Midterm I with Solutions

Name ______________________________

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UNIVERSITY OF UTAH
ELECTRICAL & COMPUTER ENGINEERING DEPARTMENT

ANTENNA THEORY AND DESIGN

ECE 5324/6324

MIDTERM I

February 20, 2013

1. (25 points)

pts

13 a. Calculate the directivity of a dipole antenna of length L = 12 cm at a frequency of 835 MHz.

5 b. For this dipole antenna, calculate the feed point resistance R_A.

7 c. Calculate the maximum power received P_r for an incident power density S_{inc} = 10 $\mu W/m^2$.

1. b. From p. 7 of the Class Notes, for this antenna

$$\frac{L}{\lambda} = \frac{12}{35.93} = \boxed{0.334}$$

$$\lambda\Big|_{\substack{835\\MHz}} = \frac{30}{0.835} = 35.93\ \text{cm}$$

$$\frac{L}{2\lambda} = 0.167$$

$$R_a = 2\left[11.674 + (13.447 - 11.674) \times \frac{0.07}{0.1}\right]$$

$$= \boxed{25.83\ \Omega}$$

a. From Eq. (6) on p. 6 of Class Notes

$$D = \frac{120}{R_a} \frac{F^2(\theta)\Big|_{max\ @\ \theta = 90°}}{\sin^2\left(\frac{\pi L}{\lambda}\right)}$$

From Eq. (2) on p. 6 of Class Notes

$$F(\theta)\Big|_{\theta = 90°} = \frac{\cos\left(\frac{\pi L}{\lambda} \times 0\right) - \cos\left(\frac{\pi L}{\lambda}\right)}{1} = 1 - \cos\left(\frac{\pi L}{\lambda}\right) = 0.5018$$

$$D = \frac{120}{25.83} \times \frac{(0.5018)^2}{\sin^2\left(\frac{\pi L}{\lambda}\right)\ 0.7518} = \boxed{1.556}$$

This is reasonable since for $L = 0.5\lambda$; $D = 1.64$

c. $$P_r = S_{inc} A_{em}$$

$$\frac{4\pi A_{em}}{\lambda^2} = D = 1.556 \Rightarrow A_{em} = \frac{\lambda^2}{4\pi} \times 1.556$$

$$= \frac{(35.93)^2}{4\pi} \times \frac{1.556}{(100)^2} = \boxed{0.016\ m^2}$$

$$P_r = 10^{-5} \times 0.016 = \boxed{1.6 \times 10^{-7}\ W}$$

2. (25 points)

pts

18 a. Calculate the pulsed power received by a monostatic radar antenna radiating 100 kW pulsed power at 10 GHz given that the gain of the radar antenna is 37 dBi and the target has a radar cross section (RCS) of 30 m^2 and is at a distance of 25 km.

7 b. Calculate the effective area A_e for the radar antenna in m^2.

2. a. From Eq. 4-66 on p. 122 of the Text

$G_r = G_t = 10^{3.7}$

$R = 25 \times 10^{3}$ m

$\lambda = 3$ cm $= 0.03$ m

$$P_r = P_t \frac{\lambda^2 G_r G_t \sigma}{(4\pi)^3 R^4} = \frac{10^5 (0.03)^2 \times 10^{7.4} \times 30}{(4\pi)^3 (25)^4 \times 10^{12}}$$

$$= \frac{0.0678}{1984.4 \times 39.06 \times 10^{4}} \; 10^{-7} = 8.75 \times 10^{-11} \text{ W}$$

b. $\frac{4\pi A_e}{\lambda^2} = G_t = 10^{3.7}$

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$$A_e = 10^{3.7} \times \frac{(0.03)^2}{4\pi} = \frac{4.51}{4\pi} = \boxed{0.359 \text{ m}^2}$$

3. (25 points)

pts

18 a. Calculate the power received by a cellular telephone antenna of gain 1 dBi from a base station radiating 25 W of power at a frequency of 835 MHz. It is given that the gain of the base station antenna is 12 dBi, and the base station is located at a distance of 10 km from the user of the cell phone.

7 b. What is the open-circuit voltage developed across the cell phone antenna given that its feed point resistance is 50 ohms?

3. a.

$G_r = 10^{0.1} = 1.259$

$G_t = 10^{1.2} = 15.85$

$R = 10\,Km = 10^4\,m$

$\lambda = 0.3593\,m$

From Eq. 4-33

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi R)^2}$$ Friis transmission formula

$$P_r = \frac{25 \times 15.85 \times 1.259 \times (0.3593)^2}{(4\pi)^2 \times 10^8} = \frac{64.4}{157.9} \times 10^{-8}$$

$$= \boxed{0.408 \times 10^{-8}}\,W = 4.08 \times 10^{-6}\,mW = -53.89\,dBm$$

$= 4.08 \times 10^{-9}\,W$

b. $V_{oc} = V_A = \sqrt{8 R_A P_r} = \sqrt{8 \times 50 \times 0.408 \times 10^{-8}}$

$$= \boxed{12.77 \times 10^{-4}\,V} \text{ or } \boxed{1.277\,mV}$$

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Score:

Problem 1	_________	of a possible 25 points
Problem 2	_________	of a possible 25 points
Problem 3	_________	of a possible 25 points
Total	_________	of a possible 75 points