K.S.R. COLLEGE OF ENGINEERING (Autonomous) **R 2020**

SEMESTER - VII

20EC712	**RF AND MICROWAVE ENGINEERING**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Prerequisite: *Electronic Devices and Circuits*

Course Outcomes : On completion of this course, the student will be able to		***Cognitive Level***
CO1:	*Describe the Z,Y,h,ABCD and S parameters for two port network.*	*Understand*
CO2:	*Elaborate the process of microwave signal generation using Reflex klystron, TWTA and Magnetron.*	*Understand*
CO3:	*Describe the characteristics of passive and active microwave devices.*	*Understand*
CO4:	*Compute the stability for microwave amplifier and design of matching networks.*	*Apply*
CO5:	*Measure the power, impedance, VSWR and S-parameters using microwave measuring instruments.*	*Understand*

UNIT - I TWO PORT NETWORK PARAMETERS [9]

Review of low frequency parameters: Impedance, Admittance, Hybrid and ABCD parameters-Different types of interconnections in two port network - High frequency parameters: Formulation of S parameter for two port network and multiport network - Properties of S parameters - Reciprocal and lossless networks –Transmission matrix-RF behavior of resistors, capacitors and inductors.

UNIT - II MICROWAVE TUBES [9]

Two cavity klystron: Transit time effect, velocity modulation, current modulation and bunching - Reflex klystron -Slow wave structures - Helix traveling wave tube, its analysis and gain considerations – Magnetron : Operation of Cylindrical magnetron, Hull cutoff magnetic and Hull cutoff voltage Equation.

UNIT - III MICROWAVE COMPONENTS AND DEVICES [9]

Terminations, Attenuators, Phase shifters, Power dividers, Circulator, Isolators-S matrix of power dividers and directional coupler- Rat race coupler–Impedance matching devices: Crystal diode, Schottkey diode, PIN diode, Gunn diode, READ diode and IMPATT diode.

UNIT - IV RF AMPLIFIER AND MATCHING NETWORKS [9]

Characteristics of amplifiers - Amplifier power relations - Stability considerations - Stabilization methods - Constant VSWR circles-Constant Noise figure circles-Broadband, high power and multistage amplifiers -Matching Networks: Impedance matching using discrete components -Two component matching networks - Frequency response and quality factor -T and Pi matching networks – Micro strip line matching networks - Single stub and Double stub matching networks.

UNIT - V MICROWAVE MEASUREMENTS [9]

Measuring instruments: VSWR meter, Power meter, Spectrum analyzer, Network analyzer-Measurement of impedance, frequency, Power, VSWR, Q-factor, dielectric constant, scattering coefficients, attenuation, S-parameters.

Total (L= 45) = 45 Periods

Text Books:

1 Samuel Y.Liao, Microwave Devices and Circuits, Pearson Education Inc.,New Delhi,Third edition,2012.

2 Reinhold Ludwig and Gene Bogdanov, RF Circuit Design: Theory and Applications, PearsonEducation Inc.,New Delhi, Second edition,2012.

Reference Books:

1 David M.Pozar, Microwave Engineering, Wiley India(P)Ltd, New Delhi, Fourth edition, 2011.

2 S.Vasuki, D.Margaret Helena and R.Rajeswari, Microwave Engineering, McGraw Hill Education, New York, First edition,2015.

3 Annapurna Das and Sisir K Das, Microwave Engineering, Tata McGraw Hill, New Delhi, Second edition,2012.

4 Thomas H Lee, Planar Microwave Engineering: A Practical Guide to Theory, Measurements and Circuits, Cambridge University Press, United Kingdom, First edition, 2010.

K.S.R. COLLEGE OF ENGINEERING (Autonomous), TIRUCHENCODE – 637215.
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
COURSE / LESSON PLAN SCHEDULE

NAME : Mr.M.JOTHIMANI **CLASS : IV-ECE (A&B)**
COURSE CODE / NAME : 20EC712 / RF AND MICROWAVE ENGINEERING

TEXT BOOKS:

1. Samuel Y.Liao, Microwave Devices and Circuits, Pearson Education Inc.,New Delhi,Third edition,2012.
2. Reinhold Ludwig and Gene Bogdanov, RF Circuit Design: Theory and Applications, PearsonEducation Inc.,New Delhi, Second edition,2012.

REFERENCES:

1. David M.Pozar, Microwave Engineering, Wiley India(P)Ltd, New Delhi, Fourth edition, 2011.
2. S.Vasuki, D.Margaret Helena and R.Rajeswari, Microwave Engineering, McGraw Hill Education, New York, First edition,2015.
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4. Thomas H Lee, Planar Microwave Engineering: A Practical Guide to Theory, Measurements and Circuits, Cambridge University Press, United Kingdom, First edition, 2010.

C. LEGEND:

L 1	-	Lecture 1	BB	-	Black Board
T 1	-	Tutorial 1	OHP	-	Over Head Projector
Tx 1	-	Text 1	pp	-	Pages
Rx 1	-	Reference 1			

Sl.No.	Lecture Hour	Topics to be covered	Teaching Aid Required	Book No. / Page No.
UNIT-ITWO PORT NETWORK PARAMETERS				
1	L-1	Review of Low frequency parameters : impedance, admittance	BB	Rx 4/pp-170-171
2	L-2	Hybrid and ABCD parameters	BB	Tx 2/pp-158-162 Rx 2/pp-168-171
3	L-3	Different types of interconnections of two port networks	BB	Rx 2/pp-172-173
4	L-4	High frequency parameters: Formulation of S parameter for two port network and multiport network	BB	Tx 2/pp-169-177 Rx 2/pp-155-159
5	L-5	Properties of S parameters	BB	Rx 2/pp-157-159
6	L-6	Reciprocal and lossless networks	BB	Rx 2/pp-154 Rx 4/pp-171-173
7	L-7	Transmission matrix	BB	Rx 4/pp-183-184
8	L-8	RF behavior of resistors	BB	Tx 2/pp-10-16
9	L-9	Capacitors and inductors	BB	Tx 2/pp-19-22
UNIT-II MICROWAVE TUBES				
10	L-10	Two cavity klystron	BB	Rx 1/pp-679-686 TX 2/pp-359-370 TX1/pp-341-372
11	L-11	Transit time effect- Velocity modulation	BB	TX 1/pp-339-347 TX 2/pp-350-359
12	L-12	Current modulation-bunching	BB	TX1/pp-348-354 T X2/pp-348-350
13	L-13	Reflex Klystron	OHP	TX1/pp-373-379 Rx 1/pp-686-689

