UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: EE5201 **Module Name: Communication Systems (C-23)**

[Three Hours]

[Answer **all questions,** each question carries **10 marks]**

Notes:

- **All notations have their usual meaning.**
- **Use the Smith Chart provided to answer Q1.**
- **State any assumption made in calculations clearly.**

Q1 a) A 50Ω transmission line is terminated with a load impedance of 50+j45Ω. Using the Smith Chart provided, answer the following questions. You are required to mark all relevant points on the Smith Chart and refer to these points in your written answers to support your explanations.

i) Mark the load impedance in the Smith Chart and find the reflection coefficient in polar form.

ii) Find the reflection coefficient and impedance at 0.15λ away from the load end of the line.

iii) Find the voltage standing wave ratio (VSWR) value of the line.

iv) Find the distance to the voltage maximum and minimum points from the load.

v) The load impedance is to be matched to the 75Ω line using a quarter wave transformer. Design the matching setup.

[6.0 Marks]

b) Briefly explain what is meant by susceptance cancellation in single-stub matching and how it is achieved, with reference to the Smith Chart.

[1.5 Marks]

c) Using your understanding of the Smith Chart, explain how the type of a load connected to a transmission line can be determined by observing the standing wave pattern in a plot of voltage magnitude versus distance from the load. Your answer should describe how the positions and spacing of voltage maxima and minima, as well as their shift relative to the load, can be used to infer the type of load impedance. Use appropriate sketches of the standing wave patterns for each load type to support your answer.

[2.5 Marks]

Q2 a) Answer the following questions based on your knowledge of transmission lines.

i) Why does the analysis of transmission lines transition from traditional lumped-element circuit theory to distributed-parameter theory at high frequencies or long line lengths?

ii) Why is the characteristic impedance of a transmission line is considered an intrinsic property of the line itself, while the input impedance depends on both the line and the load?

iii) Using the transmission line equations show that normalized impedance of the line inverts every $\lambda/4$ distance.

[6.0 Marks]

b) A transmission line has the following primary constants:

R = 0.2 Ω/m, G = 0.005 S/m, L = 0.25 μH/m, C = 80 pF/m.

The operating frequency is 3 GHz. Answer the following questions using the relevant transmission line equations.

i) Calculate the characteristic impedance Z_0 of the line at 3 GHz.

ii) The line is terminated with a load impedance Z_L= 15 + j30 Ω at 3 GHz. Determine the reflection coefficient Γ at the load end of the line, and at a point 15 cm from the load (toward the generator).

[4.0 Marks]

Q3 a) Waveguides are widely used for signal transmission at high frequencies. Answer the following questions based on your knowledge of rectangular waveguides.

i) Why are waveguides preferred over transmission lines at high frequencies?

ii) Explain why the TE_{10} mode is called the dominant mode in a rectangular waveguide.

iii) Define guided wavelength and explain how it differs from free-space wavelength.

iv) Why is single-mode operation preferred in rectangular waveguides? Discuss the limitations of multimode propagation.

[4.0 Marks]

b) A rectangular waveguide has dimensions a = 2.5 cm and b = 1.2 cm. The waveguide operates at a frequency of 14 GHz in the TE mode.

i) Determine which modes will propagate at the operating frequency.

ii) For the dominant mode, calculate:

- Free-space wavelength
- Cutoff wavelength
- Guided wavelength

iii) To ensure single-mode operation at 14 GHz, determine the maximum allowable value of $\boldsymbol{b}$ such that higher-order modes are not excited. Briefly justify your answer.

[6.0 Marks]

Q4 a) Briefly explain the following parameters relevant to antennas.

i) Radiation pattern

ii) 3dB Beamwidth

iii) Gain

iv) Polarization

[2.0 Marks]

b) The normalized radiation intensity of an antenna is expressed as

$$U(\theta) = \cos^4 \theta$$

Calculate the half-power beamwidth (HPBW), beamwidth between first nulls (BWFN), and the antenna gain (assuming pencil-beam type antenna).

[4.0 Marks]

c) Multipath propagation can act both as a source of degradation and as a means of performance enhancement in wireless communication systems. Discuss this statement with suitable explanations.

[1.5 Marks]

d) Discuss the effect of atmospheric refraction on radio wave propagation and show how it leads to an extension of the radio horizon compared to the visual horizon.

[1.5 Marks]

e) Explain how frequency and conductivity impact ground wave propagation.

[1.0 Mark]

Q5 a) Compare LEO and GEO satellite systems for rural broadband access, focusing on latency, data rates and coverage. Explain why LEO constellations are generally more suitable for modern user requirements.

[2.0 Marks]

b) Draw and explain the block diagram of a basic satellite transponder that operates as a repeater. Clearly describe the function of each major component in the transponder chain.

[2.0 Marks]

c) In modern warfare scenarios involving high-speed missiles and drone swarms, radar systems must accurately detect and distinguish multiple targets. Explain the concepts of range resolution, maximum unambiguous range, and pulse repetition frequency (PRF) in pulsed radar systems, and discuss their interrelationships in such environments.

