Strathmore UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

BEE 3202 TRANSMISSION LINES AND WAVEGUIDES

END OF SEMESTER EXAM

Date: 10th March, 2025 **Time:** 16:00-18:00 Hours

Instructions:

1. This Examination consists of **FOUR** questions
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.

QUESTION 1 (Compulsory) – 40 marks

a) Define the following transmission line parameters and explain their significance:
   i) Characteristic impedance (2 marks)
   ii) Propagation constant (2 marks)
   iii) Reflection coefficient (2 marks)
   iv) VSWR (2 marks)

b) A 50 Ω transmission line is terminated with a load of 100 Ω. Determine:
   i) The reflection coefficient. (3 marks)
   ii) The VSWR. (3 marks)

c) Explain the use of a Smith Chart to solve impedance-matching problems, and outline its advantages. (5 marks)

d) Explain the differences between waveguides and transmission lines, including:
   i) Geometry (2 marks)
   ii) Propagation modes (2 marks)
   iii) Frequency ranges (2 marks)
   iv) Power-handling capabilities (2 marks)
   v) Typical applications. (2 marks)

e) A rectangular waveguide has a length a = 4 cm and a width b = 2 cm. Calculate:
   i) The cut-off frequency for the dominant mode (TE_{10}). (4 marks)
   ii) The wave impedance at a frequency of 6 GHz. (4 marks)

f) Discuss the advantages of using waveguides for microwave signal transmission. (3 marks)

QUESTION 2 (Optional) – 30 marks

a) What is reflection coefficient and how is it significant in designing transmission lines? (2 marks)

b) Compare and contrast lumped and distributed element models for transmission lines in terms of structure and applications. (4 marks)

c) Define group velocity and phase velocity in wave propagation, and explain their relationship. (4 marks)

d) Calculate the characteristic impedance of a coaxial line which has an inner conductor radius of 1 mm and an outer conductor radius of 5 mm, filled with a dielectric of relative permittivity, $\varepsilon_r = 2$. (3 marks)

e) Describe how standing waves are formed in transmission lines and how they affect power delivery. (5 marks)

f) For a quarter wavelength long loss transmission line operating at a frequency of 2 GHz, with a characteristic impedance of 75 Ω and that is terminated with a 25 Ω load, calculate:
   i) The reflection coefficient (2 marks)
   ii) The return loss (2 marks)
   iii) The transmission coefficient (2 marks)
   iv) The phase constant (2 marks)
   v) The input impedance (4 marks)

QUESTION 3 (Optional) – 30 marks

a) Describe skin effect as a transmission line effect in terms of (i) where it originates from (ii) how it is quantified (iii) the properties of the conductor that it is dependent on. (6 marks)

b) A transmission line with a travelling wave at 3 GHz has the following transmission line equivalent circuit parameters: R=75 Ω/m; L=70nH/m; G=2 S/m and C=200 pF/m .
   i) Calculate the attenuation constant. (3 marks)

ii) What is the characteristic impedance of the line? (2 marks)

iii) What is the phase constant? (2 marks)

iv) What is the phase velocity? (2 marks)

v) If the physical length of the transmission line is 20 cm, what is the electrical length? (2 marks)

c) If a load impedance of 30 + j40 Ω terminates a 50 Ω transmission line that is 0.1λ long, using the provided Smith chart,

i) Clearly mark the point on the Smith chart that represents the normalized load impedance. (2 mark)

ii) Find both the magnitude and angle of the reflection coefficient at the load. (4 marks)

iii) What is the value of the Standing wave ratio? (2 mark)

iv) What is the Return loss? (2 mark)

v) What is the denormalized input impedance at the input of the transmission line? (3 marks)

QUESTION 4 (Optional) – 30 marks

a) Differentiate between TEM, TE, and TM modes in waveguides, highlighting their applications. (9 marks)

b) For a rectangular waveguide operates at 5 GHz with a length $a = 2\ cm$ and a width $b = 1\ cm$, determine:

i) The cut-off wavelength for the propagation mode TE_{11}. (4 marks)

ii) The mode of operation if the operating wavelength is 4 cm. (4 marks)

c) Discuss three practical limitations of waveguides in modern communication systems. (3 marks)

d) A circular waveguide with an internal radius of $r = 3\ cm$ operates at a frequency of 6 GHz.

i) Calculate the cut-off frequency for the TE_{11} mode. (4 marks)

ii) Determine if the TE_{11} mode propagates at 6 GHz. (3 marks)

iii) Explain the limitations of circular waveguides in practical applications. (3 marks)

The Complete Smith Chart

Black Magic Design