MACHAKOS UNIVERSITY

University Examinations 2017/2018

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 548: ANTENNA AND PROPAGATION

DATE: 18/12/2017 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

Answer question one and any other two

QUESTION ONE (COMPULSORY) (30 MARKS)

(a) Define an antenna radiation pattern, clearly specifying the meaning of field patterns and power patterns. Give a plot of a typical field pattern and the corresponding power pattern in 2- dimension. (6 marks)

(b) Describe the following types of antenna:

i. Isotropic antenna

ii. Directional antenna

iii. Omnidirectional antenna (6 marks)

(c) The radial component of the radiated power density of an infinitesimal linear dipole is given by:

$$\mathbf{W}_{\text{av}} = \hat{\mathbf{a}}_r W_r = \hat{\mathbf{a}}_r A_0 \frac{\sin^2\theta}{r^2} \quad (\text{W/m}^2)$$

Where A_0 is the peak value of the power density, θ is the usual spherical coordinate.

Determine: (9 marks)

i. Radiation intensity and its maximum
ii. Radiated power
iii. Maximum directivity
iv. Directivity as a function of the directional angles θ and ϕ

(d) A lossless resonant half-wavelength dipole antenna, with input impedance of 73 ohms, is connected to a transmission line whose characteristic impedance is 50 ohms. Assuming that the pattern of the antenna is given approximately by: (9 marks)

$$U = B_0 \sin^3 \theta$$

Find:

i. The maximum directivity of this antenna
ii. The reflection efficiency of this antenna in dB
iii. The overall efficiency of this antenna
iv. The maximum absolute gain of this antenna in dB

QUESTION TWO (20 MARKS)

(a) Give a brief description of the following antenna types:

i. Wire antenna (2 marks)
ii. Aperture antenna (2 marks)
iii. Microstrip antenna (2 marks)
iv. Antenna arrays (3 marks)
v. Reflector antenna (2 marks)

(b) The power radiated by an infinitesimal dipole can be expressed as:

$$P_{\text{rad}} = \eta \left(\frac{\pi}{3}\right) \left|\frac{I_0 l}{\lambda}\right|^2 :$$

i. What is the corresponding expression for radiation resistance? (3 marks)

ii. Find the radiation resistance of an infinitesimal dipole whose overall length is $l = \lambda/50$. (2 marks)

(c) Given that the radiation intensity is given as:

$$U = r^2 \ W_{\text{av}} = \frac{\eta}{2}\left(\frac{kI_0 l}{4\pi}\right)^2 \sin^2\theta$$

Determine the corresponding expressions for maximum directivity and maximum effective aperture? (4 marks)

QUESTION THREE (20 MARKS)

(a) Describe briefly a lens antenna (3 marks)

(b) For a linearly polarized antenna, performance is often described in terms of its principal *E*- and *H*-plane patterns. Describe the meaning of *E*- and *H*-planes. (2 marks)

(c) Given that the average power density radiated by a half wavelength dipole can be expressed as:

$$W_{\text{av}} = \eta\frac{|I_0|^2}{8\pi^2 r^2}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]^2 \simeq \eta\frac{|I_0|^2}{8\pi^2 r^2}\sin^3\theta$$

Determine the corresponding radiation intensity expression (2 marks)

(d) Given that the power radiated by a half wavelength dipole can be expressed as:

$$P_{\text{rad}} = \eta\frac{|I_0|^2}{8\pi}\int_0^{2\pi}\left(\frac{1-\cos y}{y}\right)dy = \eta\frac{|I_0|^2}{8\pi}C_{in}(2\pi)$$

Where

$$C_{in}(2\pi) \simeq 2.435$$

Calculate:

i. The maximum directivity (3 marks)
ii. The maximum effective aperture (2 marks)
iii. The radiation resistance (2 marks)

(e) Describe the following wave polarization classifications.

i. Linear Polarization (2 marks)
ii. Circular Polarization (2 marks)
iii. Elliptical Polarization (2 marks)

QUESTION FOUR (20 MARKS)

(a) State at least four controls that can be used to shape the overall pattern of an antenna array. (2 marks)

(b) Describe pattern multiplication theorem as applied in antenna arrays. (3 marks)

(c) Given that the array factor (AF) corresponding to a uniform linear array can be expressed as

$$\boxed{\begin{array}{l} \mathrm{AF} = \sum_{n=1}^{N} e^{j(n-1)\psi} \\ \text{where} \quad \psi = kd\cos\theta + \beta \end{array}}$$

i. Show that the same (Array Factor AF) can be expressed as

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

NB: Take the reference point as the physical center of the array. (5 marks)

ii. At which values of θ do we have array nulls and maxima? (4 marks)

(d) Explain the condition required to have a broadside array (3 marks)

(e) Describe an end-fire array. (3 marks)

QUESTION FIVE (20 MARKS)

(a) State and describe the field equivalence principle (Huygens' Principle) as applied in aperture antenna analysis. (3 marks)

(b) Loop antenna are usually classified into two categories, electrically small and electrically large. Explain the two categories. (2 marks)

(c) Give two techniques that can be used to increase the radiation resistance of a loop antenna. (3 marks)

(d) The real radial component of radiation density in a loop antenna can be expressed as:

$$W_r = \eta \frac{(ka)^4}{32} |I_0|^2 \frac{\sin^2 \theta}{r^2}$$

where a is the radius of the loop. Determine the corresponding expression for radiation intensity (2 marks)

(e) The power radiated by a loop antenna can be expressed as:

$$P_{\text{rad}} = \eta \left(\frac{\pi}{12}\right) (ka)^4 |I_0|^2$$

Where a is the radius of the loop. What is the corresponding expression for radiation resistance in terms of: (3 marks)

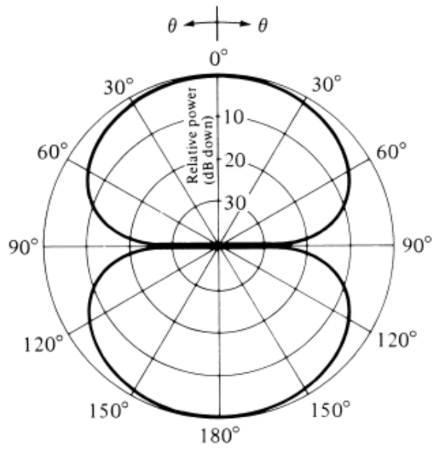
i. The circumference of the loop and wavelength

ii. The area of the loop and wavelength.

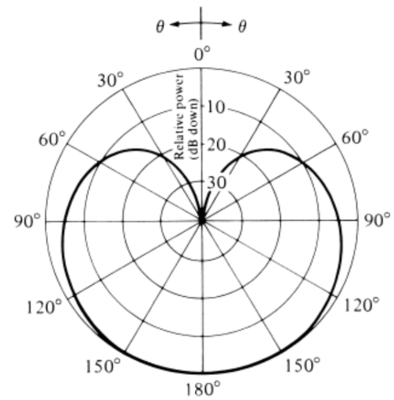
(f) Describe the term "antenna temperature". (2 marks)

(g) Describe "antenna input impedance". (2 marks)

(h) Given the below element and array factor plots corresponding to a particular uniform linear array, what would be the resultant total radiation pattern plot? (3 marks)



Element



Array factor