Department of Electrical Engineering
Mid-term Exam EE E6950 Oct.19, 1999

Closed Book *Do all Problems*

1. a. Given a two-dimensional hexagonal cellular system. Show, with a picture, how channel assignments to cells would follow a 4-reuse pattern.
b. Show how, in the scenario above, channel borrowing results in channel locking.
c. Draw typical Blocking Probability (P_B) vs. Erlang load curves for FCA (fixed channel allocation) and DCA (dynamic channel allocation). Explain the results for low and high load.

2. a. Assume a cellular system with average call duration of 5 minutes/user. Each user calls, on the average, once per hour. A cell has 1200 users. Using the Erlang-B table below, determine how many channels, N, are required per cell to have the blocking probability P_B be 1%.

A, erl. $\rightarrow$	4.5	12	29	65	84	100	132	180
N $\rightarrow$	10	20	40	80	100	120	150	200

b. Assume a cellular system as in a. above, but with 90 channels per cell. A 7-reuse cellular pattern is used. What is the total number of channels available system-wide?

c. Cell sizes are now reduced 50%. User call statistics and the number of channels per cell remain the same as in a. The blocking probability is to be kept at 1%. Compare the number of users the system can now handle with the case of a.

3. The *uplink,* mobile to base station, SIR (signal-to-interference ratio) is to be calculated for a 3-reuse two-dimensional hexagonal cellular system. All system mobiles are assumed to be transmitting at the same power. Consider first-tier interferers only. Let the average power-distance relation be given by $g(d) = kd^{-n}$. Note that $D_C/R = \sqrt{3}\sqrt{C}$ for a hexagonal cellular system, R the cell radius, D_C the spacing between interfering cells, and C the cluster size. Use a worst-case analysis.
a. Find the SIR for n = 3.
b. Repeat for n = 4, and compare with the n = 3 case.

4. a. A base station transmitts at a power level of 100mW. Omni-directional antennas are used at both the base station and mobiles, with gains of 1. The distance-dependent propagation is given by $g(d) = 10^4/d^4$. How much below the transmitter power is the *average received power* , in dB, at a distance of 100m. from the transmitter?
b. Due to shadow fading, the *local mean power* at a mobile 100m. from the base station is 10 dB *below* the average received power. The signal received at the mobile suffers from fast multipath fading. What is the probability that the *instantaneous received power* at the mobile is *greater than* 60 dB below the transmitted power?

Formulas and Equations

1. Erlangs $\equiv \lambda / \mu$, λ the average number of call attempts per time; $1/\mu$ the average duration of a call.

2. dB measure: $P|_{dB} \equiv 10\log_{10}P$

3. Instantaneous received power $P_R = \alpha^2 P_T G_T G_R g(d) 10^{x/10} \equiv \alpha^2 p$

> P_T = transmitted power; d = distance between transmitter and receiver;
> G_T and G_R are transmitter and receiver antenna gain factors, respectively;
> $10^{x/10}$ is the shadow-fading log-normal factor; x is gaussian (Normal)
> α is the Rayleigh-distributed multipath fading random variable
> p is the local-mean power: P_R is exponentially distributed with average value p

In dB: $P_R|_{dB} = 10\log_{10}\alpha^2 + P_T|_{dB} + 10\log_{10}[G_T G_R g(d)] + x$

Probability density functions:

$$f(x) = e^{-x^2/2\sigma^2} / \sqrt{2\pi\sigma^2} \qquad erf(x) \equiv \frac{2}{\sqrt{\pi}} \int_0^x e^{-x^2} dx$$

$$f(\alpha) = \frac{\alpha}{\sigma_r^2} e^{-\alpha^2/2\sigma_r^2} \quad \alpha \geq 0 \qquad \int_a^\infty f(\alpha) d\alpha = e^{-a^2/2\sigma_r^2}$$

$$f(P_R) = \frac{1}{p} e^{-P_R/p} \quad P_R \geq 0 \qquad \int_{p_o}^\infty f(P_R) dP_R = e^{-p_o/p}$$

4. SIR $\equiv$ Received signal power/ $\sum$ Interfering powers