\left(\frac{G}{T}\right)_{dB} = G_{dB} - T_{dB/K} = 28.5dB - 10\log 100 = 28.5dB - 20dB/K = 8.5dB/K$$

A cable with 0.1 dB loss represents a loss temperature of

$$T_{loss,cable} = \left(loss_{cable} - 1\right)T_{amb} = \left(10^{\frac{0.1}{10}} - 1\right)293 = 6.82\,\mathrm{K}$$

Thus, if we decrease the losses of the cable by 0.1 dB, the G/T will become

$$\left(\frac{G}{T}\right)_{dB} = G_{dB} - \left(T - T_{loss}\right)_{dB} = 28.5 - 10\log(100 - 6.73) = 28.5 - 19.7 = 8.8dB/K$$

Therefore, the G/T of this antenna will increase 0.3 dB/K.

Exercise 2

Consider an urban cellular digital communication link (path loss exponent 3) where the data rate of the transmission is 10Mbits/s at a frequency of 5 GHz. The transmitter has a power of 2 W, and an antenna having an effective surface of 0.0028. The distance to the receiver is of 500m, and the receiver has an antenna having a gain of 10. The effective temperature of the receiver (antenna + 1^{st} stage+ cable losses) is 300 K. What is the energy per bit to noise power spectral density ratio at the receiver?

Frequency = 5 GHz => λ=c/f =0.06 m, $c = 3*10^8 \frac{m}{s}$

Thus

$$P(r)_{ic,th} = S_t\left(r_{\max},\theta_{inc},\varphi_{inc}\right)G_r\left(\theta_{inc},\varphi_{inc}\right)\frac{\lambda^2}{4\pi}\left(1-\left|\Gamma^*\right|^2\right)\chi_{pol} = \frac{EIRP}{4\pi^2}\frac{\lambda^2}{4\pi r_{\max}{}^2}\chi_{pol}G_{r,real}\left(\theta,\varphi\right)$$

$$g = \frac{4\pi}{\lambda^2} A_e = 10 = 10\log 10 = 10\,dB \;\; => EIRP = P_t * g = 2W * 10 = 20 = 10\log 20 = 13dBW$$

The path loss is given by

$$P_L = \left(\frac{4\pi D}{\lambda}\right)^3 = 1.14810^{15} = 150.6dB$$

The receiver G/T is given by

$$G_{dB} - T_{dB} = 10 - 10\log 300 = -14.8dB$$

The signal to noise ratio at the receiver is thus

$$\gamma\,|_{dBHz} = EIRP\,|_{dBW} - P_L\,|_{dB} - 10\log k + G_R\,|_{dB} - 10\cdot\log_{10} T_{op} = 13 - 150.6 + 228.6 + 10 - 24.8 = 76.2\,dB_{Hz}$$

$$k = 1.38 * 10^{-23}\, J / K$$

And the energy per bit to noise power density is given by

$$\eta = \frac{E_b}{N_0} = \frac{E_b}{P_R}\gamma = \frac{1}{R_b}\gamma$$

$$\eta_{dB} = \gamma_{dB} - R_{b\,dB} = 76.2 - 70 = 6.2_{dB}$$