Question 1

The direct broadcast system in North America operates at 12.2–12.7 GHz, with a transmit carrier power of 120 W, a transmit antenna gain of 34 dB, an IF bandwidth of 20 MHz, and a worst-case slant angle (30°) distance from the geostationary satellite to Earth of 39,000 km. The 18-inch receiving dish antenna has a gain of 33.5 dB and sees an average background brightness temperature of $T_b = 50$ K, with a receiver low-noise block (LNB) having a noise figure of 0.7 dB. The required minimum CNR is 15 dB.

Find (a) the link budget for the received carrier power at the antenna terminals, (b) G/T for the receive antenna and LNB system, (c) the CNR at the output of the LNB, and (d) the link margin of the system.

Answer:

We will take the operating frequency to be 12.45 GHz, so the wavelength is 0.0241 m. From (14.26) the path loss is

$$L_0 = 20 \log \left(\frac{4\pi R}{\lambda} \right) = 20 \log \left(\frac{(4\pi)(39 \times 10^6)}{0.0241} \right) = 206.2 \text{ dB}$$

(a) The link budget for the received power is

$$\begin{aligned} P_t &= 120 \text{ W} = 50.8 \text{ dBm} \\ G_t &= 34.0 \text{ dB} \\ L_0 &= (-)206.2 \text{ dB} \\ G_r &= 33.5 \text{ dB} \\ \hline P_r &= -87.9 \text{ dBm} = 1.63 \times 10^{-12} \text{ W}. \end{aligned}$$

(b) To find G/T we first find the noise temperature of the antenna and LNB cascade, referenced at the input of the LNB:

$$T_e = T_A + T_{\text{LNB}} = T_b + (F - 1)T_0 = 50 + (1.175 - 1)(290) = 100.8 \text{ K}.$$

Then G/T for the antenna and LNB is

$$G/T \text{(dB)} = 10 \log \frac{2239}{100.8} = 13.5 \text{ dB/K}.$$

(c) The CNR at the output of the LNB is

$$\text{CNR} = \frac{P_r G_{\text{LNB}}}{k T_e B G_{\text{LNB}}} = \frac{1.63 \times 10^{-12}}{(1.38 \times 10^{-23})(100.8)(20 \times 10^6)} = 58.6 = 17.7 \text{ dB}.$$

Note that G_{LNB}, the gain of the LNB module, cancels in the ratio for the output CNR.

(d) If the minimum required CNR is 15 dB, the system link margin is 2.7 dB. ■

Question 2

A microwave receiver like that of Figure 14.14 has the following parameters:

$$f = 4.0 \text{ GHz}, \quad G_{\text{RF}} = 20 \text{ dB},$$
$$B = 1 \text{ MHz}, \quad F_{\text{RF}} = 3.0 \text{ dB},$$
$$G_A = 26 \text{ dB}, \quad L_M = 6.0 \text{ dB},$$
$$\eta_{\text{rad}} = 0.90, \quad F_M = 7.0 \text{ dB},$$
$$T_p = 300 \text{ K}, \quad G_{\text{IF}} = 30 \text{ dB},$$
$$T_b = 200 \text{ K}, \quad F_{\text{IF}} = 1.1 \text{ dB}.$$
$$L_T = 1.5 \text{ dB},$$

If the received power at the antenna terminals is $S_i = -80$ dBm, calculate the input and output SNRs.

Answer:

Solution

We first convert the above dB quantities to numerical values, and noise figures to noise temperatures:

$$
\begin{aligned}
G_{\mathrm{RF}} &= 10^{20/10} = 100, \\
G_{\mathrm{IF}} &= 10^{30/10} = 1000, \\
L_T &= 10^{1.5/10} = 1.41, \\
L_M &= 10^{6/10} = 4.0, \\
T_M &= (F_M - 1)T_0 = (10^{7/10} - 1)(290) = 1163 \text{ K}, \\
T_{\mathrm{RF}} &= (F_{\mathrm{RF}} - 1)T_0 = (10^{3/10} - 1)(290) = 289 \text{ K}, \\
T_{\mathrm{IF}} &= (F_{\mathrm{IF}} - 1)T_0 = (10^{1.1/10} - 1)(290) = 84 \text{ K}.
\end{aligned}
$$

Then from (14.27), (14.28), and (14.30) the noise temperatures of the receiver, transmission line, and antenna are

$$
\begin{aligned}
T_{\mathrm{REC}} &= T_{\mathrm{RF}} + \frac{T_M}{G_{\mathrm{RF}}} + \frac{T_{\mathrm{IF}} L_M}{G_{\mathrm{RF}}} = 289 + \frac{1163}{100} + \frac{84(4.0)}{100} = 304 \text{ K}, \\
T_{\mathrm{TL}} &= (L_T - 1)T_p = (1.41 - 1)300 = 123 \text{ K}, \\
T_A &= \eta_{\mathrm{rad}} T_b + (1 - \eta_{\mathrm{rad}})T_p = 0.9(200) + (1 - 0.9)(300) = 210 \text{ K}.
\end{aligned}
$$

