THE STATE UNIVERSITY OF NEW JERSEY

RUTGERS

College of Engineering
Department of Electrical and Computer Engineering

332:426 **Wireless PCS Takehome Exam I** **Spring 2006**

1. *(25 points)* **Reasonable or Unreasonable Fears:** Go to the URL

   http://www.winlab.rutgers.edu/∼crose/egg_cooking.htm.

   Argue QUANTITATIVELY whether the contention that an egg can be boiled using cell phones or cordless phones has merit or is groundless. The more quantitative you are, the more points you'll get. This problem will exercise your ability to gather and critically examine information as well as your common sense (which is in large measure what engineering is all about).

2. *(25 points)* **Antenna Diversity:** You are in a Rayleigh fading environment where the distribution on signal power P (a random variable) at an antenna is $ae^{-ap}u(p)$ for a some positive real constant and the powers of antennas separated by a few wavelengths is independent.

   What is the minimum number of antennas you need have probility q that at least one antenna has a power level above P_{min}?

3. *(50 points)* **Energy on Target:** You have now done a bunch of phased array examples. It's time to generalize your results.

   Assume you have a linear array of N antenna elements spaced by some distance d. Assume the operating frequency of the array is f_c and that targets are very far away from the array (many many times the array extent). You have control over BOTH the amplitude q_i of the sinusoid emitted by each element and its phase ϕ_i.

   (a) *(25 points)* You desire an antenna pattern with specific field intensities E_k at particular angular positions θ_k, $k = 1, 2, \cdots, K$ where θ is the angle relative the line perpendicular to your array. However, since you don't have an infinite number of array elements nor array extent, you might be able to exactly sate your desires. So, assuming that the far field pattern your array actually generates is $p(\theta)$, please formulate and solve the mean square optimization problem which will allow you to find the best amplitudes and phases for your N array elements:

   $$\min_{\{q_i,\phi_i\}} \sum_{k=1}^{K} |p(\theta_k) - E_k|^2$$

   where the q_i and ϕ_i are the amplitudes and phases of the antenna elements.

   To solve this problem you will first have to figure out what the far field pattern $p(\theta)$ is in terms of the phases and amplitudes of the antenna elements. Then, as we did in the old PCS class when talking about optimal quantization, you'll have to find a way to choose optimal values for these amplitudes and phases.

Solve as fully as possible and discuss how increasing the number of array elements N affects your results. Always make the far field assumption, even though the way the problem is formulated has the array elements separated by a specific distance d.

(b) *(25 points)* Now assume an infinite number of elements but a finite aperture of length L. We desire a particular far field $g(\theta)$ as opposed to particular values at discrete angular values. Please find the field in the aperture, $q(\theta)$ which provides the best mean square approximation to $g(\theta)$. That is, you want to solve

$$\min_{q(\theta)} \int |p(\theta) - g(\theta)|^2 d\theta$$

where $p(\theta)$ is the field pattern associated with the aperture field $q(\theta)$.

NOTE: I would recommend writing programs to check your results numerically for problem 3.