				Rx 2/pp-348-359
14	L-14	Slow Wave structures	BB	TX 1/pp-384-388
15	L-15	Helix Traveling Wave Tube	BB	TX 1/pp-384-387 TX 2/pp-371-372
16	L-16	Bandwidth, Power and Gain Considerations	BB	TX 1/pp-396 TX 2/pp-372-376 Rx 1/pp-698-699
17	L-17	Magnetron : Operation of Cylindrical magnetron	BB	TX 1/pp-425-426 TX 2/pp-377
18	L-18	Hull cutoff magnetic and Hull cutoff voltage Equation	BB	TX 2/pp-377-384 TX 1/pp-427-450
UNIT-III MICROWAVE COMPONENTS AND DEVICES				
19	L-19	Termination - Gyrator- Isolator	BB	Rx 2/pp-182,210-212, 26-27 Tx 1/pp-178-179 Rx 1/pp-464-465,466
20	L-20	Attenuators, Phase shifters, Power dividers, Circulator	BB	Tx 1/pp-176-178 Rx 2/pp-188-196,205
21	L-21	Scattering matrix - Concept of N port scattering matrix representation	BB	Rx 2/pp-155-157
22	L-22	Properties of S matrix- S matrix formulation of two-port junction	BB	Rx 2/pp-159-161
23	L-23	Microwave junctions - Tee junctions - Magic Tee	BB	Tx 1/pp-162-165 Rx 2/pp-197-204
24	L-24	Rat race coupler- Directional couplers - two hole directional couplers	BB	Tx 1/pp-165-167 Rx 2/pp-185,214-215, 245-247
25	L-25	Impedance matching devices: Crystal diode, Schottkey diode, PIN diode, Gunn Diode	BB	TX1/pp-270-273 TX 2/pp-403-408
26	L-26	Read Diode- Physical Description Avalanche Multiplication	BB	TX1/pp-304-305 TX 2/pp-305-306
27	L-27	IMPATT Diodes	BB	TX 1/pp-309-313
UNIT-IV RF AMPLIFIER AND MATCHING NETWORKS				
28	L-28	Characteristics of amplifiers - Amplifier power relations	BB	Tx 2/pp-487-489
29	L-29	Stability considerations, Stabilization methods	BB	Tx 2/pp-492-494
30	L-30	Gain considerations, noise figure	BB	Tx 2/pp-504-514,521
31	L-31	Matching Networks: Impedance matching using discrete components	BB	Tx1/pp-107-113 Tx 2/pp-422-430 Rx 1/pp-308-312 Rx 2/pp-111-120
32	L-32	Frequency response and quality factor	BB	Tx 2/pp-431-442
33	L-33	T matching networks	BB	Tx 2/pp-442-446
34	L-34	Π matching networks	BB	Tx 2/pp-442-446
35	L-35	Microstripline matching networks	BB	Tx1/pp-490-502
36	L-36	Single stub and Double stub matching networks	BB	Tx 2/pp-446-454
UNIT-V MICROWAVE MEASUREMENTS				
37	L-37	Measuring instruments: VSWR meter, Power meter	BB	TX 2/pp-509-513

38	L-38	Spectrum analyzer, Network analyzer	BB	TX 2/pp 501-502
39	L-39	Measurement of impedance	BB	TX 2/pp-514-518
40	L-40	Measurement of Frequency and Power	BB	TX 2/pp 503-507
41	L-41	Measurement of VSWR	BB	Rx 2/pp-520-525,541
42	L-42	Q-factor, dielectric constant	BB	Rx 2/pp-520-525,541
43	L-43	Scattering coefficients	BB	Rx 2/pp-507-512
44	L-44	Attenuation	BB	Rx 2/pp-507-512
45	L-45	Measurement of scattering parameters	BB	TX 2/pp 535-539

UNIT-I TWO PORT NETWORK PARAMETERS(CO1)

1. Define scattering matrix? (Remembering)(Nov/Dec 2013,NOV/DEC 2016)

Scattering matrix is a square matrix which gives all the combinations of power relationships betweenthe various input and output port of a microwave junction.

2.Write the properties of [S] matrix? (Applying)(Apr-11)

i)[S] is always a square matrix of order (**n*n**),ii)[S] is a symmetric matrix i.e. $\mathbf{S_{ij} = S_{ji}}$

iii)[S] is a unitary matrix i.e. **[S] [S*]=[I]**and

iv) Under perfect matched conditions, the diagonal elements of [S] are zero.

3.Define Reciprocal network. (Analyzing)

A network is said to be reciprocal, if its power transmission and co-efficient do not change when its inputs and outputs are interchanged.

4.Give ABCD matrix for a two port network(Evaluating)(Apr-11)

V_1=A B V_2

I_1=C D -I_2

5.What is ABCD matrix? (Understanding) (Nov/Dec 2013)

ABCD matrix is a transmission matrix. These parameters express voltage andcurrent at output in terms of those at input port.$V_1=AV_2$-BI2, $I_1=CV_2-DI_2$

6.What are the advantages of ABCD matrix? (Remembering)

1)They are used in power transmission lines 2)They are very helpful in the case of cascade networks.

7.What are the properties of scattering matrix for a lossless junction? (Understanding)

1) The product of any column of the S-matrix with conjugate of this column equals unity.

2) The product of any column of the scattering matrix with the complexconjugate of anyother column iszero.

8. What are nonreciprocal devices? Give two examples (Creating)

The devices which are having the property that the forward characteristics are notequal to the reversecharacteristics are called non reciprocal devices.

9. What is meant by symmetry of scattering matrix? (Understanding)

|S| is a symmetric matrix when the microwave device has the same transmission characteristics in either direction of a pair of ports.

