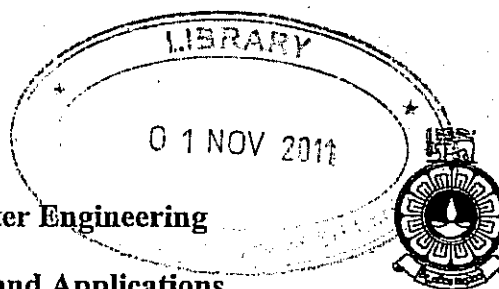


The Open University of Sri Lanka
Department of Electrical and Computer Engineering

ECX 6333 – Microwave Engineering and Applications
Final Examination – 2010/2011



Date: 04.04.2011

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 $\epsilon_r = 9$, $\mu = \mu_0$ for the medium in which a wave with frequency $f = 300\text{MHz}$ is propagating, determine propagation constant and intrinsic impedance of the medium when
 - i. $\sigma = 0$ [3 marks]
 - ii. $\sigma = 10\text{ mho/m}$ [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 $2.0\text{ mm} \times 1.0\text{ mm}$. 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 9×10^{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.

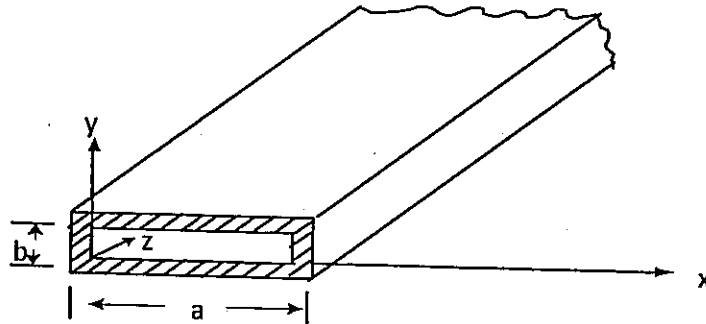


Figure Q3

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

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

- 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 $2.286\text{cm} \times 1.016\text{cm}$ supporting TE_{10} mode at 5GHz is filled with a dielectric of relative permittivity ϵ_r . What are the limits on ϵ_r if only the dominant mode TE_{10} propagates? [3 marks]
 - iii. If $\epsilon_r = 2.25$ and loss tangent $(\tan \delta) = 10^{-3}$. 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]

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

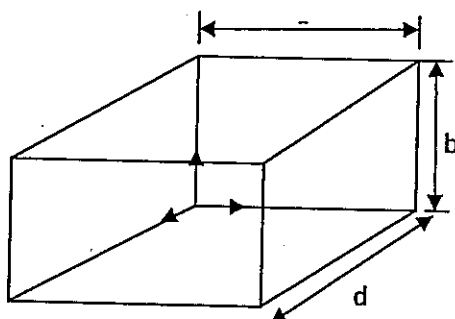


Figure Q4

- 5.
- Define the following factors related to a directional coupler.
 - Coupling factor. [2 marks]
 - Directivity [2 marks]
 - Insertion loss. [2 marks]
 - Isolation. [2 marks]
 - Write the scattering matrix for a 4 port device. [2 marks]
 - 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]
 - Write an application where you can use the fixed attenuator in the field of microwave communications. [3 marks]

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

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

- Is this network lossless? [2 marks]
- 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]
- 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]
- With the calculated values of the above b. and c. comment on the device operation. [3 marks]

7.

- Explain cell splitting and cell sectoring methods of capacity expansion. [4 marks]
 - What is frequency reuse? For $i=1$ and $j=2$ draw the cellular system structure depicting the co channel cells. [3 marks]

- iii. Derive an expression for signal to interference ratio for hexagonal cellular architecture in terms of frequency reuse factor. Also calculate the reuse factor to achieve an SIR of 30dB. [5 marks]

b.

- i. Find the coherent bandwidth of a mobile radio channel whose local average power delay profile measured at 900MHz is $P_{(\tau)} =$

$$\sum_{n=0}^2 \frac{10^{-6}}{n+1} \delta(\tau - n \cdot 10^{-6}).$$
 [4 marks]

- ii. A signal is transmitted at 30 KHz bandwidth and received by a mobile travelling at 30 Km/Hr. find out whether this will undergo fast or slow fading. [4 marks]

8.

c.

- i. Draw a block diagram of the general architecture of GSM System and briefly explain its operation. [5 marks]
- ii. In GSM system 25 MHz is used for forward link, which is broken into radio channels of 200 kHz. If 8 speech channels are supported on a signal radio channel, find the number of simultaneous users. Assume no guard band. [3 marks]

d.

- i. List the differences among SDMA/TDMA/FDMA/CDMA. [4 marks]
- ii. Find the frame efficiency, if a time slot consists of 6 trailing bits, 8.25 guard bits, 26 training bits and 2 traffic bursts of 58 bits of data. [3 marks]
- iii. The high data rates can be achieved using OFDMA than TDMA Multiple access method. Comment on the statement. [5 marks]