# Techno India NJR Institute of Technology

# Course File

# Session 2021-22

# Microwave Theory & Techniques(5EC4-05)

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**Department of ECE**

For Techno India NJR Institute of Technology
पंकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

# RAJASTHAN TECHNICAL UNIVERSITY, KOTA

**SYLLABUS**

**III Year - V Semester: B.Tech. (Electronics & Communication Engineering)**

## 5EC4-05: Microwave Theory & Techniques

**Credit: 3** **Max. Marks: 150(IA:30, ETE:120)**

**3L+0T+0P** **End Term Exam: 3 Hours**

| SN | Contents | Hours |
|---|---|---|
| 1 | Introduction: Objective, scope and outcome of the course. | 1 |
| 2 | Introduction to Microwaves-History of Microwaves, Microwave Frequency bands; Applications of Microwaves: Civil and Military, Medical, EMI/ EMC. | 4 |
| 3 | Mathematical Model of Microwave Transmission-Concept of Mode, Features of TEM, TE and TM Modes, Losses associated with microwave transmission, Concept of Impedance in Microwave transmission. | 5 |
| 4 | Analysis of RF and Microwave Transmission Lines-Coaxial line, Rectangularwaveguide, Circular waveguide, Strip line, Micro strip line. | 4 |
| 5 | Microwave Network Analysis-Equivalent voltages and currents for non-TEMlines, Networkparameters for microwave circuits, Scattering Parameters. | 4 |
| 6 | Passive and Active Microwave Devices-Microwave passive components: Directional Coupler, Power Divider, Magic Tee, Attenuator, Resonator.Microwave active components: Diodes, Transistors, Oscillators, Mixers.Microwave Semiconductor Devices: Gunn Diodes, IMPATT diodes, Schottky Barrier diodes, PIN diodes.Microwave Tubes: Klystron, TWT, Magnetron. | 6 |
| 7 | Microwave Design Principles-Impedance transformation, Impedance Matching, Microwave Filter Design, RF and Microwave Amplifier Design, Microwave Power Amplifier Design, Low Noise Amplifier Design, Microwave Mixer Design, Microwave Oscillator Design. Microwave Antennas- Antenna parameters, Antenna for ground based systems, Antennas for airborne and satellite borne systems, Planar Antennas. | 6 |
| 8 | Microwave Measurements-Power, Frequency and impedance measurement at microwave frequency, Network Analyzer and measurement of scattering parameters. Spectrum Analyzerand measurement of spectrum of a microwave signal, Noise at microwave frequency and measurement of noise figure. Measurement of Microwave antenna parameters. | 6 |
| 9 | Microwave Systems-Radar, Terrestrial and Satellite Communication, Radio Aidsto Navigation, RFID, GPS. Modern Trends in Microwaves Engineering- Effect of Microwaves on human body, Medical and Civil applications of microwaves, Electromagnetic interference and Electromagnetic Compatibility (EMI & EMC), Monolithic Microwave ICs, RFMEMS for microwave components, Microwave Imaging. | 6 |
| | **Total** | **42** |

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## Course Overview:

Student will learn fundamentals of Microwave theory and techniques from this 40-hour course. In this course, student will study the fundamental concepts and application of different microwave devices and systems. Also, they will learnto design different microwave devices like amplifier, oscillator, mixer etc. used in various communication applications.

## Course Outcomes:

| CO.NO. | Cognitive Level | Course Outcome |
|---|---|---|
| 1 | Knowledge | Explain the working of rectangular waveguides in different modes. |
| 2 | Comprehension | Evaluate impedance , admittance ,current gain and voltage gain using different types of parameters. |
| 3 | Application | Illustrate the working of microwave passive components. |
| 4 | Analysis | Calculate microwave measurements such as VSWR ,power measurements etc. |
| 5 | Analysis | Analyze the basic knowledge of the parameters related to the Microwave and RF. |
| 6 | Synthesis | Synthesize the Microwave semiconductor devices and their working. |
| 7 | Synthesis | Develop the MW devices and its application, and transmission of microwave over the satellite channel. |

## Prerequisites:

1. Fundamentals of microwave signal.
2. Must have completed the course on Electromagnetic theory.
3. Student should be able to solve the problems of physics of semiconductor devices.

