Chapter 2

2.1 Convert the following power levels to both dBm and dBW.
(a) 150 W
(b) 0.5 W
(c) 10 mW
(d) 40 μW

2.2 Convert the following back to power in Watts.
(a) -10 dBW
(b) 200 dBW
(c) -76 dBm
(d) 24 dBm

2.3 The input power to a certain system is $P_i = -80$ dBm. The system has gain/loss components of $G_1 = 24$ dB, $L_1 = 6$ dB and $L_2 = 10$ dB. Compute the output power in dBm.

2.4 Repeat the previous problem by converting the input power to Watts and converting all gain/loss terms from dB to W/W (unitless). Use the appropriate formula to calculate the output power in Watts. Convert the output power level to dBm. Note: The output power level in dBm should equal your answer in problem 2.3.

2.5 A transmitter in free space has an output power of 5 W and operates at 1.9 GHz. The transmit antenna has a gain of 10 dB. The receive antenna is located 10 km from the transmitter and has a gain of 5 dB.
(a) Calculate the free space path loss.
(b) What is the EIRP in dBm?
(c) Calculate the received power level in dBm assuming system losses of 3 dB.

2.6 A receiver is 6 km from a transmitter in free space. The transmitter operates at a frequency of 940 MHz. The output at the receiver antenna is -94 dBm. The receive antenna has a 2 dB gain. What is the EIRP in dBm? What is the transmit power in Watts if the transmit antenna has a gain of 10 dB?

2.7 A transmitter radiates an EIRP of 2 W into free space. A receive antenna 8 km away has a gain of 5 dBi. Assume 0 dB of system loss.
(a) What is the received power level if the transmitter operates at 900 MHz?
(b) What is the received power level if the transmitter operates at 1800 MHz?

2.8 The system described in problem 2.5 is located in a large city. The base station antenna is at a height of 100 m and the mobile unit is at a height of 1.5 m.
(a) Calculate the path loss using the Hata model.
(b) What is the EIRP in dBm?
(c) Calculate the median received power level (according to the Hata model) in dBm assuming system losses of 3 dB.

2.9 A wireless base station operates at 1.2 GHz in an urban (large city) environment transmitting 15 W from the top of a 30 m tower. The base station antenna’s gain is 7 dBi and the system losses are 4 dB. A receiver operating in the vicinity has a height of 1.6 m and an antenna gain of 2 dBi.
(a) Calculate the median path loss using the Hata model at a distance of 12 km.
(b) Calculate the median received signal power.
(c) Calculate the received signal power using the free-space model and compare your answer to part (b).

2.10 According to the Hata model the median received power level for an MU is $P_r = -60 \text{ dBm}$. The MU sensitivity is $p_{\text{sens}} = -70 \text{ dBm}$. What is the outage probability? Assume the received power level has an exponential distribution.

2.11 If the received power level is exponentially distributed compute the outage probability when the MU threshold (sensitivity) is 6 dB below the average (not median) received power level.

2.12 Verify your result in problem 2.11 by writing a script in Octave/MATLAB that generates a vector of 1000 exponentially distributed random variables with an average of one. (Use the exprnd function. In Octave you will need to enter “pkg load statistics” to make the exprnd function available.) Then use the vector to estimate the outage probability. Your script should display the estimated outage probability. Run the script 5 times and list the 5 estimates. Also turn in a printed copy of your script.

2.13 A base station operating at 1.8 GHz transmits a 44 dBm signal from an antenna that is 30 m above the ground in urban Philadelphia. The transmitting antenna has a gain of 4 dBi and there are 2 dB of system losses. The receiving antenna has a gain of 2 dBi and has a height of 2 m.
(a) Assuming that $\sigma_{\text{db}} = 8 \text{ dB}$, calculate the probability that the received signal power is 10 dB above the median value at 20 km. Use the Hata model.
(b) Find the probability that the received signal power at 10 km is greater than 10 dB above the median value at 20 km.

2.14 A certain system has the following parameters: $P_t = 35 \text{ W}$, $G_t = 6 \text{ dBi}$, $f_0 = 1.2 \text{ GHz}$, $L = 3 \text{ dB}$, $G_r = 3 \text{ dBi}$, $h_{\text{MU}} = 1.6 \text{ m}$. The system is to be used in a medium-sized city with $\sigma_{\text{db}} = 6 \text{ dB}$. The MU sensitivity (threshold) is -70 dBm.
(a) Find the fade margin to ensure that the received signal power is above the receiver sensitivity with 95% probability.
(b) Find the median signal level required to meet the 95% objective.
(c) What is the minimum height of the transmitting antenna required to achieve the 95% objective at a distance of 8 km. Use the Hata model.

