23

00057

The Open University of Sri Lanka
Department of Electrical and Computer Engineering

ECX 6233 – Microwave Communications
Final Examination – 2010/2011

Date: 04.04.2010 Time:1400-1700

Answer five questions

1.

a. Derive the expression for attenuation and phase constant for uniform plane electromagnetic waves propagating through a medium using Maxwell's equations. [5 marks]

b. If $\varepsilon_r = 9$, $\mu = \mu_0$ for the medium in which a wave with frequency f = 300MHz is propagating, determine propagation constant and intrinsic impedance of the medium when
   i. $\sigma = 0$ [3 marks]
   ii. $\sigma = 10$ mho/m [3 marks]

c. Comment on the propagation in the two situations. [3 marks]

d. State Poynting Theorem. [2 marks]
   i. A Plane wave traveling in free space has an average poynting vector of 5 watts/m^2. Find the average energy density of the electromagnetic wave. [4 marks]

2.

a. State the boundary conditions for Electric and Magnetic fields at the interface between air and a perfect conductor. [2 marks]

b. Explain why a rectangular waveguide of cross-sectional dimensions 'a' and 'b' has a lowest frequency at which electromagnetic waves will not propagate. Derive an expression for the lowest mode cut off frequency. [8 marks]

c. For a rectangular waveguide of cross sectional dimensions 2.0 mm x 1.0 mm. determine the cut off frequencies of the following modes TE_{10}, TE_{11}, TM_{11}. [4 marks]

d. Identify the centre of the band of frequency in the waveguide where only one mode will propagate and calculate the group and phase velocity of the propagating mode at this band centre. Show that the product of group and phase velocities is 9 x 10^{16} in SI units. [6 marks]

3. Field components of TE_{mn} modes of a rectangular waveguide are given below. 'a' and 'b' dimensions of the rectangular waveguide are shown in figure Q3.

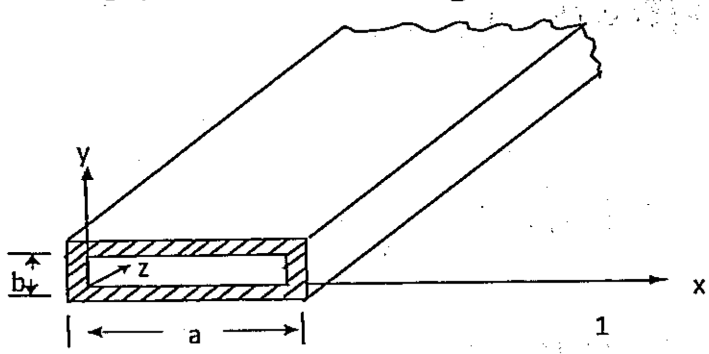

Figure Q3

$H_z = H_0 Cos\left(\frac{m\pi x}{a}\right) Cos\left(\frac{n\pi y}{b}\right)$, $\quad H_y = \frac{jk_z}{k_c^2}\frac{n\pi}{b} Cos\left(\frac{m\pi x}{a}\right) Sin\left(\frac{n\pi y}{b}\right)$

$H_x = \frac{jk_z}{k_c^2}\frac{m\pi}{a} Sin\left(\frac{m\pi x}{a}\right) Cos\left(\frac{n\pi y}{b}\right)$, $E_y = \frac{-\omega\mu}{k_z} H_x$, $E_x = \frac{\omega\mu}{k_z} H_y$

a. Write the expression for the electric field in z direction. [1 marks]

b. Draw the electric field pattern inside the wave guide, in x-y plane [4 marks]

c. Explain why TEM mode is not possible for rectangular wave guides?[3 marks]

d. A 10 MHz frequency signal is fed into the air filled wave guides that work in dominant mode, Calculate

  i. The cut off frequency. [2 marks]

  ii. Propagation constant. [2 marks]

  iii. Phase velocity. [2 marks]

  iv. Group velocity. [3 marks]

  v. Characteristic impedance. [3 marks]

4.

a.

  i. What are the factors that affect attenuation in a waveguide? [3 marks]

  ii. A rectangular waveguide with internal dimensions 2.286cm × 1.016cm supporting TE_{10} mode at 5GHz is filled with a dielectric of relative permittivityϵ_r. What are the limits on ϵ_r if only the dominant mode TE_{10} propagates? [3 marks]

  iii. If ϵ_r=2.25 and loss tangent (tan δ) =10^{-3}. Calculate

    1. guide wavelength [2 marks]
    2. phase velocity [2 marks]
    3. attenuation constant [2 marks]

b.

  i. Define unloaded quality (Q) factor for a general resonator, in terms of energy and power. [2 marks]

  ii. Derive a simple expression for the free space wavelength of a TE_{101} mode, λ_{101},in terms of its width, given that $a = 2b = \frac{d}{\sqrt{2}}$ [3 marks]

  iii. Using the results of 4 b i. and 4 b ii., calculate the approximate unloaded Q factor at resonance, for $a = 2b = \frac{d}{\sqrt{2}} = 200\mu m$, given the following equation; [3 marks]

$$Q_U = \frac{(\lambda_{101})}{4\delta}\left\{\frac{2b(a^2+d^2)^{\frac{3}{2}}}{2b(a^3+d^3) \quad + ad(a^2+d^2)}\right\}$$