## Course Outcome Mapping with Program Outcome:

| Course Outcome | Program Outcomes (PO's) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO. NO. | Domain Specific | | | | | Domain Independent | | | | | | |
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 2 | 1 | | 1 | 1 | | 0 | 0 | 0 | 0 | 0 | 0 |
| CO2 | 2 | 2 | | 1 | 1 | | | | | | | |
| CO3 | 2 | 1 | 1 | 2 | 1 | | | | | | | |
| CO4 | 3 | 2 | 1 | | 1 | | | | | | | |
| CO5 | 3 | 1 | 0 | 0 | 0 | 1 | | | | | | |
| CO6 | 2 | 1 | 0 | 0 | 2 | 1 | | | | 1 | | |
| CO7 | 2 | 2 | 1 | 0 | 2 | 1 | | | | 2 | | |
| 1: Slight (Low) , 2: Moderate (Medium), 3: Substantial (High) | | | | | | | | | | | | |

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## Course Coverage Module Wise:

| Lecture No. | Unit | Topic |
|---|---|---|
| 1 | **1** | **IMPEDANCE TRANSFORMATION AND MATCHING:** |
| 2 | 1 | Lumped elements for MICs and MMICs |
| 3 | 1 | printed inductors, capacitors and resonant elements |
| 4 | 1 | The Smith chart- combined impedance-admittance chart |
| 5 | 1 | Impedance matching with lumped elements (L networks) |
| 6 | 1 | Smith chart solutions |
| 7 | 1 | Single stub tuning in microstrip circuits using shunt stub |
| 8 | 1 | Single section quarter-wave transformer, |
| 9 | 1 | Numerical |
| 10 | **2** | **MICROWAVE DIODES AND DIODE CIRCUITS:** Detector Diodes |
| 11 | 2 | Silicon crystal diode and Schottky diode |
| 12 | 2 | V-I characteristic of detector diode |
| 13 | 2 | basic operation of detection and mixing, single diode mixer circuit |
| 14 | 2 | PIN diode - Equivalent circuit and characteristics of PIN diode |
| 15 | 2 | single-pole PIN diode switches, single bit phase shifters |
| 16 | 2 | Varactor diode- Device characteristics and circuit applications |
| 17 | 2 | Gunn diode- Gunn effect, Gunn diode principle of operation and characteristics |
| 18 | 2 | Typical oscillator circuit using Gunn diode. |
| 19 | 2 | IMPATT diode- Characteristics, |
| 20 | 2 | IMPATT negative resistance, power output and efficiency, Numerical |
| 21 | **3** | **MICROWAVE TRANSISTORS AND CIRCUITS:** |
| 22 | 3 | Bipolar Junction Transistors (BJTs) – Geometry of silicon bipolar transistor |
| 23 | 3 | BJT DC biasing, microwave equivalent circuit and characteristics. |
| 24 | 3 | Microwave Field Effect Transistors (FETs) - Physical structure and principle of operation of JFET |
| 25 | 3 | MOSFET and MESFET characteristics |
| 26 | 3 | comparison of FET devices and circuit applications |
| 27 | 3 | Single stage FET amplifier – Block schematic of a single stage FET amplifier circuit, Stability considerations |
| 28 | 3 | analysis and derivation of expression for transducer gain with unilateral transistor, design criteria for maximum gain |

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| | | |
|---|---|---|
| 29 | **4** | **KLYSTRONS:** Limitations of conventional vacuum tubes |
| 30 | 4 | Reflex klystron – Basic schematic, mechanism of operation, modes of oscillation and modulation |
| 31 | 4 | Velocity modulation and electron bunching (analytical treatment) |
| 32 | 4 | Magnetrons- Types of magnetron, Basic structure of magnetron |
| 33 | 4 | Magnetron analysis, resonant modes in magnetron, operation, mechanism of oscillations |
| 34 | 4 | practical consideration of cavity magnetron, Introduction to coaxial |
| 35 | 4 | frequency angle and voltage tunable magnetrons, Numerical |
| 36 | **5** | **TWO CAVITY KLYSTRON AMPLIFIER**- Basic schematic and mechanism of operation. |
| 37 | 5 | Travelling Wave Tube Amplifier- Basic schematic of helix type TWT tube |
| 38 | 5 | Introduction to CW power pulsed dual mode TWT |
| 39 | 5 | TWT amplifier operational characteristics |
| 40 | 5 | Applications of TWT, Crossed- field amplifier, Numerical |

