ETE 307 Microwave and Antenna Engineering

Question Analysis

2023,2022,2021 self study, 2021, 2021

Section	Topic	No. of sets	Probable Question Sets	Question Types
A	H.F. Transmission Lines	2	Q.1, Q.2, Q.3	Numerical problems (Γ, S, Z_{in} etc.), Smith Chart usage, explanation of quarter-wave transformers, significance of VSWR/reflection coefficient.
A	Wave Guides	1	Q.3, Q.4	Numerical problems (modes, cut-off frequency), explaining advantages over transmission lines, why TEM mode is not possible.
A & B	Microwave Tubes	1	A: Q.4; B: Q.5, Q.6	Explaining the operation of Klystrons and Magnetrons with diagrams, concept of velocity modulation.
B	Solid State Microwave Devices	1	Q.7, Q.8	Explaining the Gunn effect and operation of Gunn diodes, short notes on IMPATT, BARITT, TRAPATT diodes.
B	Antenna Fundamentals	1	Q.5, Q.6	Explaining how antennas radiate, defining radiation patterns, explaining near/far field regions.
B	Antenna Parameters	1	Q.6, Q.7, Q.8	Mathematical proofs (radiation from time-varying current), numerical problems (directivity, gain, HPBW, FNBW).
B	Analysis of Different Antenna Types	1	Q.6, Q.8	Explaining the construction and operation of Yagi-Uda and Rhombic antennas, questions on antenna arrays.

Section A

H.F. Transmission Lines

- Lumped-Element Circuit Model
- Field Analysis
- Terminated Loss-less Transmission Lines
- Characteristic Impedance
- Reflection Coefficient
- VSWR (Voltage Standing Wave Ratio)
- Return Loss
- Smith Chart (Annapurna + Sadiku Book examples)
- Quarter-Wave Transformers
- Generator and Load Mismatches
- Impedance Matching and Tuning
- Lossy Transmission Lines

Q.1(a) What do you understand by lumped and distributed parameters? Explain briefly. **05**

(b) What is transmission line? When should transmission line effects be considered and when may be ignored? **08**

Q.2(a) Discuss the reflection coefficient and standing wave ratio for- **12**

i) Shorted line
ii) Open circuited line
iii) Matched line

(b) A telephone line has, $R = 30\Omega/km$, $L = 100\,mH/Km$, $G = 0$, and $C = 20\mu F/km$ at $f = 1KHz$, obtain **12**

i) The characteristic impedance of the line $\frac{R}{L} \neq \frac{C}{G}$
ii) The propagation constant
iii) The phase velocity

(c) Explain why impedance matching is necessary. Briefly explain quarter-wave impedance transformer. **11**

Q.4(a) A $100 + j150\Omega$ load is connected to 75Ω lossless line. Find the

i) Γ
ii) S
iii) The total admittance, Y_L
iv) Z_{in} at 0.5λ from the load
v) The locations at V_{max} and V_{min} w.r.to the load if the line is 0.8λ long.
vi) Z_{in} at generator.

Use Smith Chart to solve.

(c) Why smith chart is inverted? Briefly discuss about smith chart.

Q.3(a) A load of $100 + j150\Omega$ is connected to a 75Ω lossless line. Find **18**

i) Γ

ii) S

iii) The load admittance, Y_L

iv) Z_{in} at 0.4λ from the load

v) The location of V_{max} and V_{min} with respect to the load if the line is $0.6\,\lambda$ long

vi) Z_{in} at the generator

Q2. (a) "Microwave transmission line can be considered as a low-pass filter" – Justify the statement. (07)

(b) What is characteristic impedance of microwave transmission lines? The mathematical expression of the characteristic impedance of microwave transmission line is $Z_o = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$ where the symbols have their usual meaning. Explain the role of all parameters (R, L, G, C) on the characteristic impedance of transmission line. (13)

(c) "A lossless line is a distortion less line, but a distortionless line is not necessarily lossless." – Explain it. (08)

(d) Explain why microwave transmission line is not suitable for high frequency transmission. (07)

(b) Show that, the characteristics impedance of a microwave transmission line is $Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$; where the symbol have their usual meaning. 23

Q3. (a) Discuss about the reflection coefficient and standing wave ration for the following condition, (10)

(i) Shorted circuited load

(ii) Open circuited load

(iii) Matched load.

(b) A load of $100+j150\Omega$ is connected to a 75Ω lossless line. Find (18)

(i) Reflection coefficient Γ

(ii) Standing wave ratio S

(iii) the load admittance Y_L

(iv) the location of V_{max} and V_{min} with respect to the load if the line is 0.6λ long

(v) Z_{in} at generator.

