4.30 Read "Path Loss, Delay Spread, and Outage Models as Functions of Antenna Height for Microcellular System Design," which appeared in the August 1994 issue of *IEEE Transactions on Vehicular Technology*, Vol. 43, No. 3. (This paper also appears on page 211 of *Cellular Radio and Personal Communications: Advanced Selected Readings* by the IEEE Press.)

(a) Derive Equation (10) in the paper from first principles and from the definition of Fresnel zone. After deriving this result, simplify your answer further.

(b) Using the models for mean path loss given in the paper, determine the received signal powers at T–R separation distances of 50 m, 100 m, and 1 km for a 1 W transmitter and unity gain antennas operating at 1900 MHz for:

(1) obstructed environments

(2) LOS environments

Assume an 8.5 m tall base station antenna and a 1.7 m tall mobile antenna are used.

(c) For your answers in (b), use a log-normal shadowing model to determine the likelihood that the received signal will be greater than or equal to –70 dBm at each of the three T–R separations, for obstructed and for LOS environments.

(d) Using the overbound model for rms delay spread given on pages 493 of the journal paper, estimate the rms delay spread at each of the three T–R separation distances, for obstructed and for LOS environments.

(e) Using your values in (d), determine the maximum unequalized symbol data rates that may be successfully transmitted by the base station at each of the three T–R separation distances in obstructed and in LOS environments. Assume an adaptive equalizer is not needed at the mobile receiver when the symbol duration is greater than 10 times the rms delay spread, and assume the noise figures of IS-136 and GSM mobile receivers are 6 dB. Would it be possible to receive IS-136 signals at these distances and environments without an equalizer? Would it be possible to transmit GSM signals at these distances without an equalizer? Hint: Consider both time delay spread and thermal noise-limited receiver power to provide answers. Assume IS-136 needs C/I = 15 dB and GSM needs C/I = 12 dB.

4.31 Design and create a computer program that produces an arbitrary number of samples of propagation path loss using a d^n path loss model with log normal shadowing. Your program is a radio propagation simulator, and should use, as inputs, the T–R separation, frequency, the path loss exponent, the standard deviation of the log-normal shadowing, the close-in-reference distance, and the number of desired predicted samples. Your program should provide a check that insures that the input T–R separation is equal to or exceeds the specified input close-in-reference distance, and should provide a graphical output of the produced samples as a function of path loss and distance (this is called a *scatter plot*).

Verify the accuracy of your computer program by running it for 50 samples at each of five different T–R separation distances (a total of 250 predicted path loss values), and determine the best fit path loss exponent and the standard deviation about the mean path loss exponent of the predicted data using the techniques described in Example 4.9. Draw the best fit mean path loss model on the scatter plot to illustrate the fit of the model to the predicted values. You will know your simulator is working if the best fit path loss model and the standard deviation for your simulated data is equal to the parameters you specified as inputs to your simulator.

4.32 Using the computer program developed in Problem 4.31, develop an interface that allows a user to specify inputs as described in Problem 4.31, as well as transmitter and receiver parameters such as transmit power, transmit antenna gain, receiver antenna gain, receiver bandwidth, and receiver noise figure. Using these additional input parameters, and using knowledge of the