Indian Institute of Technology Delhi

EEL 338 – Antennas and Propagation

Major Examination

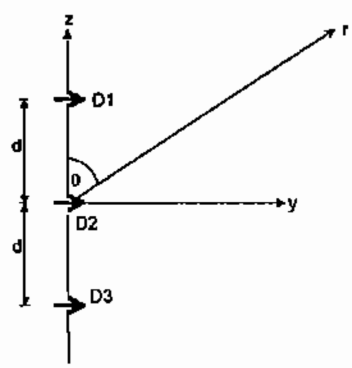
(25 Marks)

Date: May 3, 2008 **Time: 10.30-12.30**

Note: Bold numbers in the brackets indicate marks.

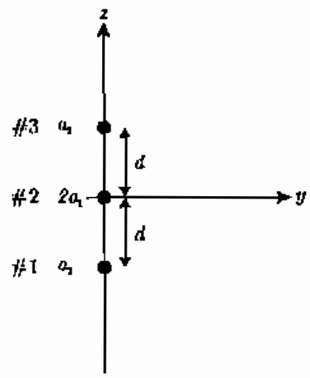
Q. 1. Assume an antenna array composed of 3 infinitesimal horizontal dipoles positioned along the z -axis, as shown in figure below. The currents on the dipoles have the following time dependence:

D1: $I_1(t) = I_0\sin(\omega t)$
D2: $I_2(t) = 2I_0\cos(\omega t)$
D2: $I_3(t) = - I_0\sin(\omega t)$



a. Calculate the array factor $AF(\theta,d)$ and the complete far field of this array as a function of d, θ and r. **[3]**
b. Calculate distance d for which the array radiates in end-fire direction. **[2]**

Q. 2. A linear array of three isotropic radiators is placed along the z -axis symmetrically over the origin. The array elements have different amplitudes ($2a1$ and $a2$), inter-element spacing d and progressive phase difference β between them. The phases of elements #1, #2, and #3 are – β, 0, and β, respectively.



a. Express the array factor in terms of $a1$, $a2$ and β. **[3]**

b. If the distance between the elements is $d = 0.5\lambda$, find the smallest phase difference β for which the array factor has its maximum at θ=60°. **[3]**

Q. 3. Five isotropic sources are placed symmetrically along the z-axis, each separated from its neighbor by an electrical distance kd=(5π/4). For a binomial array, find

a. the excitation coefficients **[2]**

b. the array factor **[2]**

Q. 4. Design a rectangular microstrip patch antenna, based on the dominant mode that can be mounted on the roof of a car to be used for satellite cellular telephone. The designed center frequency is f_0=1.6 GHz, the dielectric constant of the substrate is ε_r=10.2, and the thickness of the substrate is h=0.127cm. Determine:

a. The dimensions of the rectangular patch, **[3]**

b. The position of the feed to match the antenna to a 75Ω line. **[3]**

Q. 5. Using the equivalence principle and cavity model, explain why some sides of a microstrip patch antenna are called 'radiating edges' and some other sides are called 'non-radiating edges'. Assume that the dominant mode within the cavity is TM^x_{010} for which the fields are given as: **[4]**

$$E_x = E_0 \cos\left(\frac{\pi}{L} y'\right)$$

$$H_z = H_0 \sin\left(\frac{\pi}{L} y'\right)$$

$$E_y = E_z = H_x = H_y = 0$$

Useful formulas:

1. Far-field radiation of one single infinitesimal dipole located at the origin is given by:

$$E_\theta = j\eta \frac{I_0 l e^{-jkr}}{4\pi r}\cos\theta$$

2. Binomial expansion:

$$(1+x)^{m-1} = 1 + (m-1)x + \frac{(m-1)(m-2)}{2!}x^2 + \frac{(m-1)(m-2)(m-3)}{3!}x^3 + \dots$$

3. Array factor for non-uniform amplitude distribution:

$$(AF)_{2M}(even) = \sum_{n=1}^{M} a_n \cos[(2n-1)u] \qquad (AF)_{2M+1}(odd) = \sum_{n=1}^{M+1} a_n \cos[2(n-1)u] \qquad u = \frac{\pi d}{\lambda}\cos\theta$$

4. Array factor for uniform arrays:

$$(AF)_n = \frac{1}{N}\left[\frac{\sin\left(\frac{N}{2}\psi\right)}{\sin\left(\frac{1}{2}\psi\right)}\right]$$

$$\psi = kd\cos\theta + \beta$$

5. Expressions for a patch antenna:

$$W = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, \quad \frac{W}{h} > 1$$

$$\Delta L = 0.412\,h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

$$R_{in}(L_1) \approx \frac{1}{2G_1}\cos^2\left(\frac{\pi}{L}L_1\right)$$

$$G1 = \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2$$