5.

a. Define the following factors related to a directional coupler.

  i. Coupling factor. [2 marks]

  ii. Directivity [2 marks]

  iii. Insertion loss. [2 marks]

  iv. Isolation. [2 marks]

b. Write the scattering matrix for a 4 port device. [2 marks]

i. Evaluate the scattering matrix of a fixed attenuator using a directional coupler. Port 2 and 4 are terminated with matched loads. Coupling factor is 30 dB. [7 marks]

c. Write an application where you can use the fixed attenuator in the field of microwave communications. [3 marks]

6. A cross section of an E-plane T junction is shown in Figure Q6.

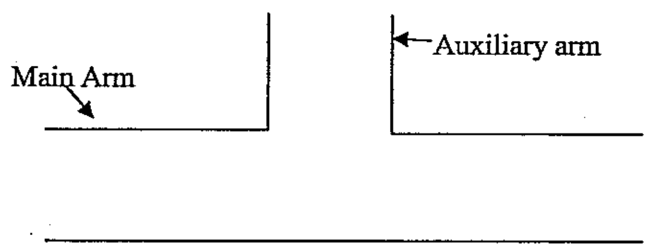

Figure Q6

a. Draw the electric and magnetic field pattern of the E-plane tee. [4 marks]

b. Derive the scattering matrix to E-plane tee taking necessary assumptions. [5 marks]

c. Prove that matching all 3 ports of an E-plane tee is not possible. [5 marks]

d. A 20-mW signal is fed into the H arm (port 4) of a loss less Magic Tee junction. Calculate the power delivered through each port when other ports are terminated in matched load. [6 marks]

7.

a. A duplexer circuit is shown in figure Q7. The circulator in the circuit is ideal.

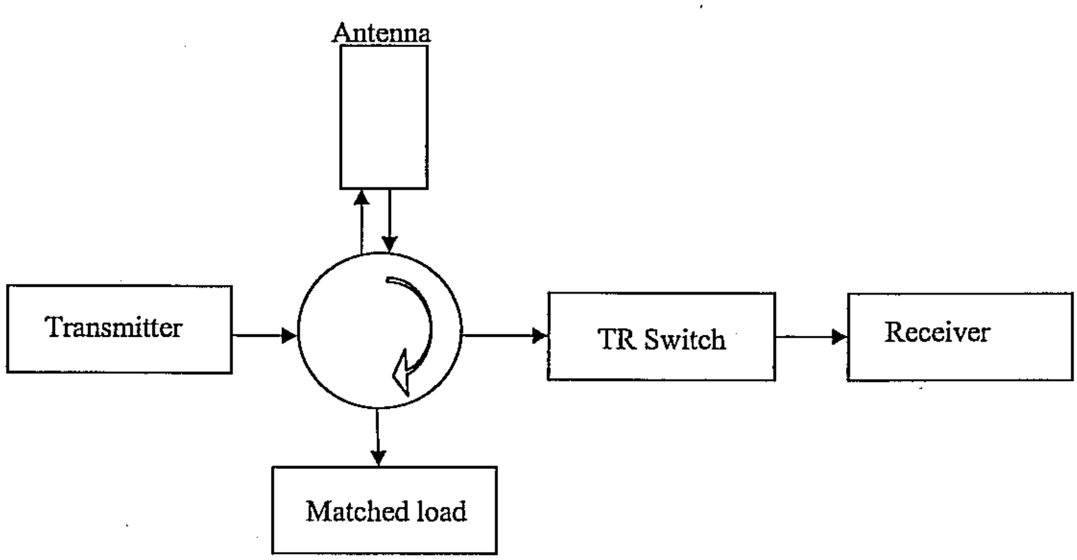

Figure Q7

i. Briefly explain the operation of this circuit. [6 marks]
ii. Evaluate the scattering matrix for the 4-Port circulator. [10 marks]
iii. Design a circuit to use the circulator as a decoupling isolator. (Give a block diagram and explain.) [4 marks]

8. The scattering matrix of a three port network is given below.

$$[S] = \frac{1}{2}\begin{bmatrix} 1 & 1 & \sqrt{2} \\ 1 & 1 & \sqrt{2} \\ \sqrt{2} & \sqrt{2} & 0 \end{bmatrix}$$

a. Is this network lossless? [2 marks]
b. A 20mW signal is fed into the port 1. Calculate the power delivered through each port when other ports are terminated with matched loads. [6 marks]
c. Compute the power delivered to the loads of 40 ohms and 60 ohms connected to arms 1 and 2, when 10mW power is incident at port 3. Junction characteristic impedance is 50ohms. [9 marks]
d. With the calculated values of the above b. and c. comment on the device operation. [3 marks]