UNIVERSITY OF TEXAS AT DALLAS
Department of Electrical Engineering

EE/TE 4367 - Telecommunications Switching & Transmission
Solution #8

Date assigned: 4/10/2008
Date due: 4/17/2008

Solution 8.1

(a) $\frac{E_b}{N_0} = 10\,dB = 10 \text{ (linear scale) } P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{20}\right) = 3.87\times10^{-6}$

(b) $N_0/2 = 0.5\times10^{-10}$ W/Hz $\quad E_b = 10N_0 = 10^{-9}$

$$E_b = \frac{A^2T_b}{2} = \frac{A^2}{2R_b} \qquad A = \sqrt{2E_bR_b} = \sqrt{2\times10^{-9}\times100\times1000} = 0.014142 \text{ volts}$$

Solution 8.2

The solution is also available on page 325-326 of Digital Telephony by Bellamy. But, I provide the solution with little more details.

The required value of E_b/N_0 for 4-PSK modulation with the desired BER of 10^{-6} can be determined as 10.7 dB from given BER expression as hint. But, the required SNR=Es/No is 10log10(2)=3 dB higher since symbol energy is twice bit energy for 4-PSK modulation. Recall the relation Es=log2(M)Eb where M is the constellation size. Thus, the required SNR is 13.7 dB.

Since 4-PSK modulation provides 2 bps/Hz, the signaling rate is 5MHz, which is the theoretical minimum (Nyquist) bandwidth. Use the second equation on slide 15 of lectureradio slides to determine the system gain. Note that we use the system gain since we look at the wireless channel as a system with an input with transmit power P_T and an output with the received power P_R. Note that SNR is defined as SNR= P_R/P_N where P_N is the total noise power which can be found the equation on slide 14. Noting the loss D and the bandwidth expansion factor 1.3 that brings the bandwidth usage 1.3B, the system gain is given by

$$A_s = 10\log_{10}\left(\frac{P_T}{P_R}\right) - D = 10\log_{10}\left(\frac{P_T}{SNR\times P_N}\right) - D = 10\log_{10}\left(\frac{P_T}{SNR\times F\times kT_0\times B\times1.3}\right) - D$$

$$A_s = 10\log_{10}\left(\frac{2.5}{4(10)^{-21}(5)10^6}\right) - 10\log_{10}(SNR) - 10\log_{10}(F) - D - 10\log_{10}(1.3) = 116 \text{ dB}$$

At a carrier frequency of 2 GHz, the wavelength is $3\times10^8/2\times10^9 = 0.15m$. Thus the fade margin can be determined from system gain expression as 38.5 dB.

Solution 8.3

$$P_{r1} = P_t K\left(\frac{d_0}{d_1}\right)^{\gamma} = 2\mu W \;\; \rightarrow \qquad P_t K d_0^{\ \gamma} = P_{r1} \times d_1^{\ \gamma} = 2 \times 2^{3.8} = 27.86$$

At other distances, use the above result

$$P_{r2} = P_{r1}\left(\frac{d_1}{d_2}\right)^{\gamma} = \frac{27.86}{3^{3.8}} = 0.4284\mu W \quad \text{at 3 km}$$

$$P_{r2} = P_{r1}\left(\frac{d_1}{d_2}\right)^{\gamma} = \frac{27.86}{6^{3.8}} = 0.0308\mu W \quad \text{at 6 km}$$

$$P_{r2} = P_{r1}\left(\frac{d_1}{d_2}\right)^{\gamma} = \frac{27.86}{15^{3.8}} = 9.458 \times 10^{-4}\mu W \quad \text{at 15 km}$$