UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2006/2007

October/November 2006

EEE 531 – ADVANCED WAVES & ELECTROMAGNETIC THEORY

Duration: 3 hours

Please check that this examination paper consists of SEVEN pages of printed material and SEVEN pages Appendices before you begin the examination.

This paper contains SIX questions. THREE questions in Section A and THREE questions in Section B.

Instructions: Answer **FIVE (5)** questions. Answer **TWO (2)** questions from Section A, **TWO (2)** questions from Section B and **ONE (1)** question from any Section. If a candidate answer more than five questions, only the first five answered will be examined and awarded marks.

Use two answer booklets which is provided where the answer for questions in Section A are in one answer booklet and for Section B in another answer booklet. Answer to any question must start on a new page.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

SECTION A : Answer TWO (2) question

1. (a) Electromagnetic wave transverse in rectangular wave guide in TM mode. If the cross section of wave guide is $a \times b$ proof that electric field in z direction in this mode is as the equation shown below where m, n and β are mode numbers and phase shift, respectively.

$$E_Z = E_O \sin\left[\frac{m\pi}{a}x\right]\sin\left[\frac{n\pi}{b}y\right]\cos(\omega t - \beta z)\ (V/m)$$

(50%)

(b) `Air Kuning' air force base going to install an air craft radar detection system using S-band frequency. Three main parts of this system are the Carsegrain antenna, a 2m long rectangular wave guide and an in-door unit. The Carsegrain antenna will transmit a signal which is 1.1 times the cutoff frequency of the mode. The wave guide is air-dielectric and it is 7.2140cm x 3.4040 cm and to be in TM_{11}. Finally the in-door-unit will generates a signal into the wave guide. Based on above statement, calculate,

(i) The phase velocity in the wave guide. (10%)

(ii) The frequency and wave length of the signal generated by the in-door unit. (15%)

(iii) The input impedance of the Carsegrain antenna. (10%)

(iv) If this radar system must radiates into air 30dB signal with the Carsegrain antenna 30dB of gain and from the waveguide data sheet was stated that ohmic losses is about 1.1250Np/m, how much power must be generated by the in-door unit (in dBm). (15%)

2. (a) VSWR and reflection coefficient are two important parameters describing condition of any network. Show that both of them are relating to each other and give some comments about the answers.

(40%)

(b) A 50Ω high-frequency lossless line with the length of 1.4160m connecting between a main processor unit and a data storage unit. The dielectric constant between conductors in this high-frequency line is 2.49. The main processor has input impedance of $(20 + j25)\Omega$ and its transmitting signal at 500MHz to the data storage unit. Using the Smith chart;

(i) Estimate the input impedance of the storage unit. (15%)

(ii) Describe the condition at the load end of the line. (20%)

(iii) An external capacitor $8.0\mu\text{F}$ is connected in parallel to the storage unit at 85.0000mm from the load end. Describe the condition of the load end after inserting the capacitor.

(25%)

3. (a) Figure 3(a) shows a small section of transmission line being model as the T-type model. In this figure the parametes R, L, G and C are resistance, inductance, conductance and capacitance, respectively, per length. Based on this model derive the wave equations and show that propagation of wave in this transmission line depends on parameters of the line.

(40%)

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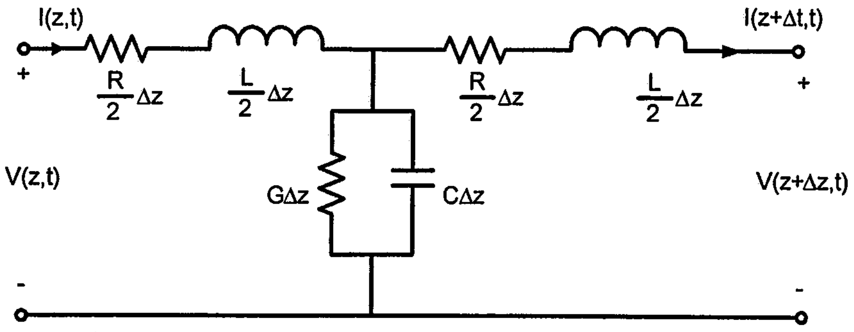

Figure 3(a)

(b) You have been selected as a field engineer in the Northen Communication Company Sdn Bhd. The company installed a 50 mile under ground telephone line from Prai to Taiping. The field manager of this company give to you some measurement results such as the measuring frequency is 5kHz , the characteristic impedance is $94.0000\angle -23.200°\Omega$, the total attenuation is 0.0600Np and the total phase shift between input and output is $8°$. The manager requires you to calculate;

(i) The line parameters of this telephone line and (20%)

(ii) The sending end input power if the minimum received power at load end must at least 14.2488dB under the condition of maximum power transferred.

