**The Open University of Sri Lanka**
**Department of Electrical and Computer Engineering**
**ECX6233– Microwave Communication Systems**
**Final Examination 2007/2008**

065

Time : 0930 - 1230 hrs. Date: 2008- 04 - 28

*Answer 05 questions only*

1.

(a) Write down Maxwell's equations.

(b) Suppose that a time-varying magnetic field is defined in free space in cylindrical coordinate system as

$$E = E_o \sin(\omega t - \beta x)\underline{u_z}$$

as shown in Fig.1. Derive an expression for the induced electric field using Maxwells equations.

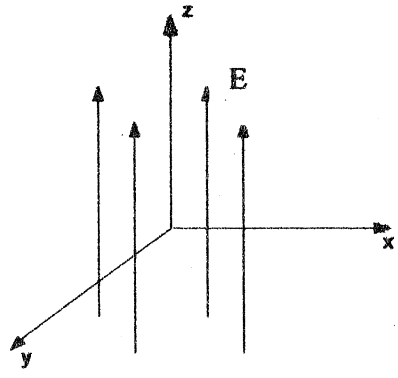


Fig. 1

(c) Show that the fields

$$\boldsymbol{E} = E_m \sin x \sin t \, \boldsymbol{u_y}$$

$$\boldsymbol{H} = \frac{E_m}{\mu_0} \cos x \cos t \, \boldsymbol{u_z}$$

in the free space are not valid solutions of Maxwell's equations.

($u_x$, $u_y$ and $u_z$ are the unit vectors in x, y and z directions respectively)

2. (a) The electric and magnetic field in free space in a spherical coordinate system are given by

$$E = \frac{10}{r}\sin\theta\cos(\omega t - \frac{4\pi}{3}r)\,\boldsymbol{u_\theta}\ \text{V/m}\quad \text{E}$$

$$H = \frac{10}{120\pi\, r}\sin\theta\cos(\omega t - \frac{4\pi}{3}r)\,\boldsymbol{u_\phi}\ \text{A/m}$$

($u_\theta$ and $u_\varphi$ are the unit vectors in $\theta$ and $\varphi$ directions respectively)

i. Determine the Poynting vector.

ii. What is the direction of power flow?

iii. Determine the total average power leaving spherical closed region of radius r = 100 m.

(b) The fields of a 500 kHz uniform plane wave in a lossless dielectric are given by

$\boldsymbol{E} = (4\boldsymbol{u_x} - \boldsymbol{u_y} + 2\boldsymbol{u_z})$ kV/m and

$\boldsymbol{H} = (6\boldsymbol{u_x} + 18\boldsymbol{u_y} - 3\boldsymbol{u_z})$ A/m,

Find

i. the unit vector on the direction in which the wave is traveling.

ii. relative permittivity $\varepsilon_r$, if $\mu_r = 1$

(c) A uniform plane wave is incident normally on a sheet of perfect dielectric as shown in Fig.2. The incident electric field is 10 V/m. Find the magnitude of the transmitted component ($E_t$) of the electric field in region 3. The relative permittivity of the dielectric is 20.

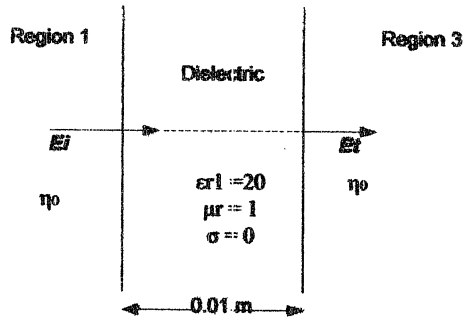


Fig.2

3. (a) What do you mean by the term "cut-off frequency" in waveguide theory?

(b) Prove that the phase constant β of an air filled rectangular waveguide is given by

$$\frac{2\pi f}{c}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

Here $f$ – Operating frequency

$f_c$ – Cut-off frequency

$c$ – Velocity of light in free space

(c) A rectangular waveguide has dimensions of 2.29 cm and 1.02 cm. If the guide is air filled and the frequency of operation is 25 GHz, list all possible propagating modes of this guide.

(d) If the wave guide in part (c) operates in the $TM_{11}$ mode, determine.

(i) Phase constant.

(ii) Guide wave length

(iii)Phase velocity of this mode.

4. (a) What are the desirable properties of cavity resonators?

(b) Determine the length of the cavity which will resonate at 10 GHz. The cavity is made from WG 16 of the shortest length. Calculate the Q factor. (The dominant mode in WG 16 is $TE_{10}$ and the resonant frequency is 6.55 GHz)

(c) The Fig.4 shows a ring shaped cavity resonator used in some microwave tubes. The central narrow part of dimension $d << \lambda$ can be considered to be a capacitor in parallel with the inductance of the rest of the structure.

(i) Show that the resonant frequency of the structure is $\frac{c}{\pi a\sqrt{\frac{2l}{d}\ln b/a}}$ where

c is the velocity of light in free space.

(ii) Find its approximate wavelength.