Chapter 3

3.1 A 200 MHz carrier is AM modulated by a 2 kHz sinusoid (tone modulation). The modulation index is 0.8. Assume a carrier amplitude of 4 V. What is the bandwidth of the AM signal? How much power is being transmitted in the carrier? In the sidebands? What percent of the total transmitted power is in the carrier?

3.2 Draw the block diagram for a QAM modulator that transmits both the left and right channels of a stereo signal at a frequency of 1500 kHz. If each signal has a bandwidth of 15 kHz, what is the bandwidth of the QAM signal?
3.3 A 200 MHz carrier is FM modulated by a 2 kHz sinusoid (tone modulation). The modulation index is 0.8. Assume a carrier amplitude of 4 V. What is the bandwidth of the FM signal? How much power is being transmitted?

3.4 A voice signal is sampled using an 8-bit A/D converter at a 5 kHz sampling rate. The baseband binary pulse train is then BPSK modulated.
(a) If sinc pulses are used, what is the null-to-null bandwidth of the modulated signal?
(b) If raised-cosine pulses with a roll-off parameter of $\alpha = 1$ are used what is the null-to-null bandwidth of the modulated signal?

3.5 Assume rectangular pulses are used in the previous problem. Find the following: (a) Absolute bandwidth, (b) 3-dB bandwidth, (c) equivalent bandwidth, (d) null-to-null bandwidth, (e) 99% power bandwidth.

3.6 Given the two signals in Figure 3.6, sketch the impulse response for the corresponding matched filter. If $N_0 / 2 = 0.1$ W/Hz, what is the bit error rate?

![Figure 3.6](image)

3.7 Given $s(t) = \sin(2\pi t) \text{ rect}((t - 2)/4)$. Determine the output of both a matched filter receiver and a correlation receiver. Sketch both outputs. The output of the matched filter is

$$y_{mf}(t) = \int_0^t s(\tau) s(T + \tau - t) d\tau$$

where $T = 4$. The output of the correlation receiver is

$$y_{co}(t) = \int_0^t s^2(\tau) d\tau$$
3.8 Signals \( s_1(t) \) and \( s_0(t) \) are used to represent bits 1 and 0 respectively in a digital modulation system. Find the energy in each signal \( (E_1 \) and \( E_0) \) and the correlation coefficient \((\rho)\). Express the probability of error in terms of the \( Q \) function, \( E \) and \( N_0 \) (\( N_0 / 2 \) is the noise spectral density level).

\[
s_1(t) = \sqrt{E} \sqrt{\frac{2}{T}} \cos \left( 2 \pi f_0 t + \frac{3\pi}{8} \right), \quad 0 \leq t \leq T
\]

\[
s_0(t) = \sqrt{E} \sqrt{\frac{2}{T}} \cos \left( 2 \pi f_0 t - \frac{3\pi}{8} \right), \quad 0 \leq t \leq T
\]

where \( T = 4 \) \( T_0 = 4 / f_0 \).

3.9 Express signals \( s_1(t) \) and \( s_0(t) \) in the previous problem in terms of orthonormal functions \( \psi_1(t) \) and \( \psi_2(t) \) (defined below). Draw the signal constellation. Find the distance \((d_{\text{min}})\) between the constellation points. Verify that the probability of error calculated using \( Q \left( d_{\text{min}} / \sqrt{2N_0} \right) \) is equal to the error probability expression obtained in the previous problem.

\[
\psi_1(t) = \sqrt{\frac{2}{T}} \cos \left( 2 \pi f_0 t \right), \quad 0 \leq t \leq T
\]

\[
\psi_2(t) = -\sqrt{\frac{2}{T}} \sin \left( 2 \pi f_0 t \right), \quad 0 \leq t \leq T
\]

3.10 Use MATLAB/Octave to reproduce Figure 3.28 as closely as possible. Add the ASK performance curve to the graph.

3.11 The output of a DPSK encoder is \( d_k = \{1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 0 \ 0 \ 0 \ 1\} \). What is the corresponding decoded sequence \((b_k)\)?

3.12 (a) What is the probability of a bit error for ASK, BPSK and DPSK if the EBNO ratio is 16 dB? (b) What is the required EBNO ratio for ASK, BPSK and DPSK if the probability of a bit error is \(5 \times 10^{-6}\)?

