GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

B.Sc. Engineering Degree

Semester 7 Examination – July 2025

(Intake 39 – ET)

ET4153 – MICROWAVE ENGINEERING

Time allowed: 3 Hours   25th July 2025

ADDITIONAL DATA

- Speed of light, $c = 3 \times 10^8$ m/s

INSTRUCTIONS TO CANDIDATES

This paper contains 5 questions on 6 pages.

Answer all 5 questions.

This is **a limited open book examination. Handwritten notes, printed notes, and textbooks are permitted**. Mobile phones, tablets, electronic notes or media **are not allowed**.

This examination accounts for 70% of the module assessment.

The total marks attainable for this examination are 100. The marks assigned for each question and sections thereof are included in square brackets.

All questions carry equal marks.

All symbols, notations and abbreviations not defined have their usual meanings.

Illustrate your answer with clear sketches when appropriate.

Clearly state any assumptions and approximations made when applicable.

DETAILS OF ASSESSMENT

Learning Outcome (LO)	Questions that assess LO	Marks allocated (Total 100%)
LO1	Q1	20
LO2	Q2	10
LO3	Q2, Q3, Q4	20
LO4	Q3, Q4	20
LO5	Q4, Q5	30

This Page is Intentionally Left Blank

Question 1

(a) Using clear diagrams shows the typical electric and magnetic fields for cross sections of [10 marks]

i. a slotline
ii. a microstrip and
iii. a stripline

Based on the result comment on the typical loss of each substrate transmission line.

(b) A microwave antenna is found to have a temperature of 80 K. It is connected to an amplifier cascade with the noise figures and gains of the table given below with Stage 1 being the LNA and the ambient temperature being 300 K. [10 marks]

Stage	1	2	3
Noise Figure (dB)	1.9	1.2	1.2
Gain (dB)	29.3	13	13

Determine the system noise factor and noise temperature of the entire system.

Question 2

A conical horn antenna has feed and aperture diameters of 36 mm and 96 mm respectively. It has a length of 110 mm and aperture efficiency of 0.7. It is to be used for a communication link at 16.5 GHz. You are required to design, and 3D print a protective lens antenna cover for the conical horn. You may ignore the extinction length for all calculations.

(a) State two benefits and two drawbacks of using a lens antenna as a protective cover for a conical horn antenna as suggested. [04 marks]

(b) If the material used to fabricate the lens has a relative permittivity, ε_r of 2.4 determine the required thickness of the lens t. [05 marks]

$\eta = \sqrt{\varepsilon_r \mu_r}$

(c) When the thickness t is taken in millimeters it related to the absorption loss of the material in decibels according to

$$L_{dB} = 0.03t.$$

What is the absorption loss of the lens when a further 8 mm are added to t for a mounting plate? [02 marks]

(d) Determine the gain of the conical horn without the lens. [04 marks]

(e) If the lens increases the aperture efficiency of the horn by 0.9, determine the change of the gain once the lens antenna is connected to the aperture end of the conical horn antenna. [05 marks]

Question 3

(a) Briefly explain how isolation between the transmitting the receiving subsystems is achieved using a 4-port directional coupler. [08 marks]

(b) A solid-state microwave power amplifier consists of HEMT device connected to a source with an impedance of 45Ω and a load with an impedance of 61Ω. The 50Ω normalized scatter parameters for the device at 12 GHz are given by

$$S = \begin{pmatrix} 0.47\angle 105^\circ & 0.053\angle 0.9^\circ \\ 3.4\angle -20^\circ & 0.36\angle -120^\circ \end{pmatrix}$$

Determine,

i. The source reflection coefficient Γ_S and resulting power loss G_s. $|1-|\Gamma_s|^2$ [02 marks]
ii. The load reflection coefficient Γ_L and resulting power loss G_L [02 marks]
iii. The source to load voltage gain given by

$$G_V = \frac{s_{21}}{(1 - s_{11}\Gamma_S)(1 - s_{22}\Gamma_L) - s_{12}s_{21}\Gamma_L\Gamma_S}$$

[03 marks]

iv. The transducer power gain given by $G_T = G_S|G_V|^2 G_L$ [01 mark]
v. Stating the necessary assumptions, obtain the expression using the previous results and calculate the unilateral transducer power gain G_{UT} of the amplifier. [04 marks]

Question 4

(a) Show how the charge, electric current and magnetic field occurs during a cycle of a typical *symmetric split ring resonator* when excited by an external electric field. [04 marks]

(b) Briefly explain a benefit and a drawback of each of the following types of antennas
   i. The slot antenna [04 marks]
   ii. The patch antenna [04 marks]

(c) Figure Q4.1 shows the dimensions of a cylindrical dielectric resonator. The Kajfez and Guillon empirical formula for the resonance frequency of mode TE_{011} in gigahertz is given by

$$f_{GHz} = \frac{34}{d\sqrt{\varepsilon_r}}\left(\frac{d}{L} + 3.45\right)$$

Where $0.5 < \frac{d}{L} < 2$ and both d and L are in millimeters. The material used is barium titanate with $\varepsilon_r = 35$ and d = 6 mm.