Sij = Sji

10. Why are S parameters used in microwaves? (Remembering)

The S parameters are used in microwaves because of the following characteristics,

i. Increased stability at higher frequencies

ii. Mismatch loss is less

iii. Attenuation loss is less

11. State the different types of high frequency capacitors. (Remembering)(APR/MAY 2016)

The different types of high frequency capacitors are,

i. Parallel plate capacitor

ii. Leaded capacitor
iii. Perfect capacitor

12. State the different types of high frequency resistors. (Remembering)(APR/MAY 2016)

The different types of high frequency resistors are,
i. Carbon composite resistors
ii. Metal film resistors
iii. Thin-film chip resistors

13. State the different types of high frequency inductors. (Remembering)

The different types of high frequency inductors are,
i. Simple wire inductor
ii. Coiled wire inductor

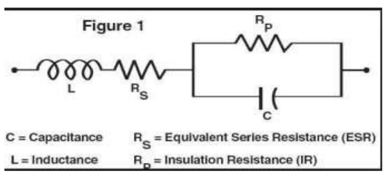
14. Define − Straight Wire Inductance(Understanding)

When alternating current is applied in a wire medium, the magnetic field is alternatelyexpanding and contracting. This produces an induced voltage in the wire that opposes any change in the current flow. This opposition to change is called 'Straight Wire Inductance'.

15. Define − Lossless Network(Analyzing)

In lossless passive network, the power entering the circuit is always equal to power leaving network which leads to the conservation of power.

16. Draw the equivalent circuit of a practical capacitor. (Creating)



17. State the limitations in measuring Z, Y and ABCD parameters at microwave frequencies.(Understanding) (NOV/DEC 2017)

The limitations in measuring Z, Y and ABCD parameters at microwave frequencies are,
i. Equipment is not readily available to measure total voltage and current at the ports of the network.
ii. Short circuit and open circuit are difficult to achieve over a wide range of frequencies.
iii. Presence of active devices such as power transistors and tunnel diodes makes the circuitunstable

UNIT I - 16MARKS

1. What is scattering Matrix? Derive 'S' matrix for n-port network.(8)**(Applying)(Nov/Dec 2013, APR/MAY 2016, NOV/DEC 2017 ,APR/MAY2018)**
2. Relate z, y and ABCD parameter with S parameter. (6) **(Applying)(Apr-11, Nov-11, Nov/Dec 2013, APR/MAY 2016,APR/MAY2017)**
3. Prove that it is not possible to construct a perfectly matched lossless reciprocal 3port junction.**(Evaluating)(Nov-07,09, Dec 2022)**
4. State and prove the properties of S parameters. (8) **(Understanding)(APR/MAY2018)**
5. Explain symmetrical Z and Y matrices for reciprocal network. (8) **(Analyzing)(Nov-11, APR/MAY 2016, NOV/DEC 2016)**
6. What are the advantages of S parameter over Z and Y parameters? **(Remembering)**
7. Write in brief about basic microwave components. **(Understanding)**
8. Applications of RF. **(Remembering)(APR/MAY2018)**
9. Discuss the importance of low frequency and high frequency parameters.**(Creating)(APR/MAY2018)**

UNIT-II MICROWAVE TUBES (CO2)

1. What is called reentrant cavity?(Remembering)

A reentrant cavity is one in which the metallic boundaries extend into the interior of the cavity. The reentrant cavities are designed for use in klystrons and microwave triodes.

2. Define electronic efficiency?(Remembering)

The electronic efficiency of the klystron amplifier is defined as the ratio of the output power to the input power.
Efficiency = $\mathbf{P_{out}/ P_{in}}$Efficiency = $\mathbf{(\beta_o I_2 V_2)/ (2 I_o V_o)}$

3. What do you meant by mutual conductance?(Remembering)

The mutual conductance of the klystron amplifier can be defined as the ratio of the induced output current to input voltage. $\mathbf{G_m = i_2ind/ V_1}$ $\mathbf{G_m = 2\beta_0 I_0 J_1(X)/ V_1}$

4. What is meant by beam loading?(Remembering)

The difference between the average exit energy and entrance energy must be supplied by the buncher cavity to bunch the electron beam, thus the electron beam is loaded by cavity energy. This phenomenon is called "beam loading".

5. Define electron plasma frequency?(Remembering)

The electron plasma frequency is the frequency at which the electrons will oscillate in the electron beam. This plasma frequency applies only to a beam of infinite diameter

6. What educed plasma frequency?(Remembering)

In practical beams of finite diameter are characterized by plasma frequency that is less than ω_p. This lower plasma frequency is called the reduced plasma frequency is called the reduced plasma frequency and is designated ω_q.

7. Define space charge reduction factor.(Remembering)

The space charge reduction factor R is a function of the beam radius r and the ratio n of the beam tunnel radius to the beam radius.$R = \omega_q / \omega_p$

8. Define reflex klystron.(Remembering)

The reflex klystron is an oscillator with a built in feedback mechanism. It used the same cavity for bunching and for the output cavity.

9. What do you meant by Applegate diagram?(Remembering)

The electrons passing through the buncher grids are accelerated/retarder/passed through with unchanged initial dc velocity depending upon when they encounter the RF signal field at the buncher cavity gap at positive/negative/zero crossing phase of the cycle, respectively, as shown by distance-time plot. This is called the Applegate diagram.

10. Define electronic admittance.(Remembering)

The electronic admittance of the reflex klystron is defined by the ratio of induced bunch beam current and cavity gap voltage.

11. State the application of reflex klystrons.(Remembering)

i.This type is widely used in the laboratory for microwave measurements.

ii.In microwave receivers as local oscillators in commercial and military application's

iii.Also plays a role in airborne Doppler radars as well as missiles.

12. What is meant by multi-cavity klystron?(Remembering)

The multi-cavity klystron passed intermediate cavities placed at a distance of the bunchingparameter X of 1.841 away from the cavity, acts as a buncher with the passing electron beam inducing a more enhanced RF voltage than the previous cavity, which in turn sits up an increased velocity –modulation.Multicavity klystron is to serve the high-gain requirement.

13. What are slow wave structures? Why and where are they used?(Apr-11,Nov-11,June 16)(Remembering)

Slow wave structures is either the helical type or folded back line, that are used in microwave tubes to reduce the wave velocity in a certain direction so that the electron beam and the signal wave can interact.

