Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007-2008 (2 hours)

Antennas and Propagation 4

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.** *Where a symbol is not defined it can be assumed to have its usual meaning, with which candidates should be familiar.*

1. a. Show that for a circular aperture of area A lying in the x-y plane, which is uniformly illuminated with an x-directed electric field, the gain is given by

$$G = \frac{4\pi}{\lambda^2} A$$

The following relation should be of use:

$$|\underline{E}| \approx \frac{1}{2\lambda r}(1 + \cos\theta)\left\{(\hat{\theta}\cos\phi - \hat{\phi}\sin\phi)|F_x|\right\}$$

(10)

1. b. Estimate the gain in *dBi* of a *45cm* diameter reflector antenna used for satellite TV reception at *11GHz*, explaining any assumptions made. **(4)**

1. c. What is the maximum effective aperture of a typical Yagi-Uda antenna used for terrestrial TV reception at *600MHz*? **(4)**

1. d. Why are reflector antennas not used for terrestrial TV reception and Yagi-Uda arrays not used for satellite TV? **(2)**

2. a. The radiation pattern of a $\lambda/4$ long perfectly conducting wire monopole fed against a perfect electrical conductor (PEC) infinite ground plane is given by

$$|E_\theta| = \frac{2\eta I_o}{4\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)}\right]$$

in the half-space above the ground plane. Calculate the gain of the monopole in dBi. The following relation should be of use:

$$\int_0^{\pi/2} \frac{\cos^2\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)} d\theta = 0.61$$

(10)

2. b. If a 37Ω resistor is placed in series with the monopole at its base just above the feed point, what is the new gain? (3)

2. c. If this resistor is now moved half way up the monopole, describe any alteration in the gain. (2)

2. d. Assuming the monopole is resonant in both cases, what would be the input impedance in cases (a) and (b)? (3)

2. e. How would the gain be affected if a real earth with finite conductivity replaced the PEC ground plane? (2)

3. a. Explain the forces that act on an electron in an ionospheric plasma through which a radio wave propagates. (6)

3. b. Hence show that a Cartesian component of the plasma polarisation current is given by

$$J = -j\omega \frac{Ne^2}{m\omega^2} E$$

stating any assumptions made. (8)

3. c. Define and explain the significance of the plasma critical frequency. (4)

3. d. Estimate the plasma critical frequency for an electron density of $10^{12}\,/m^3$. (2)

4. a. Write down the analytic formulation of Maxwell's equations used as the starting point for the numerical approximations in each of the following computational techniques for antenna design:

1) Finite Difference Time Domain (FDTD)
2) Finite Integration Technique (FIT)
3) Method of Moments (MoM)

There is no need to actually derive the discrete field equations. **(6)**

4. b. Compare and explain the suitability of the above techniques for solving the following electromagnetic problems:

1) The input impedance of a Yagi-Uda TV antenna in free space
2) The radiation pattern of a WiFi 2.4GHz patch antenna printed on an electrically large grounded dielectric substrate
3) The electric fields induced inside the head by a mobile phone
4) The radar cross section of a small aircraft **(8)**

4. c. A 1D FDTD mesh contains E_x and H_y fields propagating in the z direction in free space. If two adjacent H field mesh points have values $H_y\big|_{k-1/2}^{n-1/2} = 1A/m$, $H_y\big|_{k+1/2}^{n-1/2} = 0.5A/m$ at time step n-1/2, calculate the intervening updated value of $E_x\big|_k^n$ at time step n. Assume $E_x\big|_k^{n-1} = 0$, $\varepsilon = 8.854 \times 10^{-12} F/m$, $\Delta t / \Delta z = 8.854 \times 10^{-10} s/m$. **(6)**