FNU FIJI NATIONAL UNIVERSITY
College of Engineering, Science & Technology

SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

BACHELOR OF ENGINEERING

EEE792 – ANTENNAS AND PROPAGATION

SEMESTER 1, 2017

DAY/DATE: As timetabled   DURATION : Three hours
ROOM: As timetabled

INSTRUCTION TO STUDENTS

1. You are allowed 10 minutes extra reading time during which you are **NOT** to write.
2. **Begin the answer to each Question** on a fresh page and use both sides of the sheet.
3. There are **SIX** questions in the paper. Answer any **FIVE** questions only
4. Write clearly the number of the question attempted on the top of each sheet.
5. Write your candidate number at the top of each additional sheet & attach them.
6. Insert all written foolscaps, graph paper etc. in their correct sequence and secure with a string.
7. All sheets of paper on which rough/draft work has been done, cross it through and attach all of them to your answer scripts.
8. Where ever possible, **draw clear neat diagrams**

Total number of pages including instruction page = 4

PTO

Answer ONLY FIVE questions

1. *i)* The general expressions for the component **E** field of a Hertz dipole antenna are

$$E_r = Z_0 \frac{I_0 \delta l \cos\theta}{2\pi r^2}\left[1 + \frac{1}{j\beta r}\right] e^{j(\omega t - \beta r)}\ \mathbf{r}$$

$$E_\theta = jZ_0 \frac{\beta I_0 \delta l \sin\theta}{4\pi r}\left[1 + \frac{1}{j\beta r} - \frac{1}{(\beta r)^2}\right] e^{j(\omega t - \beta r)}\ \boldsymbol{\theta} \qquad \text{and} \quad E_\phi = 0$$

where $\beta = 2\pi/\lambda$

a) Defining all the terms, state **ALL** the assumptions made in deriving the above expressions, and explain the significance of the term $e^{j(\omega t - \beta r)}$.

b) **Explaining** the reasons, write down **ALL** the far – field components of the **E** and **H** fields.

(3+3 marks)

ii) *a)* Explain the concept of radiation resistance of an antenna.

b) Assuming the input (feed) terminals are at the center of the dipole, the impedance of a $\lambda/2$ dipole antenna is $73 + j41.5\ \Omega$. Explain how the reactive component in the impedance can be practically compensated.

c) The equivalent *loss* resistance of a compensated antenna as above in (*b*) is 2 Ω. Calculate the radiation efficiency of the antenna

(3+2+3 marks)

iii) *a)* Naming the different parts, draw a Yagi antenna and explain its operation.

b) Explain how a monopole antenna operate in an indoor environment

(3+3 marks)

2. *i)* Giving typical expressions and for the intensity patterns of an *Isotropic antenna* and an *Omnidirectional antenna* distinguish between their radiation characteristics.

(4 marks)

ii) A hypothetical isotropic antenna is radiating in free space. At a point P, 1.2 km away from the antenna the electric field (E_θ) is measured to be 0.5 V/m. Find:

a) The power density at P.

b) The total power radiated by the antenna

(2+2 marks)

iii) The power radiated by an antennas is $U = U_{max} \sin^2\theta \sin^3\phi \quad 0 \le \theta \le \pi;\ 0 \le \phi \le \pi$. The pattern is 3D and in only one hemisphere.

a) Calculate the half power beam widths (HPBW) in the **xy** and the **yz** planes.

b) Calculate the directivity of the antenna in dB.

Hint: $\int_a^b \sin^n x\, dx = -\frac{1}{n}\left[\sin^{n-1} x \cos x\right]_a^b + \frac{n-1}{n}\int_a^b \sin^{n-2} x\, dx$

(5+3 marks)

iv) Depending on the applications the radiation patterns of antenna vary. In a ground-mapping radar, the pattern

$$U(\theta, \phi) = \begin{cases} 0.5 & 0^\circ \le \theta < 20^\circ \\ 0.3 \operatorname{cosec}\theta & 20^\circ \le \theta < 60^\circ \\ 0 & 60^\circ \le \theta \le 180^\circ \end{cases} \qquad 0^\circ \le \phi \le 360^\circ$$

Find the directivity of the antenna (in dB).

