Assignment 1

Due Friday, January 21, 2000

1.5 Assume a 1 Amp-hour battery is used on a cellular telephone (often called a cellular subscriber unit). Also assume that the cellular telephone draws 35 mA in idle mode and 250 mA during a call. How long would the phone work (i.e. what is the battery life) if the user leaves the phone on continually and has one 3-minute call every day? every 6 hours? every hour? What is the maximum talk time available on the cellular phone in this example?

1.6 Assume a CT2 subscriber unit has the same size battery as the phone in Problem 1.5, but the paging receiver draws 5 mA in idle mode and the transceiver draws 80 mA during a call. Recompute the CT2 battery life for the call rates given in Problem 1.5. Recompute the maximum talk time for the CT2 handset.

1.7 Why would one expect the CT2 handset in Problem 1.6 to have a smaller battery drain during transmission than a cellular telephone?

2.2 Show that the frequency reuse factor for a cellular system is given by k/S, where k is the average number of channels per cell and S is the total number of channels available to the cellular service provider.

2.3 A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal-to-interference ratio of 15 dB in the worst case. Find the optimal value of N for (a) omni-directional antennas, (b) 120° sectoring, and (c) 60° sectoring. Should sectoring be used? If so, which case (60° or 120°) should be used? (Assume a path loss exponent of $n = 4$ and consider trunking efficiency).

2.5 For a $N = 7$ system with a $Pr[Blocking] = 1\,\%$ and average call length of 2 minutes, find the traffic capacity loss due to trunking for 57 channels when going from omni-directional antennas to 60° sectored antennas. (Assume that blocked calls are cleared and the average per user call rate is $\lambda = 1$ per hour.

2.7 Exercises in trunking (queueing) theory:

(a) What is the maximum system capacity (*total* and *per channel*) in Erlangs when providing a 2% blocking probability with 4 channels, with 20 channels, with 40 channels?

(b) How many users can be supported with 40 channels at 2% blocking? Assume $H = 105$ s, $\lambda = 1$ call/hour.

2.8 A receiver in an urban cellular radio system detects a 1 mW signal at $d = d_0 = 1$ meter from the transmitter. In order to mitigate co-channel interference effects, it is required that the signal received at any base station receiver from another base station transmitter which operates with the same channel must be below -100 dBm. A measurement team has determined that the average path loss exponent in the system is $n = 3$. Determine the major radius of each cell if a 7-cell reuse pattern is used. What is the major radius if a 4-cell reuse pattern is used?

2.9 A cellular system using a cluster size of 7 is described in Problem 2.8. It is operated with 660 channels, 30 of which are designated as setup (control) channels so that there are about 90 voice channels available per cell. If there is a potential user density of 9000 users/km^2 in the system, and each user makes an average of one call per hour and each call lasts 1 minute during peak hours, determine the GOS

2.18 Assume each user of a single base station mobile radio system averages three calls per hour, each call lasting an average of 5 minutes.

(a) What is the traffic intensity for each user?

(b) Find the number of users that could use the system with 1% blocking if only one channel is available.

(c) Find the number of users that could use the system with 1% blocking if five trunked channels are available.

(d) If the number of users you found in (c) is suddenly doubled, what is the new blocking probability of the five channel trunked mobile radio system? Would this be acceptable performance? Justify why or why not.

2.20 Pretend your company won a license to build a U.S. cellular system (the application cost for the license was only $500!). Your license is to cover 140 square km. Assume a base station costs $500,000 and a MTSO costs $1,500,000. An extra $500,000 is needed to advertise and start the business. You have convinced the bank to loan you $6 million, with the idea that in four years you will have earned $10 million in gross billing revenues, and will have paid off the loan.

(a) How many base stations (i.e. cell sites) will you be able to install for $6 million?

(b) Assuming the earth is flat and subscribers are uniformly distributed on the ground, what assumption can you make about the coverage area of each of your cell sites? What is the major radius of each of your cells, assuming a hexagonal mosaic?

(c) Assume that the average customer will pay $50 per month over a 4 year period. Assume that on the first day you turn your system on, you have a certain number of customers which remains fixed throughout the year. On the first day of each new year the number of customers using your system doubles and then remains fixed for the rest of that year. What is the minimum number of customers you must have on the first day of service in order to have earned $10 million in gross billing revenues by the end of the 4th year of operation?

(d) For your answer in (c), how many users per square km are needed on the first day of service in order to reach the $10 million mark after the 4th year?

3.6 *Compute* the received power for the approximate (equation (3.52)) expression for the 2-ray ground reflection model. Assume the height of the transmitter is 40 m and the height of the receiver is 3 m. The frequency is 1800 MHz, and unity gain antennas are used. Plot the received *power over 1 to 20 km if the reflection coefficient is −1.*

3.10 If P_t = 10 W, G_t = 10 dB, G_r = 3 dB, and L = 1 dB at 900 MHz, compute the received power for the knife-edge geometry shown in Figure P3.10. Compare this value with the theoretical free space received power if an obstruction did not exist. What is the path loss due to diffraction for this case?

