



UNIVERSITY OF SURREY

Department of Electronic Engineering

MSc EXAMINATION

Module EEM.mwe

MICROWAVE ENGINEERING PRINCIPLES

Duration: 3 Hours

Autumn 2002/03

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.

2 Smith Charts are provided

SECTION A

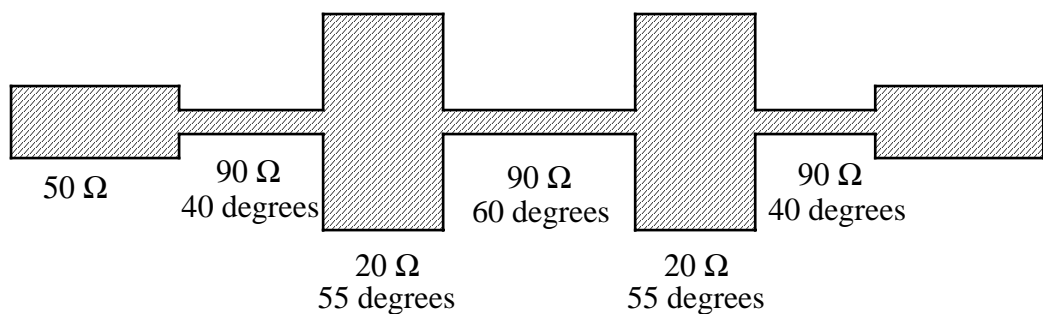
- A1** (a) Define the terms "*complex wave amplitude*", *reflection coefficient characteristic impedance*, *wave velocity*, and *velocity factor* for waves travelling on a transmission line. **[25%]**
- (b) Forward waves travel in the positive x direction. State how the forward wave complex amplitude depends on distance along the line. **[10%]**
- (c) State how the phase of the reflection coefficient depends on x . **[10%]**
- (d) Derive an expression for the reflection coefficient Γ' at $x = 0$ in terms of the reflection coefficient Γ at $x = L$. **[15%]**
- (e) A load impedance Z_L is connected to the transmission line having characteristic impedance Z_0 , at $x = L$. Write down expressions for Γ' and Γ and write an expression for the input impedance at $x = 0$. **[15%]**
- (f) A 10 metre length of coaxial cable has measured inductance 2083 nH and capacitance 833 pF on a LCR digital meter at a frequency of 10kHz. Estimate the characteristic impedance and velocity factor of this cable at microwave frequencies. **[15%]**
- (g) If the 10 m length of cable has insertion loss of 6dB at a certain frequency, estimate the maximum input impedance at this frequency if the cable is shorted at its far end. **[10%]**

- A2** (a) Write the formula for the guide wavelength and phase velocity of the TE₁₀ mode in a rectangular waveguide of internal dimensions a by b metres. Express your answers in SI units. **[10%]**
- (b) A certain rectangular waveguide has internal dimensions 0.010 metres by 0.022 metres. Suggest, giving reasons, which range of frequencies would be most appropriately covered by this guide. **[15%]**
- (c) Explain how waves might be launched in this guide using a coaxial cable to waveguide transition. Explain where on the two guide walls non-radiating slots may be cut. Sketch the construction of a tuned slotted line standing wave detector for this guide. **[25%]**
- (d) For this guide, enumerate the guide modes and their respective cutoff frequencies up to 25 GHz. Calculate the guide phase velocities at 20 GHz of the highest and lowest modes which will propagate at this frequency. **[35%]**
- (e) Explain how the applications of this guide would change if it were to be filled with solid dielectric of microwave relative permittivity $\epsilon_r = 7$. **[15%]**

- A3** (a) Explain what is meant by the term *scattering matrix* for a microwave N -port network. [15%]
- (b) Write down typical scattering matrices for the following microwave components:-
- (i) A length of lossless waveguide [10%]
- (ii) A perfect 3-port circulator [10%]
- (iii) A 20dB amplifier [10%]
- (iv) A -3dB dual directional coupler [10%]
- (c) Explain using a diagram how a circulator and filter tree structure may be used to combine the output of four high power amplifiers. [25%]
- (d) A certain 2-port network has the hypothetical \mathbf{S} -matrix
- $$\mathbf{S} = \begin{bmatrix} 0.1 & 0.2 \\ 0.3 & 0.4 \end{bmatrix}$$
- Determine the reflection coefficient on port 1 if the port 2 is short circuited. [20%]
- A4** (a) Explain, with the aid of a SMITH chart, how a short circuit stub may be used to generate any value of capacitance or inductance at a given frequency. Explain how the frequency-dependence of this reactance differs from that of a lumped component. [25%]
- (b) Using another SMITH chart diagram, explain the procedure for a single series stub match to an arbitrary load impedance Z_L . [25%]
- (c) A certain 50 ohm coaxial cable, with velocity factor 0.8, feeds a parallel combination of a 2 pF capacitor and a 100 ohm resistor. Design a shunt stub match using a length of open circuit cable at 1GHz. [40%]
- (d) Explain any advantages of a double stub match over the single stub equivalent. [10%]

SECTION B

- B5** (a) The microstrip lowpass filter in figure B5 has its element values given in terms of characteristic impedances and electrical lengths defined at the cut-off frequency. Calculate its physical dimensions for a substrate with $\epsilon_r = 10$ and $h = 0.635$ mm, for a cut-off frequency of 5 GHz and sketch the corresponding physical layout at a scale of 10 : 1 (use the information in the graphs for Z_0 and ϵ_{eff}). [50%]



