The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX6233– Microwave Communication Systems
Final Examination 2005

Time : 0930 - 1230 hrs. Date: 2006- 03 - 17

Answer any *Five* questions

1.
Write Maxwell's equations.

A long vertical current carrying conductor induces a magnetic field on a wire mesh.

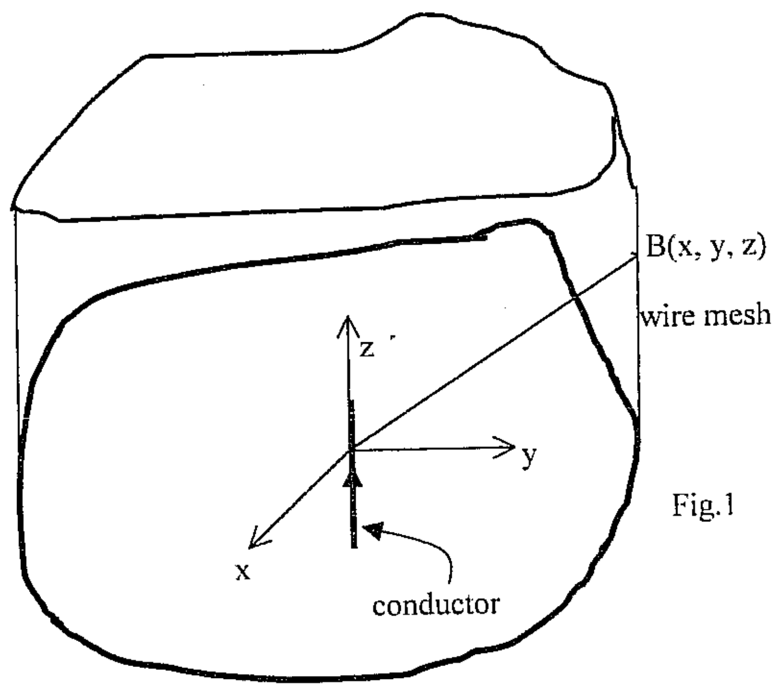

Fig.1

Induced B-field on the fence is given by $B(x, y, z) = \frac{1}{x^2yz^2}i + \frac{1}{y^2xz^2}j - \frac{4cd^2}{x^3y^3z}k$ where

i, j and k are the unit vectors and c, d are constants.

Find the shape of the wire mesh. [Hint: Using Maxwell's equations derive an equation which relates x,y and z coordinates of a given point on the wire mesh.]

If the area of the wire mesh is *cd*, calculate the height of the mesh.

2.

An electromagnetic wave is propagating in a metal.

Derive an expression for charge density (ρ) using Maxwell's equations.
Does ρ grow or decay with time? How fast does it grow / decay?

3.

(a) The propagation constant γ inside a waveguide is given by the equation

$$\omega^2 \mu \varepsilon + \gamma^2 = k_c^2$$

Using the above equation explain how the propagation characteristics of the wave vary with the value of k_c.
Also derive an expression for the maximum allowable frequency for wave propagation.

(b) E and H fields inside a waveguide are given by

$$\underline{E} = \underline{i}\,2p + \underline{j}\,3p; \quad \underline{H} = \underline{k}\,p$$

where p = p(x, y, t). ie. p depends on x coordinate, y coordinate and time only.

Calculate

(i) total power flow.
(ii) wave impdence

4.

Field components inside a Waveguide for Transverse Magnetic Waves are given in following equations:

$$E_z = E \sin k_x x \sin k_y y$$

$$H_x = \frac{j\omega\varepsilon}{k_c^2} E k_y \sin k_x x \cos k_y y$$

$$H_y = \frac{j\omega\varepsilon}{k_c^2} E k_x \cos k_x x \sin k_y y$$

$$E_x = -\frac{j\beta_z}{k_c^2} E k_x \cos k_x x \sin k_y y$$

$$E_y = -\frac{j\beta_z}{k_c^2} E k_y \sin k_x x \cos k_y y$$

$$where\ k_x = \frac{m\pi}{a}, k_y = \frac{n\pi}{b} \text{ and } k_c^2 = k_x^2 + k_y^2$$

