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The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2009-2010   (2 hours)

Antennas and Propagation 6

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 or abbreviation is not defined it can be assumed to have its usual meaning, with which candidates should be familiar.

1. **a.** Show that the Array Factor for a phased array antenna comprising *N* elements, all driven with equal current magnitude I_o and uniform phase shift γ between elements, and with equal separation *d* along the *z-axis* is given by

$$P(\theta) = I_o \frac{sin\left(\frac{N}{2}\psi\right)}{sin\left(\frac{1}{2}\psi\right)} \qquad (1.1)$$

where $\psi = kd\,cos\theta + \gamma$. Assume as a starting point that

$$P(\theta) = I_o e^{j\frac{(1-N)}{2}\Psi} \times \sum_{m=0}^{N-1} e^{jm\Psi} \qquad (1.2).$$

(10)

b. Calculate the value of γ required so that the antenna operates as:

(i) A broadside array,

(ii) An end-fire array,

(iii) An array with a beam shift of 30^o from broadside.

at *500MHz* for *d=30cm*. **(6)**

c. What happens to the beam shift in (iii) as the frequency is varied by $\pm 100MHz$? (Assume all other parameters remain the same). **(4)**

2. **a.** Explain how an *HF* radio wave can be 'reflected' back to earth by the ionosphere, and hence show that

$$\cos i_o = \frac{\omega_c}{\omega} \qquad (2.1)$$

(6)

b. An ionosonde transmits a *9MHz* signal which takes *3ms* to be reflected back to earth. Calculate the height and electron density of the reflection layer, and identify it. Assume the speed of propagation of radio waves is $3 \times 10^8 m/s$. **(6)**

c. A signal is transmitted at zero elevation angle and is reflected by this layer. What must the frequency of this transmission therefore be? Assume the radius of the earth is *6000km*. **(6)**

d. Assuming this is the sole ionospheric layer, what can be said about the propagation of signals with frequencies higher and lower than this? **(2)**

3. **a.** Using the following equations, calculate the radiation resistance of a centre fed $3\lambda/2$ dipole.

$$|E_\theta| = \frac{\eta I_o}{2\pi r}\left[\frac{\cos\left(\frac{3\pi}{2}\cos(\theta)\right)}{\sin(\theta)}\right] \qquad (3.1)$$

$$\int_0^\pi \frac{\cos^2\left(\frac{3\pi}{2}\cos(\theta)\right)}{\sin(\theta)}d\theta = 1.76 \qquad (3.2)$$

(10)

b. Comment on the input impedance of the $3\lambda/2$ dipole when it is made of (i) bare wire and (ii) insulated wire. **(4)**

c. What is the radiation resistance of a $3\lambda/4$ monopole fed against an infinite perfectly conducting ground plane? **(4)**

d. Compare the directivities of the $3\lambda/4$ monopole and the $3\lambda/2$ dipole. **(2)**

4. a.

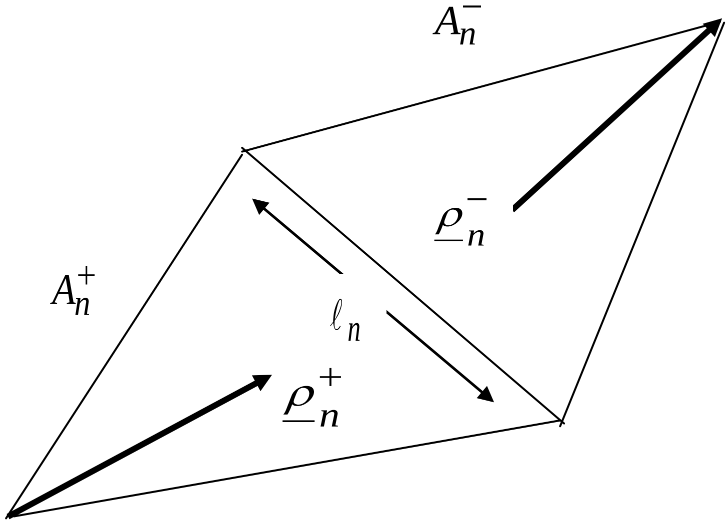

Fig 4.1

An RWG triangular patch moment method uses vector basis functions of the form

$$f_n = \begin{cases} \dfrac{\ell_n}{2A_n^+}\rho_n^+ & \textit{for triangle of area } A_n^+ \\ \dfrac{\ell_n}{2A_n^-}\rho_n^- & \textit{for triangle of area } A_n^- \end{cases} \qquad (4.1),$$

with reference to Fig 4.1. Show that:

(i) The component of current normal to the nth edge common to the two triangles is constant and continuous across the edge

(ii) The charge density is constant within each triangle and sums to zero over a triangle pair.

The following relation should be of use

$$\nabla \bullet f(\rho) = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho f_\rho) \qquad (4.2).$$

(10)

b. Sketch a typical segmentation strategy for an RWG moment method analysis of a printed dipole using triangular patches, and show the current density vectors. **(4)**

c. A centre fed printed half-wave dipole of width 0.5mm is modelled at 3GHz using 10 triangle pairs. If the system of equations $[Z][I]=[V]$ is then solved for $[I]$ with excitation $V_{10} = 0.1Vm$, to yield $I_{10} = 5\times10^3 A/m$, calculate the dipole input impedance. **(6)**

GGC