(4 marks)

PTO

3. *a*) Giving appropriate labeled diagrams of antenna arrangement together with intensity patterns, distinguish between *broadside radiation pattern* and *end-fire radiation pattern*

(4 marks)

b) A 2 element antenna array is shown in Fig 1. Show that in, carrying currents of equal amplitude but with phase difference γ, the *array factor* is " $\cos\left[\frac{1}{2}\left(\frac{2\pi}{\lambda}\, d\cos\phi + \gamma\right)\right]$ " where d is the separation between them and ϕ is the observation angle with the array axis.

(6 marks)

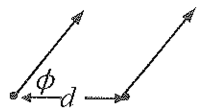

Fig 1

c) State and prove the condition for the pattern to be "broadside". For this arrangement draw the broadside radiation pattern and describe it. (2 marks)

d) If $d = \lambda$, find the positions of **ALL** (*i*) maxima, (*ii*) nulls and

(8 marks)

4. *i*) Summarize the factors that can be used to control the shape of the radiation pattern of an antenna array.

(5 marks)

ii) The array factor of a 2 element array of antennas with separation *d*, and carrying equal currents, but with phase difference γ is $\cos\left(\frac{kd\cos\phi + \gamma}{2}\right)$, where k is the wave number, ϕ is the angle between the direction of E field and the antenna array axis. State and verify the conditions to be satisfied to produce an ordinary end-fire pattern?

(3 marks)

iii) It is desired to have a two element antenna array so that the pattern has <u>**ONLY**</u> maximum along $\phi = 0°$.

a) Design, stating the reasons, a two-element uniform array of isotropic sources, which would satisfy the said requirement. ***Hint:*** Begin with ordinary end-fire conditions.

b) Give the **polar plot** of the variation of the *array factor* with ϕ (label the axes properly).

c) If the two point sources are now replaced by $\lambda/2$ dipoles with lengths perpendicular to the array axis, give the **polar plot** of the resultant intensity pattern (label the axes properly).

(5 + 4+ 3 marks)

PTO

5. The following characteristics of h – the height of the layers of the ionosphere, charge density N and f_N – the plasma frequencies are available:

	h(km)	Nm^{-3}	f_N(MHz)
C layer	~80	~ 10^8	~0.1
D layer	~90	~ 10^9	~0.3
E layer	~100	~10^{11}	~3
F_1 layer	~200	~9×10^{11}	~5
F_2 layer	~300	~8×10^{12}	~4.8
(*F2 layer continues*)	~700	~7×10^{11}	

The relative permittivity of a layer is $\varepsilon_r = 1-\left(\frac{f_N}{f}\right)^2$ where 'f' is the frequency of e.m. waves.

a) In the data provided it is seen that the N is varying with h. Explain why?

b) Defining the *critical frequency* f_C of the different layers of the ionosphere qualitatively discuss its effect on the propagation of e.m. waves in the range 50 kHz to 20 MHz generated on the surface of the earth.

c) Obtain the "secant law" for propagation of em waves in the presence of the ionosphere.

d) A communication link has been designed at 6.5 MHz utilizing the reflection off the F_1 layer of the ionosphere. Assuming the surface of the earth as flat estimate the "skip distance" for this communication link.

e) Discuss how communication can be provided in this region of the skip distance.

(3+5+4+4+4) marks)

6. *i*) *a*) Stating all the assumptions made, obtain the Friis transmission equation in free space.

b) Starting with the Friis transmission equation, derive the radar equation

c) A radar used for monitoring automobiles of radar cross section 100 m^2 up to a distance of 1.0 km operates at 5 GHz. At this frequency, the antenna gain of the radar gun is 150. If the transmitter power is 100 kW, what is the received power?

(5 +4+ 4 marks)

ii) *a*) stating the advantages and disadvantages, distinguish between the different satellites used for communication

b) Using Kepler's law, calculate the radius of earth's geostationary orbit from the centre of earth. (Assume the Kepler's constant = 3.986004×10^5 km^3 s^{-2}.

(4 + 3 marks)

THE END