[2.0 Marks]

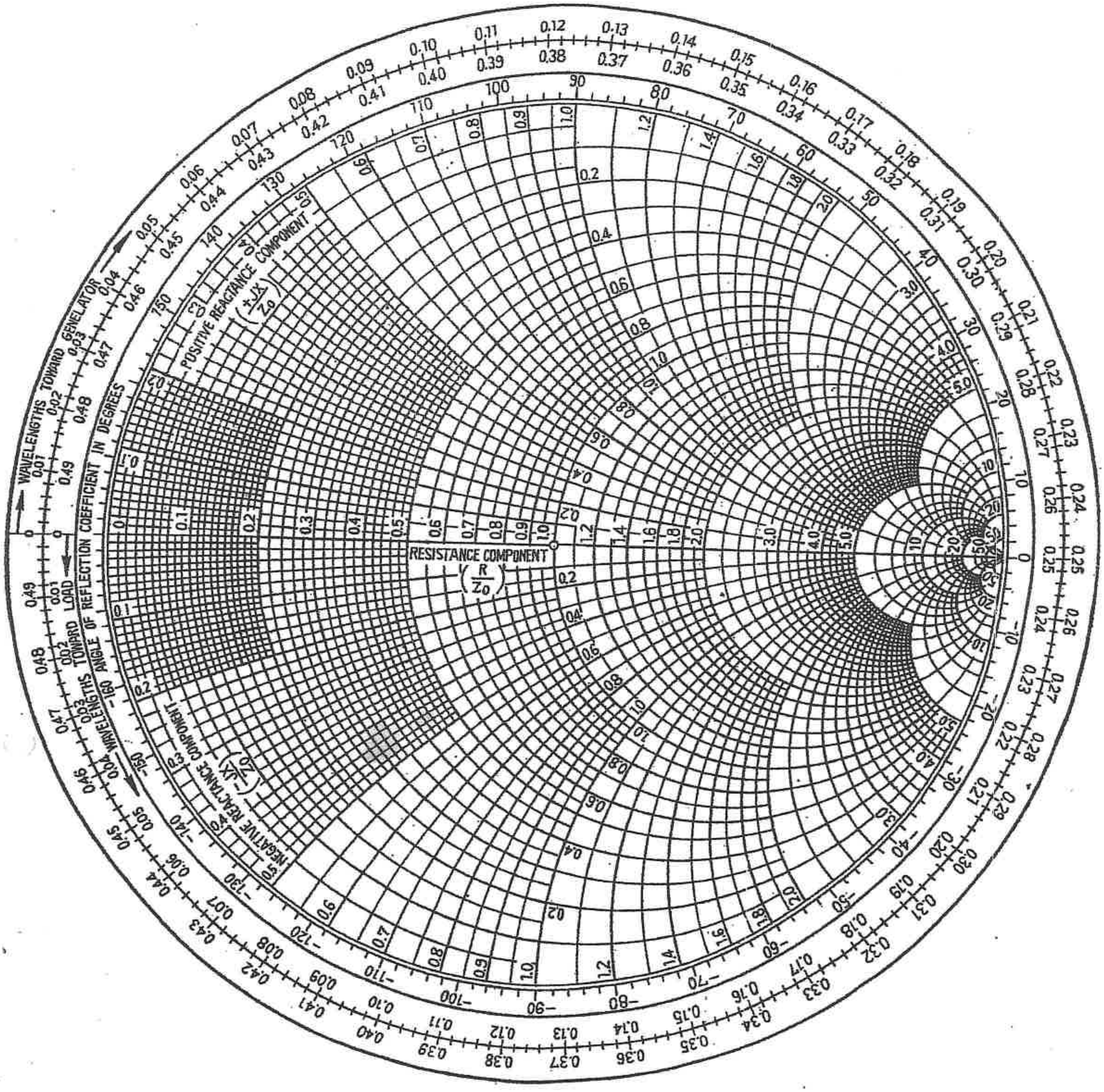
d) A radar system operates with a transmitted power of 1 MW, antenna gain of 30 dB, operating wavelength of 0.03 m, and a minimum detectable signal of 10^{-13}W. A stealth aircraft is present in the coverage area.

i) Assume a bistatic scenario where distance from the transmitter to the target is 40 km, and from the target to the receiver is 30 km. The radar cross-section of the target for this configuration is 5 m^2. Calculate the received power at the receiver and determine whether the target can be detected.

ii) Now consider a single radar unit operating with the same transmitted power and antenna gain (1 MW, and 30 dB). The target is located at 35 km, and its radar cross-section for this configuration is 0.1 m^2. Calculate the received power and determine whether the target is detectable.

iii) Compare the results obtained in parts i) and ii) and explain why the detection performance differs for the two configurations, particularly for a stealth aircraft.

[4.0 Marks]



The Smith Chart