UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2010/2011

COURSE : APPLIED ELECTROMAGNETICS

COURSE CODE : BEE 3223

PROGRAMME : 3 BEE

EXAMINATION DATE : NOVEMBER/DECEMBER 2010

DURATION : 3 HOURS

INSTRUCTION : ANSWER **FIVE (5)** QUESTIONS ONLY

THIS PAPER CONSISTS OF SEVEN (7) PAGES

Q1 (a) Define the relationship of the line parameters of a distortionless transmission line.

(1 mark)

(b) Illustrate the concept of standing wave along a mismatched transmission line. You may use a short as the load impedance.

(2 marks)

(c) Describe the advantage of using a shorted stub at high frequency as compared to an open stub in transmission line matching.

(1 mark)

(d) A 50 Ω lossless transmission line terminated in an open circuited load uses an insulating material with $\varepsilon_r = 2.25$. Determine the length of the transmission line for its input impedance, Z_{in} to be equivalent to a 10 pF capacitor at 50 MHz.

(8 marks)

(e) A stub length of 0.12λ is used to match a 60Ω lossless line to a load. If the shorted-stub is located at 0.3λ from the load, propose:

(i) The load impedance, Z_L
(ii) The length of an alternative stub and its location from the load.

(8 marks)

Q2 (a) Differentiate between Transverse Electric (TE) and Transverse Magnetic (TM) modes.

(1 mark)

(b) In a rectangular waveguide for which:

$$a = 1.5\,\text{cm}, \quad b = 0.8\,\text{cm}, \quad \sigma = 0, \quad \mu = \mu_0, \quad \varepsilon = 4\varepsilon_0$$

$$H_x = 2\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\sin\left(\pi\times10^{11}t - \beta z\right) \quad \text{A/m}$$

Deduce:

(i) The mode of operation
(ii) The cutoff frequency, f_c
(iii) The phase constant, β

(8 marks)

(c) An air-filled cubical cavity operates at a resonant frequency of 12.6 GHz when excited at TE_{101} mode.

(i) Design the dimensions of the cavity.
(ii) Propose the cavity bandwidth at the resonant frequency of 12.6 GHz if the Quality Factor of the cavity is 9512.

(8 marks)

(d) An air-filled WR 90 rectangular waveguide has dimensions a = 2.286 cm and b = 1.016 cm.

(i) Evaluate the range of frequencies for which the guide will support only TE_{10} and TE_{20} modes.
(ii) Explain and show the technique to excite the TE_{10} mode in the waveguide.

(3 marks)

Q3 (a) A 12 GHz dish antenna with radius of 300 mm is tested at an open space for its radiation pattern.

(i) Differentiate between near field and far field zones of the antenna.
(ii) Show that the boundary between the near and far field zones is 28.8 meters from the antenna.

(4 marks)

(b) A probe measured 2μV/m of field strength 100 km away from a parabolic antenna with directive gain of 1000 and efficiency of 0.85. Calculate:

(i) The power gain, G_p
(ii) The Effective Isotropic Radiated Power, EIRP of the parabolic antenna.
(iii) The radiated power, P_{rad} and input power, P_{in}
(iv) The distance of the probe if an isotropic antenna is used for the same amount of field strength.

(8 marks)

(c) Construct using array of five (5) dipole antennas to produce radiation patterns as described below. The length and spacing must be labeled clearly.

(i) Broad side
(ii) End fire

(8 marks)

Q4 (a) Explain the difference between *refraction* and *scattering* in radio wave propagation.

(2 marks)

(b) Illustrate the effect of refraction on the radio horizon of a space wave communication mode with the help of a suitable diagram.

(2 marks)

(c) A 3 GHz signal is transmitted from Batu Pahat towards a receiving antenna that is 250 km away. A knife edge hill with height of 50 m from the sea level is found located 50 km from the transmitter.

(i) Propose the height of the transmitter and receiver tower so that the diffraction loss due to the knife edge hill can be neglected. Assume the same transmitter and receiver height.

(8 marks)

(ii) Calculate the knife edge loss if both the transmitting and receiving tower is only 10 m in height from sea level.

(5 marks)

(iii) Calculate the free space loss and total path loss between the transmitter and receiver for the same condition as in part (ii).

(3 marks)

Q5 (a) Discuss the importance of achieving electromagnetic compatibility (EMC) for electrical and electronic equipment. (1 mark)

(b) Illustrate one typical example of radiated emission of EMC sub-problem by indicating the source, coupling path and receptor. The figure must be labeled clearly.

