Name: ____________________

GTID: ____________________

ECE 4370: Antenna Engineering
TEST 2 (Fall 2011)

- Please read all instructions before continuing with the test.
- This is a **closed** notes, **closed** book, **closed** friend, **open** mind test. On your desk you should only have writing instruments and a calculator. **No internet-enabled devices.**
- Show all work. (It helps me to give partial credit.) Work all problems in the spaces below the problem statement. If you need more room, use the back of the page. DO NOT use or attach extra sheets of paper for work.
- Work intelligently – read through the exam and do the easiest problems first. Save the hard ones for last.
- All necessary mathematical formulas are included either in the problem statements or the last page of this test.
- You have 80 minutes to complete this examination. When the proctor announces a "last call" for examination papers, he will leave the room in 5 minutes. The fact that the proctor does not have your examination in hand will not stop him.
- I will not grade your examination if you fail to 1) put your name and GTID number in the upper left-hand blanks on this page or 2) sign the blank below acknowledging the terms of this test and the honor code policy.
- Have a nice day!

Pledge Signature: ____

I acknowledge the above terms for taking this examination. I have neither given nor received unauthorized help on this test. I have followed the Georgia Tech honor code in preparing and submitting the test.

1. **Linear Antenna Arrays:** In the space below, sketch the magnitude for the array factor for each uniform linear antenna array. Assume that the array elements are placed along the y-axis and that all points of observation are in azimuth ($\theta = 90°$). Only a sketch is required, but be sure to label where the main lobes and nulls of the array factor point. (**30 points**)

   (a) $N = 2$ elements, $\beta = 90°$, $d = \lambda/4$

   (b) $N = 2$ elements, $\beta = 0°$, $d = \lambda$

   (c) $N = 4$ elements, $\beta = 60°$, $d = \lambda/2$

2. **Fading:** In a local area, an omnidirectional antenna receives 400 nW/m^2 from a single plane wave due to a line-of-sight component and 200 nW/m^2 of root-mean-square power density from diffuse waves arriving from various directions in space. Answer the following questions based on this scenario: (**40 points**)

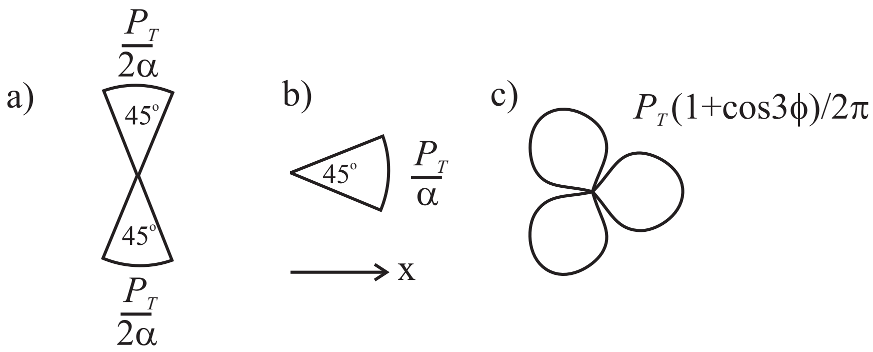
   (a) If the antenna is moved around in space, what is the *average* total power (in nW/m^2) that will be received? (**10 points**)

   (b) We would expect the received power levels to follow a Rician distribution. What would the K-factor be in dB? (**10 points**)

   (c) Using the CDF chart at the end of this test, what is the probability that a received power level at a randomly selected point in space falls 10 dB *below* the average power level? (**10 points**)

   (d) If a second, switched-diversity antenna is added to the scenario in the previous question, what is the probability that the receiver connected to these antennas will experience a 10 dB fade? Assume that the two antennas are sufficiently separated in space to produce independently fading signal strengths. (**10 points**)

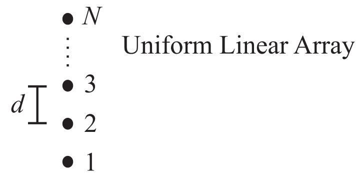
3. **Antenna Diversity:** Below are three different power azimuth spectra of multipath power arriving at an otherwise omnidirectional antenna element. For each case, *estimate* the shape factors (angular spread, angular constriction, and, if appropriate, direction of maximum fading) and the minimum distance in wavelengths that must separate two identical receiver antennas with random orientation to be used in a space diversity scheme. You do not need to compute the shape factors; a reasoned guess based on geometry will suffice. (**30 points**)