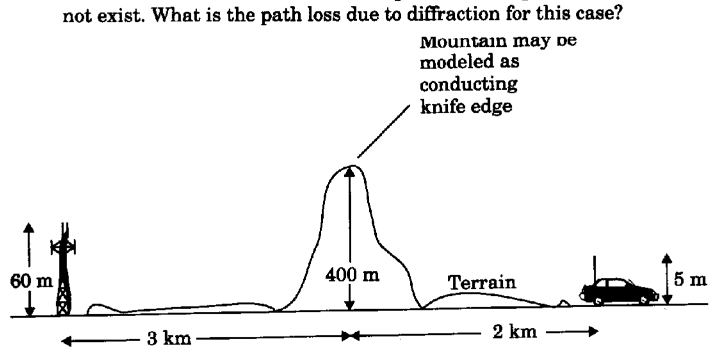

Figure P3.10 Knife-edge geometry for Problem 3.10.

3.11 If the geometry and all other system parameters remain exactly the same in Problem 3.10, but the frequency is changed, redo Problem 3.10 for the case of (a) f = 50 MHz and (b) f = 1900 MHz.

3.13 If the received power at a reference distance $d_0 = 1$ km is equal to 1 microwatt, find the received powers at distances of 2 km, 5 km, 10 km, and 20 km from the same transmitter for the following path loss models: (a) Free space; (b) n = 3; (c) n = 4; (d) 2-ray ground reflection using the approximate expression; (e) extended Hata model. Assume f =1800 MHz, h_t = 40m, h_r = 3m, $G_t = G_r = 0$ dB. Plot each of these models on the same graph over the range of 1 km to 20 km.

3.16 A transmitter provides 15 W to an antenna having 12 dB gain. The receiver antenna has a gain of 3 dB and the receiver bandwidth is 30 kHz. If the receiver system noise figure is 8 dB and the carrier frequency is 1800 MHz, find the maximum T-R separation that will ensure that a SNR of 20 dB is provided for 95% of the time. Assume $n = 4$, $\sigma = 8$ dB, and $d_0 = 1$ km.

3.17 Assume a SNR of 25 dB is desired at the receiver. If a 900 MHz cellular transmitter has an EIRP of 100 W, and the AMPS receiver uses a 0 dB gain antenna and has a 10 dB noise figure, find the percentage of time that the desired SNR is achieved at a distance of 10 km from the transmitter. Assume n=4, $\sigma = 8$ dB, and $d_0 = 1$ km.

3.21 Consider 7-cell frequency reuse. Cell B1 is the desired cell and B2 is a co-channel cell as shown in Figure P3.21.1 For a mobile located in cell B1, find the minimum cell radius R to give a forward link C/I ratio of at least 18 dB at least 99% of the time. Assume the following:

Co-channel interference is due to base B2 only.

Carrier frequency, f_c = 890 MHz.

Reference distance, $d_0 = 1$ km (assume free space propagation from the transmitter to d_0).

Assume omni-directional antennas for both transmitter and receiver where, G_{base} = 6 dBi and G_{mobile} = 3 dBi

Transmitter power, P_t = 10 W (assume equal power for all base stations).

PL(dB) between the mobile and base B1 is given as

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10(2.5)\log\left(\frac{d_1}{d_0}\right) - X_\sigma \qquad (\sigma = 0 \text{ dB}) .$$

PL(dB) between the mobile and base B2 is given as

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10(4.0)\log\left(\frac{d_2}{d_0}\right) - X_\sigma \qquad (\sigma = 7 \text{ dB}) .$$

Cell boundaries are shown in the Figure P3.21.2.

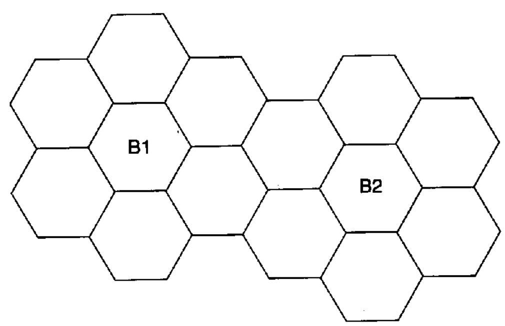

Figure P3.21.1 7-cell reuse structure.

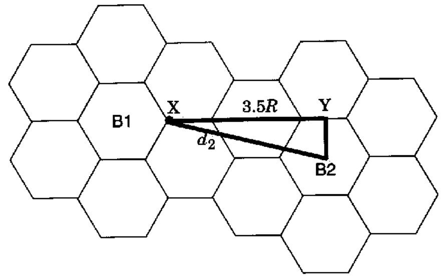

Figure P3.21.2 Co-channel interference geometry between B1 and B2.