(3 marks)

(c) One of the reasons to consider electromagnetic compatibility is to achieve desired functional performance of a digital circuitry system. Recommend FOUR (4) control techniques of electromagnetic interference while designing the system. Draw appropriate figures to explain the techniques.

(8 marks)

(d) Compare between the test methods of radiated emission and conducted emission for IT equipment as indicated in CISPR 22.You should describe the procedures and explain with the help of proper figures.

(8 marks)

Q6 (a) An electric field strength of $10\mu\text{V/m}$ is to be measured at an observation point $\theta = \pi/2$, 500 km from a half-wave dipole antenna operating in air at 50 MHz. Determine:

(i) The length of the dipole.
(ii) The current that must be fed to the antenna.
(iii) The average power radiated by the antenna.
(iv) The average power radiated if the antenna is replaced by a $\lambda/4$ monopole antenna.
(v) The standing wave ratio, if a transmission line with $Z_o = 50\,\Omega$ is connected to the antenna.

(10 marks)

(b) An antenna is used to transmit radio wave signal between two points on the surface of the earth separated by a distance of 600 km by using sky wave propagation mode. It is found that the virtual height, h_v of the layer of interest is 150 km and its critical frequency, f_{crit} is 3.486 MHz. Predict the maximum usable frequency (MUF) for the two points if the earth is assumed to be a round surface with radius of 6400 km.

(8 marks)

(c) Show that the minimum value of the optimum working frequency (OWF) for the problem in Q6 (b) is 6.02 MHz.

(2 marks)

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FORMULAS

IMPORTANT EQUATIONS FOR TM AND TE MODES

TM Modes	TE Modes
$\mathrm{Exs} = -\frac{j\beta}{h^2}\left(\frac{m\pi}{a}\right)E_o \cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$	$\mathrm{Exs} = \frac{j\omega\mu}{h^2}\left(\frac{n\pi}{b}\right)H_o \cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$
$\mathrm{Eys} = -\frac{j\beta}{h^2}\left(\frac{n\pi}{b}\right)E_o \sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$	$\mathrm{Eys} = -\frac{j\omega\mu}{h^2}\left(\frac{m\pi}{a}\right)H_o \sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$
$\mathrm{Ezs} = E_o \sin\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$	$\mathrm{Ezs} = 0$
$\mathrm{Hxs} = \frac{j\omega\varepsilon}{h^2}\left(\frac{n\pi}{b}\right)E_o \sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$	$\mathrm{Hxs} = \frac{j\beta}{h^2}\left(\frac{m\pi}{a}\right)H_o \sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$
$\mathrm{Hys} = -\frac{j\omega\varepsilon}{h^2}\left(\frac{m\pi}{a}\right)E_o \cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$	$\mathrm{Hys} = \frac{j\beta}{h^2}\left(\frac{n\pi}{b}\right)H_o \cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$
$\mathrm{Hzs} = 0$	$\mathrm{Hzs} = H_o \cos\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-\gamma z}$
$\eta = \eta'\sqrt{1-\left(\frac{f_c}{f}\right)^2}$	$\eta = \frac{\eta'}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

These formulas below can be used for both TM and TE modes:

$$f_c = \frac{u'}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$\lambda_c = \frac{u'}{f_c}$$

$$\beta = \beta'\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$$u_{ph} = \frac{\omega}{\beta} = f\lambda$$

Where: $h^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$, $u' = \frac{1}{\sqrt{\mu\varepsilon}}$, $\beta' = \frac{\omega}{u'}$, $\eta' = \sqrt{\frac{\mu}{\varepsilon}}$

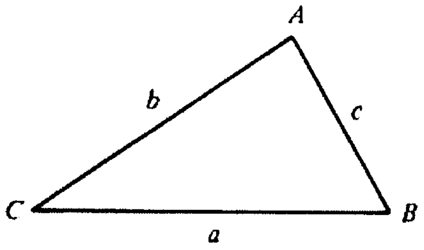
For Hertzian Dipole:

$$H_{\phi s} = \frac{jI_o\beta(d\ell)}{4\pi r}(\sin\theta)e^{-j\beta r}, E_{\theta s} = \eta H_{\phi s}$$

For Half-Wave Dipole:

$$H_{\phi s} = \frac{jI_o e^{-j\beta r}\cos\left(\frac{\pi}{2}\cos\theta\right)}{2\pi r(\sin\theta)}, E_{\theta s} = \eta H_{\phi s}$$

For any plane triangle ABC:



$$c^2 = a^2 + b^2 - 2ab(\cos C) \quad \text{(Cosine Law)}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \quad \text{(Sine Law)}$$

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The Complete Smith Chart

Black Magic Design