Name: ______________________

GTID: ______________________

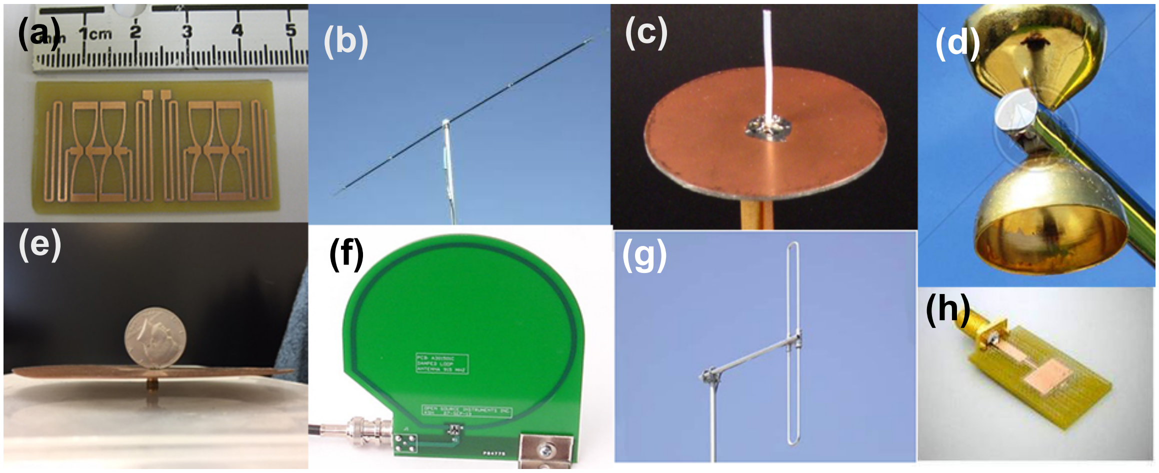
ECE 4370: Antenna Engineering
TEST 1 (Fall 2017)

- 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.

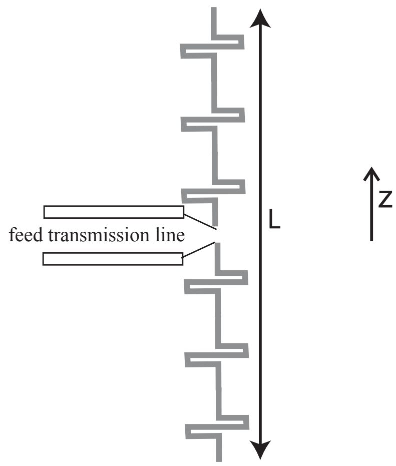
1. **Antenna Recognition:** Match the following photographs of antennas to the antenna type listed below **(16 points)**.



1. Half-Wave Dipole ____________
2. $\frac{\lambda}{4}$-Monopole ____________
3. Patch Antenna ____________
4. Folded Dipole ____________
5. Meandered Dipole ____________
6. Biconical Antenna ____________
7. Loop Antenna ____________
8. Broadband Monopole ____________

2. **Directivity:** An ideal antenna at the origin radiates with uniform power density in one octant of free space, definited by the surfaces $x > 0$, $y > 0$, and $z > 0$. Elsewhere, the antenna does not radiate. What is the peak directivity (in dBi) of this antenna? (**14 points**).

3. **Shortened Dipole:**



The dipole antenna to the right has been shortened with bent segments that act as phase-changers, reducing the total size of the antenna so that it is electrically small ($L \ll \lambda$). Along the z-axis, the phasor-form current distribution along the antenna is approximately given by:

$$I(z') = I \cos \frac{z'\pi}{L} \text{ for } |z'| < \frac{L}{2}$$

Answer the following questions based on this scenario, in terms of I, L, λ, and physical constants. (**45 points**)

(a) Estimate the total distance if the above antenna is stretched out straight. (**10 points**)

(b) Write expressions for the far-field electric and magnetic fields as a function of r, θ, and ϕ. Hint: you may approximate this structure as electrically small ($z' << \lambda$). (**20 points**)

(c) What is the half-power beamwidth in elevation for this antenna? (**5 points**)

(d) What is the radiation resistance for this antenna? (**10 points**)

