



UNIVERSITY OF SURREY

Department of Electronic Engineering

MSc EXAMINATION

Module EEM.mwe

MICROWAVE ENGINEERING PRINCIPLES

Duration: 2 Hours

Autumn 2003/04

READ THESE INSTRUCTIONS

Answer **THREE** questions, 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) Write notes on the following terms

uniform transmission line

propagation constant

reflection coefficient

scattering parameters

characteristic impedance

[25%]

(b) Evaluate the 1-port scattering parameter s_{11} for a lossy transmission line connected to a load of normalised impedance $z = 2+j3$. Give a value for s_{11} at the load, and also at the input to the transmission line which may be assumed to have a loss of 3dB for a single pass. **[25%]**

(c) Explain how a single short circuit shunt stub may be used to match an arbitrary load admittance to a lossless transmission line. Use the SMITH chart to illustrate your answer. **[25%]**

(d) A power splitter is constructed by connecting two outgoing coaxial 75 ohm cables in parallel to a single incoming 75 ohm cable. Determine the 3-port scattering matrix for this arrangement. Explain what modification would be needed to make $s_{11} = s_{22} = s_{33} = 0$, and comment on any disadvantages of your method for application as a power splitter. **[25%]**

- A2** (a) Derive the formula which relates the guide wavelength of the (m, n) mode in a rectangular waveguide of cross section dimensions (a, b) to the frequency and the dielectric constant of the material filling the guide. **[25%]**
- (b) A 2 metre length of X-band waveguide made of air-filled WG90 guide is excited with 10-cycle pulses of radiation at 10 GHz. Calculate the length of guide occupied by these 10-cycle pulses, and determine the transit time of one of the pulses along the guide. **[40%]**
- (c) Describe the construction of a hybrid tee four port dual directional coupler and state its typical properties with the aid of the 4-port S matrix description. Compare and contrast this form of a dual directional coupler with the multiple-hole parallel waveguide version. **[35%]**

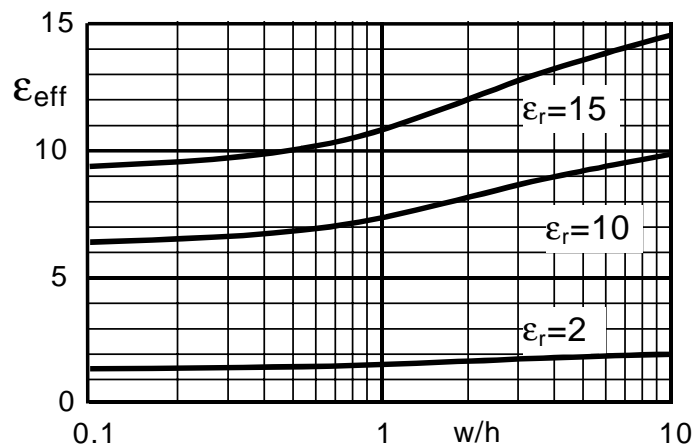
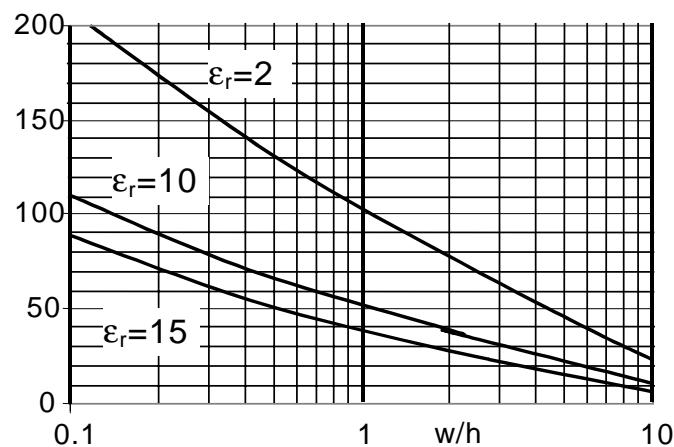
- B3** (a) Draw the schematic of a branch-line coupler and label the ports. Indicate the lengths and characteristic impedances required to achieve an equal power split.

[15%]

- (b) For a substrate with $\epsilon_r = 10$ and $h = 0.635\text{mm}$, use the graphs below to design a microstrip branch-line 3dB coupler operating at 5 GHz in a 50 Ohm system.

[40%]

Z_0 /ohms



- (c) Sketch your layout to scale, and draw a schematic diagram which includes all the discontinuity elements that should be modelled.

