UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2005/2006

November 2005

EEE 531 – ADVANCED WAVES & ELECTROMAGNETIC THEORY

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **NINE (9)** printed pages including Appendices (2 pages) and **SIX (6)** questions before answering.

This question paper has two sections, **Section A** and **Section B**.

Answer **TWO (2)** questions in **Section A** and **TWO (2)** questions in **Section B** and **ONE (1)** question from any **Section**. Answer **FIVE (5)** questions.

Use two answer booklets which is provided where the answer for questions in **Section A** are in one answer booklets and for **Section B** in another answer booklet.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

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Section A: Answer TWO (2) question

A1. (a) A researcher gives to you a T-type of transmission line equivalent model as shown in Figure A1. Based on this model proof that you can derive the wave equation and also shows that propagation of wave in the line depends to the transmission line parameters.

(40%)

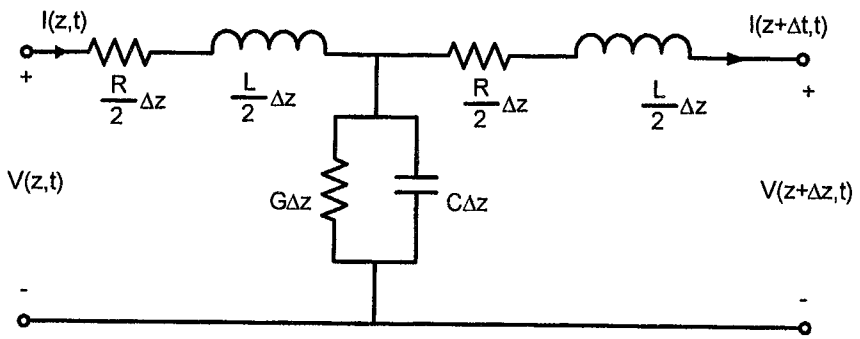

Figure A1

In this figure the R, L, G and C are line parameters named as resistance, inductance, conductance and capacitance, respectively, per length.

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(b) You have been selected as 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° . Your job is to calculate and show to him;

(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) It had been decided that 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.

(20%)

A2. (a) A rectangular wave guide is made up from perfect conductor and is filled with perfect dielectric. Derive the expended Maxwell's equations of electric and magnetic waves propagating in the wave guide. Mention any assumptions made.

(20%)

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(b) Based on the above equations what are other equations that you want to learn?

(15%)

(c) Explain the meaning of modes of wave propagating in wave guide and how they are defined.

(15%)

(d) You have been selected as ocean-field manager in defense ministry. Your first duty is to test and commission a military navigation positioning system for ocean-space war combat. Under this system several electromagnetic indicators will be located at scattered archipelagos over ocean. Actually the electromagnetic indicator consists of an electromagnetic resonator connected to a TE mode horn antenna through dielectric-filled silver made, 22.8600mm by 10.1600mm waveguide. The dielectric material in the wave guide has relative permeability (ε_r) and permitivity (μ_r) 4 and 1, respectively. The normalized E_y wave transverses in the wave guide is as follows,

$$E_y = \sin\left(\frac{22}{8001}\times 10^5 x\right)\cos\left(\frac{33}{3556}\times 10^5 y\right)\cos\left(\frac{22}{7}\times 10^{11} t - \beta z\right)(V/m)$$

Based on the above statement,

(i) Prove that the signal generated by the resonator could transverse in the waveguide.

(15%)

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(ii) Compute the intrinsic input impedance of the horn antenna.

(15%)

(iii) If the electromagnetic indicator must radiates into air 30dB signal using the 30dB gain horn antenna and from the waveguide data sheet was stated that an ohmic losses is about 1.1250Np/m, how much power must be generated by the electromagnetic resonator (in dBm).

(20%)

A3. (a) Write a short note, about one and a half page of your answer paper, describes a Smith chart and utility of the chart.

(30%)

(b) A post-graduate student designed a micro-strip circuit on high frequency PCB board. The circuit is used to deliver maximum power from a LNA amplifier to a low pass filter (LPF). The calculated characteristic impedance on this circuit is 70Ω at operating frequency 375MHz and the strip assumed to be lossless over short distance. The measured input impedance of LPF is $(140 + j91)\,\Omega$.

Use the Smith chart to determine:

(i) The load reflection coefficient, (5%)

(ii) The voltage standing wave ratio, (5%)

(iii) The distance of the first voltage maximum and the first voltage minimum from load (in cm),

(20%)

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Section B: Answer TWO (2) question

B4. (a) Find the S-parameter of the matched 3dB attenuator circuit shown in Figure 1 below:

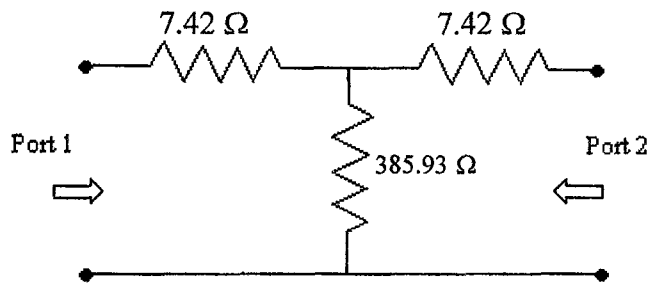

Figure 1

(40%)

(b) Can the TE100 mode exist in a resonant cavity? Justify your answer.

(20%)

(c) A rectangular cavity resonator made of aluminum has dimensions a = 5cm, b = 6cm and *l* = 12 cm and operates at the TM_{110} mode. Determine the resonant frequency and the quality factor of this resonator. The conductivity of aluiminum is 35.4 MS/m

(40%)

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B5. (a) What is the difference between directive gain and directivity? What can you conclude if the directivity of an antenna is unity?

(10%)

(b) An electric dipole of length 40 cm is situated in free space. If the maximum value of the current is 35 A and its frequency is 50 MHz. Determine

(i) The electric and magnetic fields in the far zone

(ii) The average power density

(iii) The radiation resistance

(40%)

(c) Sketch the field pattern in the xy-plane of a 10 elements, Hertzian dipole, linear array when the spacing between the elements is $\lambda/4$ and the phase shift is 90^0.

(25%)

(d) A 9 GHz tracking radar is tracking a 0.02 m^2 target at a range of 100 km. If the gain of the common transmitting and receiving antenna is 45 dB and the transmitter power is 1 MW, find the received signal P_R in dBm.

(25%)

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B6. (a) What is the finite-element method (FEM)? Explain the procedures in the FEM.

(20%)

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

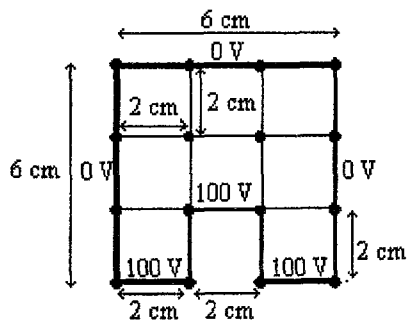

Figure 2

(40%)

(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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Data Sheet

[S] matrix:

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

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, $\delta_c = \frac{1}{\sqrt{\pi f \sigma_c \mu}}$, $\mu = 4\pi\times10^{-7}$

E dan H fields:

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

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

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

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

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