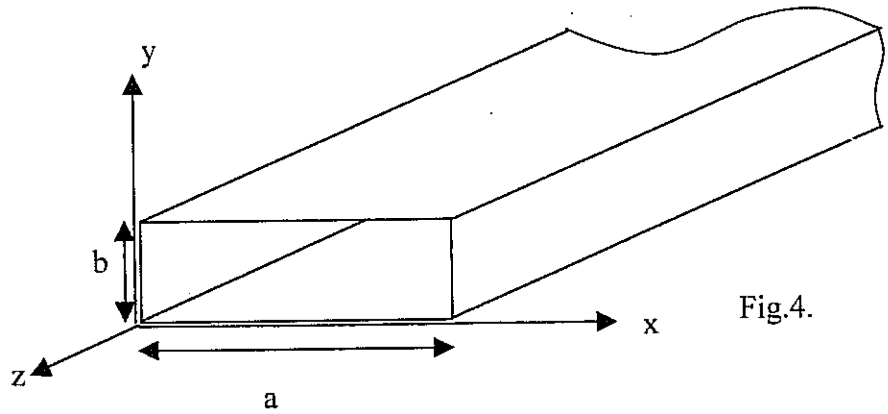

Fig.4.

(a) Calculate the value of H_z.

(b) Calculate the tangential field components at the inner walls of the waveguide.

(c) Assuming that the surface current density J at the inner walls is <u>numerically</u> equal to the tangential magnetic field (H_{tan}) at that point answer the following:

(i) What can you say about the directions of **J** and the corresponding H_{tan}?(Hint: use right hand screw rule)

(ii) Show that $\mathbf{J} = \mathbf{k}\, J_z$, where **k** is the unity vector in the z-direction. (Hint: prove that $J_x = J_y = 0$)

(iii) Derive expressions for J_z for the four inner walls of the waveguide for TM_{12} mode.

(iv) Plot the distribution of J_z given in (iii).

5.

The scattering matrix of a 4-port microwave device is given by

$$\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

(a) What are $[a] = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$ and $[b] = \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$? What parameters are represented by them?

(b) What important parameters are indicated by s_{11} and s_{22}?

(c) Find the values of s_{11} and s_{12} if the port 1 is matched and port 2 is terminated with a short circuit.

(d) Write the general form of [s] matrix for H-plane TEE.

The junction is symmetric about arms 1 and 2.

(i) Rewrite [s] with minimal number of parameters. Justify your answer.
(ii) If the junction is lossless write equations to show relationship among the various parameters of [s].
(iii) Solve [s] in (ii) if the arms 1 and 2 are simultaneously matched. Write final [s] with numerical values.

6.

(a) All the ports of a 3-port lossless microwave junction are matched.

(i) Write down the [s] matrix. Give the values of diagonal elements. Justify your answer.
(ii) Calculate the values of non-diagonal elements using the lossless property of the junction.
(iii) Name this device.

(b) The scattering matrix of a directional coupler is given below:

$$[s] = \begin{bmatrix} 0 & 0.5 & 0 & j\beta \\ 0.5 & 0 & j\beta & 0 \\ 0 & j\beta & 0 & 0.5 \\ j\beta & 0 & 0.5 & 0 \end{bmatrix}$$

(i) Calculate the value of β.
(ii) Calculate the *coupling* of the directional coupler.

7.

(a) An air-filled rectangular cavity with brass walls $\varepsilon_0 = \dfrac{1}{36\pi 10^9}$ SI units, $\sigma = 1.60 \times 10^7$ (S/m) has following dimensions: $a = 5$ cm, $b = 2.5$ cm, and $d = 5$ cm.

(i) Determine the dominant mode and its resonant frequency for this cavity if the cavity is operating in the Transverse Electric mode.
(ii) Calculate the *quality factor* (Q_0).

(b) (i) What is an isolator?
(ii) Describe its operation. Write the [s] matrix for it.
(iii) With the help of a diagram give a typical application of an isolator.

