Name: ______________________

GTID: ______________________

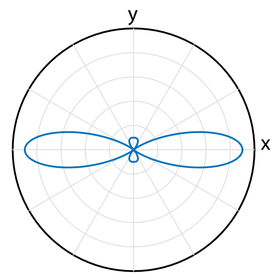
# ECE 4370: Antenna Engineering
# TEST 2 (Spring 2015)

- 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!

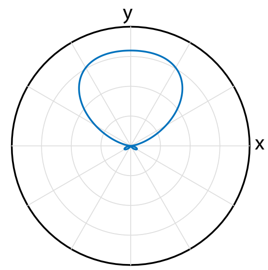
Pledge Signature: ______________________________________

*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.*

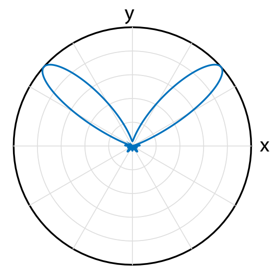
1. **Uniform Linear Antenna Arrays:** In the blanks below, place the letter of the array pattern sketch that corresponds to the design parameters (number of elements, element phase offset, and element spacing) next to each blank. Assume that the array elements are placed along the y-axis and that all points of observation are in azimuth ($\theta = 90°$). (**40 points**)



(a)



(b)



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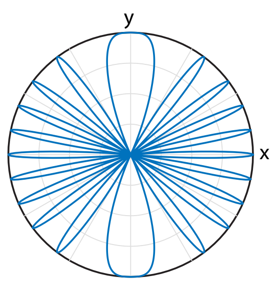

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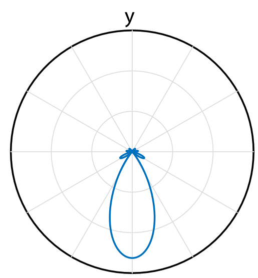

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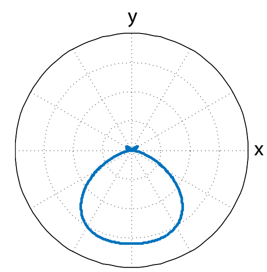

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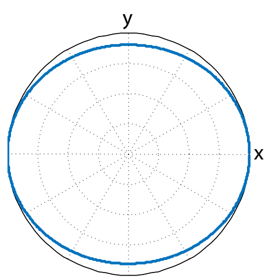
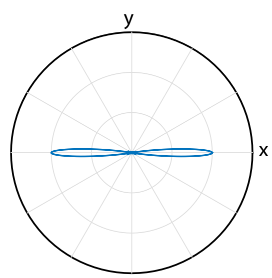
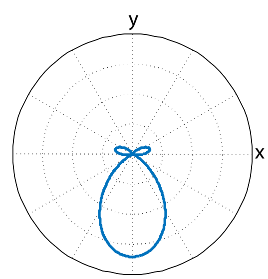


(g)



(h)



(i)

(1) ______ $N = 4$, $\beta = -90°$, $d = \frac{\lambda}{4}$ (ordinary endfire)

(2) ______ $N = 4$, $\beta = +90°$, $d = \frac{\lambda}{4}$ (ordinary endfire)

(3) ______ $N = 5$, $\beta = -120°$, $d = \frac{\lambda}{2}$

(4) ______ $N = 3$, $\beta = 0°$, $d = \frac{\lambda}{2}$

(5) ______ $N = 4$, $\beta = 112.5°$, $d = \frac{3\lambda}{16}$ (Hansen-Woodward endfire)

(6) ______ $N = 8$, $\beta = 101.75°$, $d = \frac{7\lambda}{32}$ (Hansen-Woodward endfire)

(7) ______ $N = 2$, $\beta = 0°$, $d = 5\lambda$

(8) ______ $N = 10$, $\beta = 0°$, $d = \frac{\lambda}{2}$

2. **Small-Scale Fading:** The single antenna of a mobile device is operating in a heavy multipath fading environment in which an average of -85 dBm is available within the local area. Answer the questions below based on this scenario (**25 points**)

   (a) What percentage of the time would you expect this antenna to have an instantaneous received power *below* $5 \times 10^{-11}$ mW? (10 points)

   (b) What percentage of the time would you expect this antenna to have an instantaneous received power *above* -78 dBm? (10 points)

   (c) If link outages are too frequent for this device under these conditions, what could you change about the RF design of the mobile device to mitigate the fading? (5 points)

3. **Design of a Helical Antenna: (25 points)** An axial-mode helical antenna is designed at 3 GHz to have a wavelength circumference, a pitch angle of $\alpha = 13°$, and a peak gain of 14 dBi. Answer the following questions based on this scenario. (**25 points**)

   (a) How long is this antenna in cm if the target gain is 14 dBi? (10 points)

   (b) Given the same 14 dBi requirement, what is the half-power beamwidth of this antenna? (10 points)

   (c) If the helical antenna can be used for $\frac{3\lambda}{4} \leq C \leq \frac{4\lambda}{3}$, what frequency range of operation does this correspond to? (5 points)

4. **Horn or Yagi?:** You are the lead antenna design engineer for the following scenario. Write H for Horn antenna or Y for Yagi antenna beside each scenario for the antenna that would work best for the specification. (**10 points**)

   (a) ______ You need to put a directional antenna high on a thin, steerable mast with minimal wind shear forces.

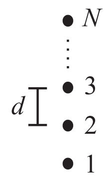
   (b) ______ You need to make a directional antenna that operates at 20 GHz.

   (c) ______ You need to make a directional antenna that operates at 300 MHz.

   (d) ______ You need to make an antenna that operates at 2 GHz with 9 dBi of peak gain and *maximal* bandwidth.

   (e) ______ You need to make an antenna named after a Japanese professor.

# Cheat Sheet




Uniform Linear Array

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

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

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

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

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

| | |
|---|---|
| $S$ | turn spacing |
| $N$ | number of turns |
| $C$ | circumference, $\pi D$ |
| $\alpha$ | pitch angle, $\tan^{-1}(S/C)$ |
| $h$ | total height, $NS$ |

**Link Budget Formula (Logarithmic)**

$$\text{P}_R = \text{P}_T + G_T + G_R - 20\log_{10}(4\pi/\lambda) - 10n\log_{10}(r)$$

**Raleigh Fading Probability**

$$\Pr\{P_a \leq P \leq P_b\} = \int_{P_a}^{P_b} \frac{1}{P_R} \exp\left(-\frac{p}{P_R}\right) dp$$