Zo /ohms

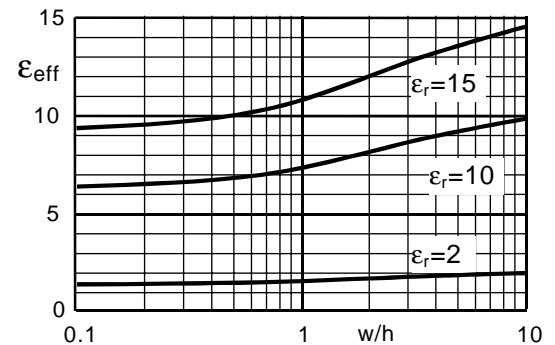
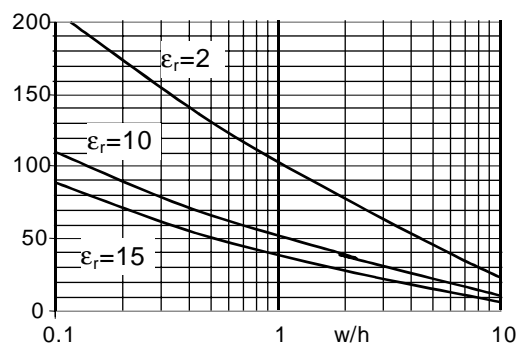


Figure B5

- (b) Write a Touchstone™-style network list for the filter in part (a). Put in as much information as you can. [25%]
- (c) Explain why there is a practical upper frequency limit for microstrip lines, and discuss methods that can be used to improve the performance of microstrip above 100 GHz. [25%]

- B6** (a) Draw the typical small-signal equivalent circuit of a GaAs MESFET. Briefly describe how each parameter relates to the physical structure of the device. **[30%]**
- (b) A “4 × 75” device (four fingers, with 75 microns unit gate width) has the equivalent circuit parameters shown in Table 1. Calculate the parameters you would expect from a 6 × 150 device. **[30%]**

L_g	0.02 nH	g_m	40mS	C_{gs}	0.3 pF	R_{ds}	350 Ω
R_g	2 Ω	C_{ds}	0.06 pF	R_I	8 Ω	R_s	2 Ω
C_{dg}	0.04 pF	L_s	0.05 nH	R_d	2 Ω		
		V_{ds}	3 V	V_{gs}	-0.5 V	I_{ds}	10 mA

Table 1

- (c) To obtain the highest output power from a FET structure, the gate width must be made large as possible. Explain in detail the factors which will ultimately limit this attempt to increase the power, and describe TWO methods which can be used to overcome these limits in a monolithic power amplifier. **[30%]**
- (d) Briefly explain the relevance of wide bandgap materials to microwave power amplifier technology. **[10%]**

SECTION C

C7 (a) What are the advantages of using MCM (Multichip Module) technology for the fabrication of microwave circuits? [20%]

(b) Explain the differences between the following classes of MCM:

MCM-L

MCM-D

MCM-C

Indicate briefly why MCM-C technology is attractive for microwave applications.

[30%]

(c) Discuss the physical principles that lead to the phenomenon known as *skin effect* and state two implications that skin effect has for the fabrication of planar microwave circuits. [30%]

(d) The interconnection tracks in a 10GHz microwave MCM are to be made of gold ($\rho = 2.25 \times 10^{-6} \Omega \text{ cm}$). Determine a suitable thickness for the track, giving reasons to support the answer.

(Note: permeability of free space = $4\pi \times 10^{-7} \text{ H/m}$)

[20%]

- C8** (a) Describe, with the aid of suitable diagrams, the construction and principle of operation of a cylindrical cavity magnetron. [40%]
- (b) The line driver circuit for a high power magnetron is shown in figure C8. Explain the operation of this circuit, using waveform diagrams to supplement the description. [25%]

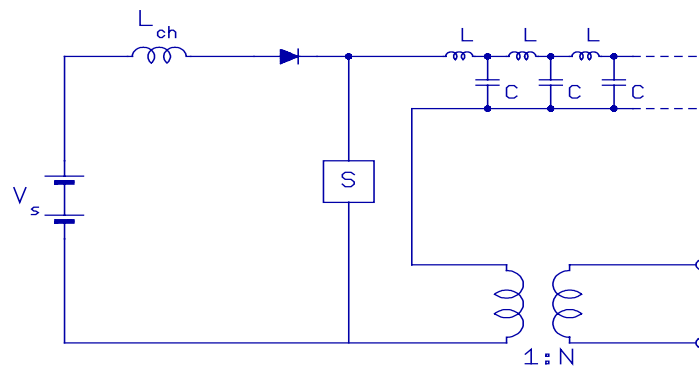


Figure C8

- (c) A line driver circuit of the form shown in figure C8 is to be used to power a magnetron source in a ground-scanning pulse radar system. The radar system requires a pulse duration of $1\mu\text{s}$ and a pulse period of 1ms . If the magnetron has a DC input impedance of 600Ω and requires an input pulse power of 1kW to give a satisfactory output, determine the required values of L_{ch} , L , C and N , given that the DC supply voltage (V_s) is 250V and that there are 20 sections in the artificial delay line. [35%]

Examiners: D.Jefferies
I.D.Robertson
C.Free

External Examiners: G.D. Smith
P.F.Lister