(c) Describe the following:

(i) Operation of *a two hole coupler.*
(ii) Use of the directional coupler in conjunction with a reflectometer to measure power flow in a microwave circuit.

8.
(a) Describe the principle of operation of *a parametric amplifier.*

(b) Explain how the efficiency of a horn antenna could be improved.

(c)

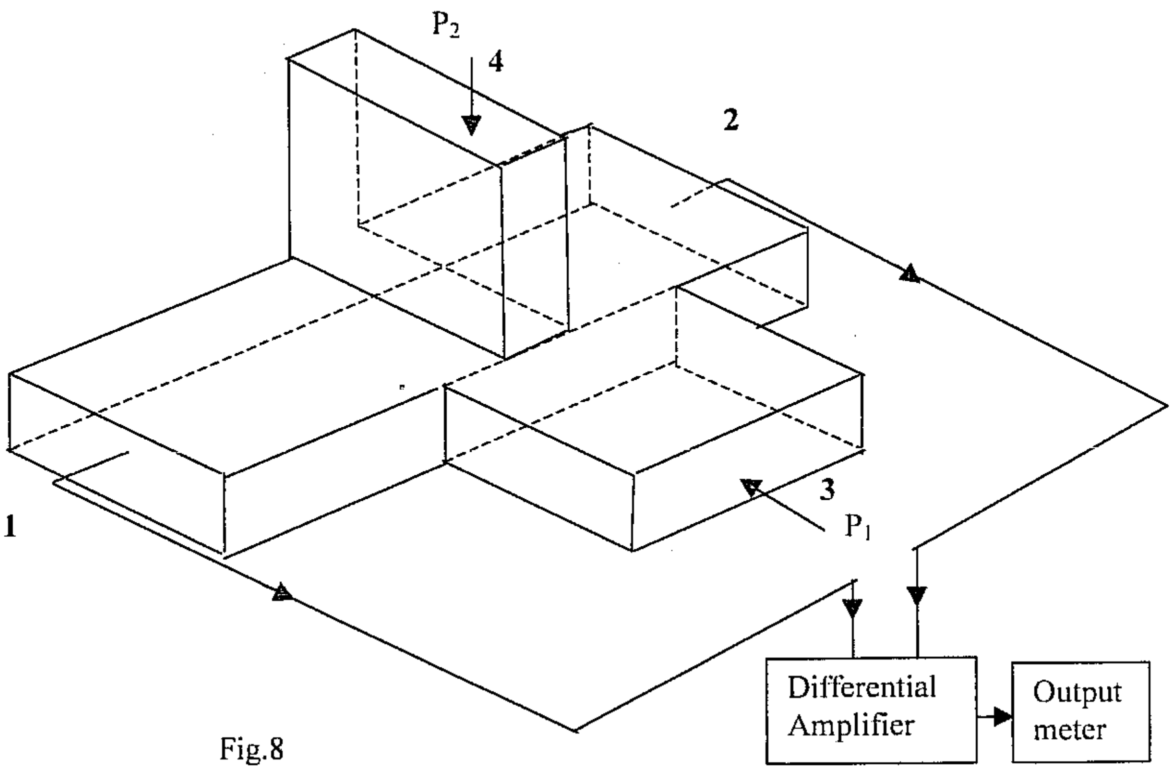

Fig.8

Fig.8 shows a microwave phase detector circuit using a Magic Tee. The two signals (signal powers P_1 and P_2), equal in magnitude but different in phase are fed at ports 3 and 4 respectively.

The output power of the differential amplifier is given by

$P_{out} = G[\{\frac{1}{\sqrt{2}}(P_1 + P_2)\}^2 - \{\frac{1}{\sqrt{2}}(P_1 - P_2)\}^2]$, where G is the power gain of the amplifier.

(i) Write down the relationship between P_1 *and* P_2. Assume that the phase difference between P_1 and P_2 is θ.

(ii) Simplify the expression for P_{out} using the answer in (i).

(iii) Explain how the output meter should be calibrated.