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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
Final Examination - 2009
ECX6233 – Microwave Communication Systems

Closed Book Test

Date: 18.03.2010 Time: 09.30 – 12.30

Answer any **FIVE** Questions

1)

a) Field components of an electromagnetic wave can be solved using Maxwell's equations.
   i) Write Maxwell equations.
   ii) Derive the wave equation for the Electric field, staring with the Maxwell's curl equation for the magnetic field.
   iii) Re- write the wave equation in phase notation.
   iv) Find the propagation constant for the following
      (1) A perfect dielectric
      (2) A good conductor
   v) Show that the velocity of an electromagnetic wave in a dielectric medium is inversely proportional to the square root of its relative permittivity.

b)
   i) Derive an expression for the charge density (ρ) using Maxwell's equations.
   ii) Does the charge density grow or decay with time? Give reasons to prove your answer.

2) Field Components inside a wave guide for TE mode is given below.

$$Hz = H\cos\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)$$

$$Hx = \frac{Hjk_z}{k_c^{\,2}}\frac{m\pi}{a}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)$$

$$Hy = \frac{Hjk_z}{k_c^{\,2}}\frac{n\pi}{b}\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)$$

$$Ey = \frac{-\omega\mu}{k_z}\left(\frac{Hjk_z}{k_c^{\,2}}\frac{m\pi}{a}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)\right)$$

$$Ex = \frac{\omega\mu}{k_z}\left(\frac{Hjk_z}{k_c^{\,2}}\frac{n\pi}{b}\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)\right)$$

where $k_z \pm j\sqrt{\left(\omega^2\mu\varepsilon - k_c^{\,2}\right)}$ *and* $k_c = \sqrt{\left(k_x^{\,2} + k_y^{\,2}\right)}$

a)
   i) What is the value of *Ez*?
   ii) Using the above equations draw the *H* field patterns inside the wave guide for TE_{10} mode.
   (Hint: Find the values of *H* between $x = 0$ and $x = a$)

b)

i) Write an expression for cutoff wave length of a rectangular waveguide.
ii) If a perfect dielectric is used inside the wave guide, write an expression for the propagation constant.
iii) Derive an expression for wave the impedance.

3)

a) The Electric field of a uniform plane wave is given by,

$$E = 20\sin\left(\left(3\pi \times 10^8 \times t\right) - \pi z\right)\hat{x} + 20\cos\left(\left(3\pi \times 10^8 \times t\right) - \pi z\right)\hat{y}$$

Find,

i) Phase velocity.
ii) Dielectric Constant.
iii) Magnetic field intensity.
iv) Polarization of the wave.

b) The Electric field radiated by an antenna located at the origin of a spherical coordinate system is given by ,

$$E = \frac{E_0 \sin\theta}{r}\cos(\omega t - \beta r)\hat{\theta}$$

where E_0, ω and $\beta = \omega\sqrt{\mu\varepsilon}$ are constants.

i) Determine the magnetic induction associated with the Electric field.
ii) Find the power radiated by the antenna within a sphere of radius r centered at the antenna.

4)

a) An air filled cavity resonates at 10.6 GHz. If a dielectric of relative permittivity of 1.63 is filled into the cavity,

i) What will be the new resonant frequency of the cavity?
ii) What will be the new quality factor if the quality factor and the loss tangent of the cavity filled with air, are 8200 and 10^{-3} respectively?

b) Briefly explain the operation of followings

i) Klystron
ii) Parametric amplifier

5) Many Microwave applications make use of lossless 3 port Junctions.

a) Write a general S-matrix for a 3 port junction.

b)

i) If the junction is reciprocal, what parameters will be affected?

ii) If this junction is electrically symmetric about port 1 & 2, what S parameters will be affected?

iii) Evaluate the matrix, assuming the port 1 and 2 are matched.

iv) Name the device, having the characteristics given in (i), (ii) & (iii).

c)

If the 3-port junction of part(b) is non- reciprocal and all it's ports are perfectly matched.

i) Evaluate the scattering matrix.

ii) Name the device.

6)

a) Write the characteristics of the magic T when all the ports are terminated with the matched loads.

b) A magic T is terminated at collinear ports 1 and 2 and difference port 4 by impedances of reflection coefficients T1= 0.5, T2= 0.6 and T4= 0.8 respectively.
Calculate the power reflected at Port 3 and power transmitted to other ports, if 1W power is fed at sum port 3.

S matrix for a matched magic-T with sum and difference Ports 3 & 4 respectively, is given by

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

c) Figure Q6 shows a balanced microwave mixer configuration. Prove that if equal power fed to the inputs at isolated port 3 and 4, Output power will be two times of input power.