Use smith chart for calculation and also confirm it by standard calculation.

(c) Write a short note on Quarter wave impedance transformer. (07)

(b) How do transmission lines are used for load matching using a quarter wave transformers. Demonstrate it. 1

Q.1(a) What do you understand by Microwave Engineering? Discuss the blessings of microwave engineering in everyday life. **10**

Q.1(b) What is a transmission line? Explain why microwave transmission line parameters are considered as distributed? **10**

Q.1(c) Find the mathematical expression for the input-impedance for a transmission line. **15**

Q.1(a) What do you understand by Microwave Engineering? In brief talk the blessings of microwave engineering in everydaylife. 10

(b) Enumerate the basic advantages of Microwave. 07

(c) Why are S-parameters used at microwave frequencies explain. Give the properties of S-parameters. 09

(d) Characterize skin effect and its impact on high frequency signal transmission. 11.5

Q.2(a) "Transmission line can be considered as a low-pass filter"- Justify. **05**

Q.2(b) What is the significance of reflection co-efficient and standing wave ratio? Explain both for- **10**

i) Short-circuited load
ii) Open-circuited load
iii) Matched condition

Q.2(c) Why are S-parameters used at microwave frequencies? Explain the properties of S-parameters. **10**

Q.2(d) Define characteristics impedance and input impedance of microwave transmission line with mathematical expression. **10**

Q.1(a) Explain why DC is not suitable for wireless communication. 05

(b) What is VSWR? Why do we need it? 10

(d) Define characteristic impedance and input impedance of microwave transmission line. 08

Wave Guides

- Guided Electromagnetic (E.M) Waves
- Propagation in:
  - Parallel-Plate Wave Guides
  - Rectangular and Circular Wave Guides
- Dominant and Degenerate Modes
- Field Patterns
- Cavity Resonators

(c) Explain the working principle of microwave oven. Also explain how you can measure the frequency of microwave oven when you have only a measuring tape. **22**

(rectangular waveguide)

Q.4(a) Mention the advantages and disadvantages of waveguide over transmission line. **08**

(b) Explain why TEM mode is not possible for waveguide. **05**

(c) A rectangular waveguide with dimensions a=2.5cm, b=1cm is to operate below 12.1GHz. How many TE and TM modes can the waveguide transmit if the guide is filled with a medium characterized by $\sigma = 0, \epsilon = 4\epsilon_0, \mu_r = 1$? **12**

Q.4(a) What do you understand by waveguide? Mention the advantages of waveguide over microwave transmission line. 08

(b) Draw the field configuration of TM_{21} mode. TM_{10} and TM_{01} are not possible. – Justify. 07

(c) A rectangular waveguide with dimensions a=2.5 cm, b=1 cm is to operate below 18.1 GHz. How many TE and TM modes can the waveguide transmit if the guide is filled with a medium characterized by $\sigma = 0, \epsilon = 4\epsilon_0 and\ \mu_r = 1$? Calculate the cut off frequencies of the modes. 2(

Q.2(a) Find if there is any difference between a transmission line and waveguide and explain it. 7.5

(b) Discuss TM,TE and TEM mode. 10

(c) A rectangular waveguide with dimensions a=2.5cm, b=1cm is to operate belowe 15.1 GHz. How many TE and TM modes can the waveguide transmit if the guide is filled with a medium characterized by σ=0, $\varepsilon=4\varepsilon_0$, μ_r=1. Calculate the cutoff freauencies of the modes. 20

(c) Explain how can you replace a waveguide with a filter. **05**

Q4. (a) Waveguides are not suitable for low-frequency transmission – Explain. (07)

(b) With necessary diagram, explain TEM, TE, TM and HE mode. (08)

(c) Explain the wave propagation through a waveguide with proper illustration. (10)

(d) In a rectangular waveguide for which a = 1.5 cm, b = 0.8 cm, σ = 0, $\mu = \mu_0$ (10)

and $\varepsilon = 4\varepsilon_0$

$$H_x = 2\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\sin(\pi \times 10^{11}t - \beta z)\ \text{A/m}$$

...mine

(i) The mode of operation

(ii) The cutoff frequency

(iii) The phase constant β

(iv) The propagation constant γ

(v) The intrinsic wave impedance η

Hint: $\beta = \omega\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$

$$\eta_{TM_H} = \eta'\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

Q.3(a) What do you mean by dominant mode in a waveguide? **05**

Q.3(b) Define rectangular and circular waveguide. Mention the advantages and disadvantages of waveguides. **15**

Q.3(c) An air-filled rectangular waveguide of dimensions $7 \times 3.5\ cm$ inside operates in the dominant TE_{10} mode. **15**

i) Find the cutoff frequency.
ii) Determine the phase velocity of wave in the guide at a frequency of $3.5\ GHz$.
iii) Determine the guided wavelength at the same frequency.