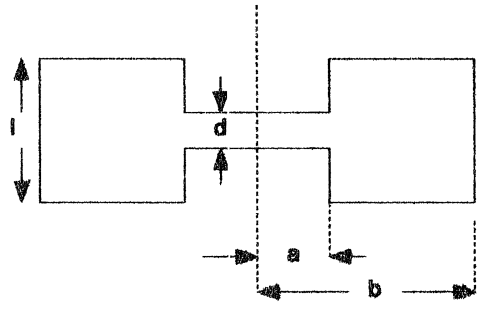


Fig.4

5.

(a) Draw the following T-junctions and indicate the direction of E-field in each of the arms for $TE_{10}$ mode. Assume that one end of the main arm is connected to a generator.

(i) E-plane Tee.

(ii) H-plane Tee.

(b) Scattering matrix of a 3-port junction is given by

$$[s]=\begin{bmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{bmatrix}$$

(i) If the junction is perfectly matched, simplify the above matrix.

(ii) Write the relationship between various elements of the matrix if the junction is lossless.

(iii) For a perfectly matched lossless junction, prove that

$$s_{13}^{*}s_{32}^{*}=0$$
$$|s_{12}|^2=1-|s_{13}|^2=1-|s_{23}|^2$$
$$|s_{13}|^2+|s_{23}|^2=1$$

(iv) Show that the equations given in (iii) cannot be satisfied simultaneously.

(v) Prove that the perfect matching of a lossless 3-port junction is impossible.

6.

I

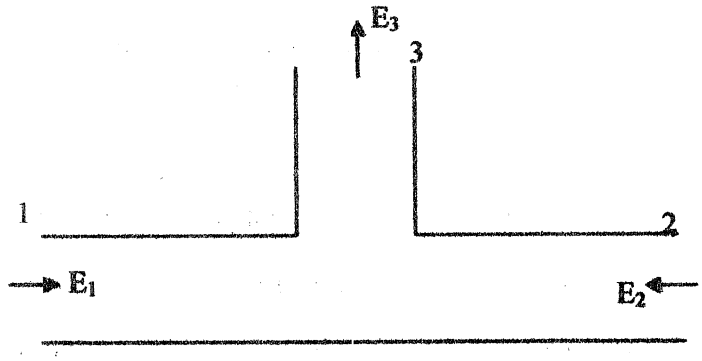


Fig. 6 E-plane Tee as a power combiner

An E-plane Tee is to be used as a power combiner as shown in Fig.6. Two sources $S_1$ and $S_2$ are connected to port 1 and port 2 respectively. The resultant E-field at port 3 is $E_3$.

(a) Draw the E-field pattern in each of the arms ($E_1$, $E_2$ and $E_3$) when the power combiner is in action.
What is the relationship between the E-fields $E_1$, $E_2$ and $E_3$ now?

(b) Redraw the field patterns in each of the arms, if the polarity of $E_2$ is changed.
Comment on the magnitude of $E_3$ now.

(c) Two microwave transmitters share the same transmitting antenna.

(i) Suggest a suitable method to connect the two transmitters to the antenna.
Briefly explain the operation of this system.

(ii) If one of the transmitters has a coaxial type output, redo (i).

(Draw clear diagrams for both (i) and (ii)).

II

Describe the principle of operation of a magic Tee.

Two antennas A and B are used for both transmitting and receiving. The signals received by the antennas are to be fed to a low noise amplifier (LNA).

Draw a clear diagram to show how the two antennas, the transmitter and the LNA can be interconnected via a magic Tee.

7.

A lossless H-plane Tee has ports 1 and 2 as main ports and port 3 as the auxiliary port.

(a) Draw the T-junction and indicate its plane of symmetry.

(b) Write the s-matrix for the junction with minimum number of parameters. Give justifications for your choice.

(c) Evaluate the s-matrix, if

(i) ports 1 and 2 are matched.
(ii) port 3 is matched.

8.

(a) Describe the operation of a directional coupler.

Define following parameters for a directional coupler:

(i) coupling
(ii) isolation
(iii) directivity

(b) A reflectometer can be used to measure the incident- and the reflected power at a certain location ($P$) of the wave guide.

A load $L$ is fed from a source $S$ through a wave guide.
Explain how a reflectometer can be connected to the wave guide using two directional couplers, so that it measures the incident- and the reflected power at the input of the waveguide. (A reflectometer has two input channels)

If an isolator is placed between $P$ and $L$(closer to $L$), what would be the VSWR at the location $P$? Justify your answer.

(c) (i) Name the types of High Power Amplifiers (HPA) used in microwave amplification.

Explain the working principle of one of them.

(ii) What is the type of polarization associated with the receiving signal of a satellite communication antenna?

(iii) The signal mentioned in (ii) is first sent to the device *X* through the medium *M*.
Name *M* and draw a cross-section of it.

Name *X* and describe its functions.

(iv) Draw a block diagram to show the signal receiving path in a satellite communication receiver. **[Draw all the intermediate blocks from Antenna to MUX]**