Cheat Sheet

$$\lambda f = c \qquad c = 3 \times 10^8 \text{ m/s} \qquad \mu_o = 4\pi \times 10^{-7} \text{ H/m} \qquad \epsilon_o = 8.85 \times 10^{-12} \text{ F/m} \qquad k = \frac{2\pi}{\lambda}$$

$$\text{Average Power} = \text{Specular Power} + \text{Diffuse Power} \qquad K = \frac{\text{Specular Power}}{\text{Diffuse Power}}$$



$$|AF| = \left| \frac{\sin\left(\frac{\pi}{\lambda} N d \sin\phi - N\beta\right)}{\sin\left(\frac{\pi}{\lambda} d \sin\phi - \beta\right)} \right| \quad \text{for } \theta = 90^\circ$$

$$F_n = \int_0^{2\pi} p(\phi) \exp(jn\phi)\, d\phi$$

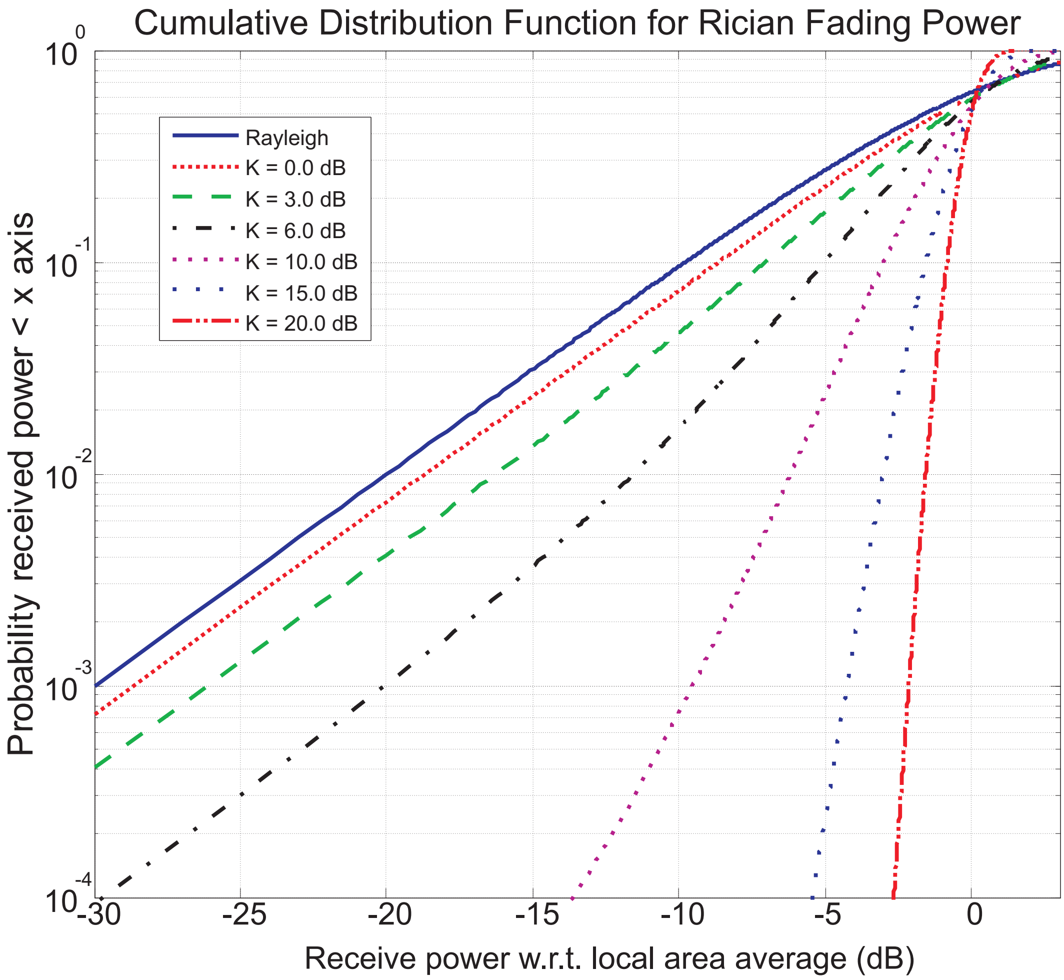
$$\text{Angular Spread: } \Lambda = \sqrt{1 - \frac{|F_1|^2}{|F_0|^2}} \qquad 0 \le \Lambda \le 1$$

$$\text{Angular Constriction: } \gamma = \frac{|F_2 F_0 - F_1^2|}{|F_0|^2 - |F_1|^2} \qquad 0 \le \gamma \le 1$$

$$\text{Direction of Maximum Fading: } \phi_{\max} = \frac{1}{2} \arg\{F_2 F_0 - F_1^2\}$$

$$\text{Decorrelation Length: } D_c = \frac{\lambda}{\Lambda\sqrt{23[1 + \gamma\cos(2[\phi - \phi_{\max}])]}} \qquad \frac{\lambda}{\Lambda\sqrt{1+\gamma}} \le D_c \le \frac{\lambda}{\Lambda\sqrt{1-\gamma}}$$

$$\sin x \approx x \quad \text{for small } x$$



Cumulative Distribution Function for Rician Fading Power
Rayleigh
K = 0.0 dB
K = 3.0 dB
K = 6.0 dB
K = 10.0 dB
K = 15.0 dB
K = 20.0 dB
Probability received power < x axis
Receive power w.r.t. local area average (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
-30
-25
-20
-15
-10
-5
0