Microwave Tubes

- Microwave System Overview
- Classification of Tubes
- Klystron Amplifier
- Reentrant Cavities
- Velocity Modulation
- Space Charge Wave
- Multi-cavity Klystron Amplifier
- Reflex Klystron Oscillator
- Magnetron
- Travelling Wave Tube (TWT) Amplifier
- Backward Wave Oscillator (BWO)
- Waveguide Components

Q.4(b) Define ring loop and ring bar Travelling wave tube.

(d) Mention some applications of magnetron with necessary diagram. Explain the operation of two-cavity klystron. **15**

(b) What is velocity modulation? Explain how it is achieved. **07**

(b) Mention the microwave radiation effect on human. **07**

Q1. (a) Mention the properties of microwave signal. Explain why cellular communication is interrupted during rain drops. (10)

(b) Microwave radiation has some bad effect on human and living body. Mention some of them. Despite these effects, why microwave communication is still popular? (10)

(c) Microwave oven has three major components: Magnetron, waveguide and turn table. Explain the basic operation of microwave oven. In addition, explain how you can measure the operating frequency of microwave oven without frequency measuring device. (15)

Q5. (a) With neat sketch, explain the operation of basic magnetron oscillator. (12)

(b) A two-cavity klystron operates at 5 GHz with a dc beam voltage of 10kV and a 2mm cavity gap. For a given input RF voltage, the magnitude of the gap voltage is 100 volts. Calculate the transit time at the cavity gap, the transit angle, and the velocity of the electrons leaving the gap. (15)

(c) "ATTD provides negative resistance at microwave frequency." – Justify. (08)

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Q.3(a) Describe the limitations of conventional microwave tubes in microwave applications. 7.5

(b) With neat sketch illustrate velocity modulation process of electron. 12

(c) A two-cavity klystron operates at 5GHz with a dc beam voltage of 10kV and a 2mm cavity gap. For a given input RF voltage, the magnitude of the gap voltage is 100Volts. Calculate the transit time at the cavity gap, the transit angle, and the velocity of the electrons leaving the gap. 18

Section B

Solid State Microwave Devices

- Gunn Diode
- Energy Band Structure
- Gunn Oscillator
- Modes of Gunn Oscillator
- Applications of Gunn Diode
- Solid State Devices as Microwave Amplifier and Oscillator

Q.7 (a) Differentiate between p-n junction diode and tunnel diode? **10**

(b) What is the significance of negative resistance? **05**

(c) Briefly explain the background story of the invention of TED. **10**

(d) With necessary diagram, explain Differential negative resistance. **10**

Q.8 (a) What is Gun effect? Explain with necessary diagram. **20**

(b) With necessary diagram, explain Two-Valley Model theory. **15**

(c) "ATTD provides negative resistance at microwave frequency." – Justify. (08)

Q6. (a) Differentiate between Schottky diode and p-n diode. (10)

(b) Illustrate the physical structure and operational mechanism of PIN diode with neat sketch. (13)

(c) Briefly explain IMPATT diodes, BARITT diodes, and TRAPATT diodes. (12)

Antenna Fundamentals

- Types of Antennas and Their Applications
- Radiating Field Regions
- Radiation Pattern:
  - Isotropic
  - Directional
  - Omni-directional

Q8. (a) Describe the various methods of feed mechanism in microstrip patch antenna. (10)

(c) "Linear and circular polarization are the special case of elliptical polarization." – Justify it. (07)

(d) Find the HPBW and FNBW, in radians and degrees, for the following normalized radiation intensities: (08)

(i) $U(\theta) = \cos(2\theta)$

(ii) $U(\theta) = cos^2\theta$

Q.5 (a) "DC is not suitable for wireless communication" -Explain why. **08**

Q.6(a) "Antennas are the vital element of wireless communication." Justify. **10**

Q.6(b) A mobile transmitter is located $10m$ above roof of Bangabandhu hall, transmitting $2W$ power uniformly. Calculate the received power. The strength of mobile phone located in the central playground with a gain of $3dB$, $260\ m$ apart in the earth surface from the hall. **10**

Q.6(a) With the help of neat block diagram explain how the gain of the antenna is measured.

