The Open University of Sri Lanka
Department of Electrical and Computer Engineering
Final Examination - 2009
ECX6333 – Microwave Engineering and Applications

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.

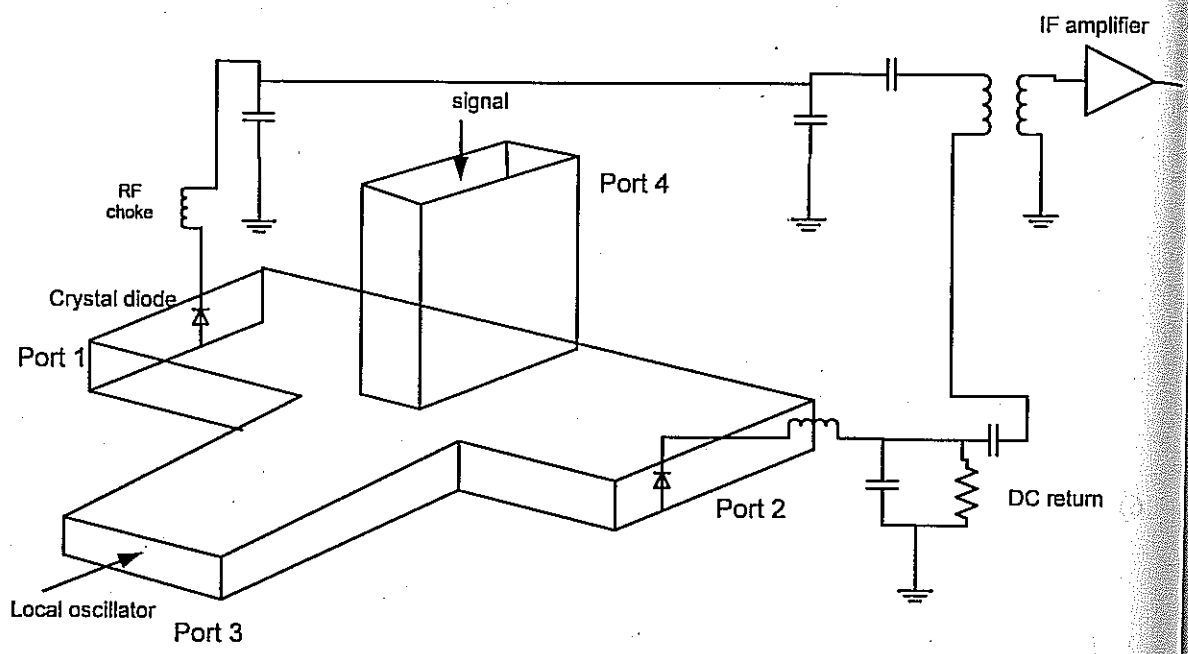

Figure Q6

7)

a)

i) Define the Frequency reuse factor

ii) What are the methods used to increase the coverage and the capacity of a cellular system? Explain each method.

b) A cellular service provider has a total spectrum of 30 MHz. A Duplex Channel of 50kHz has been allocated as the RF bandwidth. The provider allocates 300 channels per cell, what will be the frequency reuse factor that the provider needs to propose.

c)

i) Find the transmit power required to obtain a received power of 1 dBm in a wireless system with an antennas gain of 1 and a carrier frequency (f) = 5 GHz, assuming the free space path loss model, and a distance (d) of 10m.

ii) What are the additional parameters that you require to find the transmitted power using the Ground reflection (Two Ray) model? (Use the same parameters given in part c i).)

iii) Calculate those parameters if the parameters mention in part c) ii) above are equal.

8)

a) A cellular service provider use GSM technology to serve the customers. Due to the demand of high speed, data and multimedia support from the customer the technology needs to upgrade or a change.
   i) State the suitable technology that can support customer requirement.
   ii) Is the technology that you stated in i) cost effective? Explain this with reasons.
   iii) Explain the principle of data flow used in the technology that you suggest in i).

b)

A base band binary message with a bit rate of 1kbps is modulated on a RF carrier using BPSK. The carrier frequency is 6MHz is used. A mobile moves at a speed of 50Km/h.
   i) What will be the coherence time of the channel?
   ii) Identify the type of fading experienced by the mobile user.