UNIVERSITY OF SURREY

Department of Electronic and Electrical Engineering

MSc EXAMINATION

Module EEM.mwe

MICROWAVE ENGINEERING PRINCIPLES

Duration: 3 Hours | Autumn 2001/02

READ THESE INSTRUCTIONS

Answer **FIVE** questions

If you attempt more than **FIVE** questions, only your best **FIVE** answers will be taken into account.

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.

SECTION A

A1 (a) Define the terms *characteristic impedance*, *velocity factor*, *forward travelling wave*, *reflection coefficient*, and *return loss*, for wave propagation on a transmission line. **[30%]**

(b) A building is wired with coaxial cable having velocity factor 0.63. The cable is cut 17 metres from a time domain reflectometer (TDR) which emits a very short rectangular pulse. What is the time delay until the return of the reflection from the cut? **[30%]**

(c) See the figure below:

A shunt short circuit side cable of length 5 metres is added at a distance 9 metres from the TDR. The rest of the cable is undamaged and is now terminated at 17 metres with a matched load. Describe quantitatively, and draw, the pulse sequence seen on the TDR. **[40%]**

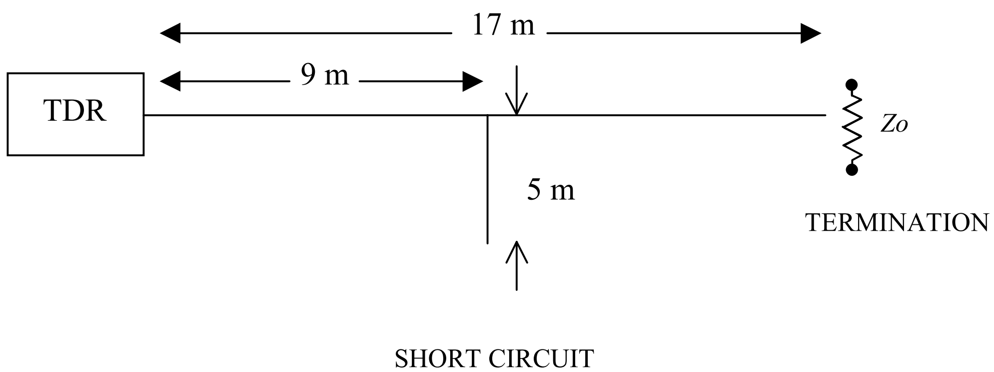

Figure A1

A2 (a) Describe with the aid of diagram, the electromagnetic boundary conditions at the interface between air and a perfect conductor. Define what is meant by the term *transverse electromagnetic wave*, and give a diagram showing the directions of propagation, electric field, and magnetic field in such a wave. Give another diagram showing the orientation of a stack of metal plates spaced an arbitrary distance apart which may be introduced into this transverse electromagnetic wave without disturbing it. Indicate the direction of the magnetic field. **[40%]**

(b) Describe how the electromagnetic boundary conditions are satisfied for wave propagation in a rectangular metal waveguide of cross sectional dimensions A metres by B metres, with $A > B$. If the large dimension A is 10 cm calculate the lowest possible mode cutoff frequency of this guide. **[30%]**

(c) A certain researcher proposes a scheme to make a waveguide for use over the frequency range 60 GHz to 90 GHz, using rectangular metal pipe filled with a substance of relative dielectric constant 5 at these frequencies. Suggest suitable waveguide dimensions, and calculate the guide wavelength at a frequency of 75 GHz. **[30%]**

A3 (a) Describe the construction and principles of operation of a waveguide dual directional coupler having coupling strength –20 dB and fractional bandwidth of 10% for use at X band frequencies. **[20%]**

(b) Explain how the coupling strength, at the centre frequency, may be altered. **[10%]**

(c) A –20dB coupler is used to sample the forward and backward wave amplitudes on a waveguide connected to an antenna. The detectors on the sampling arms consist of totally absorbing matched diode detectors which have accurate square law characteristics. Determine the ratio of output voltages on the detectors if the reflection from the antenna causes a VSWR of 2.6 on the main arm of the coupler. **[20%]**

Question A3 continues on the next page

SEE NEXT PAGE

Question A3 continued

(d) For the same system as part (c), a mismatch is introduced at each of the detector diodes, giving a reflection coefficient of magnitude 0.2. Estimate the ratio of output voltages at the detectors. **[30%]**

(e) Explain how the fractional bandwidth of the dual directional coupler may be increased to 50%. **[20%]**

A4 (a) Describe the *s*-parameter representation of the properties of a linear microwave 2-port circuit, giving the defining equations and also stating precisely which variables are related by the s-parameters. **[25%]**

(b) Derive formulas for the incoming and outgoing wave complex amplitudes in terms of the port currents and voltages. **[25%]**

(c) State, giving reasons for your choice, which microwave components are described by the following collections of s-parameters.