(b) Why wirelesses power representation by solid angle is better suited?

(c) Explain different field regions associated with antenna.

(d) Calculate the reduction in antenna length when 15kHz modulating signal is modulated by 1GHz carrier.

Q.7(a) Explain front feed and cassegrain feed with appropriate figure.

(b) Derive the relationship of maximum directivity and maximum effective area of antenna in receiving mode.

Q.5(a) Define antenna. Explain how antenna radiates.

Q.5(b) Explain near field and far field regions of an antenna.

Q.5(c) Discuss between power gain and directive gain.

Q.7(a) State the radiation pattern of an antenna. With a neat sketch, explain omnidirectional radiation pattern of antenna. **10**

Q.7(b) Prove mathematically, "To create radiation there must be time varying current should exist." **15**

Q.7(c) What is the duality principle of radiation? **10**

Q.5(a) What do you understand by radiation pattern? Draw the two dimensional normalized field pattern and power pattern in linear scale.

(b) "Antenna are the vital elements of wireless communication"-Justify the statement.

(c) Demonstrate the typical changes of antenna amplitude pattern in different antenna field region.

Radiation Concepts & Parameters

- Radiation Patterns
- Radiation Power Density
- Radiation Intensity
- Beamwidth
- Directivity
- Antenna Efficiency and Gain
- Polarization
- Vector Effective Length
- Effective Aperture
- Equivalent Circuit Model and Corresponding Parameters
- Friis Transmission Equation
- Mathematical Formalism for Far Field Analysis

(c) With necessary diagram, explain how antenna radiates. **10**

Q7. (a) "The existence of a time-varying current is a necessary condition for the occurrence of radiation." – Demonstrate it mathematically. (12)

(b) The radial component of the radiated power density of an antenna is given by (12)

$$W_{rad} = \widehat{a_r} A_o \frac{\sin\theta}{r^2} \quad (\text{w/m}^2)$$

where A_o is the peak value of power density. Find the radiation intensity and the maximum directivity of the antenna. Also, write an expression for the directivity as a function of the directional angles θ and ϕ.

(c) Show that, "The antenna gain is $G_o(dB) = 10\log_{10}(e_{cd}D_o)$". The symbols have their usual meaning. (11)

Q.5(a) Define

i) Radiation pattern
ii) FNBW
iii) Radiation lobe
iv) Omnidirectional antenna
v) Gain

(b) Prove that, average radiated power by an antenna is,

$$P_{rad} = 1/2 \oiint_{s} Re(E \times H^{*})ds$$

(c) What is polarization of waves? With mathematical expression and necessary diagram, explain linear and elliptical polarization. 12

Analysis of Different Antenna Types

- Yagi-Uda
- Dipole
- Monopole
- Rhombic
- Horn
- Frequency Independent
- Lens
- N-element array antenna

(d) Write a short note on microstrip antenna. **10**

(b) Explain the principle of operation and the key elements of a Yagi-Uda antenna. Provide a labelled diagram to aid your explanation. (10)

Q.6 (a) What is smart antenna? Why smart antenna systems can said to be an extension of cell sectoring? **10**

(b) Into how many different categories can DOA estimation techniques can be classified? Explain briefly. **10**

(c) How many categories are there in monopulse radar system techniques? If you have four element –array antenna and the signal arrival angle is theta (θ), how would you determine the angle of incoming signal (Derive the mathematical equation)? **10**

(d) What are the key differences between MUSIC and ESPRIT? **05**

Q.8(a) What is meant by antenna arrays? Explain its various forms that are used in practice. **10**

Q.8(b) What do you mean by Rhombic antenna? Explain how unidirectional pattern is obtained in properly terminated Rhombic antenna. **15**

Q.8(c) What is Yagi-Uda antenna? What are its advantages? Explain how you can design Yagi antenna for 450 MHz. **10**

(c) Write down the advantages of microstrip patch antenna. Also mention its application.

Q.8(a) Explain the construction of log periodic antenna.

(b) Write a short note on frequency independent antenna.

(c) Explain about antenna miniaturization techniques.

(d) Write down the principles of Yagi-Uda array. Describe its construction, operation and field pattern.

Q.6(c) A lossless horn antenna with 74Ω is connected to a 50Ω transmission line. Find the absolute gain where antenna pattern is $U = B\sin^3\theta$. **15**

12.5

Q.6(a) Define antenna arrays and it's various forms used in practice. 25

(b) Find total electrical field of two isotropic point sources arrays with equal amplitude and phase and sketch the field pattern.

12.5

(b) Illustrate the expression of beam width for broad side array and end fire array.