**TEXT/REFERENCE BOOKS**


1. Microwave Engineering,David M. Pozar,Wiley.
2. Microwave Devices and circuits, Samuel Y. Liao, Prentice Hall
3. Microwave and Radar Engineering, M. Kulkarni, Umesh Publication


## Teaching and Learning resources:

- **MOOC (NPTEL): -**https://nptel.ac.in/courses/108/101/108101112/

## Assessment Methodology:

1. Practical exam using lab instruments.
2. Two Midterm exams where student have to showcase subjective learning.
3. Final Exam (subjective paper) at the end of the semester.


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5E1395

Roll No. _____ Total No of Pages: 3

# 5E1395

## B. Tech. V - Sem. (Main / Back) Exam., Feb.-March - 2021

## PCC/PEC Electronics & Communication Engineering

## 5EC 4–05 Microwave Theory & Techniques

Time: 2 Hours [To be converted as per scheme]

Max. Marks: 82

Min. Marks: 29

*Instructions to Candidates:*

***Attempt all ten questions from Part A, four questions out of eight questions from Part B and two questions out of seven from Part C.***

*Schematic diagrams must be shown wherever necessary. Any data you feel missing may suitably be assumed and stated clearly. Units of quantities used /calculated must be stated clearly.*

*Use of following supporting material is permitted during examination. (Mentioned in form No. 205)*

1. NIL 2. NIL

## PART – A

**(Answer should be given up to 25 words only)** [10×2=20]

**All questions are compulsory**

Q.1 If the cutoff frequency of an air-filled waveguide is 20 GHz then what will be its cut off frequency after filling with a dielectric material of relative dielectric constant $\varepsilon_r = 16$?

Q.2 Write S – parameter units.

Q.3 Write two differences between MIC and MMIC.

Q.4 If cutoff frequency of $TE_{11}$ mode is 5 GHz then find the operating frequency of $TE_{02}$ mode.

Q.5 Draw the structure of an E – plane horn.

Q.6 Write the name of one dominant loss in waveguide.

Q.7 Define noise figure of a MW amplifier.



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Q.8 Write the name of two MW devices which works on bulk and do not have any semiconductor junction.

Q.9 Why PIN diode speed is more than a normal PN junction? Give only the main reason.

Q.10 Write the name of two MW frequency bands used in military application.

## PART – B

**(Analytical/Problem solving questions)** **[4×8=32]**

**Attempt any four questions**

Q.1 Draw the structure of a MW BJT (Heterojunction) and explain its model and working.

Q.2 Why TEM mode is not possible inside waveguide, support the reasons with Maxwell's equations. How TE and TM modes are excited in a rectangular waveguide?

Q.3 Explain any one scheme of MW power measurement when the MW power is less than 1 Watt. https://www.rtuonline.com

Q.4 How differential negative mobility region achieved in MW devices? Draw the two valley diagram of a Gunn diode and explain its working.

Q.5 Draw the electric and magnetic field line distributions/pattern in –

(a) Microstrip line

(b) Co-planar line

Q.6 Design a power divider with matched terminations and operating at 10 GHz.

Q.7 Explain and write the s-parameter of a magic tee when it's all port are matched. What will be the effect on port mismatch and how S-parameter change with it?

Q.8 Draw the electric and magnetic field pattern inside a waveguide at –

(b) $TM_{21}$



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## PART – C

**(Descriptive/Analytical/Problem Solving/Design Questions)** **[2×15=30]**

**Attempt any two questions**

**Q.1** **Find all electric and magnetic fields expression for TM mode inside a rectangular waveguide with the help of Maxwell's equations.**

Q.2 If the S parameter of a two port MW system is $S_{11} = 2 + j1$, $S_{21} = 4 + J1$, $S_{12} = 2+j1$ and $S_{22} = 0.6 + j2$. Find its gain, reflection and transmission constant.