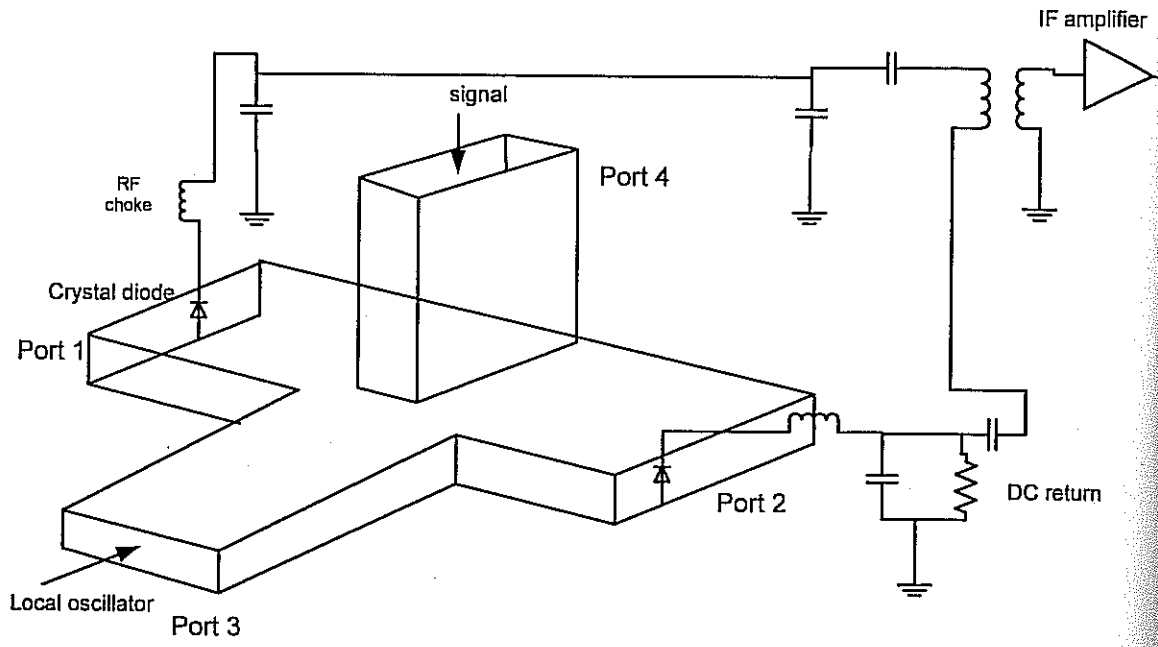

Figure Q6

7)

a) What is the purpose of a Quarter wave matching Transformer?

b)

i) Derive an expression for the impedance of the matching section of Figure Q7.

ii) Derive an expression for the magnitude of the input reflection coefficient (Γ).

iii) Sketch the response of the bandwidth

iv) Comment on the bandwidth of a quarter wave transformer.

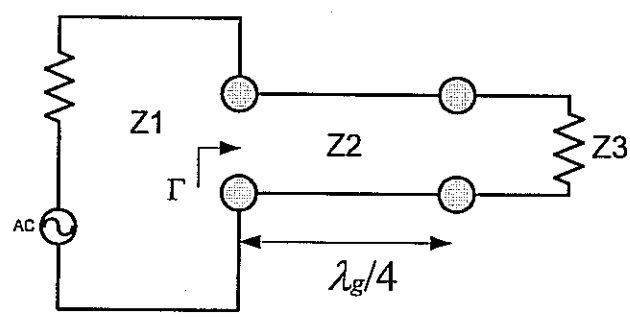

Figure Q7

c) A $\lambda_g/4$ transformer is used to match 100Ω load to a 50Ω air filled waveguide of 2.286×1 cm^2 operating at 10GHz.

i) What will be the required length of the transformer?

ii) Calculate the impedance of the matching section.

8)

a) Express the following terms related to directional coupler.
   i) Coupling.
   ii) Directivity.
   iii) Transmission loss.

b) The scattering matrix of a directional coupler is given by

$$[S]=\begin{bmatrix} 0 & \alpha & 0 & \beta \\ \alpha & 0 & \beta & 0 \\ 0 & \beta & 0 & \alpha \\ \beta & 0 & \alpha & 0 \end{bmatrix}$$

   i) If the Transmission loss of the device is 6dB, find α and β
   ii) If the coupling of the device is 10dB find the α and β

c) A waveguide stretcher (phase shifter) is shown in Figure Q8.

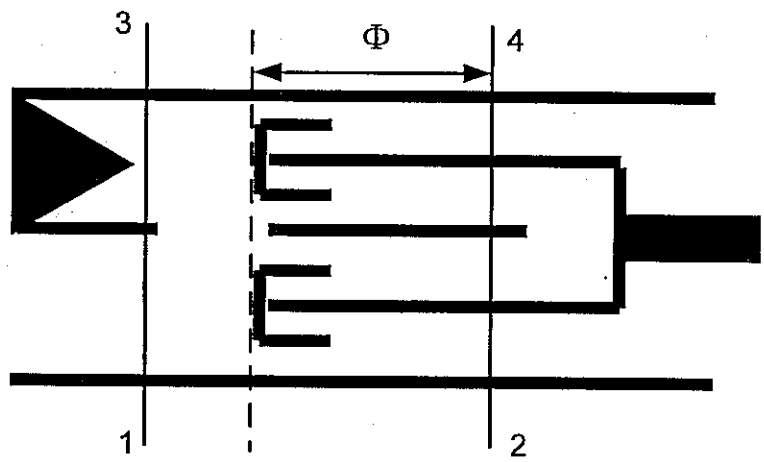

Figure Q8

Show that the phase of the out going wave can be varied by changing the position of shorting plunger.

[Hint: Show that $b_3 = a_1 e^{j(2\Phi - \pi/2)}$]