(20%)

(iii) In the worth condition the absorbed power by load must at least half of the output power at load end of telephone line. Under this condition what is the load impedance to be.

(20%)

SECTION B : Answer TWO (2) question

4. (a) A particular two port network is driven at port 1 with a matched generator and terminated at port 2 with a matched load. If the total voltage and current at port 1 are measured to be $V_1 = 1.2\angle 12.2^0$ V and $I_1 = 16.2\angle -22.5^0$ mA, and the total voltage at port 2 is measured to be $V_2 = 0.7\angle 90^0$ V. If the characteristic impedance is $50\,\Omega$, find S_{11} and S_{21}.

(30%)

(b) Use ABCD matrices to find the voltage V_L across the load resistor in the circuit shown below.

(40%)

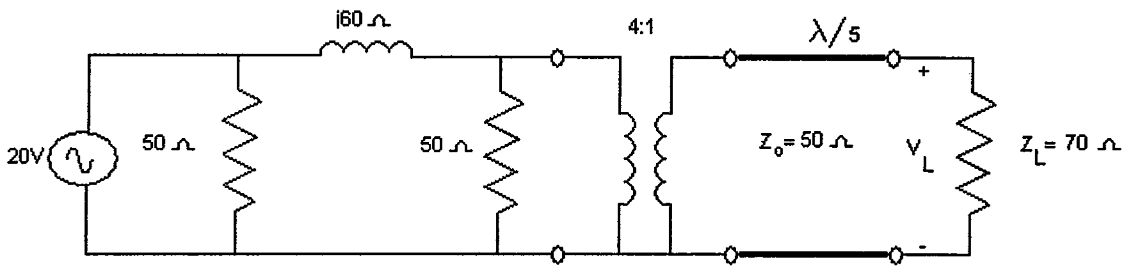

Figure 1

(c) (i) How does resonance occur in a cavity resonator

(ii) Define in words the quality factor for a cavity resonator.

(10%)

(d) A cubic cavity resonator is to operate in its dominant mode at a resonant frequency of 15GHz. It is filled with air, and its walls are copper ($\sigma_{cu} = 5.8\times10^{7} S/m$). Determine the size of the resonator in order to minimize the losses.

(20%)

5. (a) (i) Define antenna gain and beamwidth

(ii) How does the radiated field strength vary with distance from the source?

(10%)

(b) The electric field intensity in the far zone from an antenna is given in terms of its maximum input current I_0 as

$$\tilde{E}_\theta = \frac{12}{r} I_0 \text{ V/m}$$

(i) Obtain the corresponding expression for the magnetic field

(ii) What is the total power radiated ?

(iii) What is the radiation resistance?

(iv) What must I_0 be to radiate a power of 75 kW

(40%)

(c) Sketch the field pattern in the xy-plane of a 6 elements, Hertzian dipole, linear array when the spacing between the elements is λ/2 and the phase shift is 45^0.

(25%)

(d) Calculate the maximum range for detecting an object with area, $A_{eo} = 1m^2$ target if the radar specifications are

$$P_{rad} = 1MW$$
$$f = 5GHz$$
$$G = 45dB$$
$$P_{R\min} = -115dBm$$

(25%)

6. (a) What are the Method of Moments? Explain the procedures in the method of moments.

(20%)

(b) Write the coefficient for matrix A and determine the potential distribution in the geometry given in Figure 2 below using finite-difference method.

(40%)

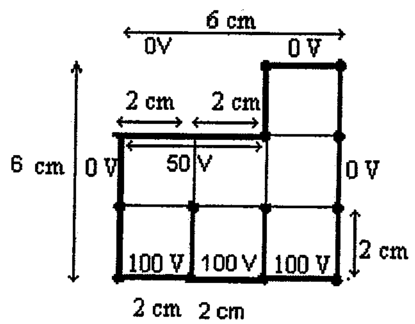

Figure 2

(c) Perform two iterations in an attempt to solve the potential distribution in the geometry shown in Figure 2 above using **SOR** method in conjunction with the finite-difference method. Assume the acceleration factor, $\alpha = 1$

(40%)

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<u>Antena tatasusunan (array):</u>

$$E_p = \frac{E_0}{\sqrt{n}}\left[1 + e^{j\theta} + e^{j2\theta} + \ldots\ldots e^{j(n-1)\theta}\right]$$

$$\left[1 + e^{j\theta} + e^{j2\theta} + \ldots. e^{j(n-1)\theta}\right] = \frac{\sin(\frac{n\theta}{2})}{\sin(\theta/2)}$$

$$\theta = \frac{2\pi d \cos\phi}{\lambda} \pm \alpha$$

$$E_p = \sqrt{2}E_0 \cos\left(\frac{\theta+\alpha}{2}\right) \text{ untuk 2 elemen}$$

<u>Normalized array:</u>

$$F(\psi) = \frac{\sin(n\psi/2)}{\sin(\psi/2)}$$

$$\alpha = \beta d \cos\phi$$

Null point: $\psi = \pm\frac{2p\pi}{n}$ p=1,2,3

Maximum point: $\psi = \pm\frac{(2q+1)\pi}{n}$ q=1,2,3….

