Name: _____

GTID: _____

ECE 4370: Antenna Engineering
TEST 2 (Fall 2018)

- 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 75 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. **Small-Scale Fading:** A noise-limited 2.4 GHz Bluetooth headset is operating in a heavy multipath environment, receiving an average of -80 dBm in a local area. (**25 points**)

   (a) What is the probability that the instantaneous receive signal power drops below -90 dBm as the user moves in a local area? (10 points)

   (b) What is the probability that the instantaneous receive signal power rises above -70 dBm as the user moves in a local area? (10 points)

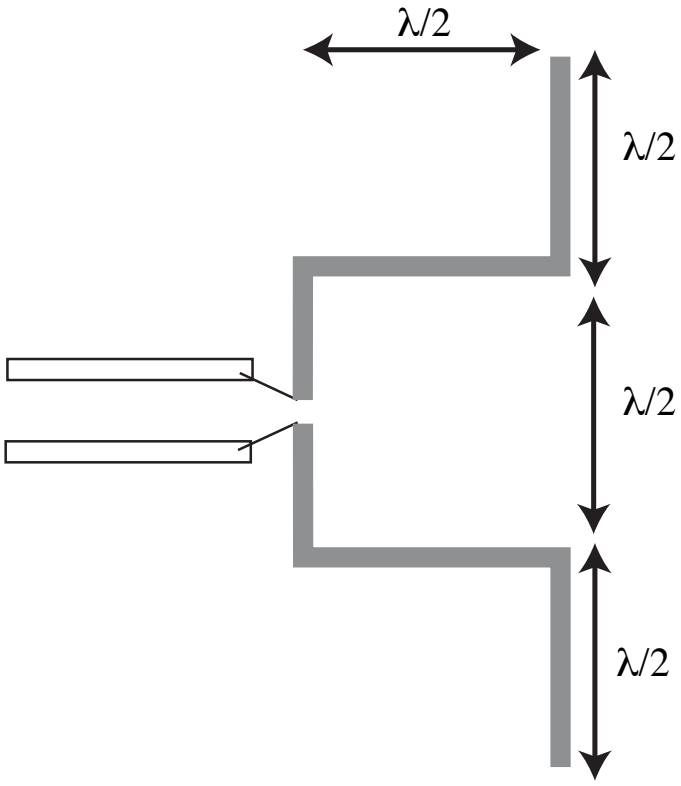
   (c) What is the probability that the instantaneous receive signal power stays between -90 dBm and -70 dBm as the user moves in a local area? (5 points)

2. **Coil Antenna:** A 50 MHz coiled receiver antenna with circular turns of 15 cm radius must be matched to a 3-Ω load. Answer the following questions based on this scenario. **(15 points)**

   (a) What number of coil turns must this antenna have to provide a radiation resistance that matches most closely the target real impedance of the load? (10 points)

   (b) What other circuit component will you likely need to connect to the terminals of the antenna to truly match the load? (5 points)

3. **Numerical Emag:** Below is a sketch of a squared version of a wire antenna known as a "gullwing" that you will be analyzing using a method-of-moments code. If each linear antenna segment must have at least 5 discrete nodes for the current distribution, what are the *minimum* dimensions of the matrix that must be inverted for estimating the radiation currents of this antenna. **(10 points)**



4. **Antenna Arrays:** For a uniform, linear, broadside array of omnidirectional radiating elements on the xy-plane, formulate an estimate of the half-power beamwidth in azimuth using the following trigonometric approximation for small arguments. **(30 points)**

$$\sin x \approx x - \frac{x^3}{6} + \cdots$$

Your answer should express the half-power beamwidth as a function of array elements N and spacing d.

(a) _____

If the product Nd exceeds λ, this array's gain pattern will exhibit $\boxed{\textit{Answer}}$ lobes.

(b) _____

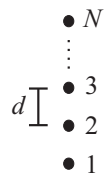
If the spacing between elements in this array exceeds λ, the array's gain pattern will exhibit $\boxed{\textit{Answer}}$ lobes.

5. **Helical Antenna:** When a directional antenna is aligned with the x-axis, it often satisfies the following rule-of-thumb relationship between peak linear gain, G_{peak}, and elevation and azimuthal half-power beamwidths in degrees:

$$G_{\text{peak}} = \frac{A}{\phi_{\text{HPBW}}\theta_{\text{HPBW}}}$$

Solve a numerical value for the constant A for a helical antenna system. **(20 points)**

Cheat Sheet



Uniform Linear Array

$$|AF| = \left| \frac{\sin\left(\frac{\pi}{\lambda} N d \sin\phi + N\beta/2\right)}{\sin\left(\frac{\pi}{\lambda} d \sin\phi + \beta/2\right)} \right| \quad \text{for } \theta = 90^\circ \qquad G_{\text{array}}(\theta,\phi) \propto G_{\text{element}}(\theta,\phi) \times |AF(\theta,\phi)|^2$$

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

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

$$\text{Loop/Coil Antenna Impedance:} \quad R_{rad} = 31,200 \left(\frac{NS}{\lambda^2}\right)^2 \Omega$$

Rayleigh Fading PDFs

$$f_R(\rho) = \frac{\rho}{\sigma^2} \exp\left(-\frac{\rho^2}{2\sigma^2}\right) \text{u}(\rho) \qquad f_P(p) = \frac{1}{P_{av}} \exp\left(-\frac{p}{P_{av}}\right) \text{u}(p)$$

Axial-Mode Helical Antenna Design (for operation over $\frac{3\lambda}{4} \leq C \leq \frac{4\lambda}{3}$):

$$G_{\text{peak}} = 15N\frac{C^2 S}{\lambda^3} \quad R_{\text{rad}} \approx 140\left(\frac{C}{\lambda}\right)\Omega \quad \text{HPBW} = \frac{52\lambda^{3/2}}{C\sqrt{NS}} \text{ degrees} \quad \text{AR} = \frac{2N+1}{2N}$$

S	turn spacing
N	number of turns
C	circumference, πD
α	pitch angle, $\tan^{-1}(S/C)$ (13° ideally)
h	total height, NS