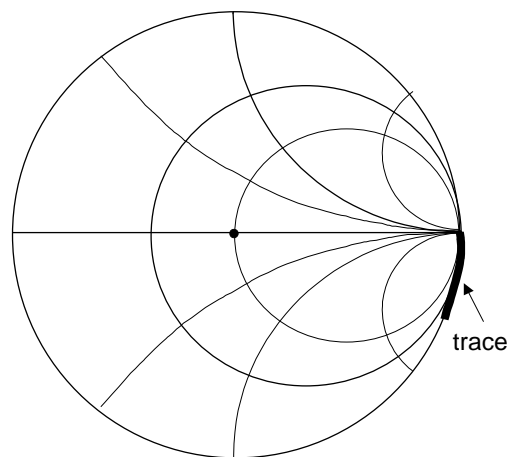
[20%]

- (d) Describe in detail the application of modern electromagnetic simulation software to the modelling of this type of component.

[25%]

SEE NEXT PAGE

- B4** (a) Describe in detail, with the aid of suitable diagram(s), why a directional coupler forms the basic core of a reflection coefficient measurement system. Explain why coaxial or stripline couplers are preferred to microstrip ones. **[30%]**
- (b) Draw the block diagram of a typical vector network analyser with an S-parameter test set. Describe the function of each component. **[40%]**
- (c) Describe the process by which the measurement system can be calibrated for one-port measurements using the “short-open-load” method, and explain why a sliding load is often required. **[20%]**
- (d) After carefully calibrating the network analyser with an APC3.5 calibration kit, the open-circuit standard is re-measured to verify the calibration, and the data trace below is obtained. Explain this result in detail.

**[10%]**

- C5** (a) The propagation constant for a low-loss dielectric that is non-magnetic is given by:

$$\gamma = 2\pi k(0.5 \tan \delta + j)$$

Define, and explain the practical significance of γ , $\tan \delta$ and k . **[15%]**

- (b) A 10GHz plane wave propagates through a semi-infinite block of low-loss LTCC dielectric that has a complex permittivity given by:

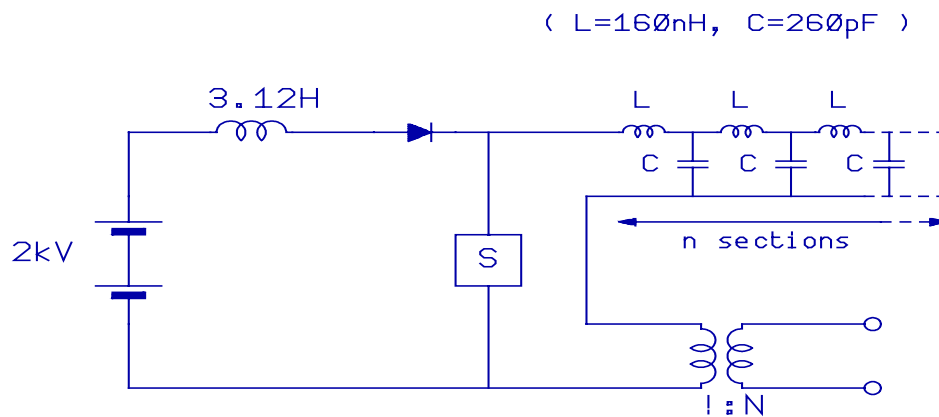
$$\epsilon_r = 7.8 - j0.005$$

Determine:

- (i) the loss tangent of the material **[10%]**
- (ii) the Q of the material **[5%]**
- (iii) the propagation constant **[10%]**
- (iv) the attenuation in dB/wavelength **[10%]**
- (c) Explain how you would measure the dielectric constant of a low-loss dielectric using a waveguide resonant cavity, and provide information on how you would design the cavity. The discussion should include reference to possible errors involved in the measurement, and the advantages of using a slit cavity. Also comment upon any constraints imposed by the sample size and the requirements for sample preparation. **[35%]**

Discuss how dielectric loss contributes to the total loss in a microstrip line. Provide some indication of the relative magnitudes of the sources of loss in a typical microstrip line, and indicate which source of loss you think is likely to become most significant at higher mm-wave frequencies. **[15%]**

- C6** (a) Figure Q2 shows the line driver circuit for a high-power magnetron.



- (i) The magnetron has an input impedance of 625Ω and a DC-RF conversion efficiency of 75%. There are 25 sections in the artificial delay line. Determine the power, duration and period of the RF pulse from the magnetron. [35%]
- (ii) Explain why, if the circuit were used to power a magnetron used in a pulse radar system, additional components would be needed for the pulse transformer. [15%]
- (b) Recent developments in materials technology, particularly in low-cost, high performance thick-film conductors and dielectrics, have made it possible to exploit multi-layer design techniques up to mm-wave frequencies. Give a critical discussion of the benefits of multi-layer fabrication techniques for the microwave circuit designer. Where appropriate, supplement the discussion with examples of practical materials and data. [50%]

Examiners: D.Jefferies
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