Q.3 **Explain the working of two hole directional coupler and design it for f = 5 GHz. Assume the waveguide is filled with $\varepsilon_r = 4$.**

Q.4 **Explain the impedance measurement technique used in MW system.**

Q.5 **Define the quality factor of a MW resonator and explain its –**

**(a) Under coupling**

**(b) Over coupling**

(c) Critical coupling conditions

Q.6 Define EMI and EMC. Draw two scheme for obtain the MW system which is compatible with required EMI/EMC.

Q.7 **How Klystron works? Draw the structure of a two cavity Klystron and explain the bunching phenomena in it.**

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5E1395

B.Tech. V- Semester (Main) Examination, Nov. 2019
PCC/PEC Electronics and Comm. Engg.
5EC 4-05 Microwave Theory and Techniques

Time : 3 Hours

Maximum Marks : 120
Min. Passing Marks : 42

*Instructions to Candidates:*

*Attempt* ***all ten*** *questions from* ***Part A****, five questions out of* ***Seven*** *from* ***Part B*** *and* ***Four*** *questions out of* ***Five*** *from* ***Part C****.*

*Schematic diagrams must be shown wherever necessary. Any data you feel missing suitably be assumed and stated clearly. Units of quantities used/calculated must be stated clearly.*

## PART - A

(Answer should be given up to 25 words only)

All questions are **compulsory** (10×2=20)

1. Define microwave.
2. Define TE mode for microwave transmission.
3. Draw the microstrip line structure.
4. Write down the S - matrix for a two port network.
5. Define coupling factor of a directional coupler.
6. Draw the energy band diagram of a Gunn diode.
7. Define transducer power gain for microwave amplifier.
8. Why do we require measuring VSWR in a microwave circuit?
9. Write down use of Network Analyzer.
10. What do you understand by monolithic microwave integrated circuits.

## PART - B

(Analytical/Problem solving questions)

Attempt any **five** questions (5×8=40)

1. Describe the losses associated with microwave transmission.



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2. A microstrip line is to be designed and its specification is strip thickness $t \leq 0.005h$; substrate board is alumina; relative dielectric constant $\epsilon_r = 10$; ratio of w/h = 0.95; Calculate

   a) effective relative dielectric constant

   b) characteristics impedance $Z_0$.

3. A shunt impedance Z is connected across a transmission line with characteristics impedance $Z_0$. Find the S - Matrix of the junction.

4. Prove that it is impossible to construct a perfectly matched, lossless, reciprocal three - port junction.

5. Explain in detail the analytic approach to optimum oscillator design using S - Parameters.

6. Explain the experimental set - up for measurement of radiation pattern and beam width. http://www.rtuonline.com

7. Draw the block diagram of a basic radar and explain how it works.

## PART - C

(Descriptive/Analytical/Problem Solving/Design Questions)

Attempt any **Four** questions **(4×15=60)**

1. The S - parameters of a two - port network are given by

   $S_{11} = 0.2\angle 0,\ S_{22} = 0.1\angle 0$

   $S_{12} = 0.6\angle 90^\circ,\ S_{21} = 0.6\angle 90^\circ$

   a) Prove that the network is reciprocal but not lossless.

   b) Find the return loss at port 1 when port 2 is short circuited.

2. Explain the velocity modulation and bunching process in two - cavity klystron. Also derive the expression for bunching parameters.

3. Design a low - pass, maximally flat lumped - element fitter having a passband of 0-2 GHz, and an attenuation of at least 20dB at 3.4 GHz. The characteristics impedance is $50\,\Omega$.

4. Describe the method of frequency and impedance measurement at microwave frequency.

5. a) Describe the process involved in fabrication of MMICs.

   b) Write down the medical and civil applications with suitable diagram of microwaves.

   c) Write short notes on microwave imaging.



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