FNU FIJI NATIONAL UNIVERSITY

College of Engineering, Science and Technology

School of Electrical & Electronics Engineering

Bachelor of Engineering (BENG)- Year 4

EEB 861- Antenna and Wave Propagation

Semester 1, 2019

(Total Marks: 100 Duration: 3 Hours)

Date: As per time table Time: As per time table

Venue: As per exam Schedule

Instructions to Candidates

1. You will be allowed 10 minutes reading time and **3 hours** to complete this paper.
2. Begin each answer on a fresh page and use both sides of the sheet.
3. Please ensure that **your ID number** is written at the top of each sheet of paper used.
4. Insert all written pages, graph paper, drawing paper etc. in their correct sequences and secure with string.
5. For all sheets of paper on which rough/ draft work has been done, cross it through and you must attach all of them to your answer scripts.
6. Write clearly the numbers of the questions attempted on the top of each sheets.
7. Answer all questions.
8. Use of mobile phones, smart watches or any other electronics devices with electronics storage of data/communication is not allowed during the examination.
9. Use of only non-programmable scientific calculator is allowed.

Total number of pages:4 (four) including this cover page.

Part A
(All Questions are compulsory)

1. The radial component of the radiated power density of an antenna is given by $W_{rad} = \hat{a}_r W_r = \hat{a}_r A_0 \frac{sin\theta}{r^2}$ $(W/_{m^2})$ where A_0 is the peak value of the power density, θ is the usual spherical coordinate, $\hat{a}_r$ is the radial unit vector.
   (a) Evaluate the total radiated power by $P_{rad} = \oiint W_{rad}\hat{n}da$. [5]

   (b) Evaluate the total radiated power by $P_{rad} = \int_0^{2\pi}\int_0^{\pi} Usin\theta d\theta d\phi$ [5] where $U = A_0 sin\theta$ and analyzee the P_{rad} in both cases.

2. The normalized radiation intensity of an antenna is represented by $\text{U}(\theta) = \cos^2(\theta)\cos^3(3\theta), (0 \le \theta \le 90^0, 0^0 \le \phi \le 360^0)$. Generate the following:
   (a) half-power beamwidth HPBW (in radians and degrees) [8]

   (b) first-null beamwidth FNBW (in radians and degrees) [7]

3. Design an antenna with omnidirectional amplitude pattern with a half-power beamwidth of 90^0. Express its radiation intensity by $U = sin^n\theta$. Determine the value of n and attempt to identify elements that exhibit such a pattern where half-power beamwidth is equal to 90^0. Investigate the directivity of the antenna using:
   (a) $\text{D}_0 = \frac{4\pi}{\text{P}_{\text{rad}}}$. Where $\text{U}_{\text{max}} = \sin^2\theta$. [10]

   (b) $\text{D}_0 \simeq \frac{101}{\text{HPBW (degrees)} - 0.0027[\text{HPBW (degrees)}]^2}$ [5]

   (c) curve-fitting form given by
   $\text{D}_0 \simeq -172.4 + 191\sqrt{0.818 + \frac{1}{\text{HPBW (degrees)}}}$ [5]

4. For most practical antennas, their radiation patterns are so complex that closed-form mathematical expressions are not available. In such a case the radiation intensity of practical antenna is given by

$$U(\theta, \emptyset) = \begin{cases} B_0 sin\theta sin^2\phi, 0 \le \theta \le \pi, 0^0 \le \phi \le \pi \\ 0 \qquad elsewhere \end{cases}$$

   Analyse the maximum directivity numerically by using
   (a) $P_{rad} = B_0\left(\frac{\pi}{N}\right)\left(\frac{\pi}{M}\right)[\sum_{j=1}^{M} sin^2\phi_j][\sum_{i=1}^{N} sin^2\theta_i]$
   With $\theta_i = i\left(\frac{\pi}{N}\right), i = 1,2,3,4, \dots N$ and $\phi_j = \left(\frac{\pi}{N}\right), j =$ [5] $1,2,3,4, \dots M$. Compare it with the exact value.
   (b) The exact value is given by $P_{rad} = B_0\int_0^{\pi} sin^2\phi d\phi \int_0^{\pi} sin^2\theta d\theta$. [5]