3.13 Determine the probably of bit error for both BPSK and QPSK if the EBNO ratio is 8. Determine the bandwidth efficiency for both is \( R = 100 \) kbps.

3.14 Use the constellation diagram in Figure 3.43 to determine the sequence of signal phases and corresponding phase changes for \( \pi/4\)-QPSK for transmission of the following binary sequence. Assume a starting point of \{-1, -1\}.

\[-1, -1, +1, -1, +1, -1, -1, +1, -1, +1, +1, +1, -1\]

3.15 Use the constellation diagram in Figure 3.43 to determine the binary sequence corresponding to the following phase changes detected at the receiver. Assume a starting point of \{-1, -1\}.

\[+3\pi/4, -3\pi/4, +3\pi/4, +\pi/4, +3\pi/4, -\pi/4, -\pi/4, +3\pi/4\]
3.16 Binary data is being transmitted via FSK at a rate of \( R = 100 \text{ kbps} \) with a BER of \( 10^{-6} \). (a) What is the minimum frequency separation between the two signals for orthogonality? (b) What is the required EBNO ratio if coherent reception is used? (c) If incoherent reception is used?

3.17 Calculate the BER for M-ary PSK with an EBNO ratio of 20 dB for (a) \( M = 4 \) and (b) \( M = 16 \).

3.18 Determine the EBNO ratio required for a BER of \( 10^{-4} \) with (a) \( M = 8 \) and (b) \( M = 32 \).

3.19 According to Shannon’s theorem, what signal-to-noise ratio (in dB) is necessary to achieve a channel capacity of 100 kbps in a 10 kHz bandwidth channel? What is the EBNO ratio corresponding to this signal-to-noise ratio if this channel were used to transmit data at \( R = 50 \text{ kbps} \)?

3.20 What is the channel capacity if \( S/N = 10 \text{ dB} \) and the channel bandwidth is 100 kHz?

---

Chapter 4

4.1 Consider a linear arrangement of base stations as shown in Figure 4.1. Assume all base stations are identical with a path loss of \( \nu \). Each base station is separated from its nearest neighbor by a distance of \( 2R \), where \( R \) is the radius of the circular coverage area (cell). Assume that the mobile unit (MU) is located at the edge of the serving cell. Assume that the nearest (or first-tier) co-channel neighbors are \( \text{BS}_k \) and \( \text{BS}_{-k} \), and the reuse distance is \( D \). (The figure shows the special case in which the first tier co-channel neighbors are \( \text{BS}_2 \) and \( \text{BS}_2 \) and the reuse distance is \( D = 4R \).)

4.2 For the system in Problem 4.1, compute the \( S/I \) ratio in dB at the MU from the first-tier interference sources located at \( \text{BS}_3 \) and \( \text{BS}_3 \) for a path loss of \( \nu = 3 \). For this case, how does the \( S/I \) degrade if we include the second-tier interference, that is, the interference from \( \text{BS}_{-6} \) and \( \text{BS}_6 \)?
4.3 What is the smallest reuse distance than can be used to ensure a 20 dB $S/I$ ratio at a cell boundary when the path-loss exponent is $\nu = 3.2$? How many cells are in a cluster for this reuse distance?

4.4 A certain metropolitan area covers 400 mi$^2$.
   a) What is the minimum number of $R = 1.5$ mi cells required to provide coverage in the entire area?
   b) If the path-loss exponent $\nu$ is 3.5, what is the minimum cluster size the will ensure a 15 dB $S/I$ at the cell boundary?
   c) If there are 490 channels allocated to provide the service, how many channels are available in each cell?

4.5 Extend Table 4.2 to provide values of $S/I$ in dB for path-loss exponents $\nu = 3$ and $\nu = 3.5$ and plot $S/I$ in dB versus $q$, the reuse ratio, for each path-loss exponent (3, 3.5, and 4).

4.6 Calculate the $S/I$ ratio in dB for a cluster size of 7 a path loss exponent of 3.5. What is the $S/I$ ratio in dB if sectoring with 60° sectors is used.

4.7 A BS transmits 5 W of power. Cell splitting is performed to increase the number of users supported. Assume cells are split so that new cells have a radius equal to $\frac{1}{4}$ the radius of the original cell. What is the required transmit power for each new BS if the $S/N$ ratio at the cell edge is to be the same before and after splitting? Assume a path-loss exponent of 3.5.