(i) $s_{11} = 0$ $\quad$ $s_{12} = \exp(-j6\pi)$

$s_{21} = \exp(-j6\pi)$ $\quad$ $s_{22} = 0$ **[15%]**

(ii) $s_{11} = 0.1\exp(-j\,\pi/4)$ $\quad$ $s_{12} = 0.2\exp(-j\,\pi/2)$

$s_{21} = 3.2\exp(-j\,\pi/2)$ $\quad$ $s_{22} = 0.2\exp(-j\,\pi/3)$ **[15%]**

(d) See Figure A4.A one-port circuit is created by taking a two-port device D, with generalised scattering matrix *S*, and adding a load to port 2 of D. The load has a complex reflection coefficient Γ. Derive an algebraic formula for the complex reflection coefficient seen looking into port 1 of D. **[20%]**

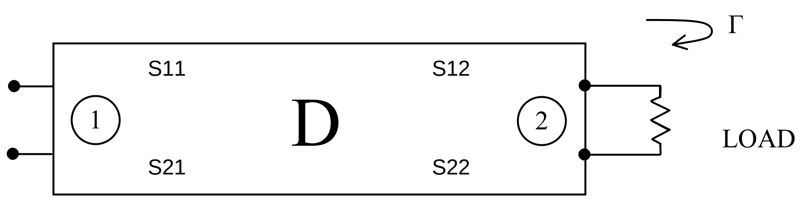

Figure A4

SECTION B

B5 For a low loss dielectric, which is non-magnetic and isotropic, the propagation constant γ and the intrinsic impedance η are given by the following expressions:

$\gamma = 2\pi k(0.5\tan\delta + j)$ and $\eta = j\omega\mu/\gamma$

where k, $\tan\delta$, ω and μ, have their usual meaning.

(a) Define the symbols k, $\tan\delta$, ω and μ, and give their units **[10%]**

If the dielectric is Perspex, having a relative permitting $\varepsilon_r = 2.6 - j0.018$, calculate the following parameters for the frequency of 10GHz:

(b) Q-factor **[10%]**

(c) Propagation constant **[20%]**

(d) Skin depth **[10%]**

(e) Thickness of a quarter-wave sheet **[10%]**

(f) Power attenuation in dB per wavelength **[20%]**

(g) Intrinsic impedance **[20%]**

B6 (a) What aspect of a diode current-voltage characteristic is important for applications in (i) mixing or detection of microwave signals, and (ii) generation of microwave power? In each case what features of the current voltage characteristic contribute towards the figure of merit of the devices? **[20%]**

(b) Draw diagrams and explain the operation of two solid-state diodes that can be used for mixing microwave signals and two solid state diodes for power generation. Give typical performance figures for the power generating devices. **[40%]**

(c) Explain, with diagrams, the advantages that heterojunctions bring to the performance of both field effect and bipolar transistors that are used in microwave circuits. Are there disadvantages in using heterojunctions? **[40%]**

B7 (a) Compare and contrast the hybrid and monolithic technologies for realising microwave integrated circuits **[30%]**

(b) Draw a block diagram of a low-noise down-converter for a domestic satellite TV receiver. For each block comment on the suitability for its implementation using monolithic technology. **[40%]**

(c) With the aid of a diagram describe an AlGaAs/GaAs heterojunction bipolar transistor HBT and draw its equivalent circuit model. If $C_{b'c'}$ = 66 fF, $R_{bb'}$ = 13 Ω and f_T = 31 GHz, calculate f_{MAX}. **[30%]**

B8 Write an essay, consisting of six or more substantive points, and including technical details and typical performance figures, for **one** of the following **[100%]**

(a) noise in microwave devices and systems

(b) microwaves as used for remote sensing,

(c) microwaves as used for ground probing radar

(d) microwaves ovens

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