Max. amplitude: $= \frac{n}{1.5\pi}$

Radar equation: $P_R = \frac{P_T G^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$

<u>Square mesh equations:</u>

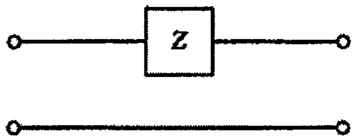
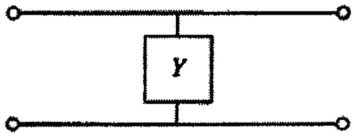
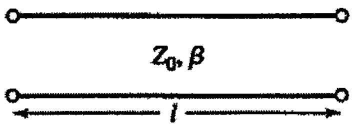
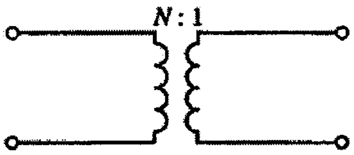
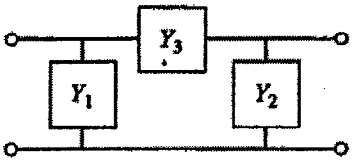
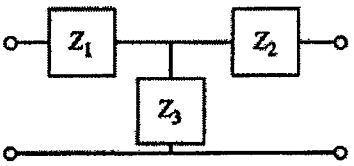
$$V_1 + V_2 + V_3 + V_4 - 4V_0 = 0$$

$$R^n = V_1^{n+1} + V_2^{n+1} + V_3^{n+1} + V_4^{n+1} - 4V_0^{n+1}$$

$$V_0^{n+1} = V_0^n + \frac{\alpha}{4}\left(V_1^{n+1} + V_2^{n+1} + V_3^{n+1} + V_4^{n+1} - 4V_0^{n+1}\right)$$

Data Sheet

TABLE 2.1 The ABCD Parameters of Some Useful Two-Port Circuits

Circuit	*ABCD* Parameters	
	$A = 1$ $C = 0$	$B = Z$ $D = 1$
	$A = 1$ $C = Y$	$B = 0$ $D = 1$
	$A = \cos \beta l$ $C = jY_0 \sin \beta l$	$B = jZ_0 \sin \beta l$ $D = \cos \beta l$
	$A = N$ $C = 0$	$B = 0$ $D = \frac{1}{N}$
	$A = 1 + \frac{Y_2}{Y_3}$ $C = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3}$	$B = \frac{1}{Y_3}$ $D = 1 + \frac{Y_1}{Y_3}$
	$A = 1 + \frac{Z_1}{Z_3}$ $C = \frac{1}{Z_3}$	$B = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$ $D = 1 + \frac{Z_2}{Z_3}$

<u>[S] matrix:</u>

$$S_{ij} = \frac{V_i^-}{V_j^+}\bigg|_{V_k^+ = 0 \, for k \neq j}$$

For TM mode:

$$f_{mnp} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{l}\right)^2}$$

$$m = 1,2,3 \ldots, \quad n = 1,2,3 \ldots, \quad p = 0,1,2,3, \ldots$$

For TE mode:

$$f_{mnp} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{l}\right)^2}$$

$$m = 1,2,3 \ldots, \quad n = 0,1,2,3 \ldots, \quad p = 1,2,3, \ldots$$

Skin depth, $\delta_c = \dfrac{1}{\sqrt{\pi f \sigma_c \mu}}$, $\mu = 4\pi \times 10^{-7}$

Quality factor, $Q = \dfrac{4\pi f^3 a^3 l^3 \mu^2 \varepsilon b \sigma_c \delta_c}{2a^3 b + a^3 l + a l^3 + 2 b l^3}$

E dan H fields:

$\vec{H} = \dfrac{j\beta I l}{4\pi r}\sin\theta e^{-j\beta r} \quad \vec{a}_\phi$

$\vec{E} = \eta \vec{H}$

$\eta = 120\pi$, $\beta = \dfrac{\varpi}{c}$

Power density, $\vec{S} = \dfrac{1}{2}[\vec{E} \times \vec{H}]$

Radiated power, $P_{rad} = \dfrac{\eta}{12\pi}\beta^2 l^2 I^2$

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The Complete Smith Chart

Black Magic Design