



GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

B.Sc. Engineering Degree
Semester 5 Examination – May 2023
(Intake 38 - ET)

ET 3122 – ANTENNAS AND PROPAGATION

Time allowed: 2 Hours

15 May 2023

ADDITIONAL MATERIAL PROVIDED

None

INSTRUCTIONS TO CANDIDATES

This paper contains 4 questions on 6 pages.

Answer **ALL** questions.

Useful constants, expressions and equations are attached on Page 6.

This is a closed book examination.

This examination accounts for 70% of the module assessment. The marks assigned for each question and parts thereof are indicated in square brackets.

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it in the script.

Assume reasonable values for any data not given in or provided with the question paper, clearly make such assumptions made in the script.

All examinations are conducted under the rules and regulations of the KDU.

DETAILS OF ASSESSMENT

Learning Outcome (LO)	Questions that assess LO	Marks allocated (Total 70%)
LO1	Q1	6.3
LO2	Q1	11.2
LO3	Q2	17.5
LO4	Q3	17.5
LO5	Q4	17.5

This Page is Intentionally Left Blank

Question 1

(a) Define the following quantities in relation to an antenna.

- (i). Half Power Beamwidth (HPBW)
- (ii). Beamwidth between First Nulls (FNBW)
- (iii). Sidelobe Suppression Ratio (SSR)

[03]

(b) The far field of a short vertical dipole is indicated in Figure 1 and is given as,

$$E_r = 0, \quad E_\theta = E_0 \sin \theta, \quad E_\phi = 0$$

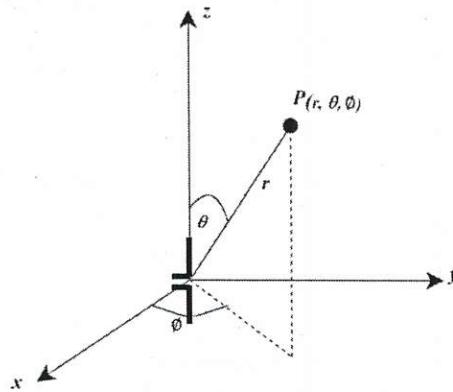


Figure 1: Far field of a short vertical dipole

- (i). Determine the Half Power Beamwidths in the Azimuth and Elevation plane. [02]
 - (ii). Draw the radiation pattern in Azimuth plane. [02]
 - (iii). Draw the radiation pattern in Elevation plane. [02]
 - (iv). State the polarization of the electromagnetic wave in the direction of the major radiation of the short dipole. [01]
 - (v). Make a brief comparison between the short vertical dipole and the half wave dipole in terms of the radiation pattern and radiation resistance. [03]
- (c) The effective aperture of a 1.22m diameter parabolic reflector antenna is 55% of the physical aperture area. Calculate the gain in dB if the operating frequency of the antenna is 11.7GHz. [06]
- (d) (i). Using suitable diagrams, explain why the radiation pattern of a dipole antenna that is longer than 1.5 times the wavelength is considered useless. [03]
- (ii). Show how the apparently useless radiation pattern in part d(i) can be converted into a directive pattern. [03]

Question 2

- (a) Describe the following aspects related to antenna arrays.
- Broadside Array
 - End fire Array
- [04]
- (b) (i). Prove that the overall radiation pattern $E_{R(\theta)}$ of a two-element isotropic array separated by a distance $d = \lambda/2$ and fed with currents of equal magnitude and phase (indicated in Figure 2) is given by,

$$E_{R(\theta)} = 2E_0 \cos\left(\frac{\pi \sin \theta}{2}\right)$$

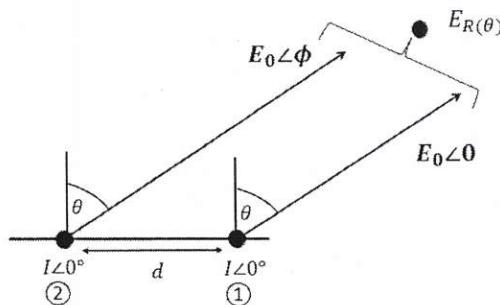


Figure 2: Two-element isotropic array separated by a distance $d=\lambda/2$

[04]

- (ii). Using the result obtained in b(i), State an expression for the same array fed with currents of equal magnitude and a phase difference $\delta = \pi$. [02]
- (c) (i). Calculate the minima, maxima and draw the radiation pattern of a 4-element isotropic array fed by currents of equal magnitudes and phase. The separation between elements is $d = \lambda/2$. [10]
(ii). Explain how the radiation pattern is affected when the number of radiating elements in an isotropic array is increased. [02]
- (d) Explain the concept of Electronic Beam Steering with applications. [03]

Question 3

- (a) State the advantages of using Microstrip Patch antennas in telecommunication applications. [04]
- (b) Using suitable diagrams, explain the concept of *fringing* in microstrip lines. [05]
- (c) Explain the advantage of using microstrip arrays and name two types of feeding methods for such an array with diagrams. [04]
- (d) It is required a design a rectangular microstrip patch antenna for a certain mobile application using the substrate which has a dielectric constant of 10.2 and a height of 0.127cm. The operating frequency of the antenna is 1.6GHz. Determine the width (in cm) and effective dielectric constant of the patch. [12]

Question 4

- (a) Briefly describe the following modes of radio wave propagation in free space.
- (i). Ground Waves
 - (ii). Sky Waves
 - (iii). Space Waves
- [03]
- (b) “Out of the modes stated in (a) Spaces Waves are preferred for mobile and high frequency communication”. Justify this statement from the perspective of antenna parameters. [03]
- (c) Using suitable diagrams, explain the concept of wave bending in high frequency communication. [05]
- (d) A certain mobile service provider is planning to set up a 6.5km microwave link. The heights of the transmitting and receiving antennas are 10m and 7.2m respectively. Recently, a construction project to build a 10.5m building has begun on the flat ground between two antennas. The distance from the transmitting antenna to the building site is 1km.
- (i). Assuming normal atmospheric conditions, calculate the earth bulge at the site, assuming atmospheric conditions. (i.e. $k=1.33$) [04]
 - (ii). Calculate the critical Mean Light of Sight and Justify whether this microwave link is feasible. [10]

-End of question paper-

Useful Constants, Expressions and Equations – Letters have their usual meanings.

- Useful constants

Speed of light in free space, $c = 3 \times 10^8 \text{ m/s}$

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$

Permittivity of free space, $\epsilon_0 = \frac{1}{4\pi \times 9 \times 10^9} \text{ F/m}$

- The array factor of a N element linear isotropic antennas

$$|E_{R(\theta)}| = \frac{E_0 \sin \left[N \frac{\phi}{2} \right]}{\sin \left[\frac{\phi}{2} \right]} \quad \text{where } \phi = \delta + \frac{2\pi}{\lambda} d \sin \theta$$

d – separation between elements N – Number of elements

- Microstrip Transmission Line

- Effective Dielectric Constant

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\left(1 + 12 \left(\frac{h}{w} \right) \right)^{-1/2} + 0.04 \left(1 - \left(\frac{w}{h} \right) \right)^2 \right]; \text{ for } \left(\frac{w}{h} \right) < 1$$

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2\sqrt{1+12\left(\frac{h}{w}\right)}}; \quad \text{for } \left(\frac{w}{h} \right) \geq 1$$

where, w – width of the strip

h – thickness of the strip

ϵ_r – relative permittivity of the solid substrate

- Width of the microstrip line

$$W = \frac{1}{2f_r \sqrt{\epsilon_r} \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}}$$