EE 359 - Wireless Communications - Winter 2009

Midterm

1. **Speeding? A ticket is not the only consequence. (40 points)**

   In this problem we investigate the impact of time-variations in the wireless channel on user performance.

   John, a famous rockband singer, is driving his car in Paris. Consider 3 positions of the car, position A, B and C. Assume the transmitted power is 30W, the carrier frequency is 900 MHz, and signal power falls off accordingly to the free space path loss formula. Also assume the antennas at the transmitter and receiver are non-directional (0 dB antenna gain), and are at the same height above the ground ($h_t = h_r = 10$ m). When John is at

   Position A: John is driving at 100 Km/hr directly away from the transmitter. The channel consists of a LOS ray, which travels a distance of d= 1 Km, and a reflected ray with an angle of arrival of 45 degrees (reflection coefficient equal to -1).

   Position B: John goes into a tunnel at a distance $d = 2$ Km from the transmitter, still driving at 100 Km/hr. Now only a LOS ray is present, which in addition to free space path loss also experiences log-normal shadowing with a mean that reduces the received power by .5 nanowatts, and STD $\sigma_{\Psi_{\text{dB}}} =$ 30 dB (the high variance is due to the wide range of building materials and large number of parks in Paris).

   Position C: The paparazzi are waiting for John at the tunnel exit, so he speeds up using his turbocharge mode to 500 Km/hr to ditch them. Now his channel at distance d= 3 Km consists of only a LOS ray.

   Assume John's guitarist is sending him voice packets with a new song idea via DPSK modulation at a rate $R = 25$ Kbps with signal bandwidth 25 KHz. Assume the received power equals the power of the sum of the LOS and any reflected rays, and and that the received signal experience Rayleigh fading in all three locations in addition to path loss (and shadowing at position B). John's receiver has a noise PSD of $N_0 = 10^{-15}$ mW/Hz. We say that John receives good voice service if $\bar{P}_b < 10^{-3}$, okay service if $10^{-3} < \bar{P}_b < 10^{-2}$ and lousy service if $\bar{P}_b > 10^{-2}$ (for path loss + shadowing, these metrics require the target BERs be met with probability .9 or above, and for this case is may be useful to note that $Q^{-1}(0.9) = -1.2816$).

   (a) Sketch the scattering function for a receiver located at the three positions A, B, and C.

   (b) Find the service quality John receives in positions A, B, and C. Be sure to include the effects of ISI and Doppler (based on the uniform scattering model).

2. **How can I get good coverage inside my home? (35 points)**

In this problem we investigate why cellphones often have lousy performance inside homess, and a recent solution to mitigate this problem called **Femtocells**. Femtocells use the idea that an off-the-shelf base-station from, say, Fry's, can be mounted inside a home to act as a personal base station for people inside. The Femtocell basestation is connected into the backbone cellular system via high-speed wires, so it acts just like a regular base station in terms of handoffs, etc. For this problem assume the cell transmitter and receiver has perfect instantaneous information about the channel gains and that the signal bandwidth is 100 KHz.

(a) Cinderella has lousy coverage inside her castle, which has a thick outer moat. Due to shadowing from the castle walls and moat, depending on Cinderella's location inside the castle, she has a received SNR of 0 dB, 3 dB, or 5 dB, each with probability 1/3. Find the Shannon capacity of Cinderella's castle.

(b) Cinderella's prince buys her a Femtocell for their anniversary. With the Femtocell, Cinderella has much better signal strength throughout the castle, she gets a received power of 5 dB, 20 dB, and 30 dB, each with probability 1/3. Find the Shannon capacity of Cinderella's castle with her new Femtocell.

(c) Cinderella is so happy with her new Femtocell that she kisses the prince and he turns into a frog. Now she must call the princess hotline to figure out how to turn him back into a prince. The hotline requires a minimum data rate of 30 Kbps and any additional rate above this leads to a higher voice quality. The clever girl has taken EE359, so she decides to use power adaptation to invert the fading on the worst channel to reach the minimum data rate, and then to split the remaining power equally between the other channels. What power and rate adaptation does she use, and what is her resulting average rate? How does this compare with the rate obtained under channel inversion? Might she increase this average rate and, if so, how (a qualitative answer is sufficient)?

3. **Better video on your IPhone (25 points)**

In this problem we investigate how diversity techniques can aid in improving system performance.

Britney Spears is watching a music video on her IPhone while being driven in her limo. The video is transmitted using DPSK at a data rate of 5 Mbps. The Doppler spread in her limo is $B_D = 100$ Hz.

(a) Suppose Britney has the new and improved IPhone with 2-branch selection-combining diversity. Assume each branch has iid fading with linear SNR uniformly distributed between 5 and 15. Find the average BER and outage probability for a target BER of 10^{-3} for this improved IPhone. Which is a better performance metric to capture Britney's viewing experience?

(b) Paris Hilton is jealous of Britney's phone, and calls up Steve Jobs to make her a better phone with more diversity branches such that her outage probability is no more than .1 percent. If all branches experience iid fading with linear SNR uniformly distributed between 5 and 15, how many branches must Jobs put on Paris' phone under selection-combining diversity?