The input noise power, from (14.31), is

$$N_i = kBT_A = 1.38 \times 10^{-23}(10^6)(210) = 2.9 \times 10^{-15}\text{W} = -115 \text{ dBm}.$$

Then the input SNR is

$$\frac{S_i}{N_i} = -80 + 115 = 35 \text{ dB}.$$

From (14.33) the total system noise temperature is

$$T_{\mathrm{SYS}} = T_A + T_{\mathrm{TL}} + L_T T_{\mathrm{REC}} = 210 + 123 + (1.41)(304) = 762 \text{ K}.$$

This result clearly shows the noise contributions of the various components. The output SNR is found from (14.34) as

$$\frac{S_o}{N_o} = \frac{S_i}{kBT_{\mathrm{SYS}}},$$

$$kBT_{\mathrm{SYS}} = 1.38 \times 10^{-23}(10^6)(762) = 1.05 \times 10^{-14} \text{ W} = -110 \text{ dBm},$$

so

$$\frac{S_o}{N_o} = -80 + 110 = 30 \text{ dB}. \qquad \blacksquare$$

Question 3

A LEO satellite at an orbital distance of 940 km uses QPSK to communicate with a handset on Earth. The satellite has a transmit power of 80 W and an antenna gain of 20 dB, while the handset has an antenna gain of 1 dB and a system temperature of 750 K. If atmospheric attenuation is 2 dB, and the required link margin is 10 dB, what is the maximum data rate for a bit error probability of 0.01?

Answer

Solution

The wavelength is 1.875 cm, so from (14.26) the path loss is

$$L_0 = 20\log\left(\frac{4\pi R}{\lambda}\right) = 20\log\left(\frac{(4\pi)\,(940\times 10^3)}{0.01875}\right) = 176.0\text{ dB}$$

The received power is

$$P_r = P_t + G_t - L_0 - L_A + G_r = 49 + 20 - 176 - 2 + 1 = -108\text{ dBm}.$$

For a link margin of 10 dB, this received power level should be 10 dB above the threshold level. Thus, the threshold received signal level is

$$S_{\min} = P_r - \text{LM} = -108 - 10 = -118\text{ dBm} = 1.58\times 10^{-15}\text{ W}.$$

From Figure 14.16, the required E_b/n_0 for a bit error rate of 0.01 for QPSK is about 5 dB = 3.16. Solving (14.36) for the maximum bit rate gives

$$R_b = \left(\frac{E_b}{n_0}\right)^{-1}\frac{S_{\min}}{n_0} = \left(\frac{E_b}{n_0}\right)^{-1}\frac{S_{\min}}{kT_{sys}} = \left(\frac{1}{3.16}\right)\frac{1.58\times 10^{-15}}{(1.38\times 10^{-23})\,(750)} = 48\text{ kbps}$$

■

Question 4

Example 1.1. *A microwave line of sight link at 10 GHz is to be designed for communication over a distance of 10 km. If the diameter of the dishes at the two ends of the link are the same and equal to 3m, calculate the transmitter power required when the receiver noise figure at the receiving end is 10 dB, receiver bandwidth is 1 GHz and the C/N ratio is required to be 40 dB.*

Ans. From equation for power received P_{ri} we have

$$P_{ri} = \frac{P_T D_1^2 D_2^2 f^2}{1.6\, d^2 c^2} = \frac{P_T D^4 f^2}{1.6\, d^2 c^2}$$

where $D_1 = D_2 = D = 3\text{m}$

$$f = 10 \text{ GHz} = 10 \times 10^9 \text{ Hz}$$

$$d = 30 \text{ km} = 30 \times 10^3 \text{ m}$$

$$c = 3 \times 10^8 \text{ m/sec}$$

$$\therefore \quad P_{ri} = \frac{P_T \times 3^4 \times [10^2 \times 10^9]^2}{1.6 \times (30 \times 10^3)^2 \times [3 \times 10^8]^2}$$

$$= \frac{P_T \times 3^4 \times 10^{20}}{1.6 \times 3^2 \times 10^8 \times 3^2 \times 10^{16}} = \frac{P_T\, 10^{-4}}{1.6} \text{ W}$$

Total noise power, N, at the receiver input is given by

$$N = F\,kTB$$

$$10 = 4 \times 1.38 \times 10^{-23} \times 300 \times 10^9$$

where $T = 273 + 27 = 300$ for the environmental temperature of 27°C.

$$= 4 \times 1.38 \times 300 \times 10^{-23} \times 10^9 \text{ W}$$

$$\equiv 10 \times 4 \times 10^{-21} \times 10^9 \text{ W}$$

$$C = 40 \times 10^{-12} \text{ watt}$$

where C is the carrier power.

