UNIVERSITY OF SURREY

School of Electronics and Physical Sciences

ELECTRONIC ENGINEERING PROGRAMMES

For BEng, MEng, MSc and MRes Degrees

Module EE3/M.mwe

MICROWAVE ENGINEERING PRINCIPLES

Duration: 2 Hours Spring 2004/05

READ THESE INSTRUCTIONS

Answer **THREE** questions, at least **ONE** from each section.

USE A SEPARATE ANSWER BOOK FOR EACH SECTION

On the front sheet of EACH answer book, complete the list of questions attempted in that book in the order they appear. Then draw a line below this list and add the question numbers you have attempted in the other answer book.

2 Smith charts are provided

SECTION A

A1 (a) Define the terms and give illustrative equations where necessary

Characteristic impedance

Velocity factor

Reflection coefficient

Return loss

Voltage Standing Wave Ratio (VSWR)

for waves on a two-wire transmission line.

[25%]

(b) A certain transmission line has inductance per unit length L Henries per metre and capacitance per unit length C Farads per metre. Express the characteristic impedance Zo and the velocity u of waves on the cable in terms of L and C. Calculate typical values of L and C for the following cases:-

(i) A coaxial cable with Zo = 75 ohms and velocity factor 0.68

(ii) A twin wire line with Zo = 280 ohms and velocity factor 0.97

[35%]

(c) Calculate the return loss in dB for reflections from a normalised load impedance 1.5 + j 0.5, and state the magnitude and phase angle of the reflection coefficient gamma at the load impedance. **[20%]**

(d) A generator is connected to this load impedance by a 2 metre length of coaxial cable of characteristic impedance 75 ohms and velocity factor 0.68. The generator frequency is 900MHz. The cable may be assumed lossless. Calculate the complex impedance (in ohms) presented by the cable and load to the generator terminals. **[20%]**

A2 (a) Write notes about the Scattering Matrix description of a microwave n-port network. Give a formula that relates the scattering matrix to the normalised Z-matrix for a network. **[25%]**

(b) Write down the typical scattering parameters for the following microwave components:-

(i) A 1.8 wavelength run of lossless transmission line

(ii) A 20 dB gain amplifier, matched at input and output ports

(iii) A 3-port circulator

(iv) A waveguide isolator

(v) A microwave lossless filter, at a frequency outside its bandpass.

[35%]

(c) A certain 2-port microwave component has s-parameters

s11 = 0.1 angle -30 degrees

s12 = 0.05 angle -60 degrees

s21 = 1.2 angle -60 degrees

s22 = 0.1 angle -30 degrees

This component is short circuited at its output reference plane. Calculate the equivalent 1-port scattering parameter at the input reference plane, and comment on the stability of this arrangement. **[40%]**

A3 (a) State the boundary conditions between a dielectric inside a waveguide, and a perfectly conducting waveguide wall. State under what conditions there can be a non-zero electric field inside the waveguide, and describe what happens when a permanent magnet is brought up to the outside of the guide. Assume the guide is made of copper. **[25%]**

(b) Write down the waveguide formula for a general TEmn mode in a rectangular waveguide of dimensions a metres by b metres. If a = 0.1 metres and b = 0.05 metres, suggest a range of operating frequencies at which only the lowest order mode will propagate. **[25%]**

(c) Define the wave impedance for the TE10 and TM11 modes in this guide and derive formulas for this impedance in terms of the guide cutoff frequencies which you calculated in part (b) of this question. **[25%]**

(d) Sketch the electric and magnetic field distributions for the TE10 mode, and show where non-radiating slots may be cut in the waveguide walls. Explain also how a slotted waveguide may be used to make a directional coupler and indicate how the coupling strength may be adjusted. **[25%]**

SECTION B

B1 (i) With the aid of suitable diagrams, describe the construction and principle of operation of a cylindrical cavity magnetron. **[30%]**

(ii) Explain two techniques for modifying the structure of the anode block of a magnetron to ensure a specific mode of operation. **[20%]**

(iii) Describe, with a suitable circuit diagram, how the concept of DC resonant charging can be employed to power a magnetron for radar applications. **[20%]**

(iv) The following data apply to a magnetron line driver circuit that employs an artificial delay line and the principle of DC resonant charging:

DC supply voltage:	600V
Charging inductor:	2H
Delay line:	20-sections
	L=12nH/section
	C=300pF/section

If the magnetron has a DC input impedance of 560Ω, and a DC to RF conversion efficiency of 65%, determine the following parameters of the magnetron output:

(a) the pulse duration

(b) the PRF

(c) the RF pulse power **[30%]**

B2 (i) A dielectric material has the following properties at 5GHz: dielectric constant = 7.5; loss tangent = 0.0008.

Determine:

(a) the complex permittivity of the material

(b) the Q of the material

(c) the wavelength of a 5GHz signal propagating through the material

(d) the phase change through a 10mm block of the material at 5GHz

[20%]

(ii) Explain how a dielectric can be used to load a microwave horn antenna so as to produce a radiation pattern with higher directivity. **[20%]**

(iii) Design a dielectric lens for a 10GHz H-plane, sectorial, microwave horn that has an aperture of 150mm and a flare angle of 60^{o}. The dielectric has a relative permittivity of 2.33. Develop any equations used from first principles. **[40%]**

(iv) Explain how, in practice, the bulk of the dielectric lens can be reduced.

[20%]

B3 Answer **TWO** of the following:

(A) (i) Explain what is meant by the following terms as applied to ferrite materials:

(a) tensor permeability

(b) precessional motion

(c) Faraday rotation

(d) resonance absorption **[20%]**

(ii) Describe, with the aid of appropriate diagrams, the construction and principle of operation of a ferrite resonance isolator in rectangular waveguide. **[30%]**

(B) (i) Discuss the behaviour of PIN diodes at microwave frequencies, and explain why these devices are particularly suitable as switching elements in microwave circuits. **[20%]**

(ii) With the aid of a suitable circuit diagram, describe the principle of operation of a multi-bit, reflection-type phase shifter suitable for inclusion in a hybrid microwave integrated circuit. State one precaution that would need to be taken when implementing this type of device in an MMIC. **[30%]**

(C) Explain how the characteristics of a microstrip line can be measured using a ring resonator. What precautions should be taken to ensure an accurate result? What other method is available to measure the properties of a microstrip line? Compare the relative advantages and disadvantages of the two methods.

[50%]

Question B3 continues on the next page

Question B3 continued

(D) The following data apply to a surface penetrating radar:

Carrier Frequency = 5GHz

Height of antennas above ground = 100m

Gain of transmit and receive antennas = 18dB

Characteristic impedance of ground = 120Ω

Attenuation of ground = 8.5db/m

Receiver sensitivity = -60dBm

What is the minimum transmitted power required? How does this requirement change if rain increases the ground loss by 300%? Comment upon the result.

[50%]

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