5. Two lossless X-band (8.2–12.4 GHz) horn antennas are separated by a distance of 100λ. The reflection coefficients at the terminals of the transmitting and receiving antennas are 0.1 and 0.2, respectively. The maximum directivities of

the transmitting and receiving antennas (over isotropic) are 16 dB and 20 dB, respectively. Assuming that the input power in the lossless transmission line connected to the transmitting antenna is 2W, and the antennas are aligned for maximum radiation between them and are polarization-matched, find the power delivered to the load of the receiver by using $\frac{P_r}{P_t} = e_{cdt}e_{cdr}(1-|\Gamma_t|^2)(1-|\Gamma_r|^2)\left(\frac{\lambda}{4\pi R}\right)^2 D_t(\theta_t,\emptyset_t)D_r(\theta_r,\emptyset_r)|\hat{\rho}_t\cdot\hat{\rho}_r|^2$.

[10]

6. Design and plot the resulting beam pattern for several values of n for an antenna array where it is required to steer the beam pattern to locate a target at 90^0 and at 270^0as shown in figure below. Consider a standard n-element linear array with uniform weighting placed at a distance of $\frac{\lambda}{2}$.

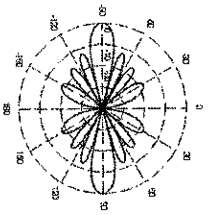


Figure for Question 6: Desired Pattern

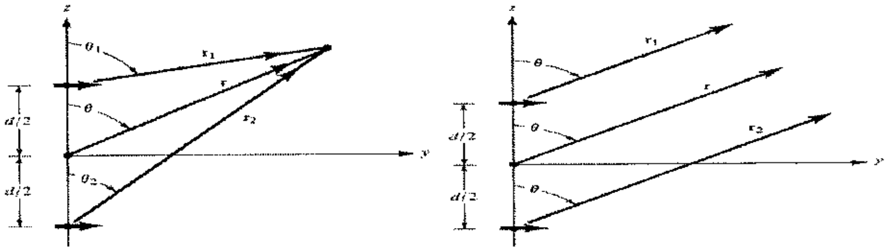
[10]

7. An Antenna array of two infinitesimal horizontal dipoles positioned along the z-axis, as shown in Figure a and b below. The total field radiated by the two elements, assuming no coupling between the elements, is equal to $E_t = \hat{a}_\theta j\eta\frac{kI_0le^{-jkr}}{4\pi r}\cos\theta\left\{2\cos\left[\frac{1}{2}(kd\cos\theta+\beta)\right]\right\}$. Compute the nulls of the total field when $d = \frac{\lambda}{4}$ and

(a) $\beta = 0$ [5]

(b) $\beta = \frac{\pi}{2}$ [5]

(c) $\beta = -\frac{\pi}{2}$ [5]



(a) Two infinitesimal dipoles (b) Far-field observations

Figure for Question 7: Geometry of a two-element array positioned along the z-axis.

Part B

(Answer any one Question)

1. Design a uniform linear scanning array whose maximum of the array factor is 30^0 from the axis of the array ($\theta_0 = 30^0$). The desired half-power beamwidth is 2^0 while the spacing between the elements is λ/4. Analyze the excitation of the elements (amplitude and phase), length of the array (in wavelengths), number of elements, and directivity (in dB) by Figure shown below.

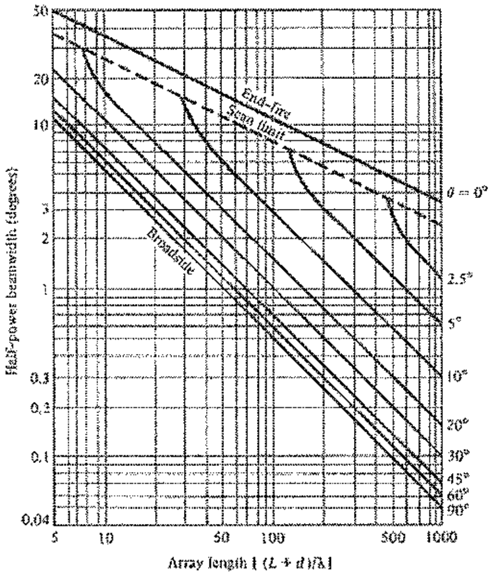


Figure for Question 8: Half-power beamwidth for broadside, ordinary end-fire, and scanning uniform linear arrays.

[10]

2. It is desired to design an aperture antenna, with uniform illumination, so that the directivity is maximized at an angle 30^0 from the normal to the aperture. Evaluate the optimum dimension and its associated directivity when the aperture is circular.

[10]

THE END.