As, the carrier power, C, is to be 40 dB above N we should have

$$C = 40 \times 10^{-12} \times 10^4 = 40 \times 10^{-8} \text{ Watt}$$

Assuming, $P_{ri} = C$, we have

$$\frac{P_T}{1.6} \times 10^{-4} = 40 \times 10^{-8}$$

$$\therefore \quad P_T = 40 \times 1.6 \times 10^{-8} \times 10^4 \text{ W}$$

$$= 64 \times 10^{-4} \text{ W} = 6.4 \times 10^{-3} \text{ W} = 6.4 \text{ mW}.$$

Question 5

Example 1.2. *A satellite communication link for earth station has got a parabolic dish antenna of diameter 10 m fed from a microwave transmitter at 6 GHz having a power of 3 kW. If the overhead geostationary satellite has a microwave dish antenna of diameter 2 m, calculate the C/N ratio at the satellite receiving terminal for the up link having a noise temperature 300 K and a bandwidth of 500 MHz.*

Solution. We have for the uplink at 6 GHz

$$P_{ri} = \frac{P_T D_1^2 D_2^2 f^2}{1.6 \times d^2 . c^2} = \frac{3 \times 10^3 \times 10^2 \times 2^2 \times (6 \times 10^9)^2}{1.6 \times (36500 \times 10^3)^2 (3 \times 10^8)^2}$$

$$= \frac{3 \times 2^2 \times 6^2 \times 10^{23}}{1.6 \times (3.65)^2 \times 10^{14} \times 3^2 \times 10^{16}}$$

$$= \frac{12 \times 36 \times 10^{23}}{1.6 \times 13.32 \times 9 \times 10^{30}} = \frac{432 \times 10^{23}}{191.81 \times 10^{30}} \text{ W}$$

$$= 2.252 \times 10^{-7} \text{ W} = 0.2252 \ \mu\text{W}$$

$$N = k\, T_{sys}\, B = 1.38 \times 10^{-23} \times 300 \times 500 \times 10^6$$

$$\cong 4 \times 10^{-21} \times 5 \times 10^8 = 20 \times 10^{13} \text{ W}$$

$$= 2 \times 10 - 12 \text{ W}$$

$$\therefore \quad \frac{C}{N} = \frac{P_{ri}}{N} = \frac{2.252 \times 10^{-7}}{2 \times 10 - 12} \cong 1 \times 10^5 = 50 \text{ dB}$$

Question 6

Example 1.3. *If the transmitter power of the satellite terminal is 200 W, calculate the C/N ratio of the down link at 4 GHz, at the earth station, assuming the noise temperature of the receiving system of the earth station to be 50 K with the receiver band width is 500 MHz.*

Solution. We have for the down link at 4 GHz

$$P_{ri} = \frac{200 \times 2^2 \times 10^2 \times (4 \times 10^9)^2}{1.6 \times (36500 \times 10^3)^2 \times (3 \times 10^8)^2} \text{ W}$$

$$= \frac{2 \times 2^2 \times 10^4 \times 4^2 \times 10^{18}}{1.6\,(3.65 \times 10^7)^2 \times 3^2 \times 10^{16}} \text{ W}$$

$$= \frac{128 \times 10^{22}}{1.6 \times 13.32 \times 10^{14} \times 9 \times 10^{16}} \text{ W}$$

$$= \frac{128 \times 10^{22}}{191.81 \times 10^{30}} \text{ W} = 0.6673 \times 10^{-8} \text{ W}$$

$$N = k\, T_{sys}\, B$$

$$= 1.38 \times 10^{-23} \times 50 \times 500 \times 10^6$$

$$= 1.38 \times 25 \times 10^{-23} \times 10^9 \text{ W}$$

$$= 1.38 \times 25 \times 10^{-14} \text{ W}$$

$$\frac{C}{N} = \frac{P_{ri}}{N} = \frac{0.6673 \times 10^{-8}}{1.38 \times 25 \times 10^{-14}}$$

$$= \frac{6.673 \times 10^{-9}}{34.5 \times 10^{-14}}$$

$$= \frac{6.673 \times 10^{-9}}{3.45 \times 10^{13}}$$

$$= 1.9342 \times 10^4$$

$$= 40 + 2.865 \text{ dB} \equiv 43 \text{ dB}$$

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