14. Comparison between TWTA and Klystron amplifiers.(Nov/Dec 2013,May/June 2014, Dec 15) (Analyzing)

Klystron Amplifier	TWTA
*Linear beam or O type device. *Uses cavities for input and output circuits. *Narrow band device due to use of resonant cavities.	*Linear beam or O type device. *Uses non-resonant wave circuit. *Wide band device because use of non resonant device.

15. What is the C-ring tuning with respect to the magnetrons?(Remembering)

The fine tuning of the magnetron oscillator can be done by changing (adding) the capacitance between the ring- strap by placing a tuning ring (C-ring). This reduces the resonant frequency of the π mode by an amount depending upon the position of C-ring.

16. Explain why TWTA has a broader bandwidth than 2-cavity klystron amplifier. (Understanding)

A TWTA circuit uses a helical slow wave non resonant microwave guiding structure and thus a widenedbandwidth.

17. Why magnetron is called a cross field device?(Remembering)

In Magnetron, the DC magnetic field and DC electric field are perpendicular to each other and hence magnetron is called as cross field device.

18. What is the other name for O-type tubes?(Remembering)

Linear beam tubes is the other name for O-type tubes.

19. Give the drawbacks of klystron amplifiers.(Remembering)

i) As the oscillator frequency changes then resonator frequency also changes and the feedback path phase shift must be readjusted for a positive feedback.ii) The multicavity klystron amplifiers suffer from the noise caused because bunching is never completeand electrons arrive at random at catcher cavity. Hence it is not used in receiver.

20. What is the effect of transit time?(Remembering)

There are two effects 1) At low frequencies, the grid and anode signals are no longer 180° out ofphase, thus causing design problems with feedback in oscillators.2) The grid begins to take power from the driving source and the power is absorbed even when the grid is negatively biased.

21. What are the applications of reflex klystron?(Remembering)

1) Signal source in MW generator 2) Local oscillators in receivers
3) It is used in FM oscillator in low power MW links 4) In parametric amplifier as pump source.

22. What is the purpose of slow wave structures used in TWT amplifiers?(May/June 2013, June 15)(Remembering)

Slow wave structures are special circuits that are used in microwave tubes to reduce wave velocity in a certain direction so that the electron beam and the signal wave can interact. In TWT,since the beam can be accelerated only to velocities that are about a fraction of the velocity of light, slow wavestructures are used.

23. How are spurious oscillations generated in TWT amplifier? State the method to suppress it.(Remembering)

In a TWT, adjacent turns of the helix are so close to each other and hence oscillations are likely to occur. To prevent these spurious signals some form of attenuator is placed near the input end of the tube which absorb the oscillations.

24. State the applications of TWT. (Understanding)

1) Low power, low noise TWT's used in radar and microwave receivers2)Laboratoryinstruments
3) Drivers for more powerful tubes 4) Medium and high power CWTWT's are used for Communicationand radar.

25.How the klystron amplifier can act as klystron oscillator? What are the applications of klystron amplifier?(Remembering)

When the klystron amplifier is given a positive feedback such that the overall phase shift becomes zero 360° and Av**= I** then klystron amplifier acts as an oscillator.

26. Distinguish between linear beam tubes and crossed field tubes. (Analyzing)

27. Compare current and velocity modulation. (June 16)

28. What is the condition for oscillation in Reflex Klystron?(Nov-11)(Remembering)

If a fraction of the output power is fed back to the input cavity and if the loop gain has a magnitude of unity with the phase shift of multiple 2π, the klystron will oscillate.

UNIT II – 16MARKS

1. (i) With mathematical explain velocity modulation and bunching process in a reflexklystron.(8)**(Nov-09,Nov/Dec 2012, Nov/Dec 2013,June-15,June 16)(Evaluating)**
(ii) Describe the mode of oscillations in a magnetron. (4) **(Apr-11) (Evaluating)**
(iii) Derive the hull cutoff voltage equation for magnetron. (4)**(Nov/Dec 2012)(Applying)**

2. (i) Schematic diagram of two cavity klystron amplifier. (4) **(Apr-08, June 2014)(Remembering)**
(ii)From the first principle, derive the expression for the power output and efficiency of twocavity klystron amplifiers.(12)**(Apr-07, Apr-11, Nov-11, Nov/Dec 2012,Nov/Dec 2013,June 2014)(Applying)**

3. (i) Draw 4 types of slow wave structure used in travelling wave tube. (8) **(Nov-09,Nov/Dec 2012) (R)**
(ii) Expression for the gain of a travelling wave tube. (8)**(Dec 15) (Remembering)**

4. (i)Draw the electrical equivalent diagram of cavity type magnetron. (8)**(Nov-08,Nov-10, Nov/Dec2012, Nov/Dec 2013,Dec 15)(Remembering)**
(ii)What is strapping with respect to magnetron. (4)**(Remembering)**
(iii)What are pushing and pulling with respect to magnetron. (4)**(Remembering)**

5. (i) Draw helix type travelling wave tube, mechanism of electric bunching. (6**)(Nov-07, Nov-11, Nov/Dec 2012,June 16) (Remembering)**
(ii) How does a travelling wave tube differ from klystron amplifier? (5)**(Remembering)**
(iii) How are the oscillations that are spontaneously generated travelling wave tube suppressed? (5)**(R)**

6. (i) Define Velocity modulation. (2) **(Apr-11, Nov-11) (Remembering)**
(ii)Explain the operation of 2 cavity klystron amplifier.Describe the expressions for bunchedbeam current and efficiency. (12) **(Evaluating)**

7. (i)Describe with neat sketch the constructional details and principles of operation of reflex klystronwith the help of electronic admittance. Illustrate the phenomenon of bunching. (8) **(Nov-09,Nov-10,June 16, Dec 2022) (E)**
(ii)Derive expressions for bunched beam current and efficiency. (8) **(Applying)**

8. With a neat diagram, explain the principle of operation of a cross field device as an oscillator. (16) **(Nov-11) (E)**

9. Derive the equation for power output and efficiency of two cavities and four cavity klystron Amplifiers. **(Nov-11) (Applying)**

10. Discuss the structure power and frequency considerations of Cylindrical Magnetron. (6) **(Nov-11,Nov/Dec 2013, May/June 2014,June-15, Dec 2022)(Creating)**

UNIT-III MICROWAVE COMPONENTS AND DEVICES (CO3)

1. What is transferred electron effect?(Dec 15)(Remembering)

Some materials like GaAs exhibit a negative differential mobility (i.e., a decrease in the carrier velocity with an increase in the electric field) when biased above a threshold value of the electric field. The electrons in the lower-energy band will be transferred into the higher – energy band. The behavior is called transferred electron effect and the device is also called transferred electron device (TED) or Gunn diode.