i. If $L = 4$ mm, find the resonance frequency. [02 marks]
ii. When resonating, the bandwidth of the device is found to be 50 MHz. If so what is the Q value of the dielectric resonator? [02 marks]
iii. If d is kept at 6 mm, determine the minimum and maximum achievable resonance frequencies by varying L according to the Kajfez and Guillon formula. [04 marks]

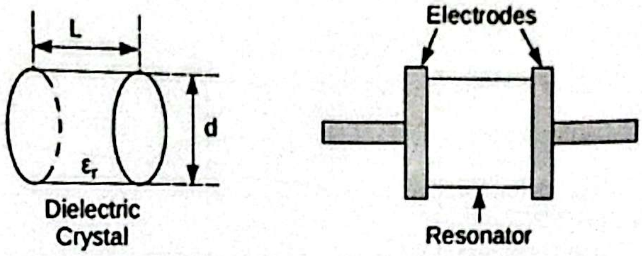

Figure Q4.1: Dimensions of a Dielectric Resonator

Question 5

Figure Q5.1 shows the plot of normalized D_λ and h_λ of an axial mode helical antenna for p = 0.70, p = 0.85 and p = 0.99. Of these values p = 0.85 is the nominal design value while p = 0.70 and p = 0.99 are extreme values that form the possible tolerance margin. Assume that the antenna operates at fundamental mode.

(a) What are the necessary normalized values of D_λ and h_λ for circular polarization? [02 marks]

(b) For the tolerance margin values of p = 0.7 and p = 0.99, determine the values of k and the resulting ratio $|E_x|/|E_y|$ of the realized helical antenna. [06 marks]

(c) If the frequency of operation of the antennas is 2.4 GHz, determine the antenna diameter D, pitch h and pitch angle α for circular polarization. [04 marks]

(d) What will be the feed impedance of the antenna according to the Krauss formula? [02 marks]

(e) Figure Q5.2 shows the transformer to be used to match the helical antenna to a 50Ω transmission line. If the width of either end of the transformer in terms of the required characteristic impedance z_0 is given by

$$w = t\left(\frac{120\pi}{\sqrt{\varepsilon_r}z_0} - 2\right)$$

Where t is the thickness of the dielectric with relative permittivity ε_r separating the conductor and ground plane. Determine the widths of either end of the required matching transformer if the thickness is 4mm and ε_r is 1.2. [06 marks]

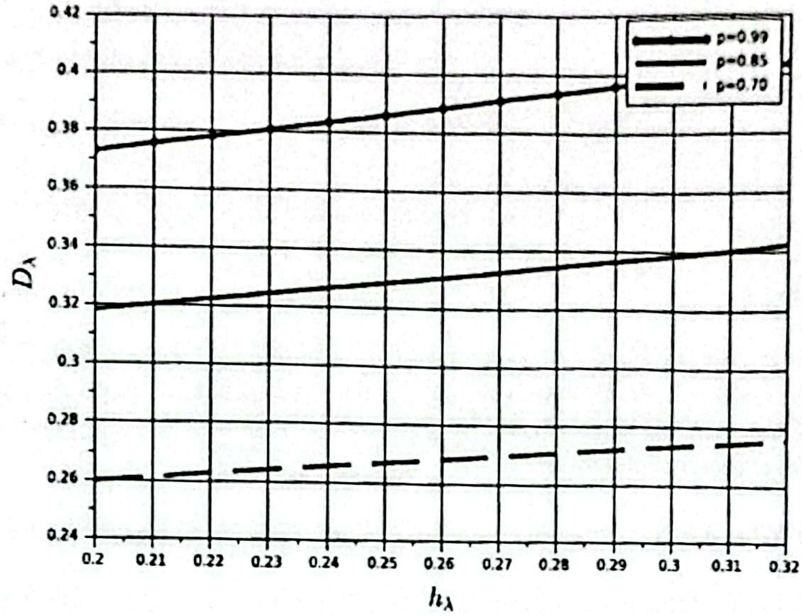

Figure Q5.1: Plot of Normalized D_λ and h_λ for Given p

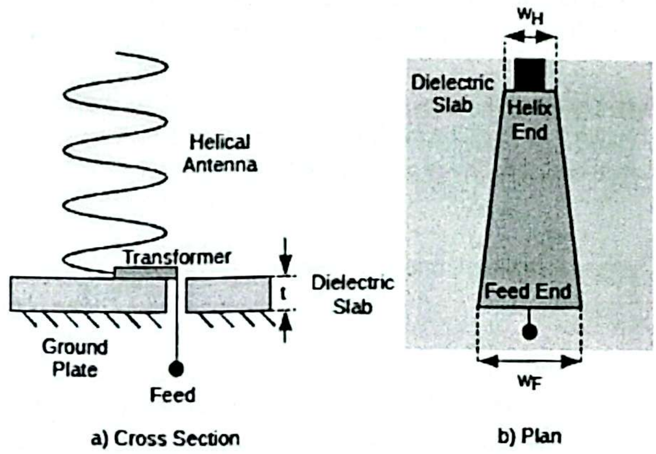

Figure Q5.2: Matching Transformer for the Helical Antenna

End of question paper