4. **Aircraft Communications:** An aircraft transmits a distress signal at 700 MHz using a 5 Watt transmitter with a 4 dBi gain transmit antenna. (**25 points**)

   (a) What is the effective isotropic radiated power (in dBW) of the aircraft transmitter? (**5 points**)

   (b) If a ground-based receiver detects the distress signal with a 6 dBi antenna at a power level of -86 dBm, estimate the distance between the receiver and the plane in kilometers. (**10 points**)

   (c) Upon closer inspection, the engineer at the ground station realizes that they have connected a 200Ω-impedance antenna to a 50Ω coaxial cable to feed the receiver. Calculate this unexpected mismatch factor and its effect on the distance calculation. (**10 points**)

Cheat Sheet

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

$$\text{Directivity} = \frac{\text{Radiated Power Density in } (\phi,\theta)}{\text{Average Isotropically Radiated Power Density}} = \frac{\left\|\vec{\mathrm{S}}_{av}(r,\theta,\phi)\right\|}{P_T/(4\pi r^2)}$$

$$D(\phi,\theta) = \eta_{rad}\, G(\phi,\theta) \qquad P_T = \frac{1}{2} I^2 R_{rad} \qquad D = \frac{4\pi}{\lambda^2} A_{em}$$

$$\int_0^{2\pi}\int_0^{\pi} D(\phi,\theta)\,\sin\theta\, d\phi\, d\theta = 4\pi\ \text{ steradians}$$

$$\tilde{A}_z(\vec{\mathrm{r}}) = \frac{\mu}{4\pi r}\exp(-jkr)\int\int_{-\infty}^{+\infty}\int \tilde{J}_z(x',y',z')\exp(+jk[x'\sin\theta\cos\phi + y'\sin\theta\sin\phi + z'\cos\theta])\ dx'\, dy'\, dz'$$

$$\text{Line Current:} \qquad \tilde{A}_z(r,\theta,\phi) = \frac{\mu}{4\pi r}\exp(-jkr)\int_{-\infty}^{+\infty}\tilde{I}_z(z')\exp(+jkz'\cos\theta)\ dz'$$

$$\tilde{\vec{\mathrm{H}}}(r,\phi,\theta) = \frac{1}{\mu}\nabla\times(\tilde{A}_z\hat{\mathrm{z}}) \approx \frac{jk\sin\theta}{\mu}\tilde{A}_z(r,\phi,\theta)\hat{\phi} \qquad \tilde{\vec{\mathrm{E}}}(r,\phi,\theta) = \frac{1}{j2\pi f\mu\epsilon}\nabla\times\nabla\times(\tilde{A}_z\hat{\mathrm{z}}) \approx \frac{jk\eta\sin\theta}{\mu}\tilde{A}_z(r,\phi,\theta)\hat{\theta}$$

$$\eta = \sqrt{\frac{\mu}{\epsilon}} = 377\ \Omega \text{ for free space} \qquad \vec{\mathrm{S}}_{av} = \frac{1}{2}\text{Real}\left\{\tilde{\vec{\mathrm{E}}}\times\tilde{\vec{\mathrm{H}}}^*\right\} \approx \frac{1}{2}\left\|\tilde{\vec{\mathrm{E}}}\right\|\left\|\tilde{\vec{\mathrm{H}}}\right\|\hat{\mathrm{r}}$$

above approximations valid for far field, $r > D^2/\lambda$

Basic Voltage Formulas

$$P_L = \underbrace{\frac{4R_L R_A}{\left|\tilde{Z}_A + \tilde{Z}_L\right|^2}}_{\text{mismatch losses}} P_R \qquad V_A = \frac{2\left|\tilde{Z}_L\right|\sqrt{2R_A P_R}}{\left|\tilde{Z}_A + \tilde{Z}_L\right|}$$

$$P_T = \int_0^{\pi}\int_0^{2\pi}\|\vec{\mathrm{S}}_{av}\|\, r^2\,\sin\theta\, d\phi\, d\theta \qquad \int_0^{\pi}\sin^3\theta\, d\theta = \frac{4}{3}$$

Friis Free Space Transmission and Logarithmic Link Budget

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi r)^2} \qquad \mathrm{P}_R = \mathrm{P}_T + G_T + G_R - 20\log_{10}(4\pi/\lambda) - 20\log_{10}(r)$$