2. What is negative resistance in Gunn diode? (Nov/Dec 2012)(Remembering)

The carrier drift velocity is linearly increased from zero to a maximum when the electric field is varied from zero to threshold value. When the electric field is beyond the threshold value of 3000V/cm, the drift velocity is decreased and the diode exhibits negative resistance.

3. What are the various modes of operation of Gunn diode?May/June 2014, Dec 15)(Remembering)

i) Gunn oscillation mode, ii) Stable amplification mode, iii) LSA oscillation mode and iv) Bias circuit oscillation mode.

4. What are the elements that exhibit Gunn Effect?(May/June 2013,June-15)(Remembering)

The elements arei)Gallium Arsenide,ii)Indium Phosphide,iii)Cadmium Telluride and iv) Indium Arsenide

5. Write the differences between microwave transistors and transferred electron devices (TEDs)?(Remembering)

i)TEDs are bulk devices having no junction or gates as compared to microwave transistors whichoperate with either junction or gates.

ii)The majority of transistors are fabricated from elemental semiconductors, such as silicon of germanium, whereas TEDs are fabricated from compound semiconductors, such as Gallium Arsenide (GaAs), Indium Phosphide (InP) or a Cadmium Telluride (CdTe).

iii)TEDs operate with hot electrons whose energy is very much greater than the thermal energy. Transistors operate with warm electrons whose energy is not much greater than their thermal energy (0.026eV at room temperature)Because of these fundamental differences the theory and technology of transistors cannot be applied to TEDs.

6.Mention the application of Gunn-diode amplifier.(Remembering)

Gunn diodes have been used in conjunction with circulator – coupled networks in the design of high – level wideband transferred electron amplifiers that have a voltage gain – bandwidth transferred electron amplifiers that have a voltage gain – bandwidth product in excess of 10dB for frequencies from 4 to about 16GHZ.

7.What is meant by stable amplification mode?(Remembering)

This mode is defined in the region where the product of frequency times length is about 10^7cm/s and the product of doping time length is between 10^{11} and 10^{12}/cm square.

8.Define LSA mode?(Remembering)

This mode is defined in the region where the product of frequency time length is above 10^7cm/s and the quotient of doping divided by frequency in between $2*10^4$ and $2*10^5$.

9.Define avalanche transit time devices? (Nov/Dec 2013)(Remembering)

Avalanche transit-time devices are p – n junction diode with the highly doped p and n regions. They could produce a negative resistance at microwave frequencies by using a carrier impact ionization avalanche breakdown and carriers drift in the high field intensity region under reverse biased condition.

10.What are modes available in avalanche device?(Remembering)

There are three modes available in avalanche device

i) IMPATT –Impact Ionization Avalanche Transit Time device
ii) TRAPATT – Trapped Plasma Triggered Transit device and
iii) BARITT –Barrier Injected Transit Time device

11.Define quality factor Q?(Remembering)

The quality factor Q of a circuit is defined as Q = (ω* maximum stored energy)/ Average dissipated power

12.What are factors exhibit differential negative resistance in IMPATT?(Remembering)

The IMPATT diodes exhibit a differential negative resistance by two effects.

i) The impact ionization avalanche effect, which causes the carrier current $I_0(t)$ and the ac voltage to be out of phase by 90º.

ii) The transit – time effect, which further delays the external current $I_e(t)$ relative to the ac voltage by 90º.

13.Write down the expression for resonant frequency of IMPATT diode?(Remembering)

The resonant frequency, $f=1/2\tau=V_d/2L$ where $\tau=L/V_d$

14.Mention the disadvantages of IMPATT diodes.(Remembering)

The major disadvantages of the IMPATT diodes arei)Dc power is drawn due to induced electron current in the external Circuit, IMPATT diodes have low efficiency.ii)Tend to be noisy due to the avalanche process and to the high level of operating current.iii) A typical noise figure is 30dB which is worse than that of Gunn diodes.

15.Define the efficiency of IMPATT diode?(Remembering)

Efficiency, **η**=RF power output/dc input power **$\eta = P_{ac} / P_{dc}$,$\eta = (V_a/V_d)(I_a/I_d)$**

16.Write down the applications of TRAPATT diodes?(Remembering)

i)Used in a low power Doppler radars.

ii)Used as local oscillators for radars, microwave beacon landing system radio altimeter, phased array radar

17.Write down the applications IMPATT diodes?(Remembering)

i)Microwavegenerators,ii)Modulated output oscillators,iii)Receiver local oscillators, iv)Parametricamplifierpumps and v) IMPATT diodes are also suitable for negative resistance amplification.

18.Explain plasma formation in TRAPATT diode. (Understanding)

During the operation of the diode a high field avalanche zone propagates through the depletion region and fills the layer with dense plasma of electrons and holes which get trapped in the low field behind the zone.

19.What is the condition for parametric up converter and parametric down converter?(Remembering)

The output frequency f_o in the idler circuit is expressed as the sum and difference of the signal frequency f_s and pump frequency f_p. i.e. $f_0 = mf_p \pm nf_s$

20.Write the properties of parametric up converter.(Remembering)

The output frequency is equal to the sum of the signal frequency and the pump frequency.There is no power flow in the parametric device at frequencies other than the signal, pump and output frequencies.

21.What are the advantages of parametric up converter over negative resistance parametric amplifier?(Remembering)

i) A positive input impedance, ii)Unconditionally stable and unilateral,iii)Power gain independent of source impedance iv)No circulator required and v)Larger bandwidth.

22.Give the application of M/R power relation.(Remembering)

Their main application of M/R power relation is to predict whether power gain is possible in a parametric amplifier.

23.What is idler frequency?(Remembering)

The idler frequency is defined as the difference between the pump frequency and the signal frequency, **$f_i = f_p + f_s$.**

24. Give the application of parametric amplifier.(Remembering)

i) Space communication systems,ii) Radio telescopes andiii)Trope-receivers.

25. What are advantages and disadvantages of parametric amplifiers?(Remembering)

Noise figure: because of minimum resistive elements, thermal noise in parametric amplifier is very less compared to that of transistor amplifier (1-2 dB).

Frequency: the upper frequency is set by source power at the pump frequency and by the frequency at which the varactor capacitance can be pump. The lower frequency is set by cut-off frequency of the microwave component.

Bandwidth: is small due to tuned circuit and is increased by stagger tune

Gain: is limited (20-80dB) by the stability of the pump sources and the time varying capacitances.

26. Define Gunn Effect.(Nov/Dec 2013)(Remembering)

When diode voltage exceeds a certain threshold value V_{th}, a high electric field (3.2 KVolts/m for GaAs) is produced across the active region and electrons are excited from the initial lower valley to the higher valley.This is called Gunn Effect.

27. What are the necessary conditions for an IMPATT diode to produce oscillations?(Remembering)

1)The impact ionization Avalanche effect, which causes the carrier current $I_0(t)$ and the ac voltage to be out of phase by 90.

2) The transit time effect, which further delays the external current $I_e(t)$ relative to the ac voltage by 90.

28. Write the differences between IMPATT and BARITT diode in terms of biasing and noise.(Remembering) (June 16)

IMPATT	BARITT
*IMPATT diodes are reversed biased *Noise figure is high.	*BARITT diodes are the only diodes which are forward biased. *Noise figure are as low as 15 dB, which is much lessnoisy than IMPATTdiode.

29. Write the differences between TED and ATTD.(Remembering)

TED	ATTD
*It is bulk device. *Here external bias is used. *TED is based on e^{-} density.	*It is junctional format. *It is doesn't have that much effect as TED. *ATTD is based on transit time.

30. State the importance of non linear reactance in parametric amplifier.(Remembering)

UNIT III - 16MARKS

1. (i) What are avalanche transit time devices? (2)**(Remembering)**

(ii) With neat diagram explain the construction and operating principles of IMPATT diode. (12)**(May/June 13,June 16) (Understanding)**

(iii) Mention any two applications of IMPATT diode. (2)**(Dec 15)(Remembering)**

(i) Write down RWH theory of Gunn diode.(6) **(May/June 13, Nov/Dec 2013)(Remembering)**

(ii) Explain the various modes of operation of Gunn diode. (10) **(Nov-09, Nov-11, June-15,June 16) (U)**

2. (i) Give the principles of parametric amplifier. (4) **(Apr-08,June 16)(Remembering)**

(ii) Derive Manley-Rowe power relations and hence explain the parametric up converter. (12) **(Apr-11, Nov-11, Nov/Dec 2012,Nov/Dec 2013, June-15,June 16) (Applying)**

3. Write short notes on (i) Gunn diode. (4),(ii) IMPATT diode (4) **(Apr-11, Nov/Dec 2012,Nov/Dec 2013,May/June2014) (Remembering)**

(iii) Manley Rowe relations, show how it can be applied to find the gain of up converter and down converter. (8) **(May/June 2014, Dec 15) (Understanding)**

4. (i) Show how negative resistance characteristics obtain in Gunn diode. (8)**(Dec 2022) (Remembering)**

(ii) A GaAsGunn diode oscillator operates at 10GHz with drift velocity of electron of 10^5m/s, determine the effectivelength of the active region. What is the required Dc voltage for oscillation? Critical field is 3mv/cm. (8) **(Evaluating)**

5. (i) Explain in detail about TRAPATT and BARITT. (8) **(Nov-09,Nov-11,Nov/Dec 2013, May/June 2014,June-15, Dec 15) (Understanding)**

(ii) Describe the operating principles of INP diode. (8) **(Understanding)**

6. Discuss the process of avalanche multiplication in Read diode and write the expression for Avalanche Multiplication Factor. (8) **(Nov-11,June-15) (Creating)**

7. From the first principles derive the S matrix of directional coupler. (10)**(June 13,14,15,Nov-10, Apr-11,Dec 15, Dec 2022) (Applying)**

UNIT-IV RF AMPLIFIERS AND MATCHING NETWORKS (CO4)

1. What are all the characteristics of RF transistor amplifiers? (Remembering)

i) Gain and gain flatness (in dB), ii) Operating frequency and bandwidth (in HZ), iii) Output Power (in dBm), iv) Power supply requirements (in V and A), v) Input and output reflection coefficients (VSWR), vi) Noise figure(in dB)

2. What are all the parameters that affect amplifier performance? (Remembering)

i)Intermodulation distortion (IMD) products, ii) Harmonics, iii) Feedback, iv) Heating effects

3. Give the equation for maximum available power from the source. (Applying)

In amplifier power relations, if the source is matched to the transmission line (Z_o=Z_s), the maximum available power(P_A) from the source is given by

$$P_A = \frac{|V_s|^2}{8Z_s}$$

4. Define Transducer power gain. (Remembering)

The transducer power gain (G_T) is defined as the ratio between the power delivered to the load to the available power from the source.

$$G_T = \frac{\text{Power delievered to the load}(P_L)}{\text{Available power from the source}(P_A)}$$

5. Define available power gain. (Remembering)

The available power gain (G_A) for load side matching is defined as the ratio between the power available from the network to the power available from the source.

$$G_A = \frac{\text{Power available from the network}(P_N)}{\text{Power available from the source}(P_A)}$$

6. Define Power gain or operating power gain. (Remembering)

The power gain (G) is defined as the ratio of the power delivered to the load to the power supplied to the amplifier.

$$G = \frac{\text{Power delivered to the load}}{\text{Power supplied to the amplifier}} = \frac{P_L}{P_{in}} = \frac{P_L}{P_A}.\frac{P_A}{P_{in}} = G_T\frac{P_A}{P_{in}}$$

7. Give the equations for output stability circle and input stability circle. (Evaluating)

Output stability circle:

$$(\Gamma_L^R - C_{out}^R)^2 + (\Gamma_L^I - C_{out}^I)^2 = r_{out}^2$$

Input stability circle:

$$(\Gamma_S^R - C_{in}^R)^2 + (\Gamma_S^I - C_{in}^I)^2 = r_{in}^2$$

8. Define Unconditional Stability. (Understanding)

Unconditional stability refers to the situation where the amplifier remains stable for any passive source and load at the selected frequency and bias conditions.

For $|S_{11}| < 1$ and $|S_{22}| < 1$, it is stated as

$$||C_{in}| - r_{in}| > 1$$

$$||C_{out}| - r_{out}| > 1$$

9. What is attenuator for stabilization? (Understanding)

An attenuator can also be used to restrict Γ_L or Γ_S to the stable region, provided the origin of the Smith Chart is in the stable region. If the attenuator is attached between the output and the load, the minimum attenuation for unconditional stability is

$$\alpha_{min}[dB] = -10 \log \mu$$

Where μ is the stability factor and it is the minimum distance from the origin to the stability circle in the Γ_L-plane. This approach makes it easy to stabilize the network over a wide frequency range.

10. Define noise figure F. (Analyzing), NOV/DEC 2016

The noise figure F is defined as the ratio of the input SNR to the output SNR. For a practical two-port amplifier, the noise figure can be stated in the form of admittance and equivalent impedance representation.

$$F = \frac{\text{Input SNR}}{\text{Output SNR}}$$

11. Define minimum noise figure F_{min}. (Evaluating)

The minimum noise figure F_{min}, whose behaviour depends on biasing condition and operating frequency. If the device were noise free, we would obtain $F_{min}=1$.

The equivalent noise resistance $R_n=1/G_n$ of the device.

12. What are all the factors to be considered for selecting one network over another? (Remembering)

i) DC biasing, ii) Stability, iii) Frequency response

13. Define frequency response of a network. (Understanding)

The frequency responses between two networks can be defined in terms of the input reflection coefficient

$\Gamma_{in} = (Z_{in} - Z_S)/(Z_{in} + Z_S)$ And the transfer function $H = V_{out}/V_S$

14. Explain T and Pi matching networks. (Understanding)APR/MAY 2017

The loaded quality factor of the matching network can be estimated from the maximum nodal Q_n. The addition of the third element into the matching network introduces an additional degree of freedom in the circuit, and allows us to control the value of QL by choosing appropriate intermediate impedance.

15. Define Tapered matching. (Remembering)

The λ/4 transformer matching of two dissimilar resistances can be modified to handle a finite bandwidth. Multiple transmission lines of fixed lengths and stepped line impedances, or gradually varying line impedances are called as tapered matching.

16. Define single-stub matching networks. (Analyzing)(NOV/DEC 2017,APR/MAY 2018)

The single-stub matching networks can be formed by two topologies; the first one involves a series transmission line connected to the parallel combination of load and stub, and the second involves a shunt stub connected to the series combination of the load and transmission line.

17. List the applications of Tuner. (Remembering)

i) Tuners with movable shorts as part of stub line adjustments allow a wide range of load impedance matching for high power applications, ii) Generally preferred over lumped element tuning in power amplifier designs.

18. Drawbacks of single-stub matching networks. (Analyzing)

The main drawbacks of single-stub matching networks are that they require a variable-length transmission line between the stub and the input port, or between the stub and the load impedance. Usually this does not pose a problem for fixed networks, but it may create difficulties for variable tuners.

19. Define Double-stub matching. (Remembering)(NOV/DEC 2017)

In double-stub matching networks, two short-or open-circuited stubs are connected in shunt with a fixed-length transmission line placed in between. The length l2 of this line is usually chosen to be one-eighth, three-eighths, or five-eighths of a wavelength.

The three-eighths and five-eighths wavelength spacing's are typically employed in high-frequency applications to simplify the tuner construction.

20. Explain about impedance matching. (Understanding)(APR/MAY 2018)

Impedance matching is very desirable with radio frequency (RF) transmission lines. Standing waves lead to increased losses and frequently cause the transmitter to malfunction. A line terminated in its characteristic impedance has a standing-wave ratio of unity and transmits a given power without reflection. Also, transmission efficiency is optimum where there is no reflected power.

UNIT IV - 16MARKS

1. A microwave amplifier is characterized by its S-parameters. Derive equations for power gain, available gain and transducer gain.**(Dec 2022) (Analyzing)**
2. What is a matching network? Why is this required? **(Understanding)**(MAY/JUNE 2016)

3. Design a lumped element 'LC' network for matching ZL= 10+j10 Ω to a 50Ω transmission line at 1 GHz. **(Dec 2022)(Creating)**
4. Explain in detail about Impedance and microstrip line matching networks. **(Applying)(APR/MAY 2017)**
5. ExplainT and π matching network. **(Evaluating)(APR/MAY 2017)**
6. Write short notes on stability and gain consideration, noise figure. **(Remembering)**

UNIT-V MICROWAVE MEASUREMENTS(CO5)

1.What are the applications of low Q-oscillators and amplifier circuits? (Remembering)

i)Final output stage of FM telecommunication transmitterii)Up converter pumpiii)CW Doppler radartransmitter.

2.List some of power detecting elements?

1) Schottky diode 2)Baretter 3)Thermistor 4) Thermocouple

3.What is microwave detector?(Remembering)

Microwave detectors are the instrumentsused to detect the presence of microwave poweris a microwavecircuit.

4.What is tunable detector?(Remembering)

The tunable detectors are used to demodulate the signal and couple the required output to high frequency scope analyzer.The low frequency demodulated output is detected using non reciprocal detector diode mounted in the microwave transmission line.

5. What is slotted section with line carriage?(Remembering)

It is a microwave sectioned coaxial line connecting a coaxial E-field probe which penetrates inside a rectangular waveguide slotted section.The longitudinal slot is cut along the center of the waveguidebroad walls.The probe is made to move along the slotted wall which samples the electric field proportional to probevoltage.

6. What is the main purpose of slotted section with line carriage?(Dec 15)(Remembering)

1) For determination of location of voltage standing wave maxima and minima along the line.
2) Measure the VSWR and standing wave pattern,3) Wavelength,4) Impedence,5) Reflection coefficient and
6) Return loss measurement

7. What is a VSWR meter?(Remembering)

VSWR meter is a highly sensitive,high gain,high theta,low noise voltage amplifier tuned normally at fixed frequency of 1KHZ of which microwave signals modulated.This meter indicates calibratedVSWR reading fir any loads.

8. What is Bolometer?(Remembering)

It is a power sensor whose resistance change with changed temperature as it absorb the microwave power.It is ashort thin metallic wire sensor with positive temperature coefficient of resistance.

9.Mention the disadvantages of single bridge circuit. (Remembering)

1)Change in resistance due to mismatch at the microwave input port results inincorrect reading.
2) The thermistor is sensitive to change in the ambient temp resulting in falsereadings.

10. Define insertion loss? (Apr-11, Nov/Dec 2012)(Remembering)

It is defined as difference in power arriving at the terminating load.with or withoutThe network incircuitInsertion loss(db)=10 log(p_o/p_i)

11.How will you determine the VSWR and return loss in reflect to meter method?(June 16)(Remembering)

The voltage ratio between port3 to port4 is known reflection coefficient (Γ). We determineVSWRand return loss asVSWR=(1+Γ)/(1-Γ), Return loss=-20 log(Γ).

12.List the different types of Impedance measurement methods?(Nov-11) (Analyzing)

1)Slotted line method2) Reflectometer method3)Reactivediscontinuity method

13.How do you measure microwave frequency?(Nov-11)(Remembering)

1) Wavemeter method2) Slotted line method 3)Down conversion method

14.What is a wavemeter?(Remembering)

It is a device used for frequency measurement in microwave.It hascylindrical cavity with a variableshort circuit termination.It changesthe resonant frequency of cavity by changing cavitylength.

15.Define dielectric constant?(Dec 2022)(Remembering)

It is defined by the ratio of permittivity of medium to permittivity offreespace.xr=x/xo=((10^-9)/36p)

16.How the S-parameter of a microwave circuit measured?(Apr-11)(Remembering)

S-parameters are conveniently measured using the deschampsmethod which utilizes the measured valueof complex inputreflection coefficient under a number of a reactive terminations.

17. List the methods for measuring dielectric constants? (Analyzing)

1) Waveguide method 2) Cavity perturbaration method

18.What is radiation pattern?(Remembering)

Radiation pattern is a representation of radiation characteristics of an antennawhich is a function of elevation angle azimuth angle for a constant radial distance andfrequency.

19. What is radiation efficiency?(Remembering)

Radiation efficiency is defined as the ratio of total power radiated to total poweraccepted at its input.

20. How do you measure the polarization?(Remembering)

The polarization of an antenna is measured using transmitting mode and probingthe polarization by a dipoleantenna in the which the dipole is rotated in the plane ofpolarization and the receivedVoltage pattern isrecorded.

21. What is spectrum analyzer?(Remembering)

Spectrum analyzer is a broad band super heterodyne receiver which is used todisplay a wave in frequency domain additionally, power measurements, side bandscan also be observed.

22.List the types of spectrum analyzer.(Analyzing)

i) Real time spectrum analyzer ii) Swept tuned frequency spectrum analyzer

23. List some application of spectrum analyzer. (Analyzing)

Identifying frequency terms and their power levels, Measuring harmonic distortion in a waveDetermine type of wave modulation,Signal to noise ratio, For identifying wave distortion.

24. What is network analyzer and list its types? (Apr-11,Nov-11, Dec 15)(Remembering)

A Network analyzer measures both amplitude and phase of a signal over awide frequency range. Itrequiresaccurate reference signal and a test signal. The types are Scalar and Vector.

25. What is return loss? (Apr-11)(May/June 2014)**(Remembering)**

It is the ratio of power of incident wave to the power of reflected wave

$RL= P_{in}/P_{ref}$

Where P_{in} is incident power and P_{ref}isreflectedpower

26. Distinguish the ranges of VSWR. (Nov/Dec 2012,June 16) (Analyzing)

Low : S<10

High : S>1

27. List the errors possible inVSWR measurements. (Analyzing)

(i)The probe thickness and depth of penetration may produce reflections in the line and also distortion in the field to be measured

(ii)Any harmonics and spurious signals from the source may be tuned by the probe to cause measurement error

(iii)A residual VSWR of slotted lines arises due to mismatch impedance between slotted and main line

28.Define Standing Wave Ratio?(Nov/Dec 2013)(Remembering)

$SWR= V_{max}/V_{min}=1+\Gamma/1-\Gamma$

29.Justify the function of reflectometer in return loss measurement.(June-15) (Evaluating)

30 Give the expression for insertion loss and attenuation.(June-15)(Remembering)

UNIT V- 16MARKS

1. Explain how a network analyzer is used to measure the amplitude and phase of a signal over a wide frequency range with necessary diagram and their applications (16) **(Nov-11, Nov/Dec 2012, May/June 14)(U)**
2. Explain the different types of Impedance measurement methods. **(Nov-09, Nov/Dec 2012) (Evaluating)**
3. Explain the methods to measure VSWR.**(Nov/Dec 2012, May/June 13, May/June 2014, June-15, Dec 15,June 16)(Evaluating)**
4. Using reflectometermethod explain impedance measurement.**(Nov-10, Nov-11) (Evaluating)**
6. Give the measurements used to measure the scattering parameters.**(Nov-09, June-15) (Remembering)**
7. Explain insertion loss and attenuation loss in detail.**(Apr-10) (Evaluating)**
8. Explain return loss measurement using directional coupler.**(Nov-10, Nov-11, Nov/Dec 2012, May/June 14,June 16) (Evaluating)**
9. Using slotted section, write the step involved in the measurement of any two microwave parameters with a suitable microwave setups. (16) **(Apr-11, Nov-11, Nov/Dec 2013) (Understanding)**
10. Describe how the frequency of a given source is measured?**(May/June 13)(Understanding)**
11. Describe the measurement of power at microwave frequency in detail?**(May/June 14) (Understanding)**
12. With neat block diagram explain the function of network analyzer. **(June-15, Dec 2022)(Evaluating)**
13. Discuss clearly any one method of power measurement in microwave